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Review

Tracheotomy: clinical review and guidelines☆

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Summary

Tracheotomy is a commonly performed procedure. The Belgian Society of Pneumology (BVP-SBP) and the Belgian Association for Cardiothoracic Surgery (BACTS) developed guidelines on tracheotomy for mechanical ventilation in adults. The levels of evidence as developed by the American College of Chest Physicians (ACCP) were used. The members of the guideline committee reviewed peer-reviewed publications on this subject. After discussion, a proposal of guidelines was placed on the website for remarks and suggestions of the members. Remarks and suggestions were discussed and used to adapt the guidelines when judged necessary. The different techniques of tracheotomy are described. The potential advantages and disadvantages of surgical and percutaneous tracheotomy versus endotracheal intubation are discussed. An overview of early and late complications is given. Low-pressure, high-volume cuffs should be used. The cuff pressure should be monitored with calibrated devices and recorded at least once every nursing shift and after manipulation of the tracheotomy tubes. Inspired gas should be humidified and heated. Regarding the timing of tracheotomy there are not enough well-designed studies to establish clear guidelines. Therefore, the timing of tracheotomy should be individualised. In critically ill adult patients requiring prolonged mechanical ventilation, tracheotomy performed at an early stage (within the first week) may shorten the duration of artificial ventilation and length of stay in intensive care. Percutaneous dilatational tracheotomy (PDT) appears to be at least as safe as surgical tracheotomy (ST) as measured in terms of peri-procedural complications. With PDT, less wound infection is observed. When PDT is compared to ST performed in the operating room, PDT is less expensive, reduces the time between the decision and the performance of tracheotomy and has a lower mortality rate. Different techniques of PDT are discussed. We recommend performing PDT under bronchoscopic guidance. Because of its technical simplicity and short procedure time, the modified Ciaglia Blue Rhino technique is advocated as technique of choice. PDT should be considered the procedure of choice in elective non-urgent tracheotomy. There are some relative contraindications for PDT, but with growing experience, they become less frequent.

Keywords: Mechanical ventilation; Artificial airway; Weaning; Tracheal stenosis; Surgical tracheostomy; Percutaneous dilatational tracheostomy

1. Introduction

Tracheotomy is a commonly performed procedure. There is still debate on optimal timing and technique of tracheotomy. Management of tracheotomy is important to prevent complications. The Belgian Society of Pneumology (BVP-SBP) and the Belgian Association of Cardiothoracic Surgery (BACTS) developed guidelines on tracheotomy for the indication of airway access for mechanical ventilation in adults.

The levels of evidence as developed by the American College of Chest Physicians (ACCP) were used. The grading scheme classifies recommendations as strong (grade 1) or weak (grade 2) according to the balance among benefits, risks and burdens, and possibly cost, and the degree of confidence in estimates of benefits, risks and burdens. The system classifies quality of evidence as high (grade A), moderate (grade B) or low (grade C) according to factors that include the study design, the consistency of the results and the directness of the evidence [1].

☆ A collaborative work of the Belgian Association of Pneumology and Belgian Association of Cardiothoracic Surgery.

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2. Methodology

The members of the guideline committee reviewed all peer-reviewed publications on this subject. Based on the literature and their experience, a proposal of guidelines was made. This paper was put on the website for discussion by all members of Belgian Society of Pneumology and Belgian Association for Cardiothoracic Surgery. Remarks and suggestions of members were discussed and used to adapt guidelines when judged necessary.

3. Terminology

Tracheotomy is the operation of 'opening the trachea', derived from the Greek words trachea arteria (rough artery) and tome (cut). Tracheostomy has an ending derived from the Greek word stoma (opening or mouth). Unless the procedure is performed with the intent of placing a permanent opening, the more correct term would be tracheotomy.

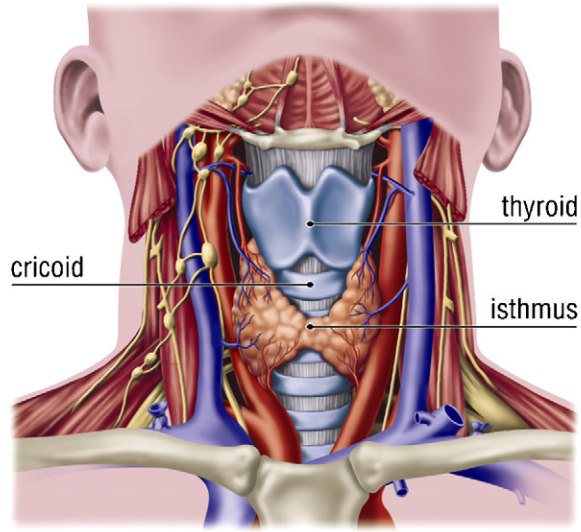

Fig. 1. Anatomy of the neck.

