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Outcome of bedside percutaneous tracheostomy with bronchoscopic guidance

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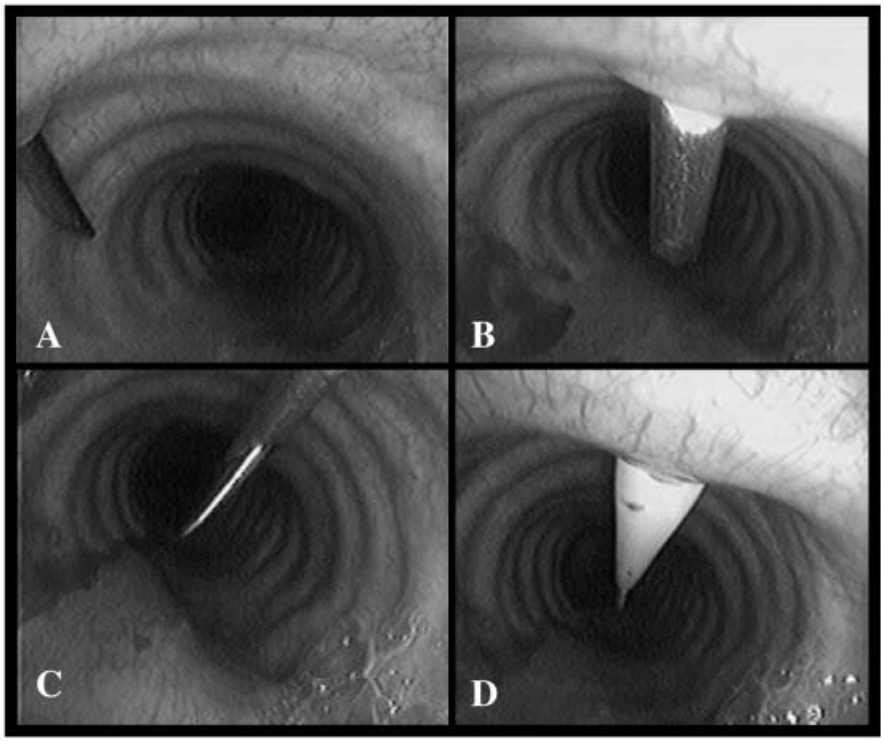
Abstract *Objective*: To determine the morbidity and mortality of percutaneous dilational tracheostomy with bronchoscopic guidance when performed by medical intensivists.
Design: A retrospective analysis.
Setting: A tertiary care university hospital.
Patients: Fifty consecutive patients who underwent percutaneous dilational tracheostomy for prolonged mechanical ventilation.
Intervention: Bedside percutaneous dilational tracheostomy with bronchoscopic guidance.
Results: Seventeen women and 33 men with a mean age of 62 ± 17 years. Operative mortality was 0 with four (8%) operative complications. Complications included one posterior tracheal abrasion, one anterior tracheal laceration, one episode of endobronchial hemorrhage requiring bronchoscopy, and one pneumothorax. Thirty-day mortality was 28% and overall mortality was 40%. All deaths were related to the patients' underlying disease.
Conclusions: Percutaneous dilational tracheostomy with bronchoscopic guidance is a safe procedure when performed by experienced medical intensive care personnel in tertiary care institutions. Bronchoscopy helps to reduce the risk of major complications and aids in the management of minor complications.

Introduction

Since the introduction of percutaneous dilational tracheostomy (PDT) by Ciaglia in 1985 [1], the procedure has steadily gained acceptance in the surgical intensive care community as a safe and cost-effective alternative to surgical tracheostomy. Medical intensivists have recently shown increasing interest in PDT as a service that they can provide at the patient's bedside. Because bedside PDT obviates the risk and cost of transporting critically ill patients to the operating room, it behooves intensivists to explore the feasibility of undertaking the procedure at their institution.

