Tracheostomy is a common critical care procedure in patients with acute respiratory failure who require prolonged mechanical ventilatory support. Tracheostomy is usually considered if weaning from mechanical ventilation has been unsuccessful for 14 to 21 days. A recent clinical trial suggested that early tracheostomy may benefit patients who are not improving and who are expected to require prolonged respiratory support. In this study, early tracheostomy improved survival and shortened duration of mechanical ventilation. Minimally invasive bedside percutaneous tracheostomy was introduced recently as an alternative to the traditional surgical technique. In expert hands, the 2 techniques are equivalent in complications and safety; however, the bedside percutaneous approach may be more cost-effective. Tracheostomy should be considered early (within the first week of mechanical ventilation) in patients with a high likelihood of prolonged mechanical ventilation. Depending on local medical expertise and costs, either the percutaneous or the surgical technique may be used.


APACHE = Acute Physiology and Chronic Health Evaluation; ICU = intensive care unit

Tracheostomy is one of the oldest known surgical procedures. The first reference to this procedure is in the ancient Indian book of medicine, the Rig-Veda, written in 1500 BC.1 Chevalier Jackson2 is credited with describing the modern-day tracheostomy in 1909. Percutaneous tracheostomy was introduced in the mid-1980s3 as an alternative to surgical tracheostomy and has gained widespread acceptance over the past decade. Although most critically ill patients with respiratory failure tolerate short-term tracheal intubation well with minimal complications, longer (>1 week) mechanical ventilation is associated independently with adverse outcome.4 Several new interventions (low tidal volume ventilation, tight glucose control, weaning and sedation protocols, and patient positioning to prevent ventilator-associated pneumonia) were shown recently to decrease morbidity and mortality in patients receiving mechanical ventilation.5-8 However, a substantial number of patients require prolonged mechanical ventilation and tracheostomy. Esteban et al9 found that 24% of patients who were receiving mechanical ventilation required tracheostomy.

In this review, we outline the recent progress in the timing and techniques of tracheostomy in critically ill patients. We searched the National Library of Medicine PubMed database of studies published between January 1980 and December 2004 for the terms tracheostomy AND (critically ill OR respiratory failure, acute) and hand-searched the references of retrieved articles. Randomized and observational clinical studies and meta-analyses were reviewed.

INDICATIONS AND TIMING OF TRACHEOSTOMY IN PATIENTS WITH ACUTE RESPIRATORY FAILURE

Tracheostomy is performed primarily in critically ill patients with acute respiratory failure who require prolonged mechanical ventilation and/or in whom multiple attempts to wean from mechanical ventilation have been unsuccessful for 14 to 21 days.10 Tracheostomy facilitates weaning by decreasing the work of breathing in patients with limited reserve.11,12 However, the effect on dead space ventilation is marginal.13 Tracheostomy decreases the requirement for sedation and may allow for earlier patient mobilization, feeding, and physical and occupational therapy. Less common indications include relief of upper airway obstruction, severe sleep apnea, difficult airway, and pulmonary secretion clearance. The main complications of prolonged tracheal intubation are ventilator-associated pneumonia and the adverse effects associated with persistent sedation. Local complications, including subglottic stenosis, are more likely if tracheal intubation is continued for more than 2 weeks. Pena et al14 found that 86% of all patients with subglottic stenosis had a history of tracheal intubation with a mean duration of ventilatory support of 17 days.

The optimal timing of tracheostomy in critically ill patients with acute respiratory failure is controversial. The standard of care has varied considerably over the years, and the current trend seems to be early tracheostomy (within the first week of tracheal intubation).15,16 The transition from “low volume, high pressure” to “high volume, low pressure” cuffs for tracheostomy tubes allowed tracheal tubes to be kept in place longer because significantly less...
damage to the trachea was seen with use of “high volume, low pressure” cuffs. In 1981, Stauffer et al reported a prospective study of the complication rate of prolonged tracheal intubation vs tracheostomy. Of patients who underwent tracheostomy, 66% experienced complications compared with 62% in the translaryngeal intubation group. The complications of tracheostomy were judged to be more severe. Stauffer et al concluded that given the complication rate of tracheostomy, it could not be recommended during the initial 3 weeks of invasive mechanical ventilation. However, no other study reproduced such extraordinarily high complication rates.

