Some Important Details in the Technique of Percutaneous Dilatational Tracheostomy via the Modified Seldinger Technique*

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Study objective: The percutaneous dilatational tracheostomy can be performed with a low complication rate if several important technical details are followed. This study delineates our experience and recommends changes in the operative technique.

Design and setting: Patients requiring tracheostomy were selected for percutaneous dilatational tracheostomy based on previously reported criteria. The procedures were performed routinely in the ICU unless there was another reason to transport the patient to the operating room. The patients were monitored with an ECG and pulse oximetry. End-tidal CO₂ and ventilator settings were noted by the respiratory therapist. The airway was controlled using the bronchoscope and manually by the respiratory therapist. Adjustments were made in respiratory rate or tidal volume as indicated by an increase in end-tidal CO₂.

Patients and measurements: We report our experience with 254 patients who underwent percutaneous dilatational tracheostomy. We prospectively recorded intraoperative, early, and late complications. From our personal experience of 170 cases previously reported and 84 recent cases, we find that there are several important technical details in performing the procedure that will minimize complications.

Results: (1) Use of a deflated endotracheal tube cuff and increased tidal volume on the ventilator to compensate for lost minute volume and maintain normal PaCO₂; (2) an adequate skin incision to more easily palpate and identify the tracheal cartilages; (3) directing the cannula needle caudally to properly identify the tracheal air column; (4) a new ridge on the 8F Teflon guiding catheter to prevent injury to the posterior tracheal wall by the dilators; (5) there is a danger of partially withdrawing the double guide when removing the largest-sized dilators that are usually tightly grasped by the tissues; (6) use of a single cannula flexible tracheostomy tube and a longer tracheostomy tube when indicated; (7) a double swivel connection and flexible tubing to connect the patient to the ventilator to lessen trauma to the stoma; (8) fenestrated tracheostomy tubes allow talking in conscious patients; and (9) use of a disposable end-tidal CO₂ monitor and bronchoscope to confirm intratracheal position of the endotracheal tube while performing the procedure and proper placement of the tracheostomy tube on completion of the procedure.

Conclusion: Using these principles, minor complications occurred in 6.5% of the patients and major complications occurred in 1.5% of the patients, with a mortality rate of 0.39%.

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Key words: complications; percutaneous dilatational tracheostomy; technique

Maintaining an adequate airway in patients requiring prolonged mechanical ventilation can be a perplexing problem. Difficulty with maintaining endotracheal tube position, oral hygiene, proper suctioning, and tracheal injury are common problems with prolonged endotracheal intubation. The tracheostomy affords a reliable method for maintaining an adequate airway in patients who require long-term ventilatory support. It is easier for the nursing staff to maintain good oral hygiene. Suctioning has been noted to be
easier and less traumatic by the respiratory therapy and nursing staffs. A tracheostomy removes a tube from the patient's oropharynx and larynx, lessens the incidence of trauma to the region, and, if performed early enough, decreases the incidence of pneumonia. Patients seem to find a tracheostomy more comfortable and tolerable than an endotracheal tube.

In 1985, Ciaglia et al developed the percutaneous dilatational tracheostomy after observing radiologists performing dilatational nephrostomies. Initially a modified Amplatz percutaneous nephrostomy dilator set was used. Later a kit was manufactured (Cook Critical Care Inc; Bloomington, Ind). The original percutaneous technique advocated making the smallest skin incision that would allow the snug fit of a flexible tracheostomy tube placed in the trachea. By performing smaller tracheostomy incisions, the incidence of unsightly scarring that occurred with the traditional tracheostomy technique was reduced.

**Materials and Methods**

Two hundred fifty-four percutaneous dilatational tracheostomies performed by us were recorded prospectively. Ventilator settings, length of endotracheal intubation, diagnosis, and short- and long-term complications were compiled. The percutaneous dilatational tracheostomy is our preferred technique for patients requiring tracheostomy unless there are contraindications of goiter, bleeding diathesis, children younger than 16 years, or emergency airway. Most of the procedures were performed in the ICU; however, some were performed in the operating room in conjunction with other procedures.

