

Tracheostomy: Why, When, and How?

Charles G Durbin Jr MD FAARC

Introduction

Why Perform a Tracheostomy?

Benefits of Tracheostomy

Improved Comfort?

Faster Weaning and Shorter Stay?

Increased Patient Safety?

Fewer Lung Infections With Tracheostomy?

When to Perform a Tracheostomy?

Do Head-Injured or Other Trauma Patients Benefit from Early Tracheostomy?

Do Medical Patients Benefit Form Early Tracheostomy?

How Should a Tracheostomy Be Performed?

Surgical Technique for Placing a Tracheostomy Tube

Techniques for Percutaneous Dilational Tracheostomy

Modifications of PDT Technique

Bedside or Operating Room Tracheostomy Placement?

Summary

Tracheostomy is one of the most frequent procedures performed in intensive care unit (ICU) patients. Of the many purported advantages of tracheostomy, only patient comfort, early movement from the ICU, and shorter ICU and hospital stay have significant supporting data. Even the belief of increased safety with tracheostomy may not be correct. Various techniques for tracheostomy have been developed; however, use of percutaneous dilation techniques with bronchoscopic control continue to expand in popularity throughout the world. Tracheostomy should occur as soon as the need for prolonged intubation (longer than 14 d) is identified. Accurate prediction of this duration by day 3 remains elusive. Mortality is not worse with tracheotomy and may be improved with earlier provision, especially in head-injured and critically ill medical patients. The timing of when to perform a tracheostomy continues to be individualized, should include daily weaning assessment, and can generally be made within 7 days of intubation. Bedside techniques are safe and efficient, allowing timely tracheostomy with low morbidity. *Key words: tracheostomy; intubation; intensive care.* [Respir Care 2010;55(8):1056–1068. © 2010 Daedalus Enterprises]

Introduction

Tracheostomy is one of the most frequently performed surgical procedures in intensive care unit (ICU) patients. As many as 10% of patients requiring at least 3 days of mechanical ventilation will eventually receive a tracheostomy for prolonged mechanical ventilation or airway support. While prolonged respiratory failure is probably the most common reason for performing tracheostomy, other

Charles G Durbin Jr MD FAARC is affiliated with the Department of Anesthesiology, University of Virginia, Charlottesville, Virginia.

Dr Durbin presented a version of this paper at the 25th New Horizons Symposium, "Airway Management: Current Practice and Future Directions," at the 55th International Respiratory Congress of the American Association for Respiratory Care, held December 5–8, 2009, in San Antonio, Texas.

indications such as decreased level of consciousness, poor airway protective reflexes, and severe alterations in physiology associated with trauma and medical illness are also indications for tracheostomy. With development of less invasive tracheostomy techniques that can be performed safely at the patient's bedside, the frequency of performing tracheostomy appears to be increasing. This paper will review the information regarding tracheostomy indications, timing, and techniques for performing the procedure. The primary focus of this review will be recently published trials and meta-analyses of studies that include appropriate comparison groups. However, where such quality data are lacking, the best available information will be used to answer the questions: In whom, when, and how to perform a tracheostomy?

Why Perform a Tracheostomy?

Placement of a tracheostomy is usually an elective procedure and there are generally 4 reasons for performing it:

- To relieve upper-airway obstruction due to tumor, surgery, trauma, foreign body, or infection
- To prevent laryngeal and upper airway damage due to prolonged translaryngeal intubation
- To allow easy or frequent access to the lower airway for suctioning and secretion removal
- To provide a stable airway in a patient who requires prolonged mechanical ventilation or oxygenation support

Two important patient benefits may result from replacing a conventional translaryngeal endotracheal tube (ETT) with a tracheostomy tube: improved comfort and increased patient safety. Although there are no comparative studies of tracheostomy (or other invasive surgical approach) for emergency relief of airway obstruction, direct entry into the trachea remains the recommended approach when manual ventilation and intubation attempts have failed and complete cessation of gas exchange occurs.^{1,2} The performance, safety, complications, and effective use of surgical emergency airways are not the subjects of this review. However, familiarity with these methods is important for all who manage airway intubations.

Benefits of Tracheostomy

Table 1 lists potential reasons that a tracheostomy would be considered the preferred prolonged artificial airway

Table 1. Reputed Benefits of Changing From a Translaryngeal Endotracheal Tube to a Tracheostomy Tube in a Patient Who Requires Prolonged Intubation

Benefit	Type and Quality of Literature Support Showing Benefit
Improved patient comfort	Uncontrolled reports, clinical opinion
Less need for sedation	Several RCTs
Lower work of breathing	Theoretical analysis, one small study
Improved patient safety	Clinical belief but minimal data, some contradictory (see text for details)
Improved oral hygiene	Clinical observation
Oral intake more likely	Opinion only
Earlier ability to speak	Uncontrolled reports
Better long-term laryngeal function	Large uncontrolled reports
Faster weaning from mechanical ventilation	One RCT
Lower risk of ventilator-associated pneumonia	Controversial, data support for both sides
Lower mortality	One RCT supports, many do not, but a large RCT supports mortality not higher with tracheostomy
Shorter intensive care unit and hospital stay	Several meta-analyses

RCT = randomized controlled trial

when compared to continued translaryngeal intubation. While some of these benefits have considerable support in the published literature, there are very few data to support most of them.

Protection of the larynx and the upper airway from prolonged intubation is an important reason to perform a tracheostomy, and to consider early provision of this surgical airway. Many anatomical structures are at risk from translaryngeal intubation. Vocal cord edema and damage, laryngeal mucosal erosions, laryngeal scarring and stenosis, and recurrent laryngeal nerve damage can lead to permanent disability. The potential for recovery or surgical repair of many of these injuries is less with continued prolonged intubation. Direct laryngeal examination demonstrates marked airway changes within several days of translaryngeal intubation. Usually these early changes are reversible and there is gradual improvement in airway examination after the tube is removed from the larynx.³ An example of a damaged larynx with fused vocal cords, which occurred after only 3 days of translaryngeal intubation, is seen in Figure 1. This patient recovered completely after a tracheostomy was placed and the oral ETT was removed.

The author has disclosed no conflicts of interest.

Charles G Durbin Jr MD FAARC, Department of Anesthesiology, University of Virginia, Box 800710, Charlottesville VA 22908. E-mail: cgd8v@virginia.edu.

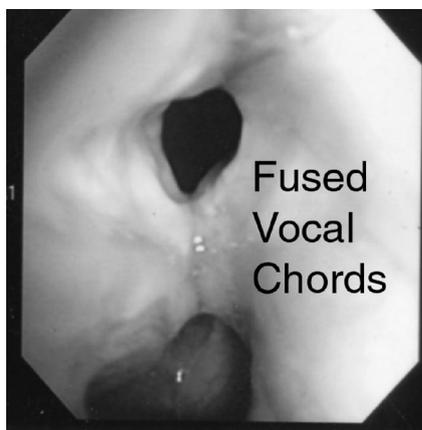


Fig. 1. Fused vocal cords were seen after only 3 days of intubation in this patient. This lesion resolved several days after the tracheostomy was placed and the endotracheal tube removed.

Improved Comfort?

Patients experience discomfort with persistent translaryngeal intubation and are more comfortable following tracheostomy.⁴ Improved patient comfort and less requirement for sedation have been reported in several studies following placement of a tracheostomy. In a follow-up study of patients who were randomized to remain intubated translaryngeally for a prolonged period or to receive an early tracheostomy, Blot and colleagues reported that oral comfort scores, mouth cleanliness, perception of change in body image, feelings of safety, and overall comfort were lower in the prolonged translaryngeal intubation group, compared to those who were randomized to early tracheostomy.⁵ Thirteen patients in that study who survived to hospital discharge and had undergone both translaryngeal intubation and tracheostomy reported tracheostomy as the more comfortable airway of the two. Patient comfort alone may be enough to justify tracheostomy rather than continuing with prolonged translaryngeal intubation if the risks of the 2 approaches are comparable.