Percutaneous dilational tracheostomy, as it was originally described, did not include bronchoscopic guidance. Correct placement of the cannula within the trachea was assumed if the operator could aspirate air with an introducer needle. Complications such as paratracheal insertion and perforation of the posterior tracheal wall probably prevented the widespread use of PDT. The addition of bronchoscopic guidance to insure intra-tracheal placement and prevent local complications has increased the popularity of the procedure among intensivists. The surgical literature is mixed. Most authors support the use of bronchoscopy as a safety measure [2, 3, 4], but some still advocate blind PDT. Cobean [5] reports that the use of bronchoscopy unnecessarily adds to the cost of PDT, and Atweh [6] suggests that it may increase the rate of complications compared to blind procedures. Recently, Trottier [7] reported an alarming rate of posterior tracheal perforation despite the use of bronchoscopy. We examine this debate and use our series as an example of a protocol that should ensure minimal morbidity and negligible mortality if carried out by experienced personnel in tertiary centers. Our retrospective analysis began as an effort to estab-

Fig. 1



lish an institutional protocol for the safe conductance of PDT in our tertiary care teaching hospital.

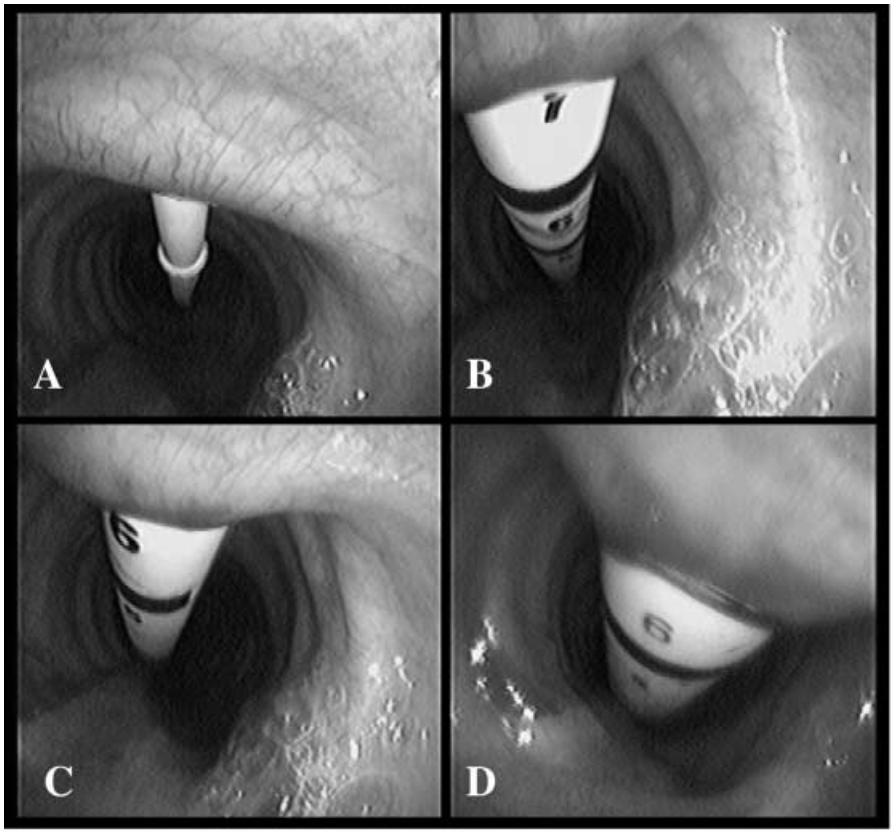
Materials and methods

This retrospective analysis includes 50 consecutive patients undergoing PDT from July 1998 through March 2000. Pulmonary and critical care medicine physicians at our institution performed all interventions. Our institution is a tertiary care teaching facility in which immediate surgical consultation is available 24 h a day. Abnormal neck anatomy, uncorrectable coagulopathy, hemodynamic instability, or excessive ventilatory requirements were considered contraindications to PDT. The outcome of patients who were evaluated but considered too high risk for PDT were not followed as part of this study. After informed consent was obtained, bedside PDT was performed by modified Seldinger technique and direct bronchoscopic visualization using the SIMS Per-fit Percutaneous Tracheostomy Kit (Smiths Industries Medical Systems Portex, Keene, N.H., USA). In most cases, two operators, one assistant, and one nurse were present at the procedure. One operator was designated to perform the bronchoscopic portion of the procedure and was primarily responsible for assuring airway patency and provision of adequate ventilation and oxygenation to the patient. The bronchoscopist was also responsible for guiding the safe introduction of guidewires and dilators into the trachea and continually conveyed this information to the other operator. Video was only employed for one procedure.

