Percutaneous Dilational Tracheostomy

David W. Hsia, MD[a,*], Uzair K. Ghori, MD[b],
Ali I. Musani, MD[c]

KEYWORDS

• Percutaneous dilational tracheostomy • Chronic respiratory failure • Flexible bronchoscopy
• Critical illness

KEY POINTS

- There are numerous indications for PDT placement in the management of chronic respiratory failure.
- PDT has been safely performed by surgical and medical physicians, including critical care intensivists and interventional pulmonologists.
- There are multiple methods of performing the procedure and the single dilator variant of the Ciaglia method is currently the most widely used.
- PDT compares favorably with surgical tracheostomy in regards to procedure time, complications, and cost.
- Flexible bronchoscopy is commonly used as a procedural adjunct and has been shown to decrease complications.
- Because of its advantages, PDT has become one of the most common procedures performed in the modern ICU.

INTRODUCTION

Tracheostomy is one of the oldest surgical procedures and has been performed for several thousand years. There are many indications for tracheostomy placement, such as the need for prolonged mechanical ventilator support, improved clearance of secretions, protection from aspiration, and maintenance of the airway because of sequelae from upper airway obstructions or trauma. In addition, tracheostomy has additional potential benefits over endotracheal tube (ETT) intubation because it decreases the work of breathing,[1] reduces ventilator-associated pneumonia,[2] provides a more secure airway, and permits patient phonation and swallowing. Tracheostomy plays a prominent role in the treatment of prolonged respiratory failure and more than 50% of all tracheostomies are placed in critically ill patients.[3]

The modern operative procedure remains largely unchanged from the methodology described by Chevalier Jackson in the early 1900s.[4] Jackson's approach involved a long incision, good exposure of the anatomic structures, and division of the thyroid isthmus. His guidelines on the procedure were instrumental in improving procedural safety and outcomes. Subsequent refinements to the procedure and improvements in equipment have resulted in decreased procedure-related morbidity and mortality.[5] In 1957, Sheldon and Pudenz[6] described a Seldinger method of percutaneous tracheostomy placement. The procedure became more widely used after the introduction of the percutaneous dilational method by Ciaglia in

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[a] Department of Medicine, Harbor-UCLA Medical Center, 1000 West Carson Street, Box #405, Torrance, CA 90509, USA; [b] Department of Medicine, Military Hospital Rawalpindi, Main Peshawar Road, 46000 Rawalpindi, Pakistan; [c] National Jewish Health, 1400 Jackson Street, J225, Molly Blank Building, Denver, CO 80206, USA
* Corresponding author.
E-mail address: dhsia@labiomed.org

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1985.[7] Percutaneous tracheostomy is now recognized as a cost-effective procedure that can be performed easily and safely at the bedside by interventional pulmonologists, critical care physicians, and surgeons in the intensive care unit (ICU).

PERCUTANEOUS DILATIONAL TRACHEOSTOMY TECHNIQUES

Percutaneous dilational tracheostomy (PDT) uses the insertion of a tracheal cannula by a modified Seldinger approach. A guidewire is inserted through the anterior tracheal wall; dilation is then performed until the tracheal stoma is large enough to permit insertion of the tracheal cannula. Cannula insertion is generally performed between the second and third tracheal rings, with a suggestion of decreased risk of bleeding when placed above the fourth tracheal ring.[8] Several variations of the procedure have been developed and are in use today.

The Ciaglia method[7] is currently the most commonly used PDT technique; it was originally described using serial dilation with progressively larger hydrophilic coated dilators and is now adapted in commercially available kits to use a single conical dilator (Ciaglia Blue Rhino Tracheostomy Introducer Kit, Cook Critical Care, Bloomington, IN; Per-Fit Kit, SIMS Portex, Keene, NH) (**Fig. 1**). Before the procedure, the distal tip of the ETT is repositioned within the subglottic space proximal to the intended tracheostomy dilation site. A midline incision is made over the anterior trachea and the pretracheal soft tissue is bluntly dissected with mosquito clamps. The underlying trachea is then identified using a needle and introducer sheath. Flexible bronchoscopic visualization is commonly used to provide endoscopic guidance from within the trachea (**Fig. 2**). Removal of the needle allows an introduction of a J-shaped guidewire through the introducer sheath into the trachea and directed caudally into the distal airways. The introducer sheath is then removed and dilation of the trachea and soft tissue is performed initially with a short dilator followed by a curved, conical dilator. Special precautions must be taken to ensure proper midline puncture of the anterior trachea wall and introduction of the guidewire and subsequent dilation through the anterior wall while avoiding puncture of the posterior membranous portion of the trachea. A trachestomy tube is loaded onto an introducer dilator and inserted into the trachea over the guidewire through the dilated stoma and secured in place. The use of the single dilator method is theorized to decrease the risk of injury to the posterior tracheal wall and prevent the risk of oxygen desaturation or