Faster Weaning and Shorter Stay?

Besides protecting the larynx, tracheostomy may shorten the duration of mechanical ventilation because of reduced work of breathing,⁶ the need for less sedation and analgesia, or because once a secure airway is in place clinician weaning behavior changes.⁷ In a prospective trial that included 74 surgical/trauma patients who were unable to complete a spontaneous breathing trial after 72 hours of mechanical ventilation, Boynton and colleagues randomly divided these patients into 2 groups: those in whom it was decided to continue translaryngeal intubation, and those in whom it was decided to proceed with immediate tracheostomy prior to any attempt at weaning.⁸ Weaning from mechanical ventilation was carried out in both groups us-

ing the same protocol of gradual reduction in pressure-support ventilation. There were 21 patients in the immediate-tracheostomy group and 54 in the continued-translaryngeal-intubation group, 25 of whom eventually underwent tracheostomy. Only immediate tracheostomy before weaning and having a lower rapid shallow breathing index predicted more rapid weaning, with the odds ratio for immediate tracheostomy being 2.1 for being weaned in 3 versus 6 days. A meta-analysis of randomized trials comparing earlier versus later tracheostomy done by Griffiths et al⁹ confirmed that weaning was more rapid with early tracheostomy.

Faster weaning may reduce ICU and hospital stay, but so may other tracheostomy attributes. Patients requiring only extended mechanical ventilation or airway support are often moved from an ICU to a less intensive care environment once a tracheostomy is in place. This appears on the surface to be reasonable, because if the tube becomes dislodged, no special equipment or skills are needed to replace it. After the stomal tract has matured, usually within 3–7 days, the tube can usually be easily reinserted without difficulty. In some institutions it is routine to electively change a tracheostomy tube after a week or two following initial insertion. This is done to confirm the stability of the tract and reduce the likelihood of difficulty at reinsertion should the tube inadvertently become dislodged or for scheduled tube changes at a later time. Earlier transition of a patient from the ICU remains a major demonstrable effect of tracheostomy. This transition to a lower level care area may not be without risk.

Increased Patient Safety?

The presumed increased safety of having a tracheostomy in a patient managed outside of an ICU or special care unit has come under scrutiny. In a prospective observational cohort study, Martinez and colleagues recently reported that patients discharged to the ward with a tracheostomy in place had almost 3 times the mortality of those who had received a tracheostomy but who were decannulated prior to ward placement.¹⁰ In that study, however, the difference was only shown as a trend with $P = .10$. Multivariate analysis identified 3 highly significant factors associated with increased ward mortality: lack of decannulation at ICU discharge (odds ratio 6.76, 95% CI 1.21–38.46, $P = .03$), body mass index $> 30 \text{ kg/m}^2$ (odds ratio 5.81, 95% CI 1.24–27.24, $P = .03$), and tenacious sputum at ICU discharge (odds ratio 7.27, 95% CI 1.00–55.46, $P = .05$). Most of the deaths on the ward were due to unexpected cardiorespiratory arrests, usually in the early morning hours. Despite the fact that only one episode of tube-associated problem was reported in the study group, inadequate monitoring of patients and failure of early treatment of tube problems may have played a part in the

increased mortality in that group. Other groups have reported similar findings in less well designed trials,^{11,12} whereas some have not identified having a tracheostomy at ward discharge a risk for increased mortality when corrected for other risk factors.¹³

Other authors have noticed the additional risks of having a tracheostomy tube, as compared to a standard trans-laryngeal tube in place, even when the patient resides in an ICU environment.^{14,15} In 2000, Kapadia and colleagues reported airway accidents occurring in all intubated patients in a 16-bed multidisciplinary ICU. The study population included 5,046 patients intubated for 9,289 days during a 4-year period. They prospectively collected data, including the number and timing of airway accidents, the type of tracheal tube used, the duration of intubation, description of the type of accident, the severity of the accident, impact on the course of the patient's illness, and whether the accident was preventable. The total number of accidents for the entire study period was only 36, and 26 occurred in the 5,043 endotracheally intubated patients during their 8,446 days of intubation. None of those accidents were severe, and no deaths occurred. There were 10 tracheostomy-related accidents in the 79 patients with tracheostomies during their 843 days of intubation. Six of those events had severe consequences, and one resulted in death. Thus, even when monitored in an ICU, airway accidents associated with tracheostomy tubes occurred more frequently and resulted in higher mortality (10%) than in patients with conventional ETTs. The clinician's reassurance of a secure airway by having a tracheostomy may not translate into actual greater safety.

Fewer Lung Infections With Tracheostomy?

Microaspiration of oral secretions past the tube cuff is thought to contribute to development of pneumonia. It was believed that incidence of ventilator-associated pneumonia (VAP) would be decreased by placing a tracheostomy early in respiratory failure. This would allow laryngeal competence to recover and lessen the quantity of aspirated secretions. Reported data are mixed in this regard: some studies have suggested a reduced VAP rate, whereas others, mostly older studies, indicate an increase in lower-respiratory-tract infections following tracheostomy. Overall, if there is an influence on the incidence or course of VAP from tracheostomy, it is small. The meta-analysis by Griffiths et al mentioned previously demonstrated only an insignificant trend to lower incidence of VAP when tracheostomy was performed earlier rather than later.⁹ A recent review and meta-analysis of early versus later tracheostomy, by Durbin and colleagues, confirmed the observation of minimal effect on the incidence of VAP.¹⁶

When to Perform a Tracheostomy?

Tracheostomy is indicated when the need for endotracheal intubation is or is projected to be prolonged. How long is "prolonged" continues to evolve. In older guidelines, tracheostomy was recommended for consideration only if extubation did not occur by 21 days; more recently it has been suggested that tracheostomy be considered within 2–10 days of intubation, and that a projected need for 14 days of intubation be used as the criterion for the procedure. In selected patients with severe multi-trauma and/or head injury with low Glasgow coma score, tracheostomy at the earliest convenient time, often within 3–4 days of intubation, appears to afford some benefits. This early placement of a tracheostomy corresponds to that proposed by the otorhinolaryngologists who suggested that tracheostomy be performed within several days of intubation, to prevent laryngeal injury from even very short periods of intubation.¹⁷ Because having a tracheostomy tube in place may add additional risks to patient safety, qualified caregivers proximate to the patient are needed to prevent injury or death when tube accidents occur.

A continuing controversy surrounding tracheostomy is when in the course of critical illness is it appropriate to perform it. In attempting to balance the risks and benefits of the procedure, an individualized patient approach has been recommended. A balance of the risks and benefits of the procedure in a particular patient should be used to determine if and when a tracheostomy should be placed. Although this approach would appear to have merit, the risks of tracheostomy in an individual patient are difficult to predict and often delayed, and are dependent on the technique selected, individual patient anatomy, comorbidities, and the experience of the operator. As discussed above, the meaningful benefits of tracheostomy are few, so the balance is greatly affected by estimation of risk. A compilation of observed problems and acute and longer-term complications of tracheostomy are listed in Table 2. Some of these are very rare but very important (eg, death), and others are frequent but carry no long-term impact on the patient (eg, transient oxygen desaturation). The long-term laryngeal and tracheal outcomes following decannulation have not been well studied, as large registries with detailed outcome data have not been established. A recently completed study performed in an attempt to provide some information on early versus late tracheostomy has provided some interesting and useful material informing the decision of when to perform a tracheostomy. The data collected during this study remains under peer review and (hopefully) will soon be published. Early release of information presented at international meetings forms the basis for the material reported here.