All procedures were performed in a medical or surgical intensive care unit. All patients were orotracheally intubated and remained on mechanical ventilation with 100% oxygen throughout the procedure. Sedation and muscle relaxation were achieved with a combination of narcotic, sedative, and paralytic agents. Pulse oximetry, blood pressure, heart rate and rhythm, tidal volume, and airway pressures were continuously monitored. Resuscitation, intubation, suctioning, and surgical tracheostomy equipment was available at all times at the bedside. As is our practice for all bronchoscopy performed in patients on mechanical ventilation, the ventilator was adjusted as necessary to assure adequate minute ventilation and minimize airway pressure. The peak flow was reduced as was the tidal volume. The breath rate was increased to compensate for the reduction in inspired volume. Further adjustments were made if peak airway pressure increased with the introduction of the scope or if exhaled tidal volume fell, due to increasing leak from the operative site.

The patients were supine with the neck hyper-extended. A bronchoscope with a 5.3 mm external diameter (Pentax Precision Instrument, Orangeburg, N.Y., USA) was introduced via a swivel adapter attached between the endotracheal and ventilator tubing. All patients had 7.5 mm or larger endotracheal tubes in place. After inspection of the airways and clearance of secretions and mucous plugs, the orotracheal tube was withdrawn to just below the vocal cords in order to transilluminate the anterior trachea. This enabled the operator to choose a puncture site (usually 2–3 rings below the cricoid cartilage) that would not compromise large blood vessels. Initial puncture of the trachea was made with a 19-gauge needle and syringe containing lidocaine with epinephrine. Intratracheal placement was confirmed by aspiration of air and bronchoscopic visualization. Repositioning of the needle was undertaken if it was not visualized in the midline trachea. Despite the use of transillumination for guiding the initial puncture and an apparent midline position at the skin, the needle often entered the trachea off-center or at an oblique angle (Fig. 1A). The need for repeated punctures did not increase morbidity, nor did it result in damage to the bronchoscope from inadvertent contact with the needle.

Fig. 2



After precise midline position was obtained, a larger bore needle replaced the finder needle (Fig. 1B), through which a guidewire was inserted and directed toward the carina (Fig. 1C). After a small skin incision and minimal dilation (Fig. 1D), the guiding catheter was placed over the wire. The guiding catheter and wire (Fig. 2A) remained intratracheal for the duration of the procedure. Sequential dilation (at an oblique angle to the skin and directed toward the carina) was undertaken with elongation of the skin incision as necessary (Fig. 2B–C). The endoscopist observed the anterior puncture site and the posterior mucosa for signs of hemorrhage, laceration, or perforation and ensured that the guiding catheter, wire, and dilators entered the trachea midline and were directed toward the carina. In a diligent effort to avoid damage to the posterior trachea, continuous communication between the bronchoscopist and operator was required in order to obtain the best angle while introducing dilators. Any mucosal hemorrhage was treated with the direct application of topical epinephrine. In most cases, a # 7 or 8 Portex tracheal cannula was placed (Fig. 3A). Only after the cannula was placed, the balloon was inflated, and adequate exhaled tidal volume from the new cannula was confirmed, was the bronchoscope removed from the orotracheal tube.

Bronchoscopy via the newly placed cannula confirmed proper positioning (Fig. 3B) and allowed for assessment and treatment of any local injury. Only after this confirmation was the orotracheal tube removed. The new cannula was held in place with a neck strap. Ventilator tubing was secured in the patient's midline to avoid intratracheal torsion of the cannula and accidental decannulation. All patients had chest X-rays within 1 h to confirm proper placement and to evaluate for pneumothorax. The ventilator was set to provide full ventilatory support until the effects of sedation and paralysis waned. Then it was returned to pre-operative settings, and the F_iO_2 was weaned by pulse oximetry. The time required to complete the procedure was not documented in this retrospective study.

