The Role of Tracheotomy in Weaning*

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Tracheotomy is commonly performed in ventilator-dependent patients. Disadvantages to the procedure are perioperative complications, long-term airway injury, and the cost of the procedure. Benefits ascribed to tracheotomy vs prolonged translaryngeal intubation include improved patient comfort, more effective airway suctioning, decreased airway resistance, enhanced patient mobility, increased potential for speech, ability to eat orally, a more secure airway, accelerated ventilator weaning, reduced ventilator-associated pneumonia, and the ability to transfer ventilator-dependent patients from the ICU. None of these benefits, however, have been demonstrated in large-scale, prospective, randomized studies. It is proposed that there should be an anticipatory approach wherein tracheotomy is considered after an initial period of stabilization with the patient receiving mechanical ventilation when it becomes apparent that the patient will require prolonged ventilator assistance. Tracheotomy then is performed when the patient appears likely to gain one or more of the benefits ascribed to the procedure. (CHEST 2001; 120:477S–481S)

Key words: dilational; endotracheal; intubation; percutaneous; perioperative; nasotracheal; tracheotomy; translaryngeal

Abbreviations: PDT = percutaneous dilational technique; WOB = work of breathing

Tracheotomy is commonly performed for critically ill, ventilator-dependent patients to provide long-term airway access. The timing of the tracheotomy remains controversial because no generally accepted approach exists for selecting patients for the procedure.1 The disadvantages of tracheotomy include perioperative complications related to the surgery, long-term airway injury, and the cost of the procedure. None of these disadvantages, however, reaches sufficient proportions to make tracheotomy any less acceptable compared with other commonly performed procedures performed in critically ill patients.

For instance, patient series2 reported during the early 1980s suggested that tracheotomy had a high risk of perioperative and long-term airway complications, such as tracheal stenosis. More recent studies3–5 however, have established that a standard surgical tracheotomy can be performed with an acceptably low risk of perioperative complications. Regarding long-term risks, analyses of longitudinal studies suggest that the risk of tracheal stenosis after tracheotomy is not clearly higher than the risks of subglottic stenosis from prolonged translaryngeal intubation.6 Also, the nonrandomized studies1,2,7–9 commonly reported in the literature bias results toward greater long-term airway injury in patients who had undergone tracheotomy because the procedure was performed after a prolonged period of translaryngeal intubation, which may prime the airway for damage from a subsequent tracheotomy. And last, the cost of tracheotomy can be lowered if it is performed in the ICU rather than in an operating room either by the standard surgical technique or by the percutaneous dilational technique (PDT). Even when performed in an operating room, the cost of tracheotomy may be balanced by cost savings if a ventilator-dependent patient can be moved from an ICU setting after the placement of a tracheotomy. The actual cost benefits of tracheotomy, however, have not been established because no rigorous cost-effectiveness analyses have been performed.

Benefits that commonly are ascribed to tracheotomy compared to prolonged translaryngeal intubation include improved patient comfort, more effective airway suctioning, decreased airway resistance, enhanced patient mobility, increased opportunities for articulated speech, the ability to eat orally, a more secure airway, accelerated weaning from mechanical ventilation, and the ability to transfer ventilator-dependent patients from the ICU.1,10 To my knowledge, however, none of these benefits of tracheotomy have been demonstrated in large-scale, prospective, randomized studies. Some of them, such as earlier transfer to a non-ICU setting, depend on local resources, such as the availability of a non-ICU ventilator service. There is a surprisingly small amount of data regarding the relative impact of tracheotomy in terms of patient outcome relative to prolonged translaryngeal intubation. Consequently, recommendations for timing the procedure to achieve these benefits have been based on expert consensus.1,8,11

This consensus proposes an anticipatory approach wherein tracheotomy is considered after an initial period of stabilization receiving mechanical ventilation when it becomes apparent that the patient will require prolonged ventilatory assistance. Tracheotomy then is performed when the patient appears likely to gain one or more of the benefits ascribed to the procedure.1,11 Observational studies, however, indicate that the absence of clear criteria for selecting patients for tracheotomy results in considerable variation in the timing of the procedure for ventilator-dependent patients, with local practice preferences, rather than patient factors, guiding care.12,13

It has been suggested11 that early tracheotomy performed within the first 7 days of mechanical ventilation decreases the duration of mechanical ventilation. Support for this beneficial effect on weaning derives from observations that patients undergoing tracheotomy experience enhanced comfort and mobility, decreased airway resistance, and a lower incidence of ventilator-associated pneumonia, which translate to a shorter duration of mechanical ventilation. The evidence for each of these factors and outcomes is reviewed below.