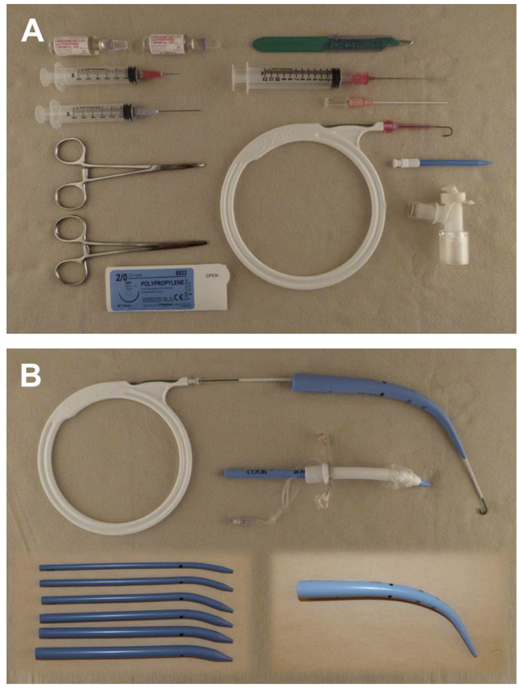

Fig. 1. Single and multiple dilator methods based on the Ciaglia technique. (*A*) Example of equipment found in commercially available PDT kits. (*B*) Multiple and single dilator systems. The guidewire and guide catheter are shown inserted through a single conical-shaped Blue Rhino dilator. A tracheostomy cannula is loaded onto a specialized introducer. Inset shows a set of multiple dilators with sizes ranging from 18F to 36F catheter compared with a single dilator.

inadequate ventilation by minimizing the period of time needed to dilate the tracheostomy stoma and insert the tracheostomy cannula. Another modification of the Ciaglia method (Ciaglia Blue Dolphin Tracheostomy Introducer Kit; Cook Critical Care) using a balloon dilator has also been developed (**Fig. 3**).[9] PDT using single dilation has been shown to decrease procedure time compared with the multiple and balloon dilation methods.[10–12]

Numerous kits using other PDT dilation methods are also commercially available. The Griggs' dilational forceps technique (Portex PDT Kit; Portex, Hyathe, Kent, UK) uses curved Howard-Kelly forceps with a special groove that permits passage of the guidewire through the forceps.[13] The guidewire directs the path of the forceps, which are used to dilate the soft tissue and trachea. The translaryngeal tracheostomy method (Translaryngeal Tracheostomy Kit; Mallinckrodt, Courtaboeuf, France) directs the guidewire caudally either within or external to the ETT. The ETT is removed and the patient is reintubated with a