Results

The 50 patients who underwent PDT included 17 women and 33 men. The mean age (± SD) was 62 ± 17 years (Table 1). The mean duration of orotracheal intubation prior to tracheostomy was 17 ± 8 days. The indication for tracheostomy was respiratory failure from a variety of medical and surgical causes. The most common causes of respiratory failure were COPD, ARDS, anoxic encephalopathy, aspiration, and neuromuscular weakness – which together comprised 70 % of the patients (Table 2).

The patients were followed until death, decannulation, or transfer to another facility. Fourteen (28 %) patients died prior to decannulation or transfer (within 30 days of tracheostomy) – none from perioperative complications. There was one (2 %) procedural failure. Six additional patients died of their underlying disease more than 30 days after tracheostomy – none from procedural complications. The overall mortality was 40 %.

Fig. 3

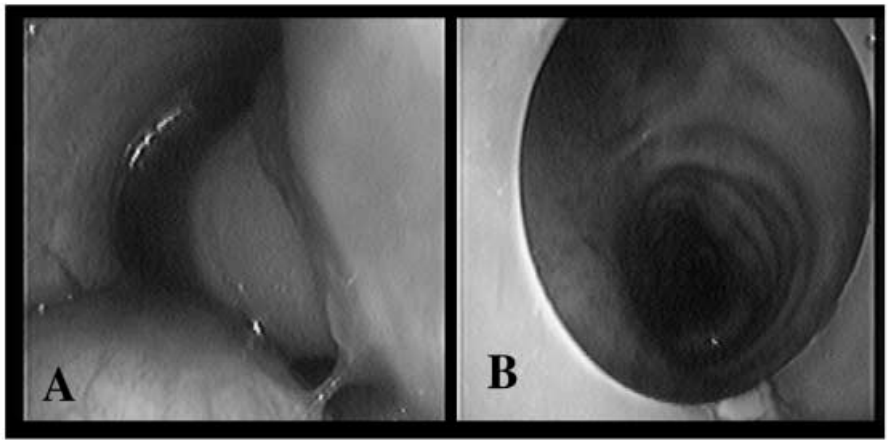


Table 1 Patients' demographics ($n = 50$). Intubation days are cumulative days of orotracheal intubation prior to tracheostomy. P/F ratio is defined as PaO_2/F_iO_2 and has a normal value of > 319

	Mathematical mean	Standard deviation
Age (years)	62	± 17
Intubation days	17	± 8
P/F ratio	258	± 81

Table 2 Indication for tracheostomy ($n = 50$)

Cause of respiratory failure	Number	Percentage of total
Neuromuscular weakness	11	22
COPD	8	16
Encephalopathy	6	12
Aspiration	5	10
ARDS	5	10
Empyema	2	4
Pulmonary fibrosis	2	4
Other[a]	11	22

[a] Includes three cases of congestive heart failure, three of pneumonia, and one each of BOOP, flail chest, lung cancer, endobronchial mucormycosis, and intra-abdominal sepsis

Thirty-one (62%) were transferred to rehabilitation, nursing, or long-term acute care hospitals (Tables 3, 4). Nine (18%) patients were eventually discharged to home from acute care hospitals or other facilities. Ten patients (20%) were successfully decannulated either before or after discharge. Eight patients were lost to follow-up after transfer to other facilities.

Case discussion

Complications were observed in four patients (8%). There were no paratracheal insertions, major hemorrhages, perioperative accidental decannulations, or posterior tracheal perforations observed. After successful PDT, one patient was noted to have suffered a superficial posterior tracheal wall abrasion when the guidewire kinked during dilation. The minimal bleeding was controlled with topical epinephrine. The patient underwent bronchoscopy again in 24 h; the abrasion was found to be healing and without inflammation or bleeding. The patient eventually died of his underlying disease.