Patients were premedicated with an intermediate-acting neuromuscular blocking agent, a benzodiazepine, and an analgesic. One percent lidocaine (Xylocaine) with epinephrine was used in all patients for anesthesia and hemostasis of the skin, subcutaneous tissue, and tracheal lumen.

All patients were monitored with continuous pulse oximetry. An end-tidal CO$_2$ monitor was attached to the endotracheal tube prior to loosening the tape securing it. The patient was administered 100% oxygen and placed on a regimen of controlled ventilation.

Bronchoscopy has been used in the last 30 patients. The bronchoscope is passed through the endotracheal tube prior to making the skin incision. It is left in place throughout the procedure. The endotracheal tube and trachea are suctioned to clear any secretions prior to starting the procedure. A 1- to 2-cm skin incision is made. After palpating the trachea through the incision, the second tracheal ring is identified (Fig 1). The cuff on the endotracheal tube is deflated. Under bronchoscopic control, the endotracheal tube is withdrawn so that the catheter introducer needle can be seen to pass into the trachea without impaling the endotracheal tube.

The previously noted minute ventilation is maintained by the respiratory therapist. The tidal volume or respiratory rate is continuously adjusted throughout the procedure to maintain the preprocedure end-tidal CO$_2$.

If the end-tidal CO$_2$ increases during the procedure, the respiratory rate or tidal volume is increased. If the arterial oxygen saturation was noted to decrease or end-tidal CO$_2$ continues to increase, the endotracheal tube is advanced or the cuff is reinflated.

The tracheal air column is identified by aspirating air into the syringe attached to the catheter introducer needle. The syringe is filled with 3 to 5 mL of lidocaine with epinephrine and this is injected into the trachea. The J-wire is inserted into the trachea. An initial dilation with the short 11F dilator is performed. After removing the dilator, an 8F guiding catheter is passed and left in place with the wire. The trachea is serially dilated by inserting six dilators, 12 to 36F, over the double guide (J-wire and 8F guiding catheter) (Fig 2). An 8-mm single cannula, flexible Shiley (R) tracheostomy tube, fitted on a dilator, is usually inserted over the double guide (Fig 3).

The tracheostomy tube flanges are secured to the skin with 2-0 nylon sutures. An umbilical tape is passed around the patient's neck to further secure the tracheostomy tube. The position in the trachea is confirmed by the return of end-tidal CO$_2$ and by passing the bronchoscope through the tracheostomy. It is not uncommon to perform a therapeutic or diagnostic bronchoscopy at the completion of the procedure. Flexible ventilator tubing with a...
double swivel connector is used to attach the tracheostomy tube to the ventilator.

**RESULTS**

Two hundred fifty-four consecutive percutaneous dilational tracheostomies were performed over a 10-year period. There were four major complications in the immediate perioperative period (Table 1).

A tension pneumothorax occurred in a patient with Down’s syndrome and a short neck. He required extensive finger dissection to reach the second tracheal cartilage that was at the level of the sternal notch. This was recognized and treated appropriately by tube thoracostomy.

There has been 1 death (0.39% mortality rate) associated with the procedure. The patient was mentally retarded and hyperactive. The tracheostomy tube was not sutured to the patient’s neck. It was connected to the ventilator with standard ventilator tubing. The next day, when turning the patient, the tube became dislodged. Attempts at reinserting the tracheostomy, which had been placed (without difficulty) 24 h before the incident, were unsuccessful. While an emergency tracheostomy was being performed, no attempt at oral endotracheal intubation was made until the patient sustained a hypoxic cardiac arrest from which she could not be resuscitated.

Minor complications occurred in 18 patients (7%). There were three patients in whom the airway was lost due to paratracheal dilatation and insertion of the tracheostomy tube. None experienced any respiratory distress because the paratracheal intubations were recognized immediately. In one patient, the tract was immediately redilated and the tracheostomy tube was inserted without difficulty. Another patient had torticollis and the airway was lost during dilator changes. This was converted immediately to an open tracheostomy. The arterial oxygen saturation did decrease from 100 to 75% while the open tracheostomy was performed. The last patient was a small woman in whom the larger dilators could not be passed. An open tracheostomy was performed and it was noted that the endotracheal tube had not been withdrawn sufficiently to allow unobstructed passage of the dilators or tracheostomy tube.

