

Care of the Chronic Tracheostomy

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A minority of patients with neuromuscular disease require placement of a tracheostomy, usually for the purpose of providing mechanical ventilation. Often the tracheostomy is performed during a hospital admission for an acute illness. The debate about the appropriate timing of tracheostomy in critically ill patients has not been resolved; however, the weight of evidence now favors performing a tracheostomy early (within 7 d of translaryngeal intubation) if the period of mechanical ventilation is likely to be prolonged beyond 3 weeks. For patients with chronic progressive weakness who develop respiratory difficulty, the consensus of opinion is that tracheostomy should be performed in patients with severe bulbar involvement, inability to effectively cough up secretions despite mechanical aids for secretion clearance, or for those who are unable to tolerate or fail noninvasive ventilation. The decision to perform tracheostomy in patients with chronic neuromuscular weakness involves consideration of several factors, including complications, resources, quality of life, ethical issues, cosmetic issues, and cost. Complications from tracheostomy and physician-perceived poor quality of life often lead to a negative bias, such that some patients may be denied this life-saving procedure. Special training is needed to provide long-term tracheostomy care, and an organized approach should be followed to decannulate patients who recover from their acute illness. Appropriate and skilled care could significantly improve the longevity and quality of life of those patients with neuromuscular disease who have a tracheostomy for long-term ventilation. *Key words:* neuromuscular disease, tracheostomy, mechanical ventilation, intubation, weakness, secretion clearance, noninvasive ventilation, quality of life. [Respir Care 2006;51(9):984–1001. © 2006 Daedalus Enterprises]

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Introduction

Mechanical ventilation is commonly employed in patients admitted to the intensive care unit (ICU).¹ Tracheostomy is performed in approximately 10% of all patients receiving mechanical ventilation,^{2,3} and in as many as 34% of patients who need mechanical ventilation for > 48 hours.⁴ Generally, neuromuscular disease accounts for less than 10% of patients receiving mechanical ventilation, but this proportion may be higher in some countries.⁵ The major indications for performing a tracheostomy are summarized in Table 1.

The New Horizons Symposium on Tracheostomy from A to Z, held during the 50th Annual Respiratory Congress of the American Association for Respiratory Care, comprehensively reviewed several aspects related to the procedure. The topics in the symposium were published in the April 2005 issue of *RESPIRATORY CARE*.⁶ In the present paper, we will focus on issues that are more relevant to tracheostomy in the population of patients with neuromuscular weakness. We will therefore discuss the indications and timing for the procedure, types of tracheostomy tubes, care of a chronic tracheostomy, and procedures for decannulation. Specifically, various procedures for performing tracheostomy and their advantages and disadvantages are reviewed elsewhere.^{7,8}

Timing of Tracheostomy

The decision to perform a tracheostomy in a patient is complex, and is influenced by several factors. Patients with neuromuscular weakness have a wide variety of clinical presentations. The patient's age, severity of illness, rate of progression of disease, severity of respiratory-muscle involvement, presence of bulbar involvement, and level of consciousness are some of the medical factors influencing the decision to recommend a tracheostomy. In addition, the patient's and family's preferences, social and economic issues, and availability of resources are other relevant considerations. For the purposes of decision making, we could broadly categorize patients with neuromuscular disease into those who already have a tracheostomy tube in place and those who do not. The latter group, which constitutes the majority of patients, could be further divided into those who present with a life-threatening acute illness that requires immediate intervention and a second group with more subacute or chronic progression of their disease, who are being considered for long-term invasive ventilation. We believe that different issues are involved in the decision to perform a tracheostomy in these 2 groups; accordingly, we will discuss them separately.