The Tracheostomy Management in Critical Care (Trac-Man) study (<http://www.tracman.org.uk>) was designed to

Table 2. Short-Term and Long-Term Complications of Tracheostomy

	Frequency	Importance
Early and Short-Term Complications		
Bleeding	Frequent	Minimal
Neck hematoma	Rare	Minimal
Desaturation during procedure	Frequent	Minimal
Loss of airway during procedure	Rare	Minimal
Hypotension	Frequent	Minimal
Arrest	Very rare	Severe
Difficulty in tube placement	Rare	Minimal
Skin infection	Frequent	Minimal
Deep tissue infection	Very rare	Moderate to severe
Creation of false passage	Rare	Moderate
Subcutaneous emphysema	Rare	Minimal
Pneumothorax	Very rare	Severe
Pneumomediastinum	Very rare	Minimal
Tracheal wall injury	Very rare	Moderate
Esophageal injury	Very rare	Severe
Tracheal ring fracture	Frequent	Minimal
Death	Very rare	Severe
Long Term Complications		
Tracheal narrowing (< 50%)	Rare	Minimal
Tracheal narrowing (> 50%)	Very rare	Severe
Granulation tissue	Rare	Moderate
Vascular erosion	Very rare	Severe
Noticeable neck scar	Frequent	Minimal
Disfiguring scar	Very rare	Moderate
Accidental decannulation	Rare	Moderate
Vocal injury	Very rare	Severe
Tracheomalacia	Very rare	Severe
Unable to decannulate	Rare	Moderate

determine if there are any important differences in patients receiving a tracheostomy within 4 days or following 10 or more days of translaryngeal intubation. Patients were screened at 72 hours after being intubated, and if their clinicians believed that they would require at least 14 days of mechanical ventilation, consent was obtained and they were entered into the study. Patients were randomized to an “early” or “late” tracheostomy group. The early group received a tracheostomy immediately, whereas the procedure was delayed for at least 10 days in the late group. This multi-institution study, carried out within the United Kingdom, involved 72 ICUs and lasted over 4 years, eventually enrolling over 900 patients. The technique of tracheostomy was not controlled by protocol, but the great majority were performed percutaneously at the patient’s bedside. Initial data analysis suggests that randomization was successful; the groups had an equal average age (± 63 y), severity of illness (via Acute Physiology and Chronic Health Evaluation II [APACHE] scores), and type of ICU (approximately 80% medical units and 20% surgical units). Important observations include an identical mortality between the groups (approximately 30%),

very few minor procedural complications, and no tracheostomy-related deaths. A positive outcome in the early-tracheostomy group was fewer days of patient sedation. However, there were no differences in ICU or hospital stay. An important, highly significant difference was seen in the number of tracheostomies actually performed in the 2 groups: over half of the patients assigned to receive tracheostomy later than 10 days never received one. Most of these patients randomized to the late-tracheostomy group were weaned and extubated prior to the 14-day projection, and a few others had died. A major implication of this study is that clinicians are poor at predicting who will need prolonged intubation and ventilation. Another important conclusion is that performing a tracheostomy appears not to increase mortality or long-term complications (patients were followed for at least 12 months to identify complications and late outcomes); however, the complete story from this study is not yet published and available for scrutiny.

A weakness of the TracMan trial protocol is that the process for identifying who would need prolonged intubation was not objectively specified. Also, the distribution of participating units largely excluded surgical and neurologically injured patients. Are there methods or markers that can accurately predict which patients will require prolonged intubation and therefore could benefit from earlier tracheostomy? An early report by Qureshi and colleagues suggested that patients with poor Glasgow Coma Score, brainstem dysfunction, or supratentorial lesions 3 days following intubation would either die or require tracheostomy for prolonged recovery because of poor airway protective reflexes.¹⁸ This has been confirmed by others, including Boudierka and colleagues, who compared prolonged intubation with early tracheostomy in patients with isolated head injury with Glasgow coma scores < 8, brainstem deficits, and cerebral contusion on computed tomogram.¹⁹ They randomized 62 patients to tracheostomy at day 4 or 5 or to continue with translaryngeal intubation. The 2 groups were comparable in terms of age, sex, and severity of illness via the Simplified Acute Physiologic Score. The average duration of mechanical ventilatory support was shorter in the tracheostomy group (14.5 ± 7.3 d), compared to the translaryngeal intubation group (17.5 ± 10.6 d) ($P = .02$). In those patients who developed pneumonia, mechanical ventilation time was shorter in the tracheostomy group (6 ± 4.7 d) than in the translaryngeal-intubation group (11.7 ± 6.7 d) ($P = .01$). However, there was no difference in frequency of pneumonia or mortality between the 2 groups.

Do Head-Injured or Other Trauma Patients Benefit from Early Tracheostomy?

Recognizing the contribution severe head injury makes to outcome from traumatic injury, the Eastern Association

for the Surgery of Trauma (EAST) has authored recent guidelines recommending that early tracheostomy be performed in these patients.²⁰ This Level II recommendation states that fewer days of mechanical ventilation will be needed and ICU stay will be shorter with early (within 5 days of injury) tracheostomy. The recommendation is supported by class II data, which includes clinical studies in which the data were collected prospectively, and retrospective analyses that were based on clearly reliable data. Types of studies classified as such included observational studies, cohort studies, prevalence studies, and case-control studies. Level II recommendations are defined as reasonably justifiable by available scientific evidence, strongly supported by expert opinion, and supported by class I or class II data.

The only Level I recommendation from that guideline is that there is no mortality difference between early or late tracheostomy, which is consistent with the TracMan trial described above. The final Eastern Association for the Surgery of Trauma recommendation from this literature evaluation process is that since early tracheostomy may decrease the total days of mechanical ventilation and ICU stay in trauma patients without head injuries, and early tracheostomy may decrease the rate of pneumonia in trauma patients, it is recommended that early tracheostomy should be considered in all trauma patients who are anticipated to require mechanical ventilation for at least 7 days. That is a Level III recommendation, suggesting only that the majority of practitioners consider it reasonable. This would apply to those patients with respiratory failure or neurologic impairment without primary head injuries.

A counterpoint argument to early tracheostomy in patients with neurologic abnormalities has been elegantly advanced by King and colleagues.²¹ They have reviewed reports and examined the impact of extubation in those patients who remained intubated purely for airway protection concerns due to a poor level of consciousness. In their review it appears that poor mental status alone is insufficient to require prolonged intubation and thus tracheostomy. Cough effectiveness, secretion quantity, and secretion viscosity all impact on the success of extubation in this group and other types of patients as well. Those authors correctly point out that many studies demonstrate that failed extubation carries increased morbidity as well as mortality, although the magnitude of the increase and reasons for it are not clear. While it is clear that delaying extubation is associated with increased morbidity and mortality, the medical literature also demonstrates harm from extubation failure. Over 55 studies, involving more than 30,000 patients, suggest that the overall rate of extubation failure is approximately 12% (range 2–25%).²² One study from a medical ICU found that re-intubation resulted in an average 12 additional days of mechanical ventilation, 21 ICU days, 30 hospital days, and an increased need for

tracheostomy and post-acute-care hospitalization.²³ Interestingly, while patients requiring re-intubation tend to be sicker, multivariate analyses have shown that premorbid health status, severity of illness, and complications directly associated with re-intubation do not explain the increased mortality associated with extubation failure.²⁴ A direct correlation between increasing time to re-intubation and mortality has led some authors to suggest that clinical deterioration prior to re-institution of mechanical ventilatory support is responsible for the increased mortality associated with extubation failure.²⁵ It has been suggested that careful monitoring and rapid intervention for respiratory failure developing following extubation may prevent this excessive mortality. However, this hypothesis has not yet been tested.