4. History

The oldest known reference identifying a procedure akin to a tracheotomy is found in a sacred Hindu book from the second millennium before Christ [2]. The first successful tracheotomy was recorded in 1546 by an Italian physician (Antonio Moussa Brasavola) for a patient suffering from a laryngeal abscess. In the mid-1800s, this procedure was performed on children with diphtheria. The technique was further refined and became widely accepted by the work of Chevalier Jackson who defined the indication and technique for performing the procedure [3].

5. Indications

There are four main indications for tracheotomy.

- Long-term mechanical ventilation.
- Weaning failure.
- Upper airway obstruction.
- Copious secretions.

6. Contraindications to tracheotomy

Absolute contraindication for tracheotomy is skin infection and prior major neck surgery which completely obscures the anatomy.

7. Anatomy

Fig. 1 illustrates the anatomy of the neck with the thyroid, the cricoid and the isthmus of the thyroid gland. It is essential that tracheotomy is carried out at least one to two rings beyond the cricoid. Usually the trachea is entered between the second and the third or between the third and the fourth cartilage rings. When the tracheotomy is too high (close to cricoid), there is a risk of a subglottic stenosis, which is difficult to treat. A too low tracheotomy may result in bleeding from the brachiocephalic trunk.

8. Technique

The patient is positioned with the neck moderately extended. General anaesthesia is preferred, but local anaesthesia may be used. In ventilated patients, 100% oxygen is given. Pulse rate, blood pressure and saturation should be monitored continuously.

8.1. Surgical tracheotomy (ST)

Elective surgical tracheotomy is ideally performed in the operation room. However, bedside tracheotomy can be performed.

A 3—5 cm transverse skin incision is made 1 cm below the cricoid cartilage. The strap muscles are retracted laterally. The thyroid isthmus is retracted superiorly, or inferiorly or divided. There is controversy whether a transverse or a vertical incision should be made (Fig. 2). The endotracheal tube is slowly withdrawn to just above the tracheotomy incision but not removed, in case difficulty in tracheotomy placement requires urgent reinsertion of the endotracheal tube.

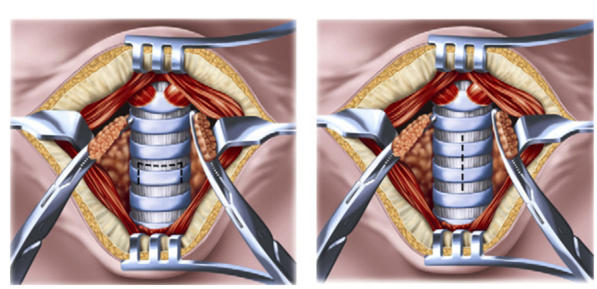
Fig. 2. During surgical tracheostomy a transverse or vertical incision can be made into the trachea.

8.2. Percutaneous dilatational tracheotomy (PDT)

Ciaglia first described PDT in 1985 [4]. The technique relies on progressive blunt dilatation of a small initial tracheal aperture created by a needle using a series of graduated dilators. The procedure involves making a very small skin incision and introducing a needle into the trachea, through which a J-tipped guidewire is passed. The needle is removed and a guiding catheter is threaded over the J-wire. Subsequent adequate blunt dilatation of the aperture over the J-wire/guiding catheter unit by means of a series of eight graduated dilators allows insertion of a preselected tracheotomy tube (Fig. 3). The entire procedure is performed under continuous endoscopic guidance, with step-by-step visualisation from beginning to end. In 1998, a modification of the technique was introduced (Ciaglia Blue Rhino Percutaneous Tracheotomy Introducer Kit; Cook Critical Care Inc., Bloomington, IN), whereby the series of dilators was replaced with a single, sharply tapered dilator with a hydrophilic coating, permitting complete dilatation in one step. Although the multiple dilators are still commercially available, the single dilator has largely supplanted them. The Ciaglia technique is the most widely used in North America [5]. Two other techniques are also available. The Griggs Guidewire Dilating Forceps (GWDF), first described in 1990, is based on enlarging a small tracheal aperture with a forceps, the tip and the edges of the forceps are blunt. Instruments required include a 14-gauge needle, a J-tipped guidewire, and the guidewire-dilating forceps [6]. After a small horizontal skin incision is made, the trachea is entered with a 14-gauge needle, through which the guidewire is threaded. The needle is then removed and the GWDF is threaded over the guidewire into the soft tissue. Opening the forceps at this point 'dilates' the soft tissue, allowing advancement of the forceps into the trachea, which is dilated to an aperture that is sufficient to accommodate the chosen tracheotomy tube.

