CME article

Percutaneous dilatational tracheostomy

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Abstract

Tracheostomy is one of the oldest surgical procedures and its technique has evolved over time. Nearly half of all tracheostomies are performed in the ICU. Most of these tracheostomies are temporary. Percutaneous dilatational tracheostomy (PDT) has become a standard practice in intensive care unit (ICU). However, many aspects of its practice are not yet clear. This bedside procedure when performed by experienced intensivists is reasonably safe but has known complications. In this review, the basics of tracheostomy, indications, contraindications, various techniques, complications, the assisting aids for PDT and the operator competence required are discussed. Finally PDT is compared with surgical tracheostomy and the feasibility of PDT in patients with coagulopathy, obesity and on high PEEP is reviewed.

Keywords: Complications, intensive care unit, percutaneous, tracheostomy.

Introduction

A tracheostomy is a surgical opening created in the anterior wall of the trachea, mostly to facilitate ventilation. It is one of the oldest described surgical procedures. It can be performed by open surgical method or percutaneously, as an emergency or elective procedure and for several indications. In the ICU, tracheostomies are performed as elective procedures using the percutaneous technique and are temporary. This article describes planned temporary tracheostomy in the critically ill rather than those performed in an emergency to relieve airway obstruction. Percutaneous dilatational tracheostomy (PDT) is a rapid, simple, easy to learn and cost-effective procedure. It has many advantages over surgical tracheostomy. Over the years, PDT has evolved as a safe bedside procedure that has enabled a temporary tracheostomy to be inserted by the intensivists in ICU.

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History of Percutaneous Dilatational Tracheostomy (PDT)

Toye and Weinstein were the first to perform percutaneous tracheostomy in 1969.[1] In 1985, Pat Ciaglia, a New York surgeon, described the first widely accepted percutaneous tracheostomy technique by sequential tracheal dilatation.[2] In 1990, Bill Griggs, an Australian Intensive care specialist described Guide Wire Dilating Forceps (GWDF) technique.[3] The only translaryngeal retrograde tracheostomy technique was described by A. Fantoni and D. Ripamonti from Milan in 1997.[4] The Ciaglia Blue Rhino technique, also known as single dilator technique was introduced in 1999.[5] Frova's Percutwist technique was designed in Italy in 2001 and introduced in Europe in 2002.[6] The Ciaglia Blue Dolphin or Balloon dilatational technique, the one stage dilatational tracheostomy was introduced in 2007.[7]

The indications and contraindications for tracheostomy are listed in *Table 1*.

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Table 1: Indications and contraindications for tracheostomy

Indications

- **To maintain airway:** In patients with reduced level of consciousness- trauma -injuries to the face, head and neck, difficult intubation.
- **Prevention of airway from aspiration of secretions in neurological conditions:** Bulbar palsy, Guillain-Barre' syndrome.
- **For bronchial toilet:** To facilitate removal of excessive secretions where the cough is ineffective - pneumonia, bronchiectasis.
- **Prolonged mechanical ventilation:** To enable long-term mechanical ventilation in ICU setting.
- **For weaning from mechanical ventilation:** To improve patient comfort, reduce sedation, COPD patients.

Contraindications

Absolute:

- In the absence of airway obstruction, the absolute contraindications to percutaneous tracheostomy are severe local sepsis or an uncontrollable coagulopathy.

Relative:

- **Difficult anatomy**: e.g. morbid obesity, lack of neck mobility, proven or potential cervical spine injury, known difficult intubation, tracheal pathology, thyroid pathology, aberrant vessels, friable tissues, COPD with hyper-expansion or bullae.
- **Moderate coagulopathy**
- **Proximity to site of recent surgery or trauma**: e.g. carotid endarterectomy, anterior cervical fixation, sternotomy, oesophageal drainage, pharyngostomy, burns in the neck region.
- **Unstable patients:** *e.g.*, Patients unable to tolerate haemodynamic or ventilatory changes, such as those with unstable intracranial pressure (ICP) after brain injury
- **Severe gas exchange problems:** e.g. FiO_2>0.6 and PEEP >10 cm H_2O
- **Age:** children under 12 years of age.