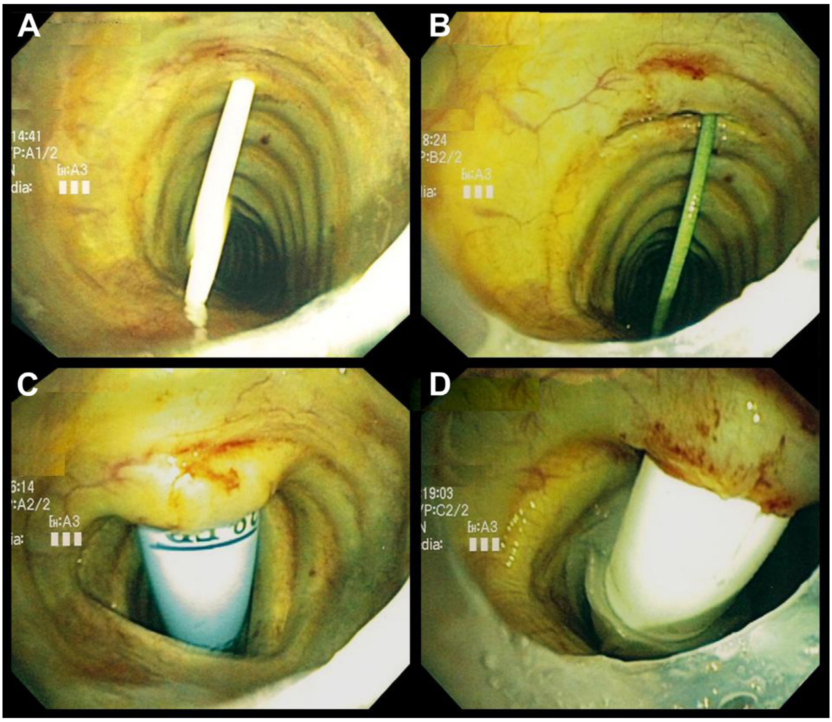

Fig. 2. Bronchoscopic guidance of PDT using a single dilator. Endotracheal images of PDT insertion visualized by a bronchoscope positioned within the ETT. The distal tip of the ETT can be seen at the bottom of each image. (*A*) Insertion of the guide catheter through the anterior tracheal wall. (*B*) Insertion of the guidewire, which is then directed distally in the trachea. (*C*) Blunt dilation with a single conical-shaped Blue Rhino dilator over the guidewire by modified Seldinger technique. (*D*) Insertion of the tracheostomy cannula through the dilated tracheostomy tract.

special 5-mm ETT. The guidewire is directed retrograde through the anterior tracheal wall until the tip exits the mouth. A conical tracheal cannula is attached to the cranial end of the dilator and pulled back into the trachea where it is used to dilate the trachea and pretracheal soft tissue from within the tracheal lumen. When the cannula protrudes from the soft tissue of the neck, the external tip is cut off and attached to the mechanical ventilator while the tracheal portion of the cannula is directed toward the carina by an obturator. One potential benefit of the translaryngeal tracheostomy method is that it avoids anterior compression of the trachea, which may be useful in younger patients with highly elastic tracheas.[14] A single-step screw-like dilator (PercuTwist; Rüsch, Kernen, Germany) has also been developed that uses rotation to advance the dilator to avoid complications associated with direct compression of the trachea (**Fig. 4**).[15] Additional methods include use of a specialized speculum-like tracheostome,[16] a cutting bougie device,[17] and Rapitrac tracheostome (SurgiTech Medical, Sydney, Australia).[18]

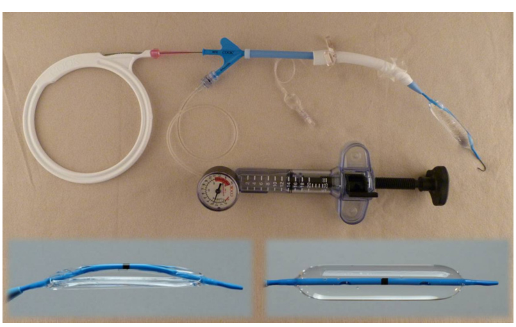

Fig. 3. Blue Dolphin balloon-assisted dilation system. The Blue Dolphin saline-filled inflation dilator is shown with guidewire and inflation syringe. The tracheostomy cannula is loaded directly onto the device and deployed after performing balloon dilation. Inset shows a close-up of the distal tip with the balloon deflated and inflated.

