Assessment of Ventilation During the Performance of Elective Endoscopic-Guided Percutaneous Tracheostomy*

Clinical Evaluation of a New Method

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Study objectives: To evaluate the feasibility of uninterrupted translaryngeal open ventilation delivered through a pediatric, uncuffed endotracheal tube during percutaneous endoscopic tracheostomy (PET).

Design and setting: Prospective, observational clinical study in a six-bed ICU of a university hospital.

Patients: Forty consecutive adult patients requiring an elective tracheostomy.

Interventions: We employed the basic Ciaglia technique with multiple dilators (n = 10), a single dilator (n = 15), and the Fantoni method (n = 15). During PET, pressure-controlled ventilation was maintained through an uncuffed, 4-mm inner-diameter pediatric tube. The fraction of inspired oxygen was 1.0. Ventilator settings were as follows: pressure-controlled ventilation, 40 cm H2O; respiratory rate, 25/min; inspiratory time, 1.2 s of inspiratory time (inspiratory/expiratory ratio, 1:1); and positive end-expiratory pressure, 0 cm H2O.

Measurements and results: Measurements of arterial blood gas (ABG) tensions were obtained before the start of each tracheostomy and every 3 min during the procedure. An average of 8.28 ± 2.28 ABG measurements were obtained from each patient (±SD). All patients were successfully assisted during performance of the tracheostomy, and no patient required ventilation through a cuffed endotracheal tube. The maximum increase in PaCO2 was 8.49 ± 5.50 mm Hg, and the maximum decrease in pH related to hypercarbia was 0.04 ± 0.04. The PaO2 increased in all patients (maximum change, 69.75 ± 57.00 mm Hg; p < 0.01), and no patient had desaturation during the procedure.

Conclusions: The technique that we propose for airway management during PET was safe and effective. A mild increase in PaCO2 was not associated with significant metabolic and hemodynamic consequences, and an adequate PaO2 was maintained throughout the study.

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Key words: pediatric tracheal tube; percutaneous endoscopic tracheostomy; pressure-controlled ventilation; translaryngeal open ventilation

Abbreviations: ABG = arterial blood gas; CBR = Ciaglia Blue Rhino; Fio2 = fraction of inspired oxygen; ID = inner diameter; PDT = percutaneous dilational tracheostomy; PET = percutaneous endoscopic tracheostomy; TLT = translaryngeal tracheostomy; TOV = translaryngeal open ventilation

Tracheostomy is a routine procedure in critically ill patients to facilitate weaning from the ventilator, nursing care, and patient comfort. In the last few years, a number of percutaneous tracheostomy procedures have been established, including percutaneous dilational tracheostomy (PDT) according to Ciaglia et al., and the translaryngeal tracheostomy (TLT) according to Fantoni and Ripamonti. Percutaneous techniques are a cost-effective alternative to traditional surgical tracheostomy performed in the operating room, and have been associated with lower postoperative risk of bleeding and infection. The

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use of bronchoscopic guidance has reduced intraprocedural complications, such as para- tracheal false passage, pneumothorax, and tracheal lesion.4–7 In the past 5 years, we have routinely performed either PDT or TLT under bronchoscopic visualization with few complications. However, some problems have not yet been solved, including the frequent onset of hypercarbia due to inadequate ventilation.8,9 Hypoventilation during these procedures is probably related to the use of bronchoscopic guidance and intraluminal dilators. Methods have been proposed10–14 to assist ventilation during the performance of percutaneous tracheostomies, but none seems to provide safe and continuous ventilation for critically ill patients who have a decreased tolerance for desaturation. During PDT, failure to place the endotracheal tube correctly may result in cuff puncture or tube transection by the needle, while a very proximal tube position provides little margin of safety against accidental extubation.10 During TLT, ventilation is not provided continuously during the whole procedure.2 The assurance of ventilation is crucial in critically ill patients, as they cannot tolerate the risks associated with prolonged apnea or accidental extubation.