The remaining complications included 5 previously reported instances of inability to intubate the trachea with an 8-mm tracheostomy tube. This has not occurred since dilating to a 36F stoma. There were three instances of subcutaneous emphysema that rapidly resolved. This did not cause any difficulty, although it extended into the mediastinum in two cases.

Hemorrhage occurred in three patients. Two of these patients were receiving anticoagulation after mitral valve surgery. Bleeding occurred when heparinization was resumed. The bleeding was controlled with topical hemostatic agents and discontinuation of the heparin therapy for an additional 12 h. One instance of bleeding occurred when an anterior jugular vein was transected. This required conversion to an open tracheostomy and ligation of the vessel. An additional three patients had minimal oozing that did not require treatment.

There have been seven late complications. Two pa-

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**Table 1—Complications**

<table>
<thead>
<tr>
<th>Complication</th>
<th>No.</th>
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<tbody>
<tr>
<td>Major</td>
<td></td>
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<tr>
<td>Death</td>
<td>1</td>
</tr>
<tr>
<td>Tension pneumothorax</td>
<td>1</td>
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<tr>
<td>Tube displacement</td>
<td>1</td>
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<tr>
<td>Left mainstem intubation</td>
<td>1</td>
</tr>
<tr>
<td>Minor</td>
<td></td>
</tr>
<tr>
<td>Paratracheal dilation</td>
<td>3</td>
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<tr>
<td>Hemorrhage</td>
<td>3</td>
</tr>
<tr>
<td>Tracheal stenosis</td>
<td>2</td>
</tr>
<tr>
<td>Cellulitis</td>
<td>1</td>
</tr>
<tr>
<td>Inability to cannulate the trachea</td>
<td>5</td>
</tr>
<tr>
<td>Subcutaneous emphysema</td>
<td>3</td>
</tr>
<tr>
<td>Persistent stoma</td>
<td>1</td>
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tients (0.7%) developed tracheal stenosis that required tracheoplasty to restore an adequate airway. Both of these patients had been endotracheally intubated for up to 45 days before a tracheostomy was performed. Stenosis was noted to be above and below the tracheostomy stoma, representing a combination injury to the trachea from the endotracheal tube and the tracheostomy.

There has been one instance (each) of a persistent stoma, cellulitis, left main stem bronchial intubation, tube displacement, and partial obstruction from twisting of the flexible tracheostomy tube.

**Discussion**

Colice described the complications associated with prolonged translaryngeal intubation. Tracheal abnormalities can be seen as soon as a few hours after intubation. Serious changes occur in 1 to 5.5% of intubated patients. The typical pattern of damage from an endotracheal tube consists of mucosal ulcerations along the posterior medial aspect of the true vocal cords. In 94% of the patients Colice studied, this was associated with varying degrees of laryngeal edema.

The glottis is small and pentagonal in shape. The endotracheal tube rests against the arytenoids and posterior subglottis. The duration of translaryngeal intubation and the size of the endotracheal tube are factors responsible for laryngeal damage. Symptoms associated with laryngeal damage range from sore throat and hoarseness to airway obstruction. These symptoms are due to the edema, ulceration, and granuloma formation. The injuries heal secondarily by the formation of more granulation tissue.

A tracheostomy can exacerbate this damage by allowing bacteria to enter the trachea with subsequent tracheitis. The tracheostomy tube interferes with the laryngeal reflexes that maintain separation of the tracheal walls. This loss leads to fusion of the abraded tracheal surfaces. Tracheal stenosis or webs form most commonly at the stoma or balloon cuff site. Gibson first noted that tracheal damage occurs from overdilatation of the balloon cuff. The tracheal cartilage softens, the epithelium sloughs, and subsequent granulation tissue narrows the tracheal lumen.

When an open tracheostomy is performed, a relatively large incision is made, there is dissection of the anterior neck, and tracheal cartilage is removed or a flap is created. These maneuvers cause many of the tracheal changes Colice reported.