Although PDT has gained in popularity, not all of these commercial kits are universally available. Recent surveys of ICU directors suggest that the Ciaglia single dilator has become the most popular tracheostomy placement technique and is the method of choice in up to 69% of ICUs.[19,20] As with any procedure, however, the experience of

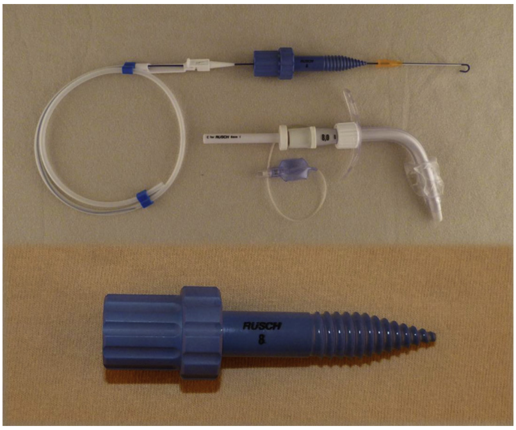

Fig. 4. "PercuTwist" screw-like dilation system. The "PercuTwist" dilator is shown with guidewire and introducer catheter. The tracheostomy cannula is introduced after single-step dilation is performed. Inset shows a close-up of the screw-like dilator.

the physician with the procedural method is of paramount importance.

PROCEDURAL ADJUNCTS

Flexible bronchoscopy is commonly used to provide endoscopic procedural guidance and is routinely used in 83% to 97.7% of ICUs.[19,20] Bronchoscopy provides real-time visual guidance from within the tracheal lumen. This includes confirmation of appropriate ETT positioning, midline placement of the introducer needle and catheter within the tracheal lumen, direction of the guidewire, proper placement of the tracheal cannula, and helps prevent injury to the posterior tracheal wall by visually guiding stoma dilation. Composite evaluation of 1385 patients (15 studies) undergoing PDT without endoscopic guidance demonstrated a complication rate of 16.8% compared with 8.7% in 1351 patients (nine studies) with endoscopic guidance.[21] PDT performed with bronchoscopy was also associated with lower rates of accidental extubation, false passage, pneumomediastinum and pneumothorax, and other technical difficulties. However, it is difficult to control for variations in patient populations, PDT technique, and operator experience across studies. Few trials have directly examined the impact of bronchoscopy on PDT complications. A prospective study by Berrouschot and colleagues[22] demonstrated a similar perioperative complication rate while prospectively evaluating PDT with and without bronchoscopy (7% vs 6%), but had more severe complications in the group without bronchoscopy. Jackson and colleagues[23] reported no difference in complications, including bleeding and late complications. Use of bronchoscopy with PDT has been associated with transient hypercarbia and respiratory acidosis[24–26]; this may lead to an elevation in intracranial pressure and decrease in cerebral perfusion pressure.[27] These findings are not surprising because transient increases in positive end-expiratory pressure (PEEP) and partial pressure of carbon dioxide are known to occur during flexible bronchoscopy on mechanically ventilated patients because of partial occlusion of the ETT by the bronchoscope.[28] Nevertheless, complications resulting from these physiologic changes are rare and bronchoscopy remains a routinely performed procedure in the ICU. Bronchoscopy also uses additional equipment and personnel resources, affects procedural costs, and may result in procedure-related damage to the bronchoscope. Nevertheless, given the benefits of endoscopic visual guidance compared with its low risk, multiple authors have recommended its use to improve procedural safety.[13,21,29–32] Care should be taken to monitor and adjust mechanical ventilator settings to account for the partial obstruction of the ETT by the flexible bronchoscope and the resulting physiologic and ventilatory effects.

Ultrasonography is another adjunct method used to ensure accurate placement of the introducer needle into the trachea, estimate the distance from the skin to the trachea, identify anomalous vascular anatomy, and prevent damage to vascular and adjacent structures (**Fig. 5**).[33] Ultrasound evaluation of the anterior neck has been shown to change the intended tracheostomy site in up to 24% of cases to avoid subcutaneous vasculature.[34] Ultrasonography can also provide real-time procedural guidance for introduction of the introducer needle and guide catheter into the tracheal lumen[35,36] and ETT positioning.[37] Bedside ultrasound machines are readily available in the ICU setting and are a familiar imaging modality to interventional pulmonologists and intensivists. Performing ultrasonography is inexpensive and has essentially no procedure-related drawbacks. However, further studies are required to evaluate its impact on procedural performance and safety.