A report by Salam and colleagues, who assessed the ability of 88 patients who had successfully completed a spontaneous breathing trial to perform 4 simple tasks (open eyes, follow with eyes, grasp hand, and stick out tongue) prior to extubation.²⁶ Patients unable to complete the 4 commands were 4 times more likely to require re-intubation (risk ratio 4.3, 95% CI 1.8–10.4). Depressed cough peak flow (risk ratio 4.8, 95% CI 1.4–16.2) and secretions greater than 2.5 mL/h (risk ratio 3.0, 95% CI 1.0–8.8) were also independent predictors of extubation failure in this study. In a prospective cohort study specifically assessing brain-injured patients, Coplin and colleagues followed the course of mechanical ventilation, weaning, and extubation in 136 patients.²⁷ Ninety-nine patients (73%) were extubated on meeting readiness criteria, and the remaining 37 patients (27%) remained intubated for an additional average of 3 days (range 2–19 d) following meeting weaning criteria. Patients with prolonged intubation had a lower median Glasgow coma score (7 vs 10, $P < .001$). Glasgow coma score was not found to be predictive of the need for re-intubation. That study is often cited as supporting the safety of extubating patients with acute brain injury, but caution should be used in interpreting those data. Given that the prolonged intubation group was delayed in their time to extubation, the natural history of that group was altered and may not reflect the outcome that would have been obtained if they had been extubated at the time they first passed a weaning trial.

Do Medical Patients Benefit From Early Tracheostomy?

Medical patients requiring prolonged intubation may have lower mortality with early tracheostomy. A study by Rumbak and colleagues performed in 3 institutions randomized severely ill patients (APACHE score > 25) to a percutaneous tracheostomy at 48 hours or to a tracheostomy at 14 days or longer. Low-tidal-volume ventilation, a ventilator weaning protocol, and daily spontaneous breath-

Table 3. Prediction of Need for More Than 14 Days of Mechanical Ventilation

	Sensitivity (%)	Specificity (%)	Predictive Value	
			Positive (%)	Negative (%)
PEEP > 10 cm H ₂ O	71	100	100	71
P _{aO₂} /P _{aO₂} < 0.40	57	80	80	57
No radiographic improvement	67	100	100	67
> 50% of lung fields with radiographic alveolar infiltrates	78	100	100	75

(Data from Reference 29.)

ing trials were specified in the research protocol.²⁸ Unfortunately, how clinicians were able to predict the need for 14 or more days of intubation was not reported. Prediction was very good, and only 10% of the late-tracheostomy group did not receive a tracheostomy (2 died before 14 days and 8 were weaned and extubated), which is much better than the prediction in the TracMan trial, where more than 50% of the late group did not need tracheostomy at 14 days. Unlike any other published study, the mortality benefit of early tracheostomy was remarkable, with mortality only 32% in the early tracheostomy group and over 61% in the late group. Infections and other complications were more common in the late-tracheostomy group. An important question is, can the need for prolonged intubation in patients with medical disorders be predicted with accuracy?

In the case of respiratory failure requiring mechanical ventilation in patients with acute lung injury/acute respiratory distress syndrome the duration of intubation may be predicted by the initial degree of injury and by the progression of disease within the first few days. As long ago as 1990, Heffner and Zamora suggested that by combining repeated evaluations of physiology and anatomy in patients with acute respiratory distress syndrome on day 7, a prediction of needing prolonged intubation (and tracheostomy) could be made. They used the ratio of arterial to alveolar P_{O₂}, presence of high PEEP (defined as ≥ 10 cm H₂O), and the chest radiograph percentage of lung-field infiltrates on day 7 to predict continued need for intubation and ventilation on day 14 (Table 3).²⁹ While these measures were able to identify all patients requiring prolonged intubation (sensitivity), they also detected many patients who were able to be weaned (false positives). As expected, the presence of more severe disease for a longer period of time is predictive of longer intubation. This was also noted in Rumbak's study, as those patients with high APACHE scores required longer intubation.²⁸ Accuracy of these and other indices in predicting the need for long-term airway support has not been assessed in a systematic way. Current recommendations for tracheostomy time are: continued

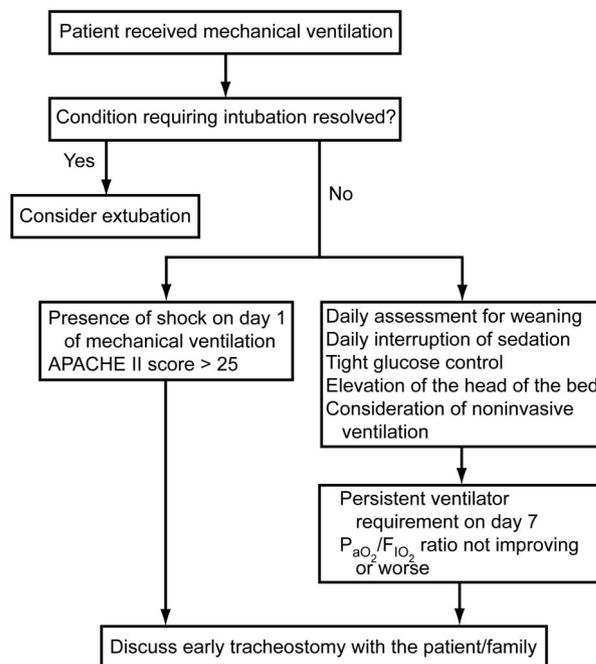


Fig. 2. Approach to the timing of tracheostomy in patients receiving mechanical ventilation. APACHE = Acute Physiology and Chronic Health Evaluation. (Adapted from Reference 30, with permission.)

need for intubation should be assessed daily, and if improvement is not observed, a decision to perform a tracheostomy should be made when the need for intubation is believed to extend for at least 14 days in patients with medical diseases and respiratory failure. The expected resolution of the particular disease and the patient's comorbidities will influence this decision. The algorithm reproduced in Figure 2 regarding the decision of tracheostomy timing used at the Mayo Clinic provides useful guidance in many patients.³⁰ Fear of the risk of unnecessary tracheostomy should be less with the reassuring mortality preliminarily reported from the TracMan study and data from large trauma registries.

How Should a Tracheostomy Be Performed?

There are many ways to perform a tracheostomy, but these can be classified into several general approaches. One common division of techniques is "open" or surgical tracheostomy and the other is "percutaneous" or percutaneous dilatory tracheostomy (PDT). Ever since Ciaglia first described his use of a guide wire and serial dilation technique for PDT in 1985 (which was an adaptation of the percutaneous nephrostomy tube placement technique, and is a variant of the vascular access technique described by Seldinger³¹ in 1953), the popularity of this technique has grown dramatically.³² Early comparisons between surgical tracheostomy and PDT suggest more (but generally

TRACHEOSTOMY: WHY, WHEN, AND HOW?

Table 4. Outcome From Meta-analysis of Open Surgical Tracheostomy Versus Percutaneous Dilational Tracheostomy

Favored Percutaneous Technique	Favored Open Surgical Tracheostomy
Wound infection ($P < .001$)	Decannulation/obstruction ($P = .009$)
Unfavorable scarring ($P = .01$)	False passage ($P = .08$)
Cost-effectiveness ($P < .001$)	Minor hemorrhage ($P = .77$)
Case length ($P < .001$)	
Overall complications ($P = .05$)	
Major hemorrhage ($P = .17$)	
Subglottic stenosis ($P = .19$)	
Death ($P = .50$)	

Data from Reference 35.

less severe) early complications during PDT placement, but fewer late problems.^{33,34} A recent meta-analysis by Higgins and Punthakee, which included almost 1,000 patients, identifies several outcome differences between surgical tracheostomy and PDT.³⁵ The findings are summarized in Table 4. In their report, pooled odds ratios revealed more difficulties during decannulation and from tracheostomy tube obstruction after PDT. These issues were minor, none were considered life-threatening, and they may have been related to differences in the type of tube used (ie, PDT rarely placed tubes with removable inner cannulas). Mortality was not clearly different between the techniques, but the trend favored PDT. There were significantly fewer stomal wound infections and smaller neck scars after PDT placement. There was no statistically significant difference between the techniques in creation of a false passage, causing minor or major hemorrhage, or developing late subglottic stenosis. There was no significant difference in overall complications between the techniques; however, there was a trend in complications favoring the percutaneous technique. PDT performance time was shorter overall by 4.6 min (not clinically important), and costs (when reported) were less by approximately \$456 per procedure; however, data were available from only 4 studies.