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IMPROVED PATIENT COMFORT

No prospective outcome studies in general populations of ventilator-dependent patients using validated measurement tools have established that tracheotomy results in greater patient comfort or mobility compared with prolonged translaryngeal intubation. Astrachan and coworkers interviewed ICU caregivers, however, and found that they believed that patients receiving mechanical ventilation were more comfortable after a tracheotomy. General consensus exists that patients supported with long-term mechanical ventilation have less facial discomfort when nasotracheal or orotracheal endotracheal tubes are removed and a tracheotomy is performed. Patient well-being is further promoted by a tracheotomy through its effects on assisting articulated speech, oral nutrition, and patient mobility, which promote the discontinuation of treatment with sedatives and analgesics. The maintenance of continuous sedation has been associated with the prolongation of mechanical ventilation.

EFFECT OF TRACHEOTOMY ON DECREASING AIRWAY RESISTANCE

The shorter length of a tracheostomy tube compared to an endotracheal tube is associated with less airway resistance when measured in vitro during constant flow and oscillatory conditions. Although the small radius of curvature of tracheostomy tubes increases turbulent airflow and airway resistance, the short length of tracheostomy tubes more than compensates for airflow turbulence. The overall lower airway resistance may decrease the loads imposed on the respiratory system and thereby promote weaning from mechanical ventilation.

Differences in airway resistance between tracheostomy and translaryngeal endotracheal tubes measured in vitro become greater when these tubes are in use for ventilator-dependent patients. Wright and coworkers demonstrated that the resistance of endotracheal tubes is greater when measured in vitro compared with in vitro. This increased resistance was ascribed by the investigators to increased airflow turbulence from luminal secretions and from increased tube angulation and deformation due to the conformation of the endotracheal tube to the upper airway anatomy.

A before/after study demonstrated that a tracheotomy reduces the mechanical workload, work of breathing (WOB), and the mouth occlusion pressure at 0.1 s after inspiratory effort, with P0.01 impedance, of ventilator-dependent patients. These investigators suggested that the subtle development of endotracheal tube occlusion increases airway resistance in patients undergoing prolonged translaryngeal intubation. Villafane and coworkers supported this speculation by observing a gradual reduction of endotracheal tube diameter during mechanical ventilation with different humidification devices. Tracheotomy tubes may be less subject to progressive occlusion because airway suctioning more readily clears secretions within their short lengths, and most tube designs have a disposable inner cannula that can be exchanged when inspissated secretions develop.

Davis and coworkers performed a before/after study of tracheotomy in 20 ventilator-dependent patients and observed only a small improvement in mean (± SD) WOB per liter of ventilation (0.97 ± 0.32 vs 0.81 ± 0.46 J/L, respectively; p = 0.09), WOB per minute (8.9 ± 2.9 vs 6.6 ± 1.4 J/min, respectively; p = 0.04), and airway resistance (9.4 ± 4.1 vs 6.3 ± 4.5 cm H2O/L/s, respectively; p = 0.07). The beneficial effects were magnified, however, as the respiratory rate increased. In contrast, Lin and coworkers did not find differences in pulmonary mechanics (ie, mean airway resistance or pressure/time product) before and after tracheotomy in 20 ventilator-dependent patients. The peak inspiratory pressure was decreased (33.4 ± 11.8 vs 28.6 ± 9.2 mm Hg), however, after a tracheotomy was performed.

No comparative data exist of the effects of different calibers of endotracheal tubes compared with tracheotomy tubes on airway resistance or WOB when measured in vivo in patients with respiratory failure.

Existing data indicate that airway resistance and WOB may decrease in some patients after the performance of a tracheotomy. The clinical impact of this improvement in pulmonary mechanics on weaning, however, has not been established. The existing data suggest that patients with borderline levels of pulmonary mechanics, however, may benefit from a tracheotomy because of decreased airway resistance, which becomes more clinically important with high respiratory rates.

OUTCOME STUDIES: THE IMPACT OF TRACHEOTOMY ON THE DURATION OF MECHANICAL VENTILATION

The impact of tracheotomy on the duration of mechanical ventilation has been examined by several different study designs. Most studies are retrospective, although a few prospective studies have been performed. Most studies have assigned patients to treatment groups on the basis of physician practice patterns rather than random assignment. Those studies that used random assignment frequently used quasi-randomization methods (eg, every other patient, every other day, hospital record number, or odd-even days). Studies have compared patients undergoing tracheotomy vs no tracheotomy and patients undergoing early vs late tracheotomy. The definition of early vs late tracheotomy varies between studies. Early may be defined as a period as short as 2 days to as late as 10 days after the patient starts receiving mechanical ventilation.

Patient populations included into studies also vary widely between investigations and include general surgical and medical patients in some studies and specific patient groups (eg, trauma patients and head-injured patients) in other studies. Most studies suffer from design flaws in collecting and analyzing data, foremost of which is the absence of blinding. The absence of blinding is especially important considering that no study has used explicit, systematic protocols for weaning to control for any effects of tracheotomy on altering clinicians’ approaches to weaning.