Most recently, in 2002, Frova and Quintel reported a new single-dilator technique called the PercuTwist [7]. The kit contains a J-tipped guidewire, a scalpel, a large-bore introducer needle, the hydrophilically coated PercuTwist dilator, a specially designed 9.0 mm internal diameter PercuTwist tracheotomy cannula and an insertion dilator. The PercuTwist dilator essentially resembles a large straight threaded screw. The procedure is performed under bronchoscopic control and is started by introducing the needle into the trachea. The needle is removed, leaving the sheath through which a J-tipped guidewire is inserted. A small horizontal skin incision is then made on either side of the guidewire to facilitate insertion of the dilating device. At this point, the PercuTwist single dilator is moistened to activate the hydrophilic coating and is advanced over the guidewire into the soft tissue using a clockwise rotation. Further rotation of the device engages the anterior tracheal wall and enlarges the aperture. When dilatation is complete, the device is removed and replaced with the 9.0 mm tracheotomy tube fitted with the insertion dilator. The purported advantage of this method is the lack of anterior tracheal wall compression.

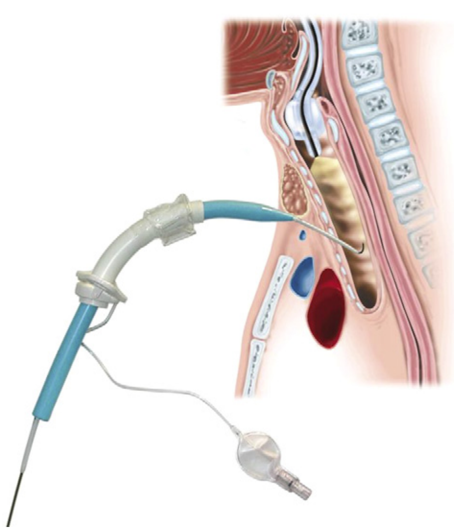

Fig. 3. Insertion of preselected tracheotomy tube by percutaneous dilatational tracheotomy.

9. Choice of tracheotomy tube

Tubes, varying in shape, are available in graded lengths and diameters [8]. Tracheotomy tubes can be metal or plastic. We suggest to use plastic cuffed tracheotomy tubes with an inner cannula, for example the Bjork-Shiley tubes or Portex tubes (*level* 2*C*).

The inner cannula is usually changed daily or more frequently when necessary. There is usually no need to change the outer tracheotomy tube. Changing of the tracheotomy should be avoided for at least 1 week after the creation of the stoma. If a difficult tracheotomy tube change is anticipated, a clinician experienced in endotracheal intubation should be present.

It is very important to mention that tracheotomy for ventilation should be distinguished from cricothyroidotomy (minitracheostomy), which is performed for aspiration of airway secretions. This small-bore cannula is placed through the cricothyroid ligament. Cricothyroidotomy is also the procedure which is performed in emergency for upper airway obstruction. Cricothyroidotomy is beyond the scope of this review.

10. Potential advantages and disadvantages of tracheotomy versus endotracheal tube

10.1. Advantages

(1) Improvement of respiratory mechanics

Anatomic dead space, contained in the upper airway and the intrathoracic conducting airways, is thought to be round 150 ml in an average adult. This is clearly more than the volume in the tracheotomy tube, which is around 5 ml, plus connecting pieces [9]. However, the difference in internal volume of standard endotracheal tubes and tracheotomy tubes of same sizes is less than 20 ml [9], and it seems unlikely that such small volume differences could significantly affect lung mechanics in vivo. This was confirmed in a clinical study showing similar dead space (measured by single-breath capnograms), tidal volume and minute ventilation, peak inspiratory and expiratory pressures and arterial blood gases before and after tracheotomy [10].

A more plausible reason to facilitate weaning would be a reduced *work of breathing* (WOB) because of a decrease in flow resistance. In a laboratory study, Davis et al. [9] showed that, under all conditions studied, WOB was lower with a tracheostomy tube than with an endotracheal tube of equivalent internal diameter. This difference increased with increasing inspiratory flows. The same investigators confirmed this in vivo and also showed that intrinsic positive end-expiratory pressure (PEEP) was also slightly reduced after tracheotomy [9]. These effects were even more pronounced in a population of COPD patients that failed weaning, when studied during spontaneous breathing at different levels of pressure support, in which marked decreases in intrinsic PEEP and WOB were observed [11].

In contrast, Lin et al. did not observe any difference in WOB in COPD patients [12]. In conclusion, assuming equivalent inner diameter of the tubes, reductions in the resistive part of the WOB most likely results from the reduction in the tube length. Whether these physiological benefits are of clinical importance in enhancing weaning success still remains unanswered.

In tracheotomised COPD patients, successful weaning obtained through non-invasive ventilation applied via a nasal or full-face mask with the tracheostomy tube capped off and its cuff deflated has been reported [13]. The extended use of non-invasive ventilation has largely reduced the indications of tracheotomy in COPD patients, but this has never been precisely investigated.

(2) Reduced laryngeal ulceration

Endotracheal intubation can result in severe injury of the upper airway [14] which can be largely prevented by early tracheotomy.