Initially, PDT was reserved for patients with few risk factors and favorable neck anatomy. With growing experience, the indications for PDT have been expanded and the patient exceptions which mandate a surgical tracheostomy have decreased. In the case of morbid obesity and moderate coagulopathy, PDT may afford better survival with fewer complications.^{36,37} Internationally, countries differ in the predominant tracheostomy technique; however, PDT is increasingly the technique of choice for critically ill patients in ICUs throughout the world (Table 5).³⁸⁻⁴³

Table 5. Tracheostomy Techniques and Use of Bronchoscopy By Country

Country	Routine Use of PDT (%)	Routine Use of FOB With PDT (%)	Preferred PDT Technique
France ³⁸	21	ND	Modified Ciaglia
Germany ³⁹	86	98	Modified Ciaglia
Netherlands ⁴⁰	62	36	Classic Ciaglia
Spain ⁴¹	72	16	Griggs Forceps
Switzerland ⁴²	57	ND	ND
United Kingdom ⁴³	97	83	Modified Ciaglia

PDT = percutaneous dilational tracheostomy
 FOB = fiberoptic bronchoscopy
 ND = no data available
 (Adapted from Reference 39.)

Surgical Technique for Placing a Tracheostomy Tube

To perform a surgical tracheostomy, the patient's shoulders are elevated and the head is extended unless contraindicated by cervical disease or injury. This position elevates the larynx and exposes more of the upper trachea. As with most surgical procedures, prophylactic antibiotics specific for skin pathogens are usually administered 30–60 min prior to skin incision. The skin from the chin to below the clavicles is sterilely prepared with either an iodine-based disinfectant or a solution of chlorhexidine. If excessive hair is present, it should be removed with electric clippers immediately prior to skin preparation. Sterile drapes are placed, creating an opening from the top of the larynx to the patient's suprasternal notch. Local anesthesia with a vasoconstrictor is infiltrated into the skin and deeper neck tissues to reduce the amount of bleeding and provide analgesia during the procedure.

The skin of the neck over the 2nd tracheal ring is identified, and a vertical incision about 2–3 cm in length is created. Care must be taken to avoid cutting deeper than the subcutaneous tissues to prevent lacerating the thyroid isthmus or a large neck vein. Sharp dissection following the skin incision is used to cut across the platysma muscle, with bleeding controlled by hemostats and ties or electrocautery. Blunt dissection parallel to the long axis of the trachea is then used to spread the submuscular tissues until the thyroid isthmus is identified (Fig. 3). If the thyroid gland lies superior to the 3rd tracheal ring, it can be bluntly undermined and retracted superiorly to gain access to the trachea. If the isthmus overlies the 2nd and 3rd ring of the trachea, it must be mobilized and either a small incision made to clear a space for the tracheostomy (Fig. 4) or complete transection of the isthmus must be accomplished (Fig. 5).

Blunt dissection is continued longitudinally through the pretracheal fascia, and the desired ring (usually the 2nd ring) is identified. One of 2 types of tracheal entry is

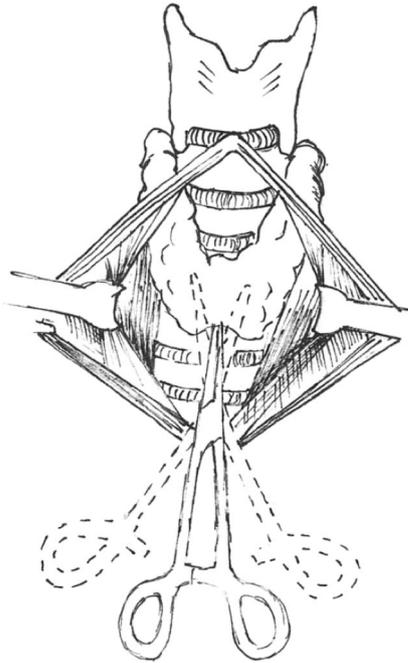


Fig. 3. Creating a surgical tracheostomy. After incising the skin and dividing the strap muscles of the neck, the thyroid isthmus is mobilized with a hemostat. (From Reference 44.)

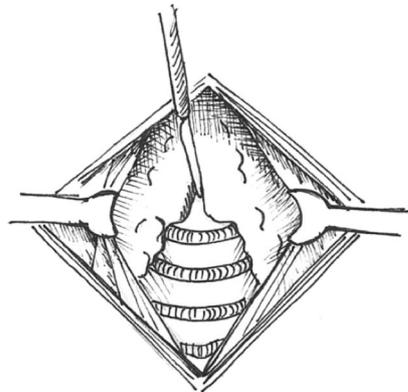


Fig. 4. Creating a surgical tracheostomy. If the thyroid cannot be retracted either superiorly or inferiorly to reveal the 2nd and 3rd tracheal rings, a small incision in the gland may be created to allow access to the trachea. (From Reference 44.)

usually used for surgical tracheostomy. These are: complete removal of the anterior part of the tracheal ring to create the stoma, and creation of a rectangular flap with the severed but still attached part of the ring. In the ring-removal approach, the ring is lifted with a tracheal hook and 2 circumferential sutures are placed around the ring laterally. The portion of ring between the secured sutures is then cut and removed, leaving a hole in the anterior tracheal wall for the tracheostomy tube. The sutures are left in place and used to provide counter-traction on the trachea as the tube is forced into the lumen. This is illus-

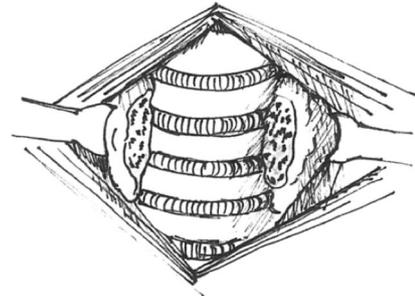


Fig. 5. Creating a surgical tracheostomy. If the thyroid isthmus remains in the way of the site of the tracheostomy, it may be completely divided, carefully ensuring there is no bleeding. This is the most common approach and gives the greatest access to the trachea. (From Reference 44.)

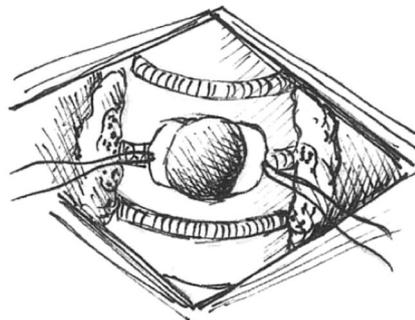


Fig. 6. Creating the tracheal portal. There are 2 basic approaches to tracheal entry. As illustrated here, the 2nd tracheal ring is divided laterally and the anterior portion removed. Lateral sutures are used to provide counter-traction during tracheostomy-tube insertion. These are left uncut to provide assistance should the tube be accidentally dislodged later. (From Reference 44.)

trated in Figure 6. The ring sutures are cut long and left out of the wound or used to secure the tracheostomy tube. These sutures can be used to identify the trachea and reinsert an inadvertently dislodged tracheostomy tube. After placement of a surgical tracheostomy, the fistula tract is not stable for at least 4–5 days, and a tube dislodged soon after placement often cannot be reinserted through the fistula into the trachea. The ring sutures may help if this situation occurs. A second method for entry into the trachea involves creating a tracheal wall flap sutured to the skin. This is done by incising the fascia over the superior ring and entering the trachea along its inferior margin. This becomes the outer lip of the flap. Lateral cuts through the lower ring complete the sharp dissection. The flap thus created is reflected downward and attached with several sutures to the skin of the neck. This fistula is truly a “stoma,” with tracheal mucosa approximated to the skin. The stability of this tract is believed to be superior to the ring resection-removal technique; however, no study has convincingly demonstrated this.