Inadvertent extubation of the ETT and puncture of the ETT cuff are potential complications that may lead to catastrophic hypoxia or loss of the airway. The laryngeal mask airway (LMA) has been considered as an alternative method of airway management during PDT. The position of the LMA external to the trachea prevents it from interfering with the PDT procedure. There are concerns that this method of ventilation is not adequately secure in critically ill patients who may require significant mechanical ventilator

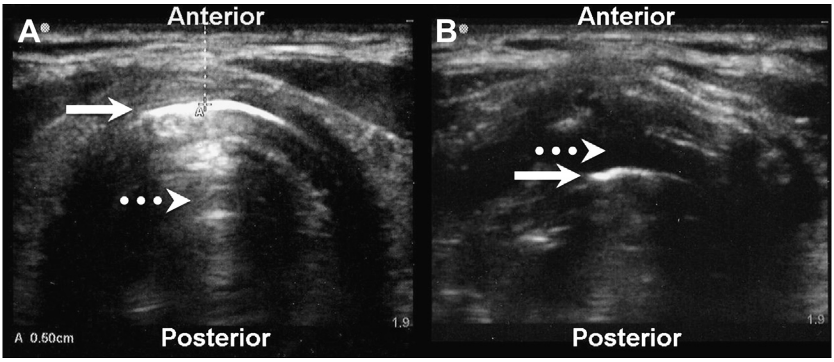

Fig. 5. Ultrasonography for PDT. Demonstration of ultrasound images of the neck and trachea. (*A*) Normal trachea imaged above a tracheal ring. Tracheal cartilage (*solid arrow*) creates a shadow artifact (*dotted arrow*). Image depth of 1.9 cm is indicated in the lower right corner. The *dotted line* measures the distance between the skin and anterior trachea to be 0.50 cm, as indicated in the lower left corner. (*B*) Intubated trachea imaged between tracheal rings. The ETT (*solid arrow*) and associated shadow artifact is visualized within the tracheal lumen (*dotted arrow*).

support with high airway pressures, levels of oxygen supplementation, or PEEP. Several trials comparing PDT with bronchoscopic guidance through an LMA versus ETT have been performed with varying results. Dosemeci and colleagues[38] demonstrated a greater incidence of hypercarbia along with higher associated rise in partial pressure of carbon dioxide ($Paco_2$) with ETT (56.7% of patients; 6.8 $\pm$ 3.5 mm Hg) compared with LMA (38.5% of patients; 4.5 $\pm$ 2.4 mm Hg). Visualization of tracheal structures during PDT has also been found to be improved with the use of an LMA.[39,40] However, in a randomized comparison of 60 patients undergoing PDT, 6.6% of patients using ETT had cuff puncture and 3.3% had accidental extubation; in comparison, 33% performed with LMA had potentially catastrophic airway-related complications, including loss of the airway, significant hypoxia, and aspiration of gastric contents.[41] Therefore, although the use of an LMA with PDT has been shown to be feasible, its safety has not been convincingly demonstrated.

PROCEDURE-RELATED COMPLICATIONS

PDT is a safe procedure when performed in the properly selected patient, in an appropriate setting, and with trained physicians and staff. Overall complication rates of 5.6% to 54% have been reported, most of which were considered minor.[21,42–45] Periprocedural and early postprocedural complications include bleeding; hemodynamic instability; cardiac arrhythmias; airway obstruction or loss of the airway (eg, accidental extubation or decannulation); hypoxia; tracheal ring fracture; underdilation or overdilation of the trachea; damage to mediastinal structures (eg, damage to the tracheal wall, creation of a false passage, development of subcutaneous emphysema, pneumomediastinum, or pneumothorax); wound infection; technical difficulties requiring conversion to a surgical approach; and death. Procedure-related mortality is low, with reported rates of 0% to 0.7%.[21,42–45]

Procedural or postprocedural bleeding is usually rare, with reported incidence of 0.4% to 8%.[21,42–45] As a result, PDT does not require routine use of electrocautery to control hemostasis. Bleeding may be reduced because of the creation of a tight tracheostomy stoma with blunt dilation, which shifts and compresses vascular structures that may be perforated with sharp surgical dissection techniques. Most bleeding results from soft tissue oozing because the procedure is performed in the midline to avoid vascular structures. Given the tight nature of the PDT tract, hemostasis is usually obtained from tamponade by the tracheostomy cannula. Bleeding may be decreased with the use of stay sutures securing the flanges of the tracheostomy tube.[46] Occasionally, digital compression or a suture may be required to control superficial bleeding.[47]