Heffner advocated an anticipatory model in which the need for tracheostomy was assessed after 1 week of ventilatory support. If the patient was expected to require ventilatory support for more than a week, then tracheostomy was advocated. Mazia et al systematically reviewed this topic in 1998. Five studies that included nearly 400 patients were reviewed, only 3 of which had randomized study designs. Primary outcomes included duration of mechanical ventilation, clinical course of patients in the intensive care unit (ICU), and tracheal lesions. The authors concluded that there was insufficient evidence to support the theory that timing of tracheostomy alters the duration of mechanical ventilation or the extent of tracheal injury.

Over the past few years, several studies have supported use of earlier tracheostomy. Brook et al conducted a prospective observational (nonrandomized) study of tracheostomies performed in a single medical center. Early tracheostomies were those performed before day 10 of mechanical ventilation, and late tracheostomies were those performed after day 10. A cohort of 90 patients was identified. Fifty-three patients underwent early tracheostomy (mean ± SD days of ventilation, 5.9 ± 7.2), and 37 patients underwent late tracheostomy (mean ± SD days of ventilation, 16.7 ± 2.9; P < .001). Of tracheostomies performed, 33% (30/90) were percutaneous. The duration of mechanical ventilation and the total cost of hospitalization were significantly lower in the early-tracheostomy group.

In a recent clinical trial by Rumbak et al, 128 patients in the ICU who were expected to require mechanical ventilation for more than 14 days were randomized either to early percutaneous tracheostomy (<48 hours) or to late tracheostomy (days 14-16). The 2 groups were well matched. The authors showed that the length ± SD of ICU stay (4.8 ± 1.4 vs 16.2 ± 3.8 days; P < .001), number of days the patient received ventilation (7.6 ± 2.0 vs 17.4 ± 5.3 days; P < .001), and mortality (31.7% vs 61.7%; P < .005) were significantly lower in the early-tracheostomy group. The trachea was evaluated in the hospital 10 weeks after extubation, and no differences were observed between the 2 groups.

Teoh et al retrospectively reviewed 30 neurosurgical patients (cerebrovascular disease in 53%, head trauma in 33%, and tumor/infection in 13%). They found that the patients who underwent early tracheostomy had significantly fewer complications and were weaned from the ventilator earlier.

Arabi et al prospectively reviewed 653 trauma patients admitted to the ICU during a 5-year period; 136 (21%) required tracheostomy (70% percutaneous). Of the 136 patients, 29 had undergone early tracheostomy (by day 7 of mechanical ventilation); these patients had a significantly shorter ICU stay and duration of receiving mechanical ventilation.

These studies, especially that of Rumbak et al, support early tracheostomy in patients expected to need long-term ventilatory support.

A recent Cochrane meta-analysis included 5 methodologically sound clinical trials that compared early vs late tracheostomy in critically ill adult patients. Although no significant differences were found in mortality and risk of hospital-acquired pneumonia, patients who underwent early tracheostomy (within a week of initiation of mechanical ventilation) spent significantly less time receiving ventilation and in the ICU. Decreased need for sedation and increased patient mobility are some potential explanations for the improved outcome. Of note, the important recent advances in the care of critically ill patients (tight glucose control, low tidal volume ventilation, weaning and sedation protocols, restrictive red blood cell transfusion) were not used consistently in these studies.