Surgical tracheostomy *versus* PDT

PDT is becoming the preferred method for tracheostomy in many centres. However, the currently available evidence suggests that apart from the risk related to intrahospital patient transport, PDT is comparable to surgical tracheostomy (ST). With respect to other complications, PDT is associated with lower infection and cost but higher chances of tube block and difficulty in decannulation compared to ST.[8-10]

Timing of tracheostomy

The argument for early tracheostomy was based on the fact that it will reduce days on mechanical ventilation and thus ventilator-associated pneumonia (VAP) and mortality. A retrospective study showed early tracheostomy was associated with less days on ventilation and modest survival benefit.[11] A meta-analysis in 2005 showed that early tracheostomy led to a decrease in length of ventilation and ICU stay without effect on incidence of VAP and mortality.[12] One more meta-analysis showed that with early tracheostomy there was no decrease in length of ICU stay, ventilation or sedation.There was also no improvement in incidence of VAP and mortality.[13] The TracMan study which included 909 patients in 87 UK hospitals found no difference in antibiotic use, VAP rates and ICU stay but a moderate reduction in sedation requirement in the early tracheostomy group. The mortality rates were similar at 30 days and 2 years post-randomisation.[14] The current trend is towards late tracheostomy unless the intensivist is convinced about prolonged ventilation or prolonged weaning.

Preprocedure preparation

Consent: The patient or the closest kin should be explained the need, benefits and risks of

tracheostomy and the same should be documented. An informed consent is obtained from the patient or the closest kin.

Environment: The procedure must be performed with the patient on a tiltable bed or trolley, which is usually available in the ICU. Adequate lighting and resuscitation equipment should be kept ready.

Staffing: At least three personnel are required for performing the procedure. An anaesthetist/ bronchoscopist, the operator and a skilled assistant are required. The assistant must be familiar with the procedure and should be able to assist the clinicians in managing any complications that may develop.

Tracheostomy equipment: Commercially available kits are usually used. Reusable instruments have also been developed. Endotracheal tube or Laryngeal mask airway are used as airway adjunct, the choice depending on the patient's underlying condition and operator's choice.

Monitoring: Routine intensive care monitoring of electrocardiogram, pulse oximetry, and invasive arterial pressure monitoring can be assumed for these patients. Capnography is essential because accidental extubation can occur and the patient may require reintubation. Any obstruction to ventilation by the bronchoscope or leaks may also be detected using capnography. Capnography also confirms correct placement of tracheostomy tube *(Figure 1)*.

Figure 1: Monitoring

Anaesthesia: The anaesthesia should be deepened to adequate level levels prior to the procedure. This is typically achieved using infusions of propofol and opioids. Muscular paralysis also facilitates surgical exposure.

Rescue airway: Difficult airway equipment to deal with loss of airway should be readily available. Appropriate sizes of endotracheal tubes, laryngoscopes, bougie, laryngeal mask airways and needle cricothyrotomy sets for emergency oxygen insufflation must be kept available.

Procedural adjuncts

Bronchoscopy: Bronchoscope helps withdrawal of the endotracheal tube prior to the procedure and ascertain position of the tip. Midline placement of needle in the trachea and direction of guidewire insertion can be guided by the bronchoscope. Finally, after placement of tracheostomy tube, its position is confirmed by visualising the tracheobronchial tree *(Figure 2)*. It also helps in preventing accidental injury to the posterior tracheal wall, accidental extubation and insertion of tracheostomy tube in false track leading to pneumothorax and pneumomediastinum. A few trials which have assessed the effect of bronchoscopy on complication rates found no significant difference in complications with or without use of bronchoscope.[15,16] Bronchoscopy increases PEEP and leads to hypercarbia and acidosis. Therefore, care must be taken to adjust ventilator settings to account for partial obstruction and for the physiological effects as well.[17]

Figure 2: Bronchoscopy during percutaneous tracheostomy

Ultrasound: Ultrasound helps to measure the distance from skin to tracheal wall, define the site

of insertion of introducer needle and define the vascular anatomy. Ultrasound has also been used as real time guide for introducer needle and guidewire insertion and for repositioning the endotracheal tube before surgery. Ultrasound is readily available in the ICU and most intensivists are familiar with its usage. However, further studies are required to evaluate whether it has any role in reducing complications and improving safety.[18,19]

Percutaneous dilatational tracheostomy (PDT) technique

Preparation: The pre-procedure check list should include stopping nasogastric feeds, checking the coagulation status and bleeding profile.[20]The patient must be preoxygenated for three minutes with 100% oxygen. Anaesthesia is induced, the patient is paralysed and endotracheal intubation is done if not done already. If already intubated, the patient is sedated and ventilated with adequate PEEP and 100% oxygen.