(3) Improved nutrition, enhanced mobility and speech.
(4) Improved patient comfort. In an observational study, tracheotomised mechanically ventilated ICU patients required less intravenous administration of sedatives, spent less time heavily sedated and achieved more autonomy earlier [15].
(5) Patient can be nursed outside intensive care unit (ICU).
(6) Clearance of secretion.

10.2. Disadvantages

(1) Surgical procedure with its procedure related immediate complications.
(2) Stomal complications.
(3) Tracheo-innominate artery fistula formation (rare complication).
(4) Tracheoesophageal fistula formation (rare complication).

11. Complications

Some complications are related to the procedure and others to the cannula. Late complications of tracheotomy are difficult to categorise and to quantify, as many patients are critically ill and lost to follow-up secondary to discharge before decannulation [16—18].

11.1. Early complications

- Haemorrhage: This can be minor and can be controlled by packing and by insuring that the cuff of the tracheotomy tube is inflated. Major bleeding may require reoperation. Bleeding is reported in $\pm 5\%$ of tracheostomies.
- Wound infection: A tracheotomy is considered a clean-contaminated wound. Prophylactic antibiotics are usually not warranted. True infection is rare and requires only local therapy. In case of necrotising tracheal infection, conversion to oral tracheal intubation is necessary followed by wide debridement of involved tissues.
- Subcutaneous emphysema: Subcutaneous emphysema can be caused by positive pressure ventilation or coughing against a tightly sutured or packed wound. It can be prevented by not suturing the wound around the tube. The emphysema will resolve spontaneously within a few days. A chest radiograph should be obtained to rule out a pneumothorax.
- Tube obstruction: The tube can be obstructed by mucus, blood clots, displacement into surrounding soft tissues or abutment of the tube's open tip against the tracheal wall. Failure to re-establish adequate ventilation by suctioning through the tube requires immediate replacement of the inner cannula or the entire tube.
- Fausse route during the procedure or early tube displacement. Fausse route or early displacement (within 5 days after placement of tracheotomy) of the tube creates an airway emergency. Orotracheal intubation should be performed when the tract cannot be re-established immediately.

11.2. Late complications

- Swallowing problems. Factors that contribute to disturbed swallowing are as follows: decreased laryngeal elevation, oesophageal compression and obstruction from the tracheotomy tube cuff.
- Tracheal stenosis. Tracheal stenosis occurs in approximately 1—2% and usually results from ischaemia, devascularisation and chemical erosion. Causes include the use of high-pressure cuffs (now eliminated after the introduction of large-volume, low-pressure cuffs), forced angulation of a stiff tube or hyperinflation of the cuff which result in tracheal damage [19]. Stenosis may occur at the stoma, the cuff side or the tip of the tracheotomy tube (Fig. 4).
- Tracheo-innominate artery fistula. This complication is rare ($<0.7\%$). Most fistulas appear to result from direct pressure of the cannula against the innominate artery. Risk factors include low placement of tracheotomy, high-pressure cuffs and excessive head or tracheotomy tube movement. Overall survival is only 25%. Preventive measures include correct placement of the tracheotomy tube at the level of the second or third cartilaginous ring, avoiding prolonged or excessive hyperextension of the neck, using a soft, readjustable tracheotomy tube and

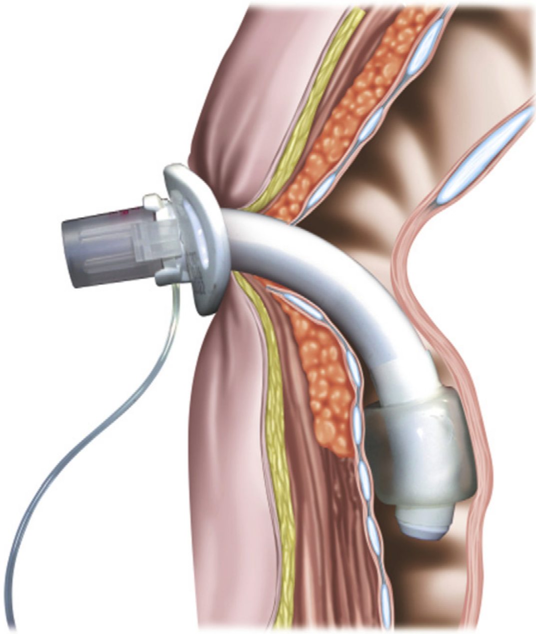

Fig. 4. Angulation of the tracheostomy tube should be avoided since this may lead to stenosis.

lightweight tubing to avoid dragging on the tracheotomy tube [20].