The main obstacle to early tracheostomy in patients likely to benefit is the inability to accurately predict the need for prolonged mechanical ventilation during the first several days of mechanical ventilation. The best predictors appear to be nonspecific markers of poor outcome: high acuity of illness (Acute Physiology and Chronic Health Evaluation [APACHE] II scores >25) and the presence of shock at the time of ICU admission. Of note, more than 70% of patients in the control group of the Rumbak et al study required mechanical ventilation for more than 14 days, suggesting a reasonably good predictive ability of the APACHE II scoring system. Therefore, it is important to ascertain the patient’s wishes about tracheostomy early in the course of critical illness. Figure 1 illustrates the suggested approach to the timing of tracheostomy in critically ill patients.

### TRACHEOSTOMY TECHNIQUES

Tracheostomy can be performed with the open technique in the operating room, with the open technique at the bedside,
or with the percutaneous approach at the bedside. In the open technique, a small transverse incision is made between the lower border of the cricoid cartilage and the suprasternal notch. The strap muscles are retracted laterally to expose the underlying thyroid gland and the trachea. The thyroid isthmus is retracted in a cephalad direction or divided, exposing the tracheal rings. An incision is made in the tracheal rings. The type of tracheal incision varies at different institutions, but the most common is a transverse incision between tracheal rings 2 and 3. The third tracheal ring is divided and hinged via connective tissue to the fourth tracheal ring. The flap is sutured to the skin, thereby creating a clear path from the skin to the trachea. This cartilage flap, sutured to the skin, is a Bjork flap. The Bjork flap is preferred among otolaryngologists at the Mayo Clinic because it creates a safe track if accidental decannulation occurs. Absorbable suture is used, and the flap falls slowly back into a more anatomical position once the suture absorbs. The tracheostomy tube is then placed under direct visualization. The open technique at the bedside does not differ in any way from the open technique in the operating room. The bedside procedure is more difficult because lighting, suction, sterility, and cautery are not optimal.

The percutaneous tracheostomy technique was introduced in the mid-1980s. It has been safe in terms of immediate and late complications and has gained widespread popularity over the past decade. The percutaneous tracheostomy can be done by the Ciaglia, Griggs, or Rapitrach method; however, the Rapitrach kit (Fresenius Kabi Ltd, Runcorn, Cheshire, UK) has been removed from the US market because of a high incidence of posterior tracheal wall tears and lacerations of the balloon cuff during tracheostomy tube insertion. Numerous studies have looked at these techniques. The Ciaglia technique has been associated with the fewest complications and is used most

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**FIGURE 1. Approach to the timing of tracheostomy in critically ill patients receiving mechanical ventilation. APACHE = Acute Physiology and Chronic Health Evaluation; FiO₂ = fraction of inspired oxygen.**

*The method of tracheostomy depends on the local medical expertise.*
widespread. For the Ciaglia technique (Figure 2), a 2-cm transverse incision is made below the cricoid cartilage. A needle is passed into the trachea after the existing tracheal tube has been withdrawn above the incision site. Once the needle is passed, a guidewire is passed through it toward the carina. Multiple dilators are used to create a tracheostoma, and the tracheostomy tube is finally passed over a guidewire. Bleeding is rare because the process is dilational, and tamponade of the vessels usually occurs. Since its introduction, the Ciaglia technique has undergone a few modifications. The incision has been moved slightly lower over tracheal rings T1-2 and T2-3. A single dilator is used in place of multiple dilators. A fiberoptic bronchoscope helps position the tracheal tube above the site of incision, prevents undue pressure over the posterior pharyngeal wall, and serves as a valuable teaching aid.

Byhahn et al compared the single-step dilation modification of the Ciaglia technique with the multistep dilational procedure and found that the single-step process was associated with significantly fewer complications. To position the existing tracheal tube above the incision site, Addas et al successfully used a light source in place of the fiberoptic bronchoscope. Portable ultrasonography can be used to guide placement of the percutaneous tracheostomy and to minimize complications by identifying the vessels and the landmarks, as described by Hatfield and Bodenham.