The patient is then positioned for optimum access by extending the head, keeping a pillow under the shoulders to move the trachea more anteriorly. A 15-20° head up position or tilting the bed helps venous drainage and may reduce bleeding *(Figure 3)*.

Figure 3: Positioning of the patient for percutaneous tracheostomy

A direct laryngoscopy is done to clear the airway of any secretions as well as to assess the grade of laryngoscopy, if reintubation is required. The tracheal tube is pulled back under direct vision and positioned so that the tip is at the level of the cricoid cartilage.The tracheal tube can be pulled back under bronchoscopy vision to aid correct positioning. Alternatively, the endotracheal tube can be removed and a supraglottic airway device (LMA) inserted.

Procedure: Aseptic precautions must be taken as for any other surgical procedure. The skin over an area of at least 10 cm around the proposed incision site is painted with 2% chlorhexidine or iodine preparations and draped appropriately. Lignocaine with adrenaline 1 in 200,000 is injected into the pretracheal tissues midway between cricoid cartilage and suprasternal notch for local anaesthesia. A 1.5- 2 cm horizontal skin incision is made midway between the cricoid cartilage and the suprasternal notch *(Figure 4)*. Blunt dissection with forceps and finger are done until the tracheal rings are felt.The introducer needle and syringe are then advanced in the midline, at 45° to the skin and directed caudally until air is aspirated from the trachea. The midline placement of the needle may be confirmed using bronchoscopy. It can also be used to confirm that the puncture is made either between second and third or the first and second tracheal rings. A puncture between 11 and 1 o'clock position is acceptable and it should be between rather than through the tracheal rings. Aspiration of air or pulmonary secretions confirms entry of the needle into the trachea. If a bronchoscope is not being used, capnography can be used to confirm intratracheal placement.The needle is then removed and cannula is left in place. The guide wire is then passed through the cannula with bronchoscopic guidance to ensure caudal passage. This is followed by the initial dilatation. Subsequent dilatation technique varies depending on the kit used and should apply progressive, controlled pressure between rather than through the tracheal rings.

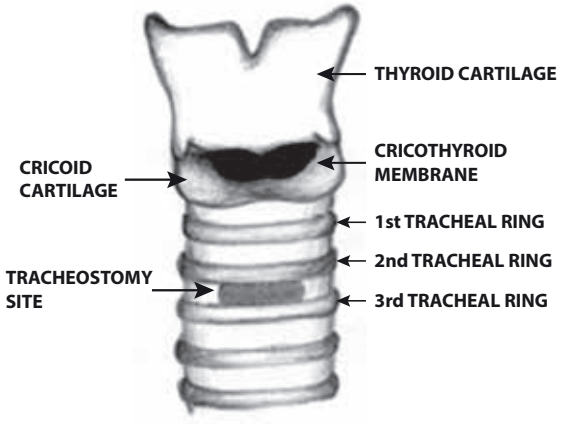

Figure 4: Site of percutaneous tracheostomy

After adequate dilatation of the trachea, a suitable tracheostomy tube is loaded over an introducer and inserted into the trachea along the guidewire. The introducer and guide wire are then removed and bronchoscope is passed through the tracheostomy tube till the carina is identified. Endotracheal suctioning must then be done to remove blood and debris. If the tracheostomy tube is too short, the cuff may be seen to be impinging on the anterior tracheal wall. Capnography also confirms correct placement of the tube. The tracheostomy tube is connected to the ventilator once correct placement of tube is confirmed, the cuff is inflated and ventilation is resumed.The tracheal tube is removed after thorough pharyngeal suctioning. The chest is auscultated for adequate ventilation and the ventilator checked for appropriate tidal volumes and airway pressures. The wings of the tracheostomy tube can be sutured. Chest X-rays are not routinely required if tube placement has been confirmed by bronchoscopy and the procedure has been uneventful. However, chest X-rays can be used as evidence for correct placement of tracheostomy tube and to exclude any pneumothorax. The dose of analgesic and anaesthetic agents should be modified as appropriate.