Head-to-head trials involving different PDT methods are rare, which makes the comparison of complication rates difficult and problematic. **Table 1** highlights findings from prospective, randomized PDT comparison trials.[10–12,24,25,48–51] The single dilator Ciaglia technique has been associated with greater rates of tracheal ring fracture compared with the multiple dilator Ciaglia and the Griggs' dilational forceps methods.[11,49] The translaryngeal tracheostomy technique has been associated with loss of the airway and technical difficulties requiring physicians to switch to an alternate tracheostomy method.[25] Other conclusions regarding complications rates are conflicting

Table 1
PDT complications from prospective, randomized direct comparison trials

Study	Number of Subjects	Dilaton Methods	Significant Findings
Johnson et al,[10] 2001	50	Multiple vs single	No significant difference in complication rates
Byhahn et al,[11] 2000	50	Multiple vs single	Decreased tracheal ring fracture with multiple dilator (8% vs 36%)
Cianchi et al,[12] 2010	70	Single vs balloon	Decreased resistance to cannula insertion (5.7% vs 28.6%) with single dilator
Nates et al,[48] 2000	100	Multiple vs forceps	Decreased surgical complications (1.9% vs 24%) and bleeding (1.9% vs 15%) with multiple dilator
Kaiser et al,[24] 2006	100	Single vs forceps	Decreased major complications (0% vs 12.5%), minor bleeding (12% vs 35%), and hypoxemia (0% vs 10%) with forceps dilator
Ambesh et al,[49] 2002	60	Single vs forceps	Decreased overdilation or underdilation (7% vs 53%) and bleeding (3% vs 17%) with single dilator Decreased change in P_{Peak} (+5 vs +16.5 cm H_2O) and tracheal ring fracture (0% vs 30%) with forceps dilator
Anon et al,[50] 2004	53	Single vs forceps	Nonsignificant trend toward decreased procedural complications with single dilator (7.4% vs 26.9%; *P* = .07)
Montcriol et al,[51] 2011	90	Forceps vs rotational	No significant difference in complication rates
Cantais et al,[25] 2002	100	Forceps vs translaryngeal	Decreased need to convert to alternate method (0% vs 23%), loss of airway (0% vs 15%), and bleeding (4% vs 23%) with forceps dilator

Abbreviation: P_{Peak}, peak airway pressure.
Data from Refs.[10–12,24,25,48–51]

or limited given the relative paucity of data available. It is therefore difficult to determine which technique is superior.

Comparison of long-term complications, such as tracheal stenosis, delayed stoma closure, airway symptoms (eg, dyspnea, cough, phonetic impairment), and scarring/cosmesis is difficult to evaluate given the low occurrence rate; analysis of these complications requires long-term follow-up of a large study population.

PERCUTANEOUS VERSUS SURGICAL TECHNIQUES

Surgical tracheostomy involves dissection through the pretracheal soft tissue until the trachea is identified. The trachea is then cannulated under direct visualization. It is typically performed in the operating room, in contrast to PDT, which is usually performed in the ICU. Meta-analysis of 15 randomized, controlled trials involving 973 patients has demonstrated several important clinical outcome differences between PDT and surgical tracheostomy.[52] Most PDTs included in this analysis were performed using the multiple dilator method placed in the ICU setting. PDT was associated with a significant decrease in unfavorable scarring (odds ratio [OR], 0.44; 95% confidence interval [CI], 0.23–0.83) and wound infections (OR, 0.31; 95% CI, 0.22–0.62). Decreased wound infection is likely related to the minimal trauma and tissue manipulation associated with PDT and is consistent with the decrease in surgical site infections associated with other minimally invasive surgical procedures.[53] There was no significant difference in minor or major hemorrhage, development of subglottic stenosis, creation of a false passage, or death. However, PDT had a higher risk of complications associated with decannulation and mucous obstruction (OR, 2.79; 95% CI, 1.29–6.03), which may be related to the use of smaller tracheostomy tracts and cannulas with PDT.