WHICH TECHNIQUE IS SUPERIOR?

Numerous studies and 2 meta-analyses in 1999 and 2000 have tried to determine which technique is superior. Dulguerov et al, in their meta-analysis, included all study designs (retrospective, observational, and prospective) and all studies of percutaneous tracheostomy irrespective of techniques analyzed. The surgical technique studies were grouped according to the historical period: 1960-1984 (17 studies including 4185 patients) and 1985-1996 (21 studies including 3512 patients). The authors identified 27 studies of percutaneous tracheostomy that enrolled 1817 patients. The complication rate was significantly greater in the studies of surgical tracheostomy reported between 1960 and 1984. Comparison of recent surgical (n=21; 3512 patients) and percutaneous (n=27; 1817 patients) tracheostomy trials has shown that perioperative complications are more frequent with the percutaneous technique (10% vs 3%), whereas postoperative complications occur more often with surgical tracheostomy (10% vs 7%).

In another meta-analysis, Freeman et al identified only prospective studies that directly compared the percutaneous dilational technique with the surgical technique. Five studies, which included 236 patients, met the inclusion criteria and were analyzed (Table 1). The authors concluded that the percutaneous technique had a slight advantage over the surgical technique for difficulty and duration of surgery, peristomal bleeding, and postoperative infection. Two editorials that commented on these meta-analyses concluded that the 2 techniques can coexist and that the complication rate during the percutaneous technique depended on local medical expertise. A larger randomized trial was recommended to assess important outcomes among patients.

Depending on the institution, the percutaneous tracheostomy techniques may be less costly than the surgical technique. Bowen et al performed a retrospective analysis of the costs of the 2 procedures and reported that an uncomplicated percutaneous tracheostomy costs $1753, whereas the surgical procedure costs $2604. The cost of fiberoptic bronchoscopy, if required, was added to the percutaneous group if necessary. Freeman et al later prospectively randomized 80 patients to either bedside percutaneous dilational technique or surgical tracheostomy. They found that the cost was significantly less in the percutaneous group (total patient charges: percutaneous dilational tracheostomy, $1569±$157 vs surgical tracheostomy, $3172±$114; P<.001), whereas the complication rates were the same. The main cost savings were related to operating room use. However, the cost advantage of percutaneous tracheostomy may not be apparent if open surgical tracheostomy is done at the bedside.

CONTRAINDICATIONS TO USE OF THE PERCUTANEOUS TECHNIQUE

Morbid obesity, repeated tracheostomy, high positive end-expiratory pressure, severe coagulopathy, and unusual neck anatomy have been cited often as contraindications to percutaneous tracheostomy. The primary concerns have
TRACHEOSTOMY IN CRITICALLY ILL PATIENTS