Specific PDT Techniques

Classic Ciaglia progressive dilatation technique:[2] The trachea is dilated over the guidewire following which a white plastic introducer sheath is passed into the trachea. The trachea is then further dilated gradually with dilators of increasing size passed one after the other. Each dilator is passed upto a safety ridge on it so as to prevent damage to the dilator tip and also kinking of the guidewire. Once the trachea is sufficiently dilated, appropriate size tracheostomy tube loaded on an appropriate size dilator is passed into the trachea over the guidewire *(Figure 5)*.

Griggs wire forceps dilator technique (GWFD):[3] In this technique, following insertion of the guidewire, a dilator forceps with a groove to allow passage of guidewire is inserted into the trachea. The forceps is then opened to dilate the trachea and soft tissues sufficiently. Tracheostomy tube is inserted after this over the guide wire under bronchoscopy guidance *(Figure 6)*.

Ciaglia Blue Rhino Technique:[5] This is a modification of the original Ciaglia serial dilatational technique, using a single tapered dilator known as a *'blue rhino'*. In this technique a stylet is introduced into the trachea over the guidewire over which the blue rhino dilator is passed to dilate the trachea in a single step. Once the trachea is sufficiently dilated the tracheostomy tube loaded over a tube loader of appropriate size is introduced into the trachea over the guidewire. The dilator has markings and it should not be inserted beyond the 40 Fr mark *(Figure 7)*.