Table 1. Indications for Tracheostomy

Upper-airway obstruction	Infection, trauma, tumor, foreign body, obstructive sleep apnea, stenosis
Mechanical ventilation	Respiratory failure, management of secretions, to promote weaning
Neuromuscular disease	Diaphragm weakness, aspiration, coma, ineffective cough

Patients With Neuromuscular Disease and Acute Life-Threatening Illness

Many patients with neuromuscular weakness are admitted to the ICU with acute life-threatening illnesses, such as pneumonia, sepsis, acute respiratory distress syndrome, congestive heart failure, or acute-on-chronic hypercapnic respiratory failure. For such patients the options include (1) immediate endotracheal intubation (generally orotracheal) and invasive mechanical ventilation, (2) noninvasive mechanical ventilation followed by endotracheal intubation and invasive mechanical ventilation if the patient fails this intervention, or (3) no intubation if the patient or their family prefers not to pursue aggressive treatment. Patients who undergo endotracheal intubation and invasive mechanical ventilation may indicate that they would like to continue mechanical ventilation for a short period, generally a few days to 2 weeks, and if they are not improving by the end of that period mechanical ventilation should then be discontinued. Alternatively, at the end of the "period of indecision," a tracheostomy is performed and mechanical ventilation continued for an extended period. It is estimated that 10–24% of critically ill patients receiving mechanical ventilation require tracheostomy during their hospital stay.^{9–11} Generally, patients with neuromuscular weakness account for a small proportion of this population.¹¹ In addition to patients with chronic, progressive neuromuscular weakness, some patients with neuromuscular weakness of acute onset who are expected to fully recover from their illness also require tracheostomy during their hospital course, to allow mechanical ventilation for an extended period.¹²

There are a wide variety of clinical scenarios and complex factors that influence the decision to perform a tracheostomy in a patient receiving invasive mechanical ventilation with an endotracheal tube. The debate about the timing of tracheostomy in such patients principally revolves around those who believe that it is safe and appropriate for the endotracheal tube to be left in place for 3–4 weeks. The use of tracheostomy after 21 days of mechanical ventilation was recommended by a consensus conference convened by the American College of Chest Physicians in 1989.¹³ These recommendations were based on reports of a high complication rate due to tracheostomy reported at that time.¹⁴ Other experts have recommended

Table 2. Proposed Advantages of Tracheostomy Versus Endotracheal Tube

Improved removal of secretions
Improved patient comfort
Reduction in sedation/analgesic requirements
Reduced laryngeal damage
Reduced oral injury
Improved communication and swallowing ability
Reduced risk of self-extubation
Ease of reinsertion (after tract matures)
Facilitates weaning from mechanical ventilation

Table 3. Disadvantages of Tracheostomy

Acute surgical complications
Bleeding
Posterior tracheal-wall injury
Barotrauma
Tube displacement
Tube occlusion
Infection
Cardiorespiratory arrest
Late surgical complications
Infection
Tracheal stenosis
Recurrent laryngeal nerve injury
Tracheomalacia
Tracheo-esophageal fistula
Tracheo-innominate fistula
Tracheo-cutaneous fistula
Scar of incision
Cost
Less suitable for emergency airway intubation*

*Translaryngeal intubation with an endotracheal tube is the preferred mode of airway intubation in an emergency.

that the timing of tracheostomy should be individualized.^{15,16} In this approach, the decision to perform a tracheostomy is based on the anticipated duration of mechanical ventilation. In critically ill patients, the patient is first stabilized, and if the patient remains ventilator-dependent after one week and prolonged mechanical ventilation is anticipated, “early” tracheostomy (after 2 weeks) is advocated.

Decisions regarding continuing mechanical ventilation with an endotracheal tube for 3–4 weeks or switching to tracheostomy earlier are generally based on individual physician preferences. The proposed advantages of tracheostomy over endotracheal tubes are listed in Table 2, and the disadvantages of tracheostomy are listed in Table 3.

The occurrence of complications is thought to be a major drawback of tracheostomy; however, investigations conducted over 20 years ago reported a high rate of compli-

cations after translaryngeal intubation as well.^{14,17} The decision to continue translaryngeal intubation for 3–4 weeks is based on the relative safety of materials employed to manufacture newer endotracheal tubes and lower risk of tracheal damage with the high-volume high-compliance cuffs that are currently employed.^{18,19} The risks of continuing endotracheal intubation are perceived to be lower than those resulting from surgery for placement of a tracheostomy tube; however, there is no firm evidence favoring this approach. It is extremely difficult to obtain definitive data, in view of the enormous variation in the types of patients who require tracheostomy, patient and family preferences, firmly entrenched physician biases for or against tracheostomy, differences in tracheostomy techniques, and differences in protocols for mechanical ventilation and weaning.

In several investigations the outcomes of patients undergoing “early” tracheostomy were compared with