We evaluated the use of an alternative method to provide continuous ventilation during percutaneous endoscopic tracheostomy (PET) through a pediatric, uncuffed endotracheal tube (inner diameter [ID], 4 mm; 220 to 245 mm in length). The aim of this study was to evaluate the effectiveness of the pediatric tube in providing ventilation during PET.

**Materials and Methods**

**Patients**

We prospectively studied 40 consecutive adult patients requiring elective tracheostomy in a general ICU of an academic institution (six beds equipped with ventilators) over a 2-year period. The study was conducted according to the principles established in the Declaration of Helsinki. Informed consent was obtained from the patients or their next of kin before each procedure. The main indications for tracheostomy were anticipated prolonged dependency on mechanical ventilation, control of the airway, and need for suctioning. Exclusion criteria for a percutaneous tracheostomy were as follows: coagulopathy (platelet count < 50,000/μL; international normalized ratio ≥ 2.5), infection and/or serious inflammation in the soft tissues of the neck, pathology of the upper airway (only in the Fantoni technique), and previous surgery or trauma of the neck.

All tracheostomies were performed at the bedside by ICU staff anesthesiologists. Ten patients underwent PDT with progressive multiple dilators (basic Ciaglia; n = 10), 15 patients underwent single one-step dilator Ciaglia Blue Rhino (CBR) technique,15 and 15 patients underwent TLT. The tracheostomy method was chosen by the operator according to clinical criteria. In particular, the TLT was generally preferred in adults with poorly visible anatomic landmarks, while the Ciaglia technique was chosen for the other cases. Table 1 presents the baseline patient clinical and respiratory characteristics.

**Technique**

Patients were anesthetized by administration of propofol (2 mg/kg) or midazolam (0.15 mg/kg), fentanyl (2 to 4 μg/kg), and neuromuscular blockade was provided with atracurium (0.5 mg/kg). Heart rate (ECG), oxygen saturation, and arterial BP were continuously monitored. Each patient had an indwelling arterial catheter. Arterial blood gas (ABG) samples were obtained before the start and every 3 min during the procedure.

Airway management was similar for all three groups. Before starting the procedure, secretions were cleared by catheter suction. The patient was extubated and reintubated by a tube exchange or direct laryngoscopy, using a 220- to 245-mm-long, 4.0-mm-ID pediatric, uncuffed endotracheal tube (Rüsch; Bjaeverskov, Denmark; Portex Limited; Hythe, Kent, UK). The rhino-tracheal insertion of the flexible fiberoptic bronchoscope (6.0 mm) was performed, and the pediatric tube position, with the tip at the carina level, was confirmed (Fig 1). We employed an Evita 2 Dura ventilator in all patients enrolled in the study. The following ventilator settings were maintained throughout the study: pressure-controlled ventilation, 40 cm H₂O; respiratory rate, 23/min; inspiratory time, 1.2 s (inspiratory/ expiratory ratio, 1:1), positive end-expiratory pressure, 0 cm H₂O; and fraction of inspired oxygen (Fio₂), 1.0. The patients were placed with their necks hyperextended; the surgical field was prepared with povidone-iodine solution and sterile drapes. The cricothyroid membrane and the trachea were palpated and manually immobilized between the forefinger and the thumb to ensure midline placement of the needle into the first or second tracheal interspace.

In the basic Ciaglia group, we used the Ciaglia Percutaneous Tracheostomy Introducer Set; in the CBR group, we used the Ciaglia Blue Rhino (William Cook Europe; Bjaeverskov, Denmark). The tracheostomy was performed with conventional methods.15 In both groups, the whole procedure, from puncture of the trachea until the tracheostomy tube placement, was performed under continuous bronchoscopic visualization and with a pediatric tube in place (Fig 2).