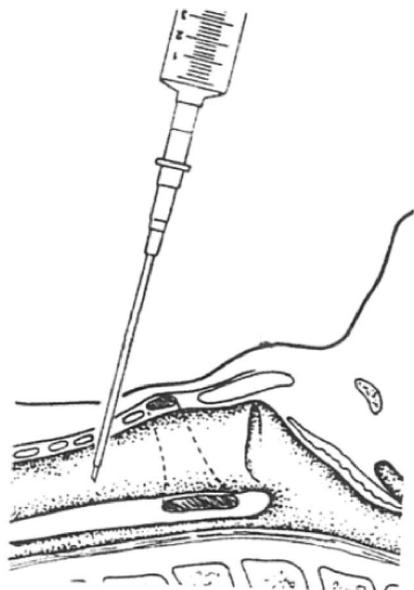


Fig. 7. The trachea is entered between the appropriate tracheal rings with an intravenous catheter, with aspiration of air to confirm correct location. The needle is withdrawn and the catheter left in place as a conduit for the guide wire. (From Reference 44.)



Fig. 8. The guide wire is threaded through the catheter to act as a guide for the dilators that follow. It also helps protect the tracheal wall by directing the pointed dilator tips down the trachea. (From Reference 44.)

Techniques for Percutaneous Dilational Tracheostomy

PDT, an alternative to surgical tracheostomy, can be performed in one of several different ways. Most of these are variants of the method described by Ciaglia,³² which is achieved by placing a guide wire between 2 tracheal rings entering the anterior tracheal wall in the midline. Follow-

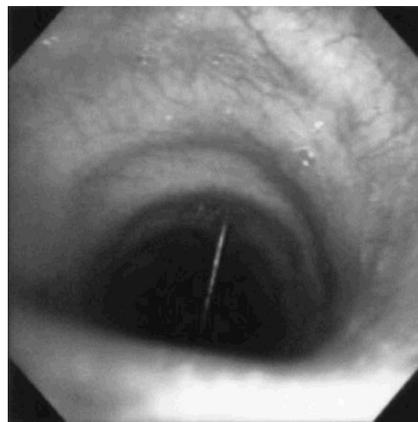


Fig. 9. Through the fiberoptic bronchoscope the wire is seen entering between the 2nd and 3rd tracheal rings, directly in the center of the trachea.

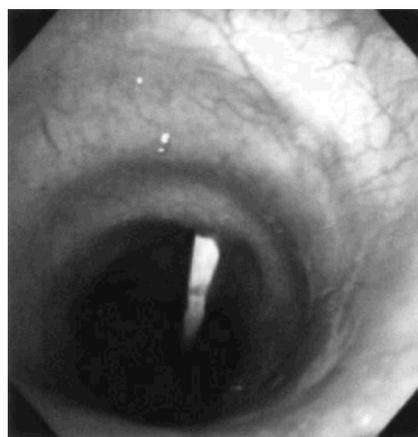


Fig. 10. The tip of the dilator is seen entering the trachea over the wire. After the stoma is created, a loading dilator with the tracheostomy tube is used to deliver the tube to its final position. (From Reference 44.)

ing this, the wire is used to direct the passage of one or more dilators over the wire to mechanically separate the rings and create the stoma for the tracheostomy tube. As with surgical tracheostomy, proper head position, sterile skin preparation, local anesthesia and epinephrine infiltration, provision of sedation or anesthesia, and complete barrier precautions are used. The earliest techniques consisted of a series of stiff plastic dilators of increasing size, advancing and removing each over the wire sequentially until one large enough for the chosen tracheostomy tube was passed. A separate loading or inserting dilator with the snugly-fitting tracheostomy tube is then passed and removed, leaving the tracheostomy tube behind in place. The steps in the PDT technique are illustrated in Figures 7, 8, 9, and 10.

Early changes in this basic technique consisted of creating a single dilator of appropriate size with a long taper to create the stoma with a single pass,⁴⁵ and designing tracheostomy tubes with tapered tips, allowing them to

more smoothly pass through the neck tissues over the insertion dilator. Soon after development of the PDT technique, complications from bent or misplaced wires were seen. This led to the development of a plastic sheath inserted over the wire to stiffen it and help prevent misplacement. Using a fiberoptic bronchoscope through the existing ETT helped direct the tracheal entry point, confirm final placement, identify tracheal injuries, and improve success and safety.^{46,47}

Modifications of PDT Technique

Several variants on the PDT have been developed and are advocated by various groups. In Europe, a wire-guided sharp, cutting forceps developed by Griggs and colleagues gained early popularity but is reported to have more serious problems, including substantial bleeding and possibly long-term risk.⁴⁸ In order to improve safety by minimizing tracheal injury, performance of PDT under bronchoscopic control, using any of the many available techniques, has been advocated.^{46,47} In order to reduce the likelihood of fracturing a tracheal ring during the forced dilation, Fantoni developed a complex system of passing the dilator from inside the trachea to the outside using a specially designed tracheostomy tube and a rigid bronchoscope.⁴⁹ Another approach to try to reduce tracheal trauma during PDT has been developed using a screw-like device (PerCuTwist) to separate the trachea rings.⁵⁰ Each of these variations came about as an attempt to improve some aspect of the basic dilation technique or observed shortcomings of particular methods.

There have been several additional modifications of PDT described. One of these, creation of the tracheal stoma using an angiographic balloon, is likely to add another group of clinicians to the groups who are now performing PDT.⁵¹ With this technique, a sausage shaped high-pressure angiographic balloon (Ciaglia Blue Dolphin Balloon Percutaneous Tracheostomy Introducer, Cook Critical Care, Bloomington, Indiana) is used to create the stoma. The trachea is entered between tracheal ring 2 and 3 in the conventional way, with a needle; then a guide wire is placed through a 1–2 cm skin incision. Bronchoscopic control is maintained with the ETT withdrawn into the larynx. The dilating balloon is placed through the tracheostomy tube and loading dilator and carefully advanced over the guide wire. When the balloon is located precisely in the center of the stoma, it is inflated with 11 atmospheres pressure for 15 seconds, spreading the tracheal rings and compressing blood vessels and other tissues. This radial pressure separates the rings and stretches the skin and may reduce bleeding and the incidence of tracheal ring fracture; however, in the first 20 cases, a 5% ring fracture rate was noted (1 out of 20). Long-term consequences of tracheal ring fractures produced during PDT



Fig. 11. Specially designed intubating supraglottic airway, which is useful as a conduit for fiberoptic bronchoscope insertion during percutaneous dilational tracheostomy. The patient can continue to breath (or be ventilated) through the large-diameter connector with the bronchoscope in the larynx during the entire procedure.

are minimal and occur with most percutaneous techniques. The effect of the dilating balloon inflation on the posterior and lateral tracheal wall integrity is not known and may pose an additional new risk associated with this technique. One patient in the initial evaluation group developed subcutaneous emphysema, suggesting the balloon inflation may have produced an airway injury.