A patient with COPD suffered rupture of the anterior trachea during dilation. The bronchoscopist recognized inappropriate lateral extension of the puncture site during dilation. Once this event was observed, the dilator was removed and the bronchoscope was advanced distally to the site of insertion and used to carefully re-position the orotracheal tube distal to the laceration. The tip of the tube was placed just above the carina, the balloon was inflated to low pressure, and airway control was regained. This maneuver prohibited significant air leak through the puncture site. The same day, a surgical tracheostomy and repair of the anterior laceration was conducted without difficulty. A heavily calcified trachea and the prolonged use of corticosteroids probably contributed to the occurrence of this particular complication. The patient recovered and was eventually transferred to a skilled nursing facility and successfully decannulated. To date he has suffered no adverse effect from this unexpected complication.

A third patient with respiratory failure secondary to recurrent pneumonia and amiodarone toxicity became cyanotic 3 h after uneventful PDT. A chest X-ray immediately after the procedure had shown the cannula in appropriate position, with no pneumothorax, and no subcutaneous emphysema. When the patient desaturated, empiric needle thoracostomy was performed, and the follow-up chest X-ray demonstrated a pneumothorax. Bilateral tube thoracostomy (one for treatment of the pneumothorax and the other to minimize further barotrauma) was then performed and the patient stabi-

Table 3 Immediate disposition ($n = 50$)

Disposition	Number	Percentage of total
Expired[a]	14	28
LTACH[b]	15	30
Rehabilitation[c]	5	10
Acute care hospital[d]	13	26
Skilled nursing[e]	1	2
Home[f]	1	2
Failed PDT[g]	1	2

[a] Patients who expired within 30 days of PDT
[b] Long-term acute care hospital for ventilator-dependent patients
[c] Those discharged to rehabilitation facilities were not on ventilators; four were still cannulated at transfer
[d] Two patients were transferred to another acute care hospital on ventilators, and eleven remained at our institution on ventilators
[e] The patient transferred to a skilled nursing facility was decannulated after transfer
[f] The patient discharged to home remains cannulated
[g] The patient who failed PDT underwent surgical tracheostomy, was transferred to a rehabilitation facility, and was eventually decannulated. He is not included in further analysis

Table 4 Long-term disposition ($n = 34$ patients who did not expire prior to 30 days or obtain discharge directly home within 30 days)

Disposition	Number	Percentage of total ($n = 49$)
Home[a]	7	14
Expired later than 30 days	5	10
LTACH	5	10
Nursing/rehabilitation[b]	9	18
Lost to follow-up[c]	8	16

[a] Of the seven additional patients discharged home, three were from acute care hospitals, two were from LTACHs, and two were from rehabilitation facilities; five were known to be decannulated
[b] Of the nine who remain in nursing or rehabilitation facilities, one was transferred from LTACH and five were transferred from acute care hospitals; only two remained cannulated
[c] Of the eight lost to follow-up, five were last in LTACH on a ventilator, one was in ACH on a ventilator, one was in rehabilitation and decannulated, and one was in rehabilitation and cannulated

lized. Bronchoscopy at this time did not demonstrate evidence of tracheal perforation or laceration. The new cannula was temporarily withdrawn to the vocal cords to rule out perforation at the entrance site. The patient subsequently developed recurrent pneumonia and a sepsis syndrome; in the context of his acute and chronic illness, his family requested withdrawal of ventilatory and inotropic support. Forty-eight hours after the tracheostomy, he expired after discontinuation of ventilatory support. While the etiology of the pneumothorax is unclear, it is included here as a perioperative complication.

The fourth complication was hemoptysis in a patient with a known coagulopathy and history of diffuse alveolar hemorrhage. Approximately 8 h after an uneventful PDT, the patient had significant bleeding from the tracheal cannula. She was placed on 1.0 F_iO_2 empirically and remained hemodynamically stable throughout the event. At the time of bronchoscopy, 1 h later, no evident source of hemorrhage could be identified, including at the puncture site. She did not require transfusion of blood products or surgical exploration. Hemoptysis did not recur, and the patient eventually weaned from mechanical ventilation. It is unclear whether this episode represents a complication of tracheostomy or an exacerbation of her underlying disease.