With these limitations in mind, the studies that assess the impact of tracheotomy timing on the duration of mechanical ventilation are reviewed below.
Lesnik and colleagues\textsuperscript{25} found in a retrospective study of patients with blunt multiple-organ trauma that tracheotomy within the first 4 days of injury had a shorter duration of ventilator support (mean duration, 6 ± 3.4 days) compared to a later performance of tracheotomy (mean duration, 20.6 ± 12.2 days). Early weaning was successful in 100\% of patients undergoing early tracheotomy, and in 62\% of patients undergoing late tracheotomy. The techniques of tracheotomy and the selection criteria for the procedure, however, were not described.

Blot and coworkers\textsuperscript{26} performed a retrospective chart review of 53 consecutive neutropenic patients who received mechanical ventilation. They categorized patients by the performance of early tracheotomy (\textit{i.e.}, within 2 days of mechanical ventilation, 20 patients) vs other, no tracheotomy, or early tracheotomy (tracheotomy after 7 days of mechanical ventilation or no tracheotomy until death or successful extubation, 33 patients). The length of hospital stay and the length of ventilation were longer in the early-tracheotomy group. The selection criteria for the decision for early tracheotomy, however, were not provided.

Koh and coworkers\textsuperscript{27} performed a retrospective chart review of 49 ventilator-dependent patients with neurosurgical conditions. They observed a shorter length of ICU stay for patients undergoing elective tracheotomy after a mean duration of ventilation of 9.8 days (eight patients) compared to patients who underwent tracheotomy after a failed extubation (mean timing of tracheotomy, 10.7 days; nine patients). Fourteen of the 17 patients undergoing elective tracheotomy were successfully weaned from mechanical ventilation within 48 h of undergoing the tracheotomy. An additional 32 patients were not entered into the analysis because they were successfully weaned without tracheotomy after a mean duration of mechanical ventilation of 4.1 days. No criteria were described for selecting patients for elective tracheotomy.

Dunham and LaMonica\textsuperscript{28} studied prospectively 74 trauma patients, and compared 34 patients who had undergone a tracheotomy within the first 4 days of receiving mechanical ventilation with 40 patients who had been extubated successfully from translaryngeal intubation (20 patients) or had undergone a tracheotomy after 14 days of ventilation (20 patients). No effect of early tracheotomy was demonstrated. Continuous data were not reported for the duration of mechanical ventilation; however, patients were categorized into discrete groups by the intervals of the duration of ventilation. Patients were randomized by the last digits of their hospital records.

A prospective study by El-Naggar and associates\textsuperscript{29} examined outcomes in 52 patients who had undergone a tracheotomy on day 3 after hospital admission vs continued intubation for 10 to 11 days, after which a tracheotomy would be performed if needed for continued ventilation. More patients in the late-tracheotomy group were successfully weaned from mechanical ventilation, but the number of tracheotomies actually performed was not reported. Continuous data for the duration of mechanical ventilation after tracheotomy were not reported.

Rodriguez and coworkers\textsuperscript{30} prospectively randomized 106 ventilator-dependent trauma patients into an early-tracheotomy group (\textit{i.e.}, those who had undergone a tracheotomy within 7 days of hospitalization; 51 patients) and a late-tracheotomy group (\textit{i.e.}, ≥ 8 days; 55 patients) tracheotomy groups. They observed a statistically significant reduction in the duration of ventilation, the duration of ICU stay, and the duration of hospital stay in the early-tracheotomy group. The study, however, did not describe the weaning protocol. Also, patients assigned to the late-tracheotomy group who had been weaned successfully before undergoing a tracheotomy were not included in the analysis of the data, thereby favoring a shorter duration of care to the early-tracheotomy group. Group assignment used a quasi-randomization method that was based on the day of hospital admission.

Sugerman et al\textsuperscript{31} examined, in a multicenter, randomized, prospective trial, early vs late tracheotomy in 155 patients, of whom 126 were evaluable. All patients were trauma victims (mainly head trauma), except for 18 patients who had medical conditions or had undergone surgery. Primary randomization to early tracheotomy (\textit{i.e.}, 3 to 5 days of mechanical ventilation) vs late tracheotomy (day 10 to 21 days) did not result in a shorter ICU length of stay. The criteria for the transfer of patients from the ICU were not presented. Continuous data for the duration of mechanical ventilation were not provided. Randomization used an acceptable random-number method.

Several of these studies were recently appraised in a systematic review.\textsuperscript{24} The authors of this review concluded that insufficient evidence existed to support the idea that the timing of tracheotomy alters the duration of mechanical ventilation in critically ill patients. Also, the review identified multiple flaws in the available studies.