A variant on the single-dilator technique of PDT placement begins by first creating a small surgical incision, using blunt dissection, to allow a gloved finger to palpate the trachea.⁵² The finger tip is used to identify the cricoid ring and tracheal rings. Operators using this technique often dispense with the fiberoptic bronchoscope, relying on tactile identification of correct position for needle entry. The needle and guide wire are then passed and if no unusual resistance is felt, the single dilator and tracheostomy tube are inserted blindly. In some ways this is similar to an open tracheostomy; however, it is less invasive, simpler, and requires little or no surgical dissection. Even when using this technique, most operators have a fiberoptic scope available for confirmation of correct placement or to view the entire process if undue resistance to passage of the wire occurs.

Use of a laryngeal mask airway (LMA) as a conduit for the bronchoscope is very helpful if the patient can be safely extubated and maintained with an LMA while the tracheostomy is being performed. Unlike withdrawing an existing ETT and attempting not to accidentally extubate the patient, planned extubation and LMA placement can be electively performed and carefully controlled. If difficulty occurs while maintaining the patient with an LMA, the trachea should be secured with a cuffed ETT. Patients requiring high airway pressures or those with a known difficult intubation are probably not good candidates for this approach. Once the LMA is in place and adequate gas exchange is established, entry into the larynx with the bronchoscope is easily accomplished as the LMA usually rests directly in front of the larynx. A specially designed supraglottic airway, the Air-Q (Mercury Medical, Clearwater, Florida), is a variant on the classic LMA: it has a larger diameter, short, rigid connecting tubes, and un-

blocked distal openings. The AirQ is recommended for blind intubation using a conventional ETT (Fig. 11). This special tube is also very useful for fiberoptic bronchoscope placement during PDT. The bronchoscope tip can be left protected in the larynx during the entire procedure, allowing precise identification of tracheal entry, the dilation process, and identification of complications if they occur.

Recently some authors suggested using ultrasonography of the neck to identify underlying anatomy with more precision than palpation. Tracheal rings are usually easily appreciated and an overlying large vessel or thyroid gland can be seen and avoided during the procedure. As with all techniques, success using the ultrasound device and interpreting the images takes practice, and expertise requires substantial experience. With adequate experience it may be possible to correctly identify the entry point; however, confirmation of correct tube placement is usually best achieved with direct visualization with a fiberoptic bronchoscope.

Bedside or Operating Room Tracheostomy Placement?

Whatever technique is chosen, there are advantages to performing the procedure in the ICU. Unstable patients experience less deterioration in vital signs and avoid the risks of travel to the operating theater if the procedure is performed in the ICU. Multiple caregivers already familiar with the patient can monitor and care for the patient if the procedure is performed in the unit. Charges for the procedure are usually less when performed in the ICU; however, actual costs are difficult to calculate and payments are unrelated to charges or costs. Occasionally a PDT procedure fails or a problem arises that would benefit from ready availability of operating room resources such as high-intensity lights or electrocautery devices. Whether to move a patient to the operating room if a surgical tracheostomy is needed or to perform it in the ICU and bring required equipment is an institutional decision. Excellent results have been reported with all of the PDT techniques as well as surgical tracheostomy performed in either the operating room environment or at the patient's bedside in the ICU. Local policy and resources should guide the decision of where to perform a tracheostomy.

Summary

Tracheostomy is the most commonly performed procedure in the critically ill, approaching 10% of intubated patients. General indications for tracheostomy include the need for a prolonged artificial airway, poor airway protective reflexes, and upper-airway obstruction for any of a number of reasons. Expected intubation for more than 14 days is considered a common reason to consider a tracheostomy. Unfortunately, a clinician's ability to predict this duration is especially poor early in the course of illness.

Patients with severe traumatic injuries, especially those with head injury or altered mental status, are likely to benefit from earlier tracheostomy. Known benefits from tracheostomy are: less need for deeper sedation, shorter weaning time, and shorter ICU and hospital stay. With a few exceptions, there is no difference in mortality with a tracheostomy or continued prolonged translaryngeal intubation. One study of very ill medical patients demonstrated markedly lower mortality with earlier tracheostomy, but the reason for that improvement remains unclear. Patients usually can be transitioned out of an ICU earlier with a tracheostomy, and consideration of early tracheostomy should be entertained when this possibility exists. Airway accidents may be more frequent and more severe in patients with tracheostomy tubes, and safety should modulate the decision to move a patient from an ICU.

Techniques for tracheostomy are evolving and improving. More tracheostomies are being performed using one of a variety of PDT techniques at the patient's bedside in the ICU. Some institutions and even entire countries are slow to adopt these changes, which are driven by clinical experience and local practice patterns. French physicians for instance, continue to perform the majority of tracheostomies using an open surgical technique.

REFERENCES

1. American Society of Anesthesiologists Task Force on Difficult Airway management. Practice guidelines for management of the difficult airway. *Anesthesiology* 2003;98(5):1269-1277. Erratum in: *Anesthesiology* 2004;101(2):565.
2. Wong DT, Pradhu AJ, Coloma M, Imasogie N, Chung FF. What is the minimum training required for successful cricothyroidotomy? *Anesthesiology* 2003;98(2):349-353.
3. McWhorter AJ. Tracheostomy: timing and techniques. *Curr Opin Otolaryngol Head Neck Surg* 2003;11(6):473-479.
4. Nieszkowska A, Combes A, Luyt CE, Ksibi H, Trouillet JL, Gilbert C, Chastre J. Impact of tracheostomy on sedative administration, sedation level, and comfort of mechanically ventilated intensive care unit patients. *Crit Care Med* 2005;33(11):2527-2533.
5. Blot F, Similowski T, Trouillet JL, Chardon P, Korach JM, Costa MA, et al. Early tracheotomy versus prolonged endotracheal intubation in unselected severely ill ICU patients. *Intensive Care Med* 2008;34(10):1779-1787.
6. Jaeger JM, Littlewood KA, Durbin CG Jr. The role of tracheostomy in weaning from mechanical ventilation. *Respir Care* 2002;47(4):469-480.
7. Pierson DJ. Tracheostomy and weaning. *Respir Care* 2005;50(4):526-533.
8. Boynton JH, Hawkins K, Eastridge BJ, O'Keefe GE. Tracheostomy timing and the duration of weaning in patients with acute respiratory failure. *Crit Care* 2004;8(4):R261-R267.
9. Griffiths J, Barber VS, Morgan L, Young JD. Systematic review and meta-analysis of studies of the timing of tracheostomy in adult patients undergoing artificial ventilation. *BMJ* 2005;330(7502):1243.
10. Martinez GH, Fernandez R, Casado MS, Cuena R, Lopez-Reina P, Zamora S, Luzon E. Tracheostomy tube in place at intensive care unit discharge is associated with increased mortality. *Respir Care* 2009;54(12):1644-1652.

TRACHEOSTOMY: WHY, WHEN, AND HOW?