In the TLT group, instead of the rigid tracheoscope from the kit (Translaryngeal Tracheostomy TLT, Fantoni Method; Mallinckrodt DAR, Mirandola, Italy), we used the flexible bron-

| Table 1—Clinical and Respiratory Characteristics of the Patients Before the Procedure* |
|---|---|
| Variables | Data |
| **Demographics** | |
| Age, yr | 66 ± 14.83 |
| Male/female gender | 18/22 |
| **APACHE III score** | 56.80 ± 24.03 |
| **Timing, d** | 7.30 ± 3.74 |
| **Diagnosis** | |
| Neurologic disease | 12 |
| COPD | 11 |
| Sepsis and acute respiratory failure | 8 |
| Cardiac disease | 9 |
| **ABG** | |
| pH | 7.39 ± 1.10 |
| Paco₂ | 39.58 ± 11.99 |
| PaO₂/Fio₂ | 233.41 ± 94.83 |

*Data are presented as mean ± SD or No.
choscope inserted parallel to the pediatric tube. The whole procedure (needle insertion, guidewire introduction, passage of the cannula through the larynx and anterior tracheal wall, and straightening and rotation of the tracheostomy tube) is performed under direct vision by bronchoscope. This step avoids the use of the rigid kit obturator, which could be dangerous for the pars membranacea during the craniocaudal rotation of the tip. Moreover, the pediatric cuffless tube allows an easier cannula rotation, so the tube can be left in place throughout the procedure (Fig 3). In all three groups, at the end of each procedure a bronchoscopic examination was performed through the tracheostomy tube to confirm its correct placement and the absence of bleeding in the airway (Fig 4).

Statistics
Results are presented as change from baseline. For each of the procedures tested, we used the value of maximal change in PaCO₂, arterial pH, and in PaO₂ from baseline for the analysis, expressed as the mean ± SD. Comparisons were made using paired Student t test. To evaluate the overall impact of each tracheostomy technique on the PaCO₂, we compared the changes of ABG tensions in the three study groups using one-way analysis of variance, followed by post hoc Newman-Keuls test when appropriate. A p value < 0.05 was considered statistically significant.

Results
Forty adult patients underwent elective PET (Table 1). There were no significant differences between the three groups in terms of age, sex, timing, acute physiology and chronic health eval-

Figure 1. Rhinotracheal insertion of the flexible fiberoptic videobronchoscope and confirmation of the pediatric tube position, with the tip at the carina level (inset).

Figure 2. CBR procedure (videobronchoscope assisted) with pediatric tube positioned. Top left, a: intercartilaginous placement of the introducer needle; top center, b: guidewire insertion; top right, c: 14F introducer dilator positioned over the guidewire; bottom left, d: placement of the guiding catheter; bottom center, e: straightening phase by CBR single dilator; bottom right, f: tracheostomy tube placement.

Figure 3. TLT procedure (videobronchoscope assisted) with pediatric tube positioned. Top left, a, and top center, b: curved needle and flexible guidewire insertion, with pediatric tube in bottom; top right, c: passage of the Fantoni cannula through the larynx and tracheal lumen, with pediatric tube on the right; bottom left, d, and bottom center, e: straightening and rotation of the cannula, with pediatric tube on the left bottom; bottom right, f: Fantoni tube positioned and tip of the pediatric tube withdrawn in bottom.