Discussion

The available literature that evaluates the technique, morbidity, and mortality of percutaneous dilational tracheostomy is rapidly expanding. Though some authors suggest that PDT without bronchoscopic guidance is a safe procedure [5, 6], others indicate that bronchoscopy is mandatory in order to achieve acceptable complication rates [2, 3, 4, 8]. Others describe significant complications despite bronchoscopic guidance [7]. Our institutional experience suggests that the addition of bronchoscopy aids in the management of most complications.

Complication rates will continue to decline as available kits evolve with additional safeguards and intensivists gain more experience in selecting patients. For example, our criteria deemed patients who had prior tracheostomy or neck surgery or who had unusually short or thick necks unsuitable for bedside PDT. In addition, extrinsic PEEP greater than 10 cm H_2O, F_iO_2 greater than 0.5 atmospheres, and uncorrectable coagulopathy were also considered contraindications to PDT.

The reported mortality rate for PDT varies by sample size and technique. Our intraoperative mortality rate of 0 is not unusual when compared to users of a similar technique [2, 4, 9]. An overall mortality of 40% in this series is not unusual [10, 11] and reflects the mortality of patients requiring long-term mechanical ventilation. No patient died as a direct or indirect result of PDT. A recent review [9] reports an average peri-operative mortality rate for 1,116 patients using six different PDT techniques – with and without bronchoscopy – at 0.4%.

The same review found an average complication rate of 10%. Our complication rate of 8% is within the range documented in the literature [2, 4, 9]. Recent literature indicates a rate of superficial mucosal laceration of 0.9–1.4% [2, 11] in those authors using a technique similar to ours. Our single (2%) mucosal abrasion might not have been detected without bronchoscopy.

The absence of posterior tracheal perforations in our series may be due to the improvement made in the Sim's kit [7]. It was also helpful to establish adequate bron-

choscopic visualization and communication between the bronchoscopist and the operator. Trottier's 12.5 % incidence of posterior perforation may have been due the angle with which dilators were introduced into the trachea [7]. An oblique angle of introduction (rather than 90 degrees) and a clear view of the posterior tracheal wall by the bronchoscopist make perforation and laceration far less likely.

The rate of paratracheal insertion and accidental intraoperative decannulation is negligible with the assistance of bronchoscopy [9, 11]. In addition, in the event of premature or inadvertent extubation, bronchoscopy allows simple and rapid replacement of the orotracheal tube over the bronchoscope. Our lack of these complications is consistent with other authors using similar technique [2, 3, 4, 10].

The occurrence of only one significant bleeding event is likely attributable to proper patient selection. Forty-nine (98 %) of our patients had platelet counts checked within one week of the procedure; of those, none was less than 73 K (normal range 150–400 K in our laboratory). Forty-four (88 %) had a coagulation profile within one week of the procedure; the maximum protime (prior to correction) was 22 s (normal range 12.6–15 s) and the maximum activated partial thromboplastin time (prior to correction) was 74 s (normal range 23.3–32.6 s). The rate of significant hemorrhage (requiring packing, suture, transfusion, or operative intervention) is between 0.8–5.7 % [2, 4, 9, 10].

Immediate post-operative chest X-rays were obtained on 100 % of our patients. This provided additional assurance and documentation of proper endotracheal positioning of the cannulas as well as detection of acute pneumothorax or subcutaneous emphysema.

In the course of hospitalization, over 52 % of the patients underwent bronchoscopy after PDT. The indication for bronchoscopy – in all but the four patients with procedural complications – was related to the patient's underlying disease. No evidence of operative complication was found in any follow-up bronchoscopy. PDT without bronchoscopy is not performed at our institution; therefore, a direct comparison of time and expense differences between the two techniques was not attempted.