- Tracheoesophageal fistula. Tracheoesophageal fistula is a rare complication occurring in less than 1% of patients. Cause is mostly iatrogenic due to erosion by the tracheotomy cuff but also a right angle of the tube can cause undue pressure against the posterior tracheal wall. It is more commonly seen when a nasogastric tube is in place as well. Fistula repair is performed by a cervical incision with interposition of viable tissue [21,22]. Post-intubation tracheoesophageal fistula is usually best treated with tracheal or laryngotracheal resection and anastomosis and primary oesophageal closure even in the absence of tracheal damage [23].
- Granuloma formation. Granulomas may result from a foreign body reaction to the tracheotomy tube or specific parts of it. They are more common with fenestrated tracheotomy tubes. These granulomas can be treated with the YAG laser. Especially worrisome are granulomas at the lower end of the tracheotomy tube where bronchoscopic removal only provides temporary relief.
- Persistent stoma. This situation usually results when the tube has been left in position for a prolonged period, permitting epithelialisation between the skin and the tracheal mucosa. Although the opening might become very small due to wound contracture, it may be troublesome for the patients. Surgical closure is proposed.

12. Tracheotomy management

Recommendations on tracheotomy management have been made by the panel on the basis of personal experience and after careful reading of several published guidelines and protocols [24—28]. Since there is a lack of rigorous scientific evidence on this issue, all following recommendations are graded as 1C.

12.1. Nursing care

Some general principles are advocated for immediate post-tracheotomy care: the tracheotomy cannula is secured in place and the tracheotomy is left to heal for 5—7 days, to allow for development of a stable and patent cutaneo-endotracheal tract. The tracheotomy wound has to be kept clean and dry to prevent post-incisional wound infection. When a dual cannula is used, there is usually no need to change the outer cannula. The inner cannula is changed daily or more frequently if necessary. Changing the outer cannula within 5—7 days after placement is potentially dangerous due to risk of collapse of the cutaneo-endotracheal tract and subsequent loss of airway. The only indication to change the outer cannula is when the cuff has been damaged or when a tracheotomy tube of different size or shape is found to be necessary. The early change of the outer tracheotomy tube, especially when a percutaneous technique has been performed, should be performed by a practitioner who is trained in the technique.

Angulation of the tracheostomy tube should be avoided since this may lead to stenosis (Fig. 4).

12.2. Tube cuff pressure

Tracheotomy tube cuffs require monitoring to maintain pressures in a range of 20—25 mmHg (Fig. 4) [25]. High cuff pressures above 25—35 mmHg exceed capillary perfusion pressure and can result in compression of mucosal capillaries, which promotes mucosal ischaemia and tracheal stenosis. Low cuff pressures below 18 mmHg may cause the cuff to develop longitudinal folds, promote microaspiration of secretions collected above the cuff and increase the risk for nosocomial pneumonia. Cuff pressures should be monitored with calibrated devices and recorded at least once every nursing shift and after manipulation of the tracheotomy tubes (Fig. 5). It has been suggested to deflate tracheotomy cuffs on a regular schedule to allow mucosal perfusion at the site of the cuff and to improve clearance of

Fig. 5. Cuff pressures should be monitored with calibrated devices.

secretions accumulated around the cuff, but too little evidence is available to advocate this practice. To minimise damage to the tracheal wall by the distal end of the tracheotomy tube, the tube has to be maintained in a central position, avoiding angling and contact between tracheal mucosa and tube. Traction as well as unnecessary movement of the tube is to be avoided. The curvature and length of the tube has to be chosen to ensure collinearity with the trachea.

12.3. Humidification of inspired air

Ensuring free airway by means of tracheotomy bypasses upper airway functions to filter, heat and humidify inspired gas. In tracheotomised patients, inspired air may have a significant humidity deficit which may lead to pathological deep airway changes such as mucosal damage, loss of mucociliary transport and thickening of airway secretions. These changes may in turn increase the risk for lower respiratory tract infection and provoke airway obstruction by endoluminal mucous impaction. These physiopathological arguments make it mandatory for inspired gas delivered through tracheotomy to be humidified and heated [25]. To ensure humidification and heating, various techniques are used. During mechanical ventilation, the most frequently applied devices are heated humidifiers and passive humidifiers, of which heat-and-moisture exchangers are most commonly used. Heated humidifiers, in which gas flow is directed through a heated water bath prior to inspiration, are the most efficient, but also the most expensive. Passive humidifiers in the shape of heat-and-moisture exchangers (so called 'artificial noses') consist of a filter placed between ventilator and tube (to which a bacterial filter is often added), collecting heat and moisture from the patient's expired air and delivering part of it at the following inspiration. Because of lesser cost and a probably decreased risk of ventilator-associated pneumonia associated with its use, heat-and-moisture exchangers have been recommended in mechanically ventilated patients.

12.4. Clearance of secretions

Because suctioning is uncomfortable and is associated with ventilatory complications such as airway collapse and alveolar derecruitment, it should be performed only when indicated and not at a fixed frequency. Frequency of airway suctioning should hence be determined on a patient level, taking into account factors such as viscosity and quantity of mucus, neurological and muscular performance and presence of active cough reflexes and efforts. The upper airway should also be suctioned periodically to remove oral secretions and to minimise stasis of pooled secretions above the tracheotomy cuff with subsequent potential aspiration into the lower airways. Shallow suctioning, involving the insertion of the aspiration catheter to a premeasured depth not beyond the distal end of the tracheotomy tube, is preferred to deep suctioning, in which the aspiration tube is inserted beyond the tracheotomy tube until resistance is met. Deep suctioning should be avoided since it is associated with airway mucosal damage and inflammation and may induce bronchial bleeding with subsequent risk of airway occlusion.