Figure 4. Bronchoscopic examination through the cannula to confirm its correct placement, with pediatric tube in place before inflating the tracheostomy tube cuff (inset).
ulation (APACHE) III score, and gas exchange values. All tracheostomies were successful; no significant intraprocedural complications (eg, hypoxia, bleeding, hypotension, lesion of posterior tracheal wall) were noted. In one case, during the performance of a CBR procedure, we observed the fracture of the tracheal ring during the dilation phase. The mean operation time, from incision of the skin to insertion of the tracheostomy tube, was significantly shorter for CBR (2.45 ± 1.36 min) than for PDT (6.12 ± 2.15 min) and TLT (9.34 ± 3.28 min) [p < 0.05]. Patients received ventilation with this method for 27.09 ± 7.00 min. No patients required standard ventilation through a cuffed endotracheal tube. An average of 8.28 ± 2.28 ABG specimens were obtained for each patient. The PaCO₂ increased in all patients (maximum change, 69.75 ± 57.00 mm Hg; p < 0.01), and no patient had desaturation during the whole procedure. The main results of the study are shown in Table 2. The average baseline PaCO₂ was 39.58 ± 11.99 mm Hg. The maximum increase in PaCO₂ was 8.49 ± 5.50 mm Hg (p < 0.001), and the maximum decrease in pH related to hypercarbia was 0.04 ± 0.04 (p < 0.01). There were no statistically significant differences among the three groups in the maximum change in PaCO₂, pH, and PaO₂.

**Discussion**

Percutaneous tracheostomy has been proven to be a valid alternative to traditional, surgical tracheostomy performed in the operating room. The addition of bronchoscopic guidance has increased the safety of the procedure and may prevent complications such as the creation of a false passage, posterior tracheal wall damage, pneumothorax, and subcutaneous emphysema. However, the presence of the bronchoscope and of the dilators inside the lumen of the tractheal tube could produce airway obstruction and lead to hypoventilation, hypercarbia, and hypoxemia. Reilly et al described the occurrence of hypercarbia during PET with the Ciaglia method. A significant increase of PaCO₂ has been also described during TLT, specifically during the placement of the cannula.

Various methods have been proposed to improve airway management during percutaneous tracheostomy, with the aim of preventing hypoventilation and avoiding interference of the needle and endoscopic devices with the endotracheal tube. The use of the laryngeal mask airway as an alternative to the endotracheal tube has proven satisfactory during the performance of PDT. However, the use of an laryngeal mask airway could be associated with a decrease in PaO₂, because the inspired oxygen flow is administered into an airway obstructed by the dilators; the same difficulty may also occur when ventilation is provided by withdrawing the endotracheal tube. Furthermore, this may contribute to the development of subcutaneous emphysema during the performance of PDT. An alternate strategy is to use an endotracheal tube exchanger (ID, 4.7 mm) inserted into the endotracheal tube to restore ventilation in case of inadvertent extubation.

During endoscopic TLT, several authors suggest using an adult flexible fiberbronchoscope introduced into the endotracheal tube after its withdrawal to the vocal cords, to directly assess the tracheal puncture and the retrograde passage of the guidewire. After the tracheal-dedicated cannula has been connected to the wire, the airway is reintubated using a smaller cuffed tube (ID, 4 mm; 400 mm in length). At the end of the procedure, the patient is extubated, and the tracheostomy cannula is straightened and settled in place under apneic conditions. During this final maneuver, ventilation and airway control are not ensured, with risk of desaturation in cases of prolonged and difficult straightening and rotation. In the first Fantoni description, the rotation of the cannula is performed without removing the set cuffed catheter, but the presence of the cuff may obstruct the rotation and correct placement of the cannula.

We evaluated the use of a pediatric, uncuffed endotracheal tube (220 to 245 mm in length; ID, 4.0 mm) to maintain ventilation during the performance

| Table 2—Duration of Each Procedure and the Maximum Change in PaCO₂, pH, and PaO₂* |
|-----------------------------------|----------------|----------------|----------------|------------------|
| Variables                        | CBR (n = 15)   | PDT (n = 10)   | TLT (n = 15)   | p Value          |
| Procedure time, min              | 2.45 ± 1.36    | 6.12 ± 2.15    | 9.34 ± 3.28    | 0.0011 ‡         |
| ΔPaCO₂ mm Hg                     | 8.53 ± 6.57    | 7.15 ± 3.60    | 9.65 ± 4.39    | 0.674 †          |
| ΔpH                              | 0.05 ± 0.04    | 0.02 ± 0.04    | 0.04 ± 0.03    | 0.146 †          |
| ΔPaO₂ mm Hg                      | 75.39 ± 52.04  | 71.06 ± 36.83  | 77.83 ± 80.30  | 0.972 †          |