Many authors do not report the amount of ventilatory support required by patients pre-operatively. One might speculate that the amount of extrinsic PEEP, PO_2/F_iO_2, mode of ventilation, and mean airway pressure greatly contribute to the patient's operative risk. Patients who required PEEP > 10 cm of H_2O, unconventional ventilation, or $F_iO_2 > 0.5$ atmospheres were not considered as candidates for PDT. The mean PO_2/F_iO_2 in this study was 258 ± 81 (Table 1). No patients experienced intra-operative desaturation or demonstrated evidence of air-trapping and dynamic hyperinflation as measured with the ventilator.

Our case of posterior tracheal abrasion was probably preventable. Careful attention to the angle of insertion when manipulating the guidewire, guiding catheter, and dilators should minimize the chance of damage to the wire, which creates a sharp edge and mucosal laceration. In this case, the use of bronchoscopy allowed for detection and appropriate intervention.

The case of anterior laceration may have been difficult to anticipate and prevent. In studies employing a variety of techniques and sample sizes, a procedure failure rate between 0–14 % [5, 6] is cited. One might wonder if a calcified trachea contributed to the difficulty in cannulation in those cases. Perhaps the most instructive point about this particular case is that one should anticipate damage to the anterior trachea and use bronchoscopy to minimize the extent of injury. As proven by our case, an effective temporizing measure (until surgical intervention is available) is advancement of the orotracheal tube over the bronchoscope so that its cuff lies distal to the laceration.

It is more difficult to make constructive commentary about the case complicated by pneumothorax. The patient may indeed have suffered a late pneumothorax related to the PDT, although a site of perforation and air entry was not located. Other possibilities include elevated airway pressure during the procedure due to the presence of the bronchoscope or after the procedure due to repeated bag-valve suctioning when the patient desaturated. The third possibility is that the patient desaturated due to deterioration of his underlying disease and suffered an iatrogenic pneumothorax from empiric needle thoracostomy. Pneumothorax is a known complication of bronchoscopy and PDT – with or without bronchoscopy. It is important to have a high index of suspicion for barotrauma and once detected to make an exhaustive search for correctable causes such as posterior tracheal perforation.

While the rate of sub-clinical complications may seem to be higher with techniques that employ bronchoscopy, it is probable that these complications occur unnoticed at a similar or higher frequency without the use of bronchoscopy. The avoidance, early recognition, and treatment of intra-operative complications can only be achieved by proper patient selection and the participation of experienced bronchoscopists. Pre-operative assessment should exclude patients with uncorrectable coagulopathy, abnormal neck anatomy, hemodynamic instability, or high ventilatory requirements. Surgical tracheostomy equipment and personnel should be immediately available, as should resuscitation and orotracheal intubation supplies. The operator should be a certified surgical operator or critical care attending operator or fellow under qualified attending supervision.

The bronchoscopist must be skilled and trained to manage all degrees of airway hemorrhage and to rapidly re-intubate the patient with the laryngoscope or bron-

choscope. S/he should be expertly familiar with the bronchoscope and large airway anatomy in order to identify and manage endobronchial complications. Ideally, the operator-bronchoscopist team should have a clearly delineated operative plan and an understanding that the operator is heavily dependent on guidance from the bronchoscopist. While video assistance may increase the comfort level of the operators, it is not necessary for the safe conductance of the procedure. The operator is still dependent on the bronchoscopist for adequate imaging and the management of the airway and any endobronchial complications.

The limitations of this study are readily evident. Its retrospective design and small numbers limit our ability to make generalizations or definitive conclusions about the best method for performing PDT. However, the current literature already has ample data documenting the complications of tracheostomy using a variety of techniques. A disproportionate number of the published series is from the surgical literature; it is our intent to begin a discourse among medical intensivists and pulmonologists regarding the safety and utility of PDT with bronchoscopic guidance. This series is unique in that it describes techniques for managing common complications in addition to providing an example of the appropriate type of patient for PDT in the medical intensive care unit.

In summary, bedside percutaneous dilational tracheostomy with bronchoscopic guidance is a safe procedure in the hands of experienced medical *or* surgical personnel in tertiary care institutions. Bronchoscopy may reduce the risk of major complications such as posterior tracheal perforation and aid in management of the airway and minor complications such as abrasions.

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