12.5. Speech

Ventilator-dependent patients who require low minute ventilations may accomplish whispered speech during periods of partial deflation of the tracheotomy tube cuff, provided a good swallowing function is present and stasis of secretions above the cuff is limited.

After removal from mechanical ventilation, the inner cannula is removed in awake and adequate patients, allowing expiratory airflow through the larynx when the external end of the tracheotomy tube is occluded transiently. Application of a one-way valve permits inspiratory airflow through the tracheotomy tube during inspiration but closes during expiration, promoting airflow around a deflated cuff (Fig. 6). Again, when loosening the airway seal, one should take into account the patient's risk of aspiration. Some centres will use a fenestrated tube promoting airflow through the tube fenestrations during expiration.

12.6. Nutrition

The presence of a tracheotomy not only provides opportunities for oral nutrition but also complicates feeding because of tube interference with normal swallowing and airway control. A tracheotomy may decrease laryngeal elevation during swallowing and an inflated cuff may compress the oesophagus. Between 20 and 70% of patients

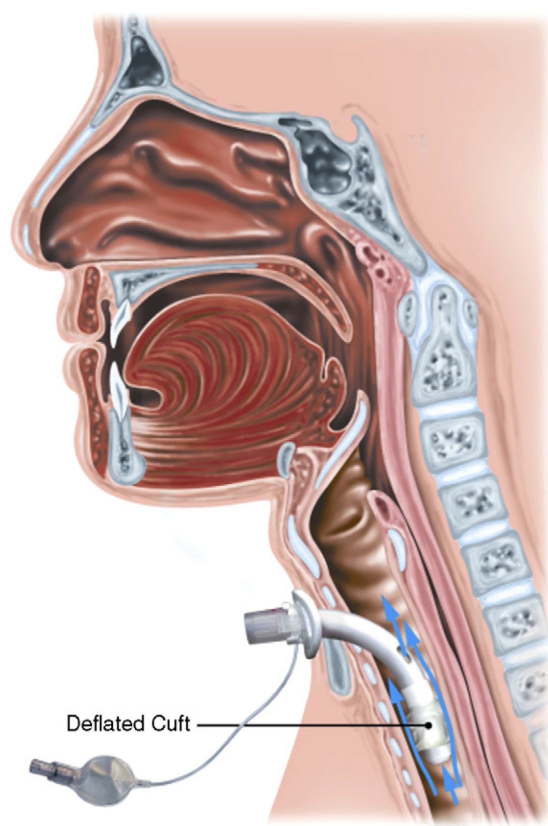

Fig. 6. When the cuff is deflated and the tube is transiently occluded during expiration by the finger, expiratory air will flow through the larynx. Some centres will use a fenestrated tube promoting airflow through the tube fenestrations during expiration.

with a chronic tracheotomy experience at least one episode of aspiration every 48 h. To decrease risks for nosocomial pneumonia caused by aspiration, patients with tracheotomy are kept with their heads elevated to 45° during periods of tube feeding. Oral feeding should be supervised by a caregiver and carefully assessed for aspiration or regurgitation. In patients with prolonged critical illness or anticipated impaired swallowing dysfunction, a first trial of oral feeding should preferably be preceded by a fiber optic evaluation of the swallowing function and guided by swallowing re-education if dysfunctional.

13. Tracheotomy and risk for ventilator-associated pneumonia

Intubated patients are at increased risk for pneumonia due to micro-aspiration of oropharyngeal or gastric secretions contaminated with potential pathogenic organisms [29]. The evidence whether the incidence of nosocomial pneumonia is affected by tracheotomy, and the timing of tracheotomy, is controversial. In a retrospective study of surgical ICU patients, patients subject to early tracheotomy (<7 days) had a significant lower rate of pneumonia as compared to patients with late tracheotomy [30]. An interventional trial randomising patients between early (within 48 h) and late (>14 days) tracheotomy showed a marked decrease in incidence of pneumonia as well as mortality in patients with early tracheotomy [31], but a second randomised trial comparing early and late tracheotomy was terminated prematurely because of lack of effect [32]. Two recent meta-analyses reported no reduction in pneumonia associated with early tracheotomy [33,34]. Performing a tracheotomy may itself lead to an increased incidence of pneumonia within a week following occurrence, which leads to the recommendation for prophylactic antibiotic administration 2 h before tracheotomy [35,36].