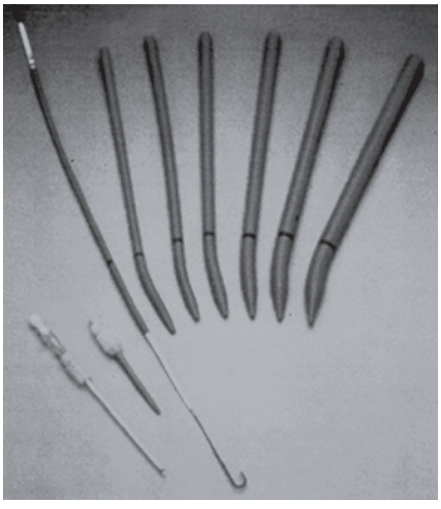

Figure 5: The Ciaglia serial dilator percutaneous tracheostomy set

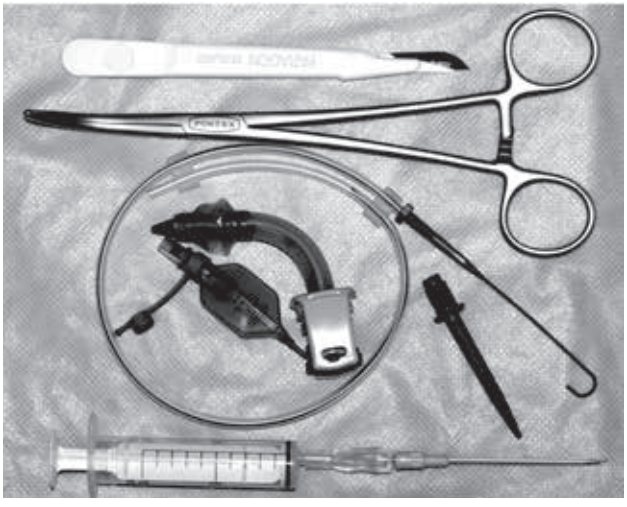

Figure 6: The Grigg's wire forceps dilator set

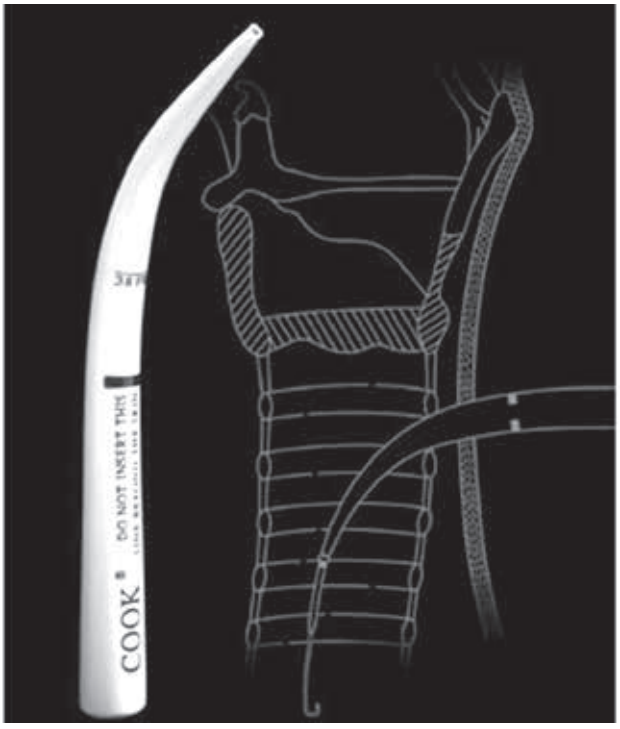

Figure 7: The Blue Rhino tracheal dilator

Fantoni's retrograde technique:[4] Retrograde translaryngeal tracheostomy (TLT) represents the only retrograde one-step minimally invasive procedure. The cannula is inserted into the trachea and the guidewire is directed cranially and brought out through the mouth. The endotracheal tube is replaced with a special 5 mm ID endotracheal tube and the ventilation is maintained. A special tracheostomy device (tracheostomy tube loaded behind the dilator) is inserted over the guidewire and brought out of the trachea to the neck surface. The dilator dilates the trachea in the process. Once the dilator and the tracheostomy tube is brought out sufficiently, the dilator is separated from the tracheostomy tube. The tracheostomy tube is then rotated 180° so that the cuff end faces the carina. Alternately, an obturator passed along the guidewire is used to push the cuff end towards the carina. This technique is not widely practised and requires special training and experience.

Ciaglia Blue Dolphin balloon dilatational technique:[7] This is the latest technique of PDT and is a modification of the Ciaglia's technique. In this technique, a single dilator which has an inflatable balloon is used to dilate the trachea. The dilator is passed into the trachea over the guidewire and the balloon is inflated to dilate the trachea. The balloon is 5.4 cm long and has an outer diameter of 16 mm when fully inflated. The maximum inflation pressure of the balloon is 11 atmospheres. The balloon is thought to generate radial rather than co-axial force and thus prevents injury to the trachea *(Figure 8)*.

Figure 8: Ciaglia Blue Dolphin balloon dilatational technique

PercuTwist:[6] The classical PDT involves the use of excessive force to dilate and insert the tracheostomy tube, which can result in the penetration of the posterior wall of the trachea. To overcome this problem, a new screw-like dilating device that lifts the anterior tracheal wall during dilatation was developed. The tracheal lumen is kept open allowing an unrestricted bronchoscopic view of the dilatation site at any given time. After dilatation, tracheostomy tube is inserted over the guidewire under bronchoscopy vision.

Other techniques: Many PDT kits have been developed on similar lines with modifications such as speculum like tracheostome, cutting bougie device, rapitrach tracheostome and Ambesh T trach kit.

Comparison of various techniques

Although PDT is a very popular procedure, not all types of kits are universally available. Ciaglia's single dilator technique is the most popular one and also

the one, which is widely available. Trials comparing complications are rare making comparison difficult. However, the limited available data show that the single dilator technique had a higher rate of tracheal ring fracture compared to the multiple dilator technique and the Griggs's forceps technique.[21] The translaryngeal technique had higher incidence of loss of airway and switching to other method of tracheostomy.[22]

Complications

Complications can be classified as periprocedural, early and late.

Periprocedural and early: Haemodynamic instability, arrhythmias, hypoxia, hypercarbia, loss of airway, obstruction of airway, trauma including tracheal ring fracture, insertion in false passage, subcutaneous emphysema, pneumothorax, pneumomediastinum, difficulty requiring conversion to surgical technique, wound infection and bleeding.

Late: Tracheal stenosis, scar formation, wound infection, persistent stoma (postdecannulation), difficulty in swallowing, voice change and poor cough.

Mortality rate is 0-0.7%. In a recent study, the authors estimated the incidence of death of 1 in 600.[23]The main causes of death were bleeding (major vessel), airway complication such as loss of airway, false passage insertion of tracheal tube and tracheal perforation.The safety measures advised by the authors include careful choice of patient and using a bronchoscope to guide the entire procedure. An experienced team must perform the procedure. A low puncture site and kinking of guidewire must be avoided. The outer flange of the tracheostomy tube must be secured with sutures.