TABLE 1. Outcome Comparison of Open vs Percutaneous Tracheostomy*

<table>
<thead>
<tr>
<th>Reference</th>
<th>Group</th>
<th>No. of patients</th>
<th>Procedure time (SD) (min)</th>
<th>Days intubated (SD)</th>
<th>All operative complications (%)</th>
<th>Operative bleeding (%)</th>
<th>All postoperative complications (%)</th>
<th>Postoperative bleeding (%)</th>
<th>Stomal infections (%)</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard et al, 1991</td>
<td>PDT 40</td>
<td>22</td>
<td>4.3 (2.2)</td>
<td>7.7 (3.9)</td>
<td>NA</td>
<td>NA</td>
<td>12</td>
<td>4</td>
<td>4</td>
<td>46</td>
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<tr>
<td></td>
<td>SCT 24</td>
<td>13.5 (7.3)</td>
<td>9.2 (3.2)</td>
<td>NA</td>
<td>NA</td>
<td>46</td>
<td>17</td>
<td>33</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>P&lt;.001</td>
<td>P=.16</td>
<td>P&lt;.01</td>
<td>P=.19</td>
<td>P&lt;.01</td>
<td>P=.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crofts et al, 1995</td>
<td>PDT 25</td>
<td>NA</td>
<td>12.5 (6.3)</td>
<td>NA</td>
<td>NA</td>
<td>25</td>
<td>12</td>
<td>0</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SCT 28</td>
<td>10.5 (5.0)</td>
<td>NA</td>
<td>NA</td>
<td>36</td>
<td>11</td>
<td>4</td>
<td>50</td>
<td></td>
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</tr>
<tr>
<td>P=.20</td>
<td>P=.16</td>
<td>P=.08</td>
<td>P=.26</td>
<td>P=.18</td>
<td>P=.70</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Friedman et al, 1996</td>
<td>PDT 26</td>
<td>8.2 (4.9)</td>
<td>17.2 (7.5)</td>
<td>35</td>
<td>13</td>
<td>12</td>
<td>8</td>
<td>0</td>
<td>42</td>
<td></td>
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<tr>
<td></td>
<td>SCT 27</td>
<td>33.9 (14.0)</td>
<td>21.3 (26.2)</td>
<td>41</td>
<td>11</td>
<td>41</td>
<td>15</td>
<td>15</td>
<td>33</td>
<td></td>
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<td>P=.44</td>
<td>P=.65</td>
<td>P=.96</td>
<td>P&lt;.008</td>
<td>P=.49</td>
<td>P=.18</td>
<td>P=.70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holdgaard et al, 1998</td>
<td>PDT 30</td>
<td>11.5 (4.25)</td>
<td>7.0 (2.7)</td>
<td>63</td>
<td>20</td>
<td>23</td>
<td>10</td>
<td>10</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SCT 30</td>
<td>15.5 (10.5)</td>
<td>6.5 (3.1)</td>
<td>87</td>
<td>87</td>
<td>100</td>
<td>33</td>
<td>63</td>
<td>NA</td>
<td></td>
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<tr>
<td>P&lt;.01</td>
<td>P=.51</td>
<td>P&lt;.05</td>
<td>P&lt;.01</td>
<td>P&lt;.05</td>
<td>P&lt;.01</td>
<td>P&lt;.05</td>
<td>P&lt;.01</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Porter &amp; Ivatury, 1999</td>
<td>PDT 12</td>
<td>15.4 (3.8)</td>
<td>9.8 (4.0)</td>
<td>42</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SCT 12</td>
<td>25.2 (9.5)</td>
<td>12.4 (6.0)</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>P=.001</td>
<td>P=.21</td>
<td>P=.05</td>
<td>P=.10</td>
<td>P=.10</td>
<td>P=.10</td>
<td>P=.10</td>
<td>P=.31</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*In studies in which actual P values were not reported, they were computed using t test or \( \chi^2 \) as appropriate. NA = not available; PDT = percutaneous dilational tracheostomy; SCT = surgically created tracheostomy.

From Chest, with permission.

been the difficulty in identifying landmarks, distortion of the anatomy, and bleeding that needs to be controlled surgically. Byhahn et al\(^5\) reported a greater complication rate in obese patients (43.8% vs 18.2%) who underwent percutaneous tracheostomy compared with nonobese patients. Several studies showed that percutaneous tracheostomy could be performed safely in this subpopulation of patients, which made obesity a relative rather than an absolute contraindication. An earlier small study by Mansharamani et al\(^5\) involving 13 obese patients (body mass index >27 kg/m\(^2\)) who underwent bedside percutaneous tracheostomy reported only 1 complication in which the tube was placed paratracheally, but the error was corrected immediately. Meyer et al\(^5\) retrospectively identified patients who had undergone repeated tracheostomy (14 patients were identified in whom the second tracheostomy was percutaneous). All had undergone successful tracheostomy with minimal complications. Two other studies showed similar results. Sustic et al\(^5\) reported no increase in complications in patients with anterior spinal fixation who underwent percutaneous tracheostomy compared with open surgical tracheostomy, whereas Mayberry et al\(^5\) reported that percutaneous tracheostomy could be performed safely in trauma patients without cervical spine clearance and neck extension, including patients with stabilized cervical spine or spinal cord injury. Kluge et al\(^5\) reported a 5% (2/42) incidence of major bleeding after percutaneous tracheostomy in patients with thrombocytopenia. All had undergone platelet transfusion before surgery. Beiderlinden et al\(^5\) found no difference in oxygenation at 1 hour and 24 hours when percutaneous tracheostomy was performed in patients requiring high positive end-expiratory pressure (16.6±4 cm H\(_2\)O vs 7.6±2.2 cm H\(_2\)O).