14. Timing of tracheotomy

14.1. Background

Timing of tracheotomy is influenced by the indications for the procedure. Because identical high-volume, low-pressure cuffs are used on both endotracheal and tracheotomy tubes, the decision about the most appropriate time to perform tracheotomy in patients undergoing artificial ventilation balances two problems: the likelihood of significant laryngeal injury with the continued use of an endotracheal tube versus the frequency of surgical and stoma-related complications following tracheotomy. There has been one systematic review and meta-analysis on this subject [33]. Five studies with 406 participants were analysed. Early tracheotomy significantly reduced duration of artificial ventilation and length of stay in the intensive care. There was one randomised control trial comparing early (less than 48 h) versus late (14–16 days) tracheotomy in patients with respiratory failure [31]. The early group had a significantly decreased mortality, pneumonia and time of mechanical ventilation. However, it is not clear if the endpoints were stated a priori and whether the outcome data were blinded as to the results of randomisation. These results need to be confirmed in subsequent clinical trials. Early tracheotomy at 7 days of mechanical ventilation is appropriate for patients in whom weaning and extubation are not likely before day 14.

A systematic review and meta-analysis comparing early tracheotomy versus late tracheotomy in trauma patients found no difference in days on mechanical ventilation, length of ICU stay, frequency of pneumonia except for patients with severe brain injury [34].

As yet, there are not enough well-designed studies to establish clear guidelines regarding the timing of tracheotomy. Factors other than absolute time may play a role in the decision to perform a tracheotomy: improved patient comfort and communication as well as enhanced nursing care. Certain types of patients such as trauma patients rather than complex medical patients, are more likely to have an increased benefit of early tracheotomy. Consequently, the timing of tracheotomy should be individualised. An international study found that a tracheotomy was performed after a median of 11 days [37].

14.2. Recommendation

In critically ill adult patients requiring prolonged mechanical ventilation, tracheotomy performed at an early stage (within the first week) may shorten the duration of artificial ventilation and length of stay in intensive care (level 1B).

15. Percutaneous dilatational tracheotomy

15.1. Percutaneous dilatational tracheotomy versus surgical tracheotomy

15.1.1. Background

When elective tracheotomy is indicated in critically ill patients, the technique of PDT offers important advantages over ST [38–44]. With PDT, less clinically significant wound infection is observed compared with ST, probably due to minimisation of local tissue trauma and a tighter fit between cannula and the surrounding tissues [44]. There is no difference in bleeding in PDT versus standard tracheotomy [44]. A sub-group analysis of the large meta-analysis by Delaney et al. showed a lower incidence of bleeding in PDT compared to ST performed in the operating theatre [44]. PDT appears at least as safe as ST, as measured in terms of peri-procedural complications [44]. The technique can be performed bedside, thus obviating the need for transport of a critically ill patient which is potentially fraught with complications. As suggested in a sub-group analysis of the meta-analysis of Delaney et al. comparing PDT with ST, this probably translates in a survival benefit associated with PDT [44].

The occurrence of long-term complications is probably not affected by the choice of technique [43,44]. A few studies suggest a reduction in tracheal stenosis with PDT [44].

PDT also results in important cost savings compared with ST, by obviating the need for operating theatre time as well as the use of operation room personnel and equipment [40,42,45]. As the operation schedule is bypassed in PDT, the time interval between deciding for tracheotomy and performing the procedure is shorter [43,46].

15.1.2. Recommendation

PDT is recommended as the procedure of choice for performing elective tracheotomy in critically ill adult patients (level 1B).

15.2. Contraindications for PDT

15.2.1. Background

Traditionally, several contraindications for PDT have been described. However, as experience with this technique increases, most of these appear to be relative rather than absolute in the hands of an experienced practitioner [47].

Performing PDT in morbidly obese patients carries an increased, although acceptable, risk for peri-operative complications [48–50]. No data are available comparing PDT and ST in this subset of patients. In these patients, a longer tracheotomy tube may be required [51].

Patient with short necks may be at no higher risk during either a PDT or ST [52]. The decision whether to perform PDT or ST should depend upon the experience of the practitioner and the possibility to identify anatomical landmarks.

PDT is safe 6–10 days after anterior spine fixation particularly in presence of spinal cord injury. In the studies reported, PDT was guided by ultrasound [53,54].

PDT may actually be an alternative to an open surgical procedure for its technical simplicity in patients with previous tracheotomy [55,56].

When performed by an experienced team, bronchoscopically guided PDT has a low complication rate in patients with severe thrombocytopenia, provided that platelets are administered at the procedure [57].

In order to minimise bleeding complications, heparin infusions should be temporarily suspended during the procedure.

PDT can be performed safely in patients with hypoxic respiratory failure with high PEEP requirements. Bronchoscopically guided PDT did not jeopardise oxygenation in a large prospective cohort of PEEP-dependent patients [58].

PDT should not be performed by an inexperienced practitioner when a free airway needs to be established urgently in case of difficult intubation.