By performing PDT at the bedside, morbidity associated with patient transport can also be avoided. Intrahospital transportation of critically ill patients has been shown to adversely impact patients physiologically and psychologically.[54] In addition, the numerous intravascular lines, endoluminal tubes, monitoring devices, and other hardware associated with the care of critically ill patients may become displaced during transport. Significant adverse events have been shown to occur in up to 8.9% of intrahospital transports of critically ill patients.[55,56] It is therefore beneficial when diagnostic or therapeutic interventions can be safely performed at the bedside without transport of the critically ill patient away from the ICU.

Performing procedures in the operating room setting uses a limited hospital resource and is associated with higher associated costs. PDT has been shown to reduce procedural costs by $851 to $1645 largely because of cost savings related to operating room and anesthesiologist charges.[57–60] Compared with surgical tracheostomy, mean PDT procedure length is shorter by approximately 4.6 minutes.[52] In some institutions, bedside PDT may also decrease the length of time between the point when a tracheostomy is deemed necessary and the time when the procedure occurs.[61,62] Logistic limitations of performing surgical tracheostomy in the operating room may play a role in the procedural delay associated with surgical tracheostomy. PDT reduces the amount of time before a permanent airway is secured and potentially decreases ICU and hospital length of stay in select patient populations[62]; benefits in logistic efficiency and length of stay, however, are not consistent in all institutions.[60]

SPECIAL CIRCUMSTANCES

It is estimated that 11% to 35% of patients with cervical spine injuries may require a tracheostomy for long-term airway management.[63] Cervical spine injury limits the amount of neck extension permissible when positioning a patient for PDT. In addition, patients undergoing anterior cervical spine fixation are at higher risk for infection given the close proximity of the wound to the tracheostomy site, concomitant use of high-dose steroids, and relative immunosuppression resulting from severe injury.[63] Several small case series involving PDT in patients with cervical spine fixation reported only rare procedural bleeding and wound infection without any worsening in neurologic status.[63,64] Retrospective comparison of PDT and surgical tracheostomy in this population demonstrated comparable procedure-related complication rates with 5.9% bleeding, 10% tracheal stenosis, and 15% stomal cellulitis.[65] In a small prospective randomized trial, PDT procedure time was significantly shorter than surgical tracheostomy (8 ± 6 vs 21 ± 7 minutes) without significant difference in periprocedure or postprocedure complications.[66] Furthermore, PDT in trauma patients clinically or radiographically cleared of cervical spine injury may not have worse outcomes compared with patients who have neck injuries or are unable to be cleared of neck injury.[67]

The critically ill obese population has greater perioperative and postprocedural complications with surgical tracheostomies and is considered another relative contraindication to PDT.[50,68] Neck landmarks may be harder to identify given the abundance of soft tissue, especially in patients with short neck length. Greater neck diameter may play a role in the formation of a false passage or inadvertent decannulation. Obesity may also compromise mechanical ventilation and oxygenation. A trial using multiple PDT techniques demonstrated a 2.7-fold increased risk for perioperative complications (43.8% vs 18.2%) and 4.9-fold increased risk for serious complications (9.6% vs 0.7%) in obese patients[69]; the complication rates in this study, however, were higher than in many comparable studies and interpretation of the results may be hindered by the use of multiple PDT methods. In contrast, several trials using a single dilator technique found no significant difference in complication rates between obese and nonobese populations.[36,70,71] Although these studies categorized obesity based on body mass index, this index may not accurately reflect the impact of obesity on the soft tissue of the neck. Tabaee and colleagues[72] stratified patients based on the cricosternal distance in the neutral and extended positions and did not find correlation between neck length and PDT outcomes. Finally, a retrospective comparison between 89 PDT and 53 surgical tracheostomies in morbidly obese patients showed no difference in serious adverse outcomes (6.5% vs 6.5%).[73] These data suggest that PDT can be safely performed by skilled operators in this potentially high-risk population.