PDT in special situations

Cervical spine injury: There will be difficult access to the trachea in patients with cervical spine injury due to immobility of the spine. The proximity of tracheostomy site to surgical wound and immune suppressed state makes them prone to wound infection. Several small studies have found PDT to be equally safe as surgical tracheostomy.[24]

Obesity: Obesity makes identification of anatomical landmarks difficult, increases risk of creation of false passage, accidental decannulation, injury to adjacent vital structures and hypoxia during the procedure. However, there are conflicting views regarding safety of PDT in obese patients based on clinical trials.[25,26]

High positive end expiratory pressure (PEEP): Endotracheal tube cuff deflation during tracheostomy can lead to loss of PEEP and derecruitment of alveoli and hypoxia. Beiderlinder*et al* demonstrated that during PDT using bronchoscopy in patients requiring high PEEP, there was no significant deterioration in oxygenation as demonstrated by PaO_2/FIO_2 ratio, 1h and 24h postprocedure compared to the preprocedure values. Use of bronchoscope prevents the loss of PEEP.[27] PDT being performed in patients receiving high frequency oscillatory ventilation (HFOV) has also been reported.[28] It is recommended to perform recruitment manoeuvre before the procedure, maintain 100% O_2 and use bronchoscope to prevent derecruitment of alveoli in patients receiving high PEEP.

Coagulopathy: Coagulopathy is very common in ICU patients and also many of them will be on antiplatelets and anticoagulants, which increases risk of periprocedural bleeding. There are reports of PDT being performed in patients with severe coagulopathy and transplant recipients but further trials are required to evaluate the safety of PDT in patients with coagulopathy.[29]

Training

PDT is safely performed by intensivists, pulmonologists, anaesthesiologists, emergency physicians and otolaryngologists. Like any other procedure, it requires adequate training. American College of Chest Physicians recommends a minimum of twenty procedures and European Respiratory Society recommends a minimum of 5-10 procedures to be performed before performing PDT independently and continue performing at least 10 procedures per year to maintain competence.[30,31] Many other practice guidelines have been published which suggest that every institute should have their own policy, which should be revised based on audit data of their own hospital and new research.[32]

Summary

PDT can be safely performed by adequately trained personnel in carefully selected patients in ICU setting with adequate facilities to deal with all potential complications.Use of bronchoscopy adds to the safety although there is no strong evidence. The type of kit used depends on availability and familiarity with the technique. More studies are required to demonstrate safety in patients with cervical spine injury, coagulopathy and in those requiring high PEEP.

References

1. Toye FJ, Weinstein JD. A percutaneous tracheostomy device. *Surgery* 1969; **65**:384-9.
2. Ciaglia P, Firsching R, Syniec C. Elective percutaneous dilatational tracheostomy: a new simple bedside procedure; preliminary report. *Chest* 1985;**87**:715-9.
3. Griggs WM, Worthley LIG, Gilligan JE, Thomas PD, Myburg JA. A simple percutaneous tracheostomy technique. *Surg Gynec Obstet* 1990;**170**:543-5.
4. Fantoni A, Ripamonti D. A non-derivative, non-surgical tracheostomy: the translaryngeal method. *Intensive Care Med* 1997; **23**:386-92.
5. Byhahn C, Wilke HJ, Halbig S *et al.* Percutaneous tracheostomy: Ciaglia Blue Rhino versus the basic Ciaglia technique of percutaneous dilational tracheostomy. *Anesth Analg* 2000; **9**:882-6.
6. Frova G, Quintel M. A new simple method for percutaneous tracheostomy: controlled rotating dilation. A preliminary report. *Intensive Care Med* 2002; **28**:299-303.
7. Gromann TW, Birkelbach O, Hetzer R. Balloon dilational tracheostomy. Technique and first clinical experience with the Ciaglia Blue Dolphin method. *Chirurg* 2009; **80**:622-7.
8. Higgins KM, Punthakee X. Meta-analysis comparison of open versus percutaneous tracheostomy. *Laryngoscope* 2007; **117**:447-54.
9. Papson JP, Russell KL, Taylor DM. Unexpected events during the intrahospital transport of critically ill patients. *Acad Emerg Med* 2007; **14**:574-7.
10. Mirski MA, Pandian V, Bhatti N, *et al.* Safety, efficiency, and cost-effectiveness of a multidisciplinary percutaneous tracheostomy program. *Crit Care Med* 2012;**40**:1827-34.
11. Scales D C, Thiruchelvam D, Kiss A, Redelmeier D A. The effect of tracheostomy timing during critical illness on long-term survival. *Crit Care Med* 2008; **36**:2547-57.
12. Griffiths J, Barber VS, Morgan L, Young DJ. Systemic review and meta analysis of studies of the timing of tracheostomy in adult patients undergoing mechanical ventilation *BMJ* 2005; **330**:1243.
13. Wang F, Wu Y, Bo L, *et al.* The timing of tracheostomy in critically ill patients undergoing mechanical ventilation. *Chest* 2011;**140**:1456-65.
14. Young D, Harrison DA, Cuthbertson BH, Rowan K. TracMan Collaborators. Effect of early vs. late tracheostomy placement on survival in patients receiving mechanical ventilation: the TracMan randomized trial. *JAMA* 2013;**303**:2121-9.
15. Kost KM. Endoscopic percutaneous dilational tracheotomy: a prospective evaluation of 500 cases. *Laryngoscope* 2005;**115**:1-30.
16. Jackson LS, Davis JW, Kaups KL, *et al.* Percutaneous tracheostomy: to bronch or not to bronch - that is the question. *J Trauma* 2011; **71**:1553-6.
17. Lindholm CE, Ollman B, Snyder JV, *et al.* Cardiorespiratory effects of flexible fiberopticbronchoscopy in critically ill patients. *Chest* 1978; **74**:362-8.
18. Kollig E, Heydenreich U, Roetman B, *et al.* Ultrasound and bronchoscopic controlled percutaneous tracheostomy on trauma ICU. *Injury* 2000; **31**:663-8.
19. Rajajee V, Fletcher JJ, Rochlen LR, *et al.* Real-time ultrasound-guided percutaneous dilatational tracheostomy: a feasibility study. *Crit Care* 2011; **15**:R67.
20. Rajendran G, Hutchinson S. Checklist for percutaneous tracheostomy in critical care. *Crit Care* 2014;**18**:425.
21. Cantais E, Kaiser E, Le-Goff Y, *et al.* Percutaneous tracheostomy: prospective comparison of the translaryngeal technique versus the forceps