15.2.2. Recommendation

Traditionally, several contraindications for PDT have been described. However, as experience with this technique increases, most of these appear to be relative rather than absolute in the hands of an experienced practitioner. When tracheotomy is indicated, PDT can be performed with an acceptable risk, provided adequate precautions are taken (e.g. anaesthesia and surgical team standby) (level 2C).

PDT should not be performed by an inexperienced practitioner when a free airway needs to be established urgently in case of difficult intubation (level 1C).

15.3. Different techniques of PDT

15.3.1. Background

Various techniques for PDT are available.

Ciaglia first described PDT in 1985 [4]. The technique relies on progressive blunt dilatation of a small initial tracheal aperture created by a needle using a series of graduated dilators (see Section 8). The Griggs Guidewire Dilating Forceps (GWDF) technique of percutaneous tracheotomy was first described in 1990 [6]. It is based on enlarging a small tracheal aperture with a forceps, the tip and edges of the forceps are blunt (see Section 8). Several studies comparing the Ciaglia and GWDF techniques have indicated a trend towards increased complications in the GWDF groups, and more particularly a consistent increase in bleeding [5,59–62].

In 1998, a modification of the Ciaglia technique was introduced (Ciaglia Blue Rhino Percutaneous Tracheotomy Introducer Kit; Cook Critical Care Inc., Bloomington, IN), whereby the series of dilators was replaced with a single, sharply tapered dilator, permitting complete dilatation in one step (see Section 8). It has been shown that the single-dilator technique decreased operative time compared with the serial-dilator technique without increasing the complication rate [63,64].

15.3.2. Recommendation

Because of its technical simplicity and short procedure time, the modified Ciaglia Blue Rhino technique is suggested as technique of choice (level 2C).

15.4. Use of adjuncts

15.4.1. Background

Although no randomised controlled trials have been performed to test whether addition of bronchoscopy to PDT leads to a lower risk for peri-procedural complications, bronchoscopy can be recommended as a simple and safe technique with the potential to avoid life-threatening complications such as Fausse route and posterior tracheal wall lacerations [41,45,65]. Half of the 17 randomised controlled trials comparing PDT with ST included in the meta-analysis of Delaney et al. used bronchoscopy as an adjunct to PDT [44]. Randomised trials comparing two 'blind' (i.e. not bronchoscopically guided) showed that PDT techniques had a higher than usual rate of complications [66,67].

No firm recommendations about the value of ultrasound to PDT can be made through lack of data. In selected cases with difficulties in identifying anatomical landmarks, for example obesity, ultrasound can be used as an adjunct to PDT [68].

Capnography is a potential alternative to bronchoscopy to confirm needle placement in PDT. In a small randomised controlled trial, capnography-guided PDT proved to be as effective as bronchoscopically guided PDT [69]. This technique has the disadvantage compared with bronchoscopy that the exact location of guidewire (relation to cricoid, exact position of needle in the tracheal midline?) is not available.

15.5. Recommendation

We recommend performing PDT under bronchoscopic control (level 1C).

In selected cases with difficulties in identifying anatomical landmarks, for example obesity, ultrasound can be used as an adjunct to PDT (level 2C).

Capnography is not advised when bronchoscopy is available (level 2C).

16. Removal of tracheotomy decannulation

16.1. Background

Tracheotomy removal after acute upper airway obstruction will only be performed if a patent airway is re-established.

Tracheotomy removal in patients who were weaned from prolonged mechanical ventilation can be considered if they are clinically stable, do not have psychiatric disorders, have adequate swallowing and are able to expectorate.

16.2. Criteria for tracheotomy decannulation [70]

- Stable arterial blood gases.
- Absence of distress.
- Haemodynamic stability.
- Absence of fever or active infection.
- $PaCO_2 < 60$ mmHg.
- Absence of delirium or psychiatric disorder.
- Normal endoscopic examination or revealing stenotic lesion occupying <30% of the airway.
- Adequate swallowing.
- Able to expectorate.

16.3. Technique of decannulation

Before removal, one can try the deflated-cuff tracheotomy occlusion procedure.

After deflation of the tracheotomy cuff, a gloved finger occludes the opening of the tube and one observes the patient for objective signs of respiratory distress.

In case of problems, one promptly returns the patient to breathing through the tracheotomy tube and performs an endoscopic examination to check for upper airway obstruction. If no lesions are present, one should consider whether the tube is not too large and try again after changing the tube.

The tube can be removed and the opening is covered with sterile dressings. The wound spontaneously heals in ± 10 days in most cases.

After a long period of breathing through a tracheotomy tube, it is common to take an intermediate step before removal by using a tracheotomy button or a speech valve.

In patients with copious sputa or expectoration problems, the tube can be downsized. Some patients benefit from logopedic support.

16.4. Recommendation

Tracheotomy removal in patients who were weaned from prolonged mechanical ventilation can be considered if they are clinically stable, do not have psychiatric disorders, have adequate swallowing and are able to expectorate (level 2C). Different techniques are used and can be tailored according to the patient's need.

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