11. Engoren M, Arslanian-Engoren C, Fenn-Buderer N. Hospital and long-term outcome after tracheostomy for respiratory failure. *Chest* 2004;125(1):220-227.
12. Clec'h C, Alberti C, Vincent F, Garrouste-Orgeas M, de Lassence A, Toledano D, et al. Tracheostomy does not improve the outcome of patients requiring prolonged mechanical ventilation: a propensity analysis. *Crit Care Med* 2007;35(1):132-138.
13. Combes A, Luyt CE, Nieszkowska A, Trouillet JL, Gibert C, Chastre J. Is tracheostomy associated with better outcomes for patients requiring long-term mechanical ventilation? *Crit Care Med* 2007;35(3):802-807.
14. Kapadia FN, Bajan KB, Raje KV. Airway accidents in intubated intensive care unit patients: an epidemiological study. *Crit Care Med* 2000;28(3):659-664.
15. Kapadia FN, Bajan KB, Singh S, Mathew B, Nath A, Wadkar S. Changing patterns of airway accidents in intubated ICU patients. *Intensive Care Med* 2001;27(1):296-300.
16. Durbin CG Jr, Perkins MP, Moores LK. Should tracheostomy be performed as early as 72 hours in patients requiring prolonged mechanical ventilation? *Respir Care* 2010;55(1):76-87.
17. McWhorter AJ. Tracheostomy: timing and techniques. *Curr Opin Otolaryngol Head Neck Surg* 2003;11(6):473-479.
18. Qureshi AI, Suarez JJ, Parekh PD, Bhardwaj A. Prediction and timing of tracheostomy in patients with infratentorial lesions requiring mechanical ventilatory support. *Crit Care Med* 2000;28(5):1383-1387.
19. Boudarka MA, Fakhir B, Bouaggad A, Hmamouchi B, Hamoudi D, Harti A. Early tracheostomy versus prolonged endotracheal intubation in severe head injury. *J Trauma* 2004;57(2):251-254.
20. Michele H, Dunham M, Brautigan R, Clancy TV, Como JJ, Ebert JB, et al. Practice management guidelines for timing of tracheostomy: The EAST Practice Management Guidelines Work Group. *J Trauma* 2009;67(4):870-874.
21. King CS, Moores LK, Epstein SK. Should patients be able to follow commands prior to extubation? *Respir Care* 2010;55(1):56-62.
22. Epstein SK. Decision to extubate. *Intensive Care Med* 2002;28(5):535-546.
23. Epstein SK, Ciubotaru RL, Wong JB. Effect of failed extubation on the outcome of mechanical ventilation. *Chest* 1997;112(1):186-192.
24. Epstein SK. Preventing postextubation respiratory failure. *Crit Care Med* 2006;34(5):1547-1548.
25. Epstein SK, Ciubotaru RL. Independent effects of etiology of failure and time to reintubation on outcome for patients failing extubation. *Am J Respir Crit Care Med* 1998;158(2):489-493.
26. Salam A, Tilluckdharry L, Amoateng-Adjepong Y, Manthous C. Neurologic status, cough, secretions and extubation outcomes. *Int Care Med* 2004;30(7):1334-1339.
27. Coplin WM, Pierson DJ, Cooley KD, Newell DW, Rubenfeld GD. Implications of extubation delay in brain-injured patients meeting standard weaning criteria. *Am J Respir Crit Care Med* 2000;161(5):1530-1536.
28. Rumbak MJ, Newton M, Truncale T, Schwartz SW, Adams JW, Hazard PB. A prospective, randomized, study comparing early percutaneous dilational tracheostomy to prolonged translaryngeal intubation (delayed tracheostomy) in critically ill medical patients. *Crit Care Med* 2004;32(8):1689-1694.
29. Heffner JF, Zamora C. Clinical predictors of prolonged translaryngeal intubation in patients with the adult respiratory distress syndrome. *Chest* 1990;97(2):447-452.
30. Sameer R, Pendem S, Pogodzinski M, Hubmayr RD, Gajic O. Tracheostomy in critically ill patients. *Mayo Clin Proc* 2005;80(12):1632-1638.
31. Seldinger SI. Catheter replacement of the needle in percutaneous arteriography: a new technique. *Acta Radiol* 1953;39(5):368-376.
32. Ciaglia P, Firsching R, Syniec C. Elective percutaneous dilational tracheostomy. A new simple bedside procedure; preliminary report. *Chest* 1985;87(6):715-719.
33. Dulguerov P, Gysin C, Perneger TV, Chevrolet JC. Percutaneous or surgical tracheostomy: a meta-analysis. *Crit Care Med* 1999;27(8):1617-1625.
34. Durbin CG Jr. Early complications of tracheostomy. *Respir Care* 2005;50(4):511-515.
35. Higgins KM, Punthakee X. Meta-analysis comparison of open versus percutaneous tracheostomy. *Laryngoscope* 2007;117(3):447-454.
36. Groves DS, Durbin CG Jr. Tracheostomy in the critically ill: indications, timing and techniques. *Curr Opin Crit Care* 2007;13(1):90-97.
37. Romero CM, Cornejo RA, Ruiz MH, Gálvez LR, Llanos OP, Tobar EA, et al. Fiberoptic bronchoscopy-assisted percutaneous tracheostomy is safe in obese critically ill patients: a prospective and comparative study. *J Crit Care* 2009;24(4):494-500.
38. Blot F, Melot C. Indications, timing, and techniques of tracheostomy in 152 French ICUs. *Chest* 2005(4):127:1347-1352.
39. Kluge S, Baumann HJ, Maier C, Klose H, Myer A, Nierhaus A, Kreyman. Tracheostomy in the intensive care unit: a national survey. *Anesth Analg* 2008;107(5):1639-1643.
40. Fikkers BG, Franssen GA, van der Hoeven JG, Briede IS, van den Hoogen FJ. Tracheostomy for long-term ventilated patients: a postal survey of ICU practice in The Netherlands. *Intensive Care Med* 2003(8):29:1390-1393.
41. Anon JM, Escuela MP, Gomez V, Garcia de LA, Montejo JC, Lopez J. Use of percutaneous tracheostomy in intensive care units in Spain: results of a national survey. *Intensive Care Med* 2004(6):30:1212-1215.
42. Fischler L, Erhart S, Kleger GR, Frutiger A. Prevalence of tracheostomy in ICU patients: a nationwide survey in Switzerland. *Intensive Care Med* 2000(10):26:1428-1433.
43. Krishnan K, Elliot SC, Mallick A. The current practice of tracheostomy in the United Kingdom: a postal survey. *Anaesthesia* 2005(6);60:360-364.
44. Durbin CG Jr. Techniques for performing tracheostomy. *Respir Care* 2005;50(4):488-496.
45. Byhahn C, Wilke HJ, Halbig S, Lischke V, Westphal K. Percutaneous tracheostomy: ciaglia blue rhino versus the basic ciaglia technique of percutaneous dilational tracheostomy. *Anesth Analg* 2000;91(4):882-886.
46. Marelli D, Paul A, Manolidis S, Walsh G, Odum JN, Burdon TA, Shennib H, et al. Endoscopic guided percutaneous tracheostomy: early results of a consecutive trial. *J Trauma* 1990;30(4):433-435.
47. Oberwalder M, Weis H, Nehoda H, Kafka-Ritsch R, Bonatti H, Prommegger R, et al. Videobronchoscopic guidance makes percutaneous dilational tracheostomy safer. *Surg Endosc* 2004;18(5):839-842.
48. Griggs WM, Worthley LI, Gilligan JE, Thomas PD, Myburg JA. A simple percutaneous tracheostomy technique. *Surg Gynecol Obstet* 1990;170(6):543-545.
49. Fantoni A, Ripamonti D. A non-derivative, non-surgical tracheostomy: the translaryngeal method. *Intensive Care Med* 1997;23(4):386-392.
50. Westphal K, Maeser D, Scheiffler G, Lischke V, Byhahn C. PercuTwist: a new single-dilator technique for percutaneous tracheostomy. *Anesth Analg* 2003;96(1):229-232.
51. Gromann TW, Birkelbach O, Hetzer R. Balloon dilatational tracheostomy: initial experience with the Ciaglia Blue Dolphin method. *Anesth Analg* 2009;108(6):1862-1866.
52. Paran H, Butnaru G, Hass I, Afanasov A, Gutman M. Evaluation of a modified percutaneous tracheostomy technique without bronchoscopic guidance. *Chest* 2004;126(3):868-871.