**Impact of Tracheotomy on Ventilator-Associated Pneumonia**

Early tracheotomy and, alternatively, the avoidance of tracheotomy by maintaining a translaryngeal endotracheal tube in place have both been proposed as strategies to promote successful weaning from mechanical ventilation by avoiding ventilator-associated pneumonia. The occurrence of pneumonia is considered to be a cause of delayed weaning from ventilator support.

Few data support the conclusion, however, that the timing of tracheotomy alters the risk of pneumonia. Three prospective studies\textsuperscript{14,28,30} have evaluated the relative risk of pneumonia in patients who had been randomized to early tracheotomy vs late tracheotomy. Two of the studies\textsuperscript{14,28} examined trauma patients, and the third study\textsuperscript{30} examined trauma and nontrauma patients. The timing of tracheotomy in the three studies was 3 to 4 days vs 14 days,\textsuperscript{28} < 7 days vs > 7 days,\textsuperscript{14} and 3 to 5 days vs 10 to 14 days.\textsuperscript{30} These studies examined 289 patients and found a relative risk for pneumonia in the early-tracheotomy group vs the late-tracheotomy group of 0.58 (95\% confidence interval, 0.70 to 1.10). A considerable number of methodological flaws in these studies, however, do not allow firm conclusions to be drawn regarding the effects of tracheotomy on pneumonia risk. Presently, to my knowledge no data support the competing contentions that early tracheotomy either decreases or increases the risk of ventilator-associated pneumonia.
Effects on Weaning of the Technique for Tracheotomy

The advent of PDT has created the impression that tracheotomy may provide greater support of weaning from mechanical ventilation because it can be performed at lower costs, and also because it might be associated with fewer complications than a standard surgical tracheotomy. Observational studies31–34 using hospital charge data have indicated that PDT performed in the ICU has lower associated charges (cost range, $1,742 to $1,370) than standard surgical tracheotomy performed in the operating room (cost range, $1,370 to $2,832). Several patient series35–39 demonstrate, however, that some centers perform PDT and standard surgical tracheotomy both in the ICU and in the operating room. Differences in costs diminish when PDT and surgical tracheotomy are performed in the same setting.

Concerning the relative risks of PDT compared with standard surgical tracheotomy, nearly 300 case series have been published since 1985 on PDT but only 735–41 have been prospective, randomized, comparative studies with the standard surgical procedure. These studies evaluated 362 patients and are characterized by extensive heterogeneity with different definitions of outcomes and varied patient populations, making pooling of their data difficult.42 Also, the quality of the study designs was compromised by the frequent use of quasi-randomization methods, the lack of severity-of-illness indexes, and the variable locations (ie, operating room vs ICU) where tracheotomies were performed. These limitations weaken the conclusions of the studies that conclude that PDT produces fewer perioperative complications than the standard surgical procedure. The studies provide sufficient support, however, for the conclusion that PDT is at least as safe as the standard surgical procedure when considering perioperative and short-term postoperative complications. Insufficient data do not allow comparisons of the long-term risk of airway injuries from either of these procedures.

There is no evidence that either method for tracheotomy is associated with advantages in weaning patients from mechanical ventilation.

Future Investigations

It is probable that the timing of tracheotomy promotes weaning from mechanical ventilation in some, but not all, ventilator-dependent patients. The quality of existing studies, however, does not establish this clinical impression. Because of the difficulty in blinding caregivers to the presence or absence of tracheotomy, studies should use explicit weaning protocols to control for different levels of approaches toward weaning that the presence of a tracheotomy may invoke. Studies also could be improved by more rigorous patient inclusion and exclusion criteria, better accounting for dropouts, the use of conventional randomization methods, multicenter designs to allow sufficient sample sizes to determine the interaction of underlying conditions, and multivariate analysis techniques. Cost-effectiveness analysis also would assist the determination of the value of tracheotomy for weaning.

Conclusion

Insufficient data support the impression that tracheotomy provides universal benefit in promoting weaning from mechanical ventilation in all ventilator-dependent patients. Subsets of patients, however, may benefit from the procedure.

Patients requiring sedation to assist their toleration of tracheotomy tubes may be more comfortable after tracheotomy (level III) and may be weaned more rapidly from mechanical ventilation with the discontinuation of treatment with sedative drugs (level III). Patients with marginal respiratory mechanics may be weaned more rapidly from mechanical ventilation after tracheotomy because of the lower airway resistance presented by a tracheotomy tube compared with a translaryngeal endotracheal tube, especially if respiratory rates are rapid (level III).

Patients who require long-term mechanical ventilation because of marginal respiratory mechanics may be weaned more rapidly from mechanical ventilation with conversion to a tracheotomy because of the enhanced psychological well-being provided by the ability to eat orally, to communicate by articulated speech, and to experience enhanced mobility (level III). Enhanced mobility also may assist physical therapy and more rapid recovery of ventilatory muscle strength (level III).

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