

Pneumothorax during percutaneous tracheostomy — a brief review of literature on attributable causes and preventable strategies

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Abstract

The significant advantages of percutaneous tracheostomy over surgical (open) tracheostomy has enabled its wide-spread acceptability and practice in intensive care units. Over the years, various modifications in the technique of percutaneous tracheostomy has increased its safety profile and reduced the overall complication rate. However, even though it is a bedside procedure, inappropriate patient selection and poor adherence to protocols can lead to devastating complications. One such complication, namely pneumothorax, is often overlooked. In this article, we have highlighted all the possible etiologies of pneumothorax during percutaneous tracheostomy. A brief insight into some of the preventable strategies is also discussed.

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Tracheostomy is one of the most frequently performed surgical procedures in intensive care unit (ICU) patients requiring prolonged ventilatory support [1, 2]. Percutaneous tracheostomy (PT), commonly performed at the bedside, has now become the method of choice for securing an airway in critically ill patients and has gained widespread acceptance as an alternative to open surgical tracheostomy (ST). Its significant advantages include a relatively easy technique, its being less time-consuming and cost effective, along with minimal bleeding and a lower infection rate [3, 4].

HISTORY

The percutaneous technique was first described by Shelden *et al.* in 1955 [5]. In 1985, Ciaglia *et al.* [6] described a percutaneous dilational tracheostomy (PDT) using progressive renal dilators to create a stoma through a small skin incision below the cricoid cartilage. Various other modifications of PT (Griggs [7], Fantoni [8], Percu-Twist [9]) were designed to minimize anterior tracheal wall compression, tissue trauma and avoid injury to the posterior wall during

the dilation of the stoma. Nevertheless, the most popular technique currently used for PT is the conic dilational tracheostomy (CDT) that was introduced in 1999 [10]. This technique is better known as the Blue Rhino technique (Ciaglia Blue Rhino, COOK Medical Inc. Bloomington, IN) and is an amalgamation of the advantages of the other techniques mentioned (i.e. Ciaglia, Griggs, Fantoni).

PNEUMOTHORAX AND ATTRIBUTABLE CAUSES

The standard technique of ST has a complication rate of up to 66% [11–13]. Even though PT is a relatively safe procedure, the rate of overall perioperative complications is still 19% [14]. It is accompanied by both trivial and non-trivial complications. One of the frequently documented lethal complications of PT is pneumothorax (unilateral or bilateral), occurring in 0.8% of cases [15]. Even though subcutaneous emphysema is not always a symptom of pneumothorax, it should always be taken into consideration when subcutaneous emphysema occurs. In this article, we have made an attempt to discuss all the possible etiologies that can lead

to pneumothorax during PT. The following discussion also gives an insight into the preventable measures that can be taken to avoid this major complication that substantially increases morbidity and mortality.

The most important cause that has been advocated for causing pneumothorax is perforation of the posterior tracheal wall, the reason being the close approximation of the posterior tracheal wall and the dome of the pleura. The distance between the dorsal tracheal wall and the pleural cavity in a cadaver model is approximately 5 mm. Moreover, pleural puncture is possible even after midline dorsal tracheal perforation, possibly resulting in pneumothorax [16–18]. This can be explained by the fact that the pleural cavity is not limited to the lateral regions of the trachea, but extends around the lateral tracheal wall to the posterior tracheal wall. Injury to the posterior tracheal wall may also be caused by improper stabilization of the guidewire and guiding catheter, allowing them to move along the posterior tracheal wall [18]. Another mechanism of damage to the posterior tracheal wall is laceration by the tip of the tracheostomy tube (TT) introducer as reported by Douglas *et al.* [19]. Even though extremely rare, direct placement of a TT in the pleural cavity has also been reported [20].

Another mechanism of pneumothorax is the paratracheal placement of the TT (false tract) complicated by positive pressure ventilation leading to pneumomediastinum, ultimately resulting in pneumothorax if the air ruptures into the mediastinal cavity. Tension pneumothorax can result when the intrapleural pressures exceed the atmospheric pressure [21].

A few publications have also described barotrauma as a possible mechanism for the development of pneumothorax. In a series of 100 consecutive patients undergoing PT, Fikkers *et al.* [22] described in their study how pneumothorax in one of the patients was due to intratracheal bleeding, eventually leading to the formation of clots and the rapid escalation of airway peak pressures (ball valve mechanism). Other factors that may result in increased peak pressures are: 1) the diameter of Blue Rhino dilator itself, which occupies a large portion of the tracheal lumen and thus decreases the tracheal cross-sectional area and increases resistance; and 2) the fact that the tracheal lumen is also compressed by the pressure required to pass the dilator over the guidewire. More important than the increased peak airway pressure is the potential for expiratory obstruction and dynamic hyperinflation of the lungs [23].

Moreover, in patients with COPD, the risk of puncturing a lung is higher because of a higher pleural dome. Rupture of an emphysematous bulla as a result of an increase in peak airway pressure and air trapping, explains another possible mechanism that results in pneumothorax [23]. A similar mechanism applies to patients who maintain oxygenation in high positive end expiratory pressure (PEEP) therapy during the period of mechanical ventilation.

PREVENTABLE STRATEGIES

PRE-PROCEDURAL PREPARATIONS

Proper selection of patients is of prime importance. The incidence of complications tend to be higher when PT is performed in conditions where it is contraindicated. Some of these contraindications include: marked obesity obscuring anatomical landmarks; coagulopathy; scarring or oedema in the operative field; emergency procedures; and unstable cervical spine. One must ensure adequate sedation and analgesia, preferably with a neuromuscular blockade using a short-acting intravenous paralytic agent in order to minimize coughing, biting and motion of the neck and trachea during the procedure. Although the literature does not convincingly support using ultrasound (US) routinely, but rather as an adjunct in selected patients, several studies have shown that ultrasound performed prior to PT may be useful in avoiding injury to pretracheal vascular structures and in avoiding high placement of the tube [24].

DURING PROCEDURE

Routine use of a fiberoptic bronchoscope (FOB) has been shown to reduce the incidence of complications and several studies advocate its routine use. Bronchoscopic visualization during PT provides additional safety in preventing posterior wall trauma and confirming the exact location of the needle placement [25, 26]. In recent times, the use of real time ultrasound (US) during PT has been shown to decrease perioperative complications. Rajajee *et al.* [27] conducted a study on 13 patients and advocated that PT performed under real time US guidance is a feasible option and accurately displays the needle path and prevents posterior wall injury.

After a careful transverse/vertical skin incision and soft tissue dissection, the trachea should always be cannulated in its midline and preferably below the level of the cricoid cartilage, aiming for the interspace between first and second, or second and third tracheal rings. Very low incision has been implicated to be one of the reason for the development of pneumothorax. This occurs due to the possibility of puncturing the dome of the pleura in case of accidental posterior tracheal wall perforation [16]. Moreover, the needle should be advanced very gradually and stabilised as soon as loss of resistance is appreciated and confirmed by the aspiration of air. The guidewire should be advanced caudally through the introducer needle and stabilised in place so as to prevent perforation of the posterior tracheal wall. Ideally, the use of an FOB can clearly delineate the direction of the needle tip and, subsequently, the advancement of the guidewire. The tract should be dilated using a series of dilators of increasing calibre and simultaneously avoiding prolonged expiratory flow obstruction and accentuating airway pressure. Once the TT is inserted, its correct placement should be confirmed immediately so as to avoid a lethal outcome.

POST-PROCEDURAL PERIOD

One should check the capnography, ventilation (visible chest rise and breath sounds) and peak airway pressures at the end of the procedure. The accurate placement of the TT, preferably using the FOB or a chest radiography (CXR), should be confirmed. One must ensure that the TT is patent and not obstructed by blood clots or tenacious secretions.

A bedside US can promptly and accurately diagnose pneumothorax. Sonographic signs, including 'lung sliding', 'B-lines' or 'comet tail artifacts', 'A-lines', and 'the lung point sign', can help in the diagnosis of a pneumothorax. US has a higher sensitivity than the traditional upright anteroposterior chest radiography (CXR) for the detection of pneumothorax. Moreover, small occult pneumothoraces may be missed on a CXR [28]. A Computed Tomography (CT scan), even though considered as a gold standard modality for the detection of pneumothorax, should only be resorted to in cases of high clinical suspicion and those not detected by either CXR or US. Finally, if pneumothorax occurs, it should be managed appropriately without delay.

Thus, even though infrequent, pneumothorax *per se* during PT increases morbidity and mortality in critically ill patients. As the saying goes: "Prevention is always better than cure", and we believe that focussing attention onto all the possible etiologies discussed above helps to prevent this unwanted lethal complication.

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