The large incision and dissection allow bacteria on the skin to enter the trachea. Removal of flaps of tracheal cartilage can cause tracheal narrowing. Arola et al demonstrated some degree of tracheal stenosis in 85% of patients studied after decannulation. Formation of granulation tissue is promoted by tracheal infection.

The percutaneous dilatational tracheostomy solves many of these problems. When patients are known to require prolonged mechanical ventilation, the percutaneous dilational technique allows earlier tracheostomy. A small incision is all that is required. There is no need to dissect the anterior neck. Secondary infection of the wound or trachea is rare. No tracheal cartilage is removed and a flap is not formed. We have been able to demonstrate that there is no increased incidence of tracheal stenosis with the percutaneous dilatational technique.

The small skin incision is used to accurately identify the cricoid cartilage and the second and third tracheal rings. This prevents an inadvertent cricothyroidotomy with its attendant complications.

Several authors have reported malposition, hypercarbia, infection, or hemorrhage associated with the percutaneous dilatational technique. Many of these can be avoided when carefully adhering to the described technique.

Bronchoscopic guidance serves several purposes. As the catheter-introducer needle is inserted, it can be seen to enter the tracheal lumen. Perforation of the back wall is avoided and submucosal flaps are not created. The guidewire and guide catheter position are confirmed with each dilator change. The dilators are confirmed to enter the tracheal lumen and not damage the membranous trachea. The ridge on the guide catheter provides additional tracheal protection. Importantly, control of the airway is maintained at all times. The endotracheal tube can be advanced or withdrawn as necessary and the tracheostomy tube can be seen to enter the tracheal lumen.

The end-tidal CO2 monitor allows real-time evaluation of the CO2 levels. If the level is noted to rise, the respiratory therapist will increase the tidal volume or respiratory rate. On occasion, the cuff has had to be reinflated. This allows maintenance of near baseline CO2 levels. The end-tidal CO2 monitor is also used to confirm intratracheal placement of the tracheostomy tube.

The flexible tracheostomy tubes are softer than the standard double cannula tubes. We believe that these tubes cause less tracheal damage since they are flexible. In patients who have short or fat necks, special flexible tubes can be ordered. Accurate tube length is assured and the risk of accidental decannulation is reduced.

Soft, flexible tubing should be used to connect the tracheostomy tube to the ventilator. This prevents "torquing" the tracheostomy tube when turning the patient. It also "absorbs" the weight of in-line suction devices and reduces traction on the tracheostomy tube.
This will decrease accidental decannulation. The tubing is of minimal length so that significant dead-space is not added to the ventilator circuit.

Should the tracheostomy become dislodged during the first 2 weeks after insertion, an oral endotracheal tube should be reinserted to secure the airway. Before 2 weeks, a stoma tract has not developed sufficiently to allow safe recannulation. The neck incision is small and there are no stay sutures in the trachea. The tracheal stoma is inaccessible until a mature tract forms.

Once the airway is secured, the tract can be dilated using bronchoscopic guidance. The stoma can be visualized easily. The tracheostomy can be reinserted with only one or two dilators. The one patient in the series died because oral endotracheal intubation was not performed.

Hemostasis is assured by having epinephrine in the lidocaine. This causes vasoconstriction, especially at the skin edges. The tracheostomy tube then tamponades the skin edges since the incision is small. By using blunt dissection, vessels are usually pushed aside and not transected. If the anterior jugular veins are visible, they should be suture-ligated. Instilling the lidocaine with epinephrine into the trachea not only anesthetizes it but also provides hemostasis during the dilations.

**Conclusion**

The complications reported in this series compare favorably with those from series of open tracheostomy. The 1.5% major complication rate and 5.5% minor complication rate are the lowest reported thus far.4,11 Following our recommended changes from the previously described technique, the percutaneous dilatational tracheostomy can be performed safely at the patient's bedside in the ICU. Bronchoscopy affords added protection from loss of the airway or from the development of submucosal flaps. Flexible tubing and suturing the tracheostomy to the patient's neck will prevent inadvertent decannulation. The procedure should be added to the armamentarium of the surgical intensivist.

**References**

5. Gibson P. Aetiology and repair of tracheal stenosis following tracheostomy and intermittent positive pressure respiration. Thorax 1967; 22:1-6