During the PDT procedure, the ETT cuff is deflated to reposition the ETT. Cuff deflation affects PEEP generated by the mechanical ventilator and may result in derecruitment of alveoli.[74] PDT may therefore adversely affect patients with severe hypoxic respiratory failure and high PEEP requirements. Beiderlinden and colleagues[75] investigated bronchoscopic-guided PDT in patients with hypoxic respiratory failure and did not demonstrate any significant decrease in arterial oxygen levels. This included patients with PEEP greater than 10 cm H_2O (mean, 16.7 $\pm$ 4 cm H_2O) whose peripheral oxygen saturation (Spo_2) did not decrease during the procedure. Furthermore, arterial oxygen to fraction of inhaled oxygen ratios (Pao_2/Fio_2) remained unchanged before the procedure compared with 1 hour and 24 hours postprocedure (243 $\pm$ 90 vs 223 $\pm$ 83 vs 260 $\pm$ 86 mm Hg) suggesting that derecruitment did not occur. It is possible, however, that the use of bronchoscopic guidance may have minimized the potential loss of PEEP during PDT because of the effect of the bronchoscope on PEEP. Recruitment maneuvers before PDT may also help prevent potential derecruitment as demonstrated in a small trial with sustained improvement in oxygenation during the procedure and postprocedure.[76] PDT has also been performed in patients undergoing high-frequency oscillatory ventilation.[77] Despite these data, it is preferable to perform PDT when hypoxic respiratory failure and PEEP requirements have improved.

Unfortunately, ICU patients often have underlying coagulopathy or thrombocytopenia related to their comorbid conditions. Critically ill patients may also require treatment of medical issues with aspirin and clopidigrel or venous thromboembolic prophylaxis with heparin products. As a result, they are often at higher risk for procedure-related bleeding. There is wide variability in physician practices regarding periprocedural holding of anticoagulation,[78] but prophylactic anticoagulation may not adversely affect bleeding risk.[78,79] Prothrombin time,[80] activated partial thromboplastin time,[79] and thrombocytopenia[79,80] are associated with increased PDT procedural bleeding risk. These data are contradicted, however, by a small prospective, randomized trial demonstrating no difference in bleeding when coagulopathy or thrombocytopenia was corrected with fresh frozen plasma or platelet transfusion.[81] PDT has also been successfully performed in patients with refractory coagulopathy from severe liver disease[82] and organ transplant.[83] Although PDT has been successfully performed in these high-risk populations, further studies to evaluate the risk of bleeding from coagulopathy and thrombocytopenia are needed.

Part of the appeal of PDT is the relative simplicity of the procedure, which allows it to be adapted to potentially difficult situations. PDT has been safely performed in several situations where the patient may be at higher risk for complications. Additional circumstances where PDT has been successfully used include establishment of an emergent airway,[84] prior tracheostomy,[80,85,86] thyromegaly,[86] difficult airway,[87] and extreme age.[88] However, it is important to recognize that the physician's experience is crucial when evaluating if PDT can be safely performed; demonstration of the ability to perform PDT in a few select cases does not imply that PDT is the method of choice in all cases involving these patient populations.

PROCEDURAL TRAINING AND GUIDELINES

PDT can be safely performed by a variety of physician specialists, including interventional pulmonologists, medical critical care intensivists, neurointensivists, surgeons, and anesthesiologists.[47,89–92] Specific training is required to perform PDT with most guidelines using expert opinion to determine a recommended number of procedures to be used as a surrogate marker for the establishment of procedural competency. Although procedure volume is not the only determinant of competency, procedural outcomes in other specialties have been demonstrated to be directly related to outcomes.[93] Procedural simulation has also been used for PDT training.[94] The American College of Chest Physicians recommends a minimum of 20 procedures, whereas the American Thoracic Society and European Respiratory Society recommend 5 to 10 procedures before performing PDT independently with a minimum of 10 procedures per year to maintain proficiency.[95,96] In addition, it is recommended that physicians performing PDT have extensive experience in airway management and the treatment of critically ill patients.[96]

SUMMARY

There are numerous indications for PDT placement in the management of chronic respiratory failure. PDT has been safely performed by surgical and medical physicians, including critical care intensivists and interventional pulmonologists. There are multiple methods of performing the procedure and the single dilator variant of the Ciaglia method is currently the most widely used. PDT compares favorably with surgical tracheostomy in regards to procedure time, complications, and cost. Flexible bronchoscopy is commonly used as a procedural adjunct and has been shown to decrease complications. Because of its advantages, PDT has become one of the most common procedures performed in the modern ICU.

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