**Complications of Tracheostomy**

Table 2 lists the most important complications of tracheostomy in critically ill patients. Most complications are reported only as case reports. Tracheal stenosis can occur at the stoma, superior to the stoma, at the level of the cuff, and at the tip of the tube. The main reason for stenosis is

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**TABLE 2. Most Important Complications of Tracheostomy**

<table>
<thead>
<tr>
<th>Adverse events associated with transport to the operating room</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemorrhage</td>
</tr>
<tr>
<td>Hoarseness</td>
</tr>
<tr>
<td>Infection of the stoma or tracheobronchial tree</td>
</tr>
<tr>
<td>Peristomal cellulitis</td>
</tr>
<tr>
<td>Aspiration pneumonia</td>
</tr>
<tr>
<td>Tracheal stenosis</td>
</tr>
<tr>
<td>Surgical emphysema</td>
</tr>
<tr>
<td>Tracheoesophageal fistula*</td>
</tr>
<tr>
<td>Tracheoesophageal fistula*</td>
</tr>
<tr>
<td>Tracheomalacia</td>
</tr>
<tr>
<td>Tracheocutaneous fistula after decannulation*</td>
</tr>
<tr>
<td>Tracheal ring rupture</td>
</tr>
<tr>
<td>Pneumothorax</td>
</tr>
<tr>
<td>False placement of cannula</td>
</tr>
<tr>
<td>Cardiopulmonary arrest</td>
</tr>
<tr>
<td>Death</td>
</tr>
</tbody>
</table>

*Fistulas also can form between the trachea, the esophagus, and the innominate artery.
mucosal ischemia. Most stenoses tend to be asymptomatic unless they reduce the tracheal lumen by more than 50%. Keeping cuff pressure below 20 cm H2O may prevent cuff stenosis. Substantial stenosis can be treated either surgically or by endoscopic stent placement. Tracheoinnominate fistula, a life-threatening condition that occurs in 0.6% to 0.7% of tracheostomies, may present with a sentinel bleed or as a pulsatile trachea. A high index of suspicion is required because bronchoscopic and angiographic findings may be inconclusive. Treatment consists of immediate surgery.52 A complication specific to the tracheostomy technique is the risk of airway fire with cautery use during open tracheostomy. Complications specific to percutaneous tracheostomy include flaps of cartilage protruding into the tracheal lumen, extraluminal placement of the tracheostomy, and postoperative decannulation with an inability to recannulate the trachea due to the absence of a well-formed tract.

CONCLUSIONS

Many critically ill patients require prolonged mechanical ventilation and tracheostomy. In patients with high risk of mortality and morbidity based on the presence of shock at onset of mechanical ventilation and high severity of illness scores and in whom no evidence of improvement can be shown during the first few days of mechanical ventilation, the option of early tracheostomy (within the first week from initiation of mechanical ventilation) should be discussed with the patient and/or family members. However, better predictors are needed to further identify patients who can benefit from tracheostomy early in the course of mechanical ventilation. Although success of tracheostomy depends on local medical expertise, bedside percutaneous tracheostomy by the modified Ciaglia technique appears to be as successful as the open surgical technique and may be associated with cost savings.

REFERENCES