dilational technique in 100 critically ill adults. *Crit Care Med* 2002;**30**:815-9.
22. Ambesh SP, Pandey CK, Srivastava S, *et al*. Percutaneous tracheostomy with single dilatation technique: a prospective, randomized comparison of Ciaglia Blue Rhino versus Griggs' guidewire dilating forceps. *Anesth Analg* 2002;**95**:1739-45.
23. Simon M, Metschke M, Braune S A, *et al*. Death after percutaneous dilatational tracheostomy: a systematic review and analysis of risk factors. *Crit Care* 2013, **17**:R258
24. Ganuza JR, Forcada AG, Gambarrutta C, *et al*. Effect of technique and timing of tracheostomy in patients with acute traumatic spinal cord injury undergoing mechanical ventilation. *J Spinal Cord Med* 2011; **34**:76-84.
25. McCague A, Aljanabi H, Wong DT. Safety analysis of percutaneous dilational tracheostomies with bronchoscopy in the obese patient. *Laryngoscope* 2012; **122**:1031-4.
26. Heyrosa MG, Melniczek DM, Rovito P, *et al*. Percutaneous tracheostomy: a safe procedure in the morbidly obese. *J Am Coll Surg* 2006; **202**: 618-22.
27. Beiderlinden M, Groeben H, Peters J. Safety of percutaneous dilational tracheostomy in patients ventilated with high positive end-expiratory pressure (PEEP). *Intensive Care Med* 2003; **29**:944-8.
28. Shah S, Morgan P. Percutaneous dilation tracheostomy during high-frequency oscillatory ventilation. *Crit Care Med* 2002; **30**:1762-4.
29. Veelo DP, Vlaar AP, Dongelmans DA, *et al*. Correction of subclinical coagulation disorders before percutaneous dilatational tracheotomy. A randomised controlled trial. *Blood Transfus* 2012; **10**:213-20.
30. Ernst A, Silvestri GA, Johnstone D, American College of Chest Physicians. Interventional pulmonary procedures: Guidelines from the American College of Chest Physicians. *Chest* 2003; **123**:1693-717.
31. Bolliger CT, Mathur PN, Beamis JF, *et al*, European Respiratory Society/American Thoracic Society. ERS/ATS statement on interventional pulmonology. *Eur Respir J* 2002; **19**:356-73.
32. Burrell T, Sampson B. ANZICS, Percutaneous dilatational tracheostomy consensus statement, 2010.