*Data are presented as mean ± SD. †One-way analysis of variance. ‡p < 0.05 for all groups with Newman-Keuls test.
of both PDT and TLT. Our results show a moderate increase in PaCO₂, similar to that of the other few reports in the literature. The degree of respiratory acidosis was not different among the three techniques employed, suggesting that this technique of airway management is safe and effective whichever tracheostomy method is used. In addition, the oxygenation was adequate without a transient drop in arterial saturation even during the dilation phase, in part because the FiO₂ was maintained at 1.0 throughout the procedure, but also because we ensured a continuous oxygen flow at the carina.

This technique of airway control requires the reintubation of the trachea. This procedure could have itself some risks in case of difficult airway management (laryngeal edema, tracheal stenosis, inflammation, etc.). In patients with prolonged timing or history of difficult intubation, we used a tube exchange for atraumatic replacement of the endotracheal tube. The endotracheal intubation and paralysis of the patient reduce the risk of airway loss during tracheal surgery. The lack of the cuff and the small size of the tube allow a large operating field and a clear visualization, so that the pediatric tube can remain in site during the whole procedure. Furthermore, the pediatric tube is shorter than the Fantoni tube used in TLT and reduces the risk of selective intubation.

During the procedure, we used translaryngeal open ventilation (TOV). Skrobik and Gregoretti employed a similar method of TOV to treat patients with COPD exacerbation, for a period of 3 days, with satisfying results. Examples of transtracheal open ventilation through a minitracheostomy tube are also reported. Uchiyama et al examined the physiologic effects that TOV provided in postexubated patients and in a lung model; their studies proved that TOV effectively assisted the inspiration of patients after extubation, also with higher level of upper airway resistance. When a small size tube is used, high airway pressure (40 to 45 cm H₂O) in the ventilator circuit will be generated. An effective way to achieve this during TOV is to use a pressure target mode. Because of the difficulty in measuring the overall expired volumes, the tidal volume and minute volume ventilation alarms were turned off. Thus, we were able to monitor only the volume delivered by the ventilator (inspiratory tidal volume). The inspiratory/expiratory ratio we used was 1:1; whereas a long inspiration time is likely to result in expiratory resistance, a shorter inspiratory time may reduce the effect of inspiratory assistance. We focussed on providing PaO₂ and PaCO₂ values in an acceptable range.

Because of difficulty in providing adequate ventilation with the bronchoscope in place (due to reduced exhaled volumes), some authors suggest minimizing the time the bronchoscope is in the endotracheal tube. We think this is inadvisable because it is important to directly visualize not only the needle puncture but the whole dilation procedure. Others prefer to use a small-size pediatric bronchoscope, but this does not permit secretions to be adequately cleared from view. The small diameter of the pediatric tube reduces the obstruction of the airway during stomal dilation and allows use of the bronchoscope throughout the procedure. As an additional safety maneuver, we carefully place the tip of the pediatric tube at the carina level under bronchoscopic visualization, which prevents the aspiration of the blood into the airway as the inspiratory oxygen flow is inflated beyond the tracheal bleeding while the expiratory flow push out the blood through the hypopharynx and the mouth.

Conclusions

The new technique we propose for the airway management during tracheostomy performance seems to be safe and effective. It is a simple and rapid technique that can be performed with materials commonly available in the ICU. This technique ensures adequate ventilation even if complications such as bleeding prolong the surgical time. The results of this preliminary experience show that the method proposed might substitute for the other techniques of airway management currently in use. However, we think further evaluation in a large randomized controlled clinical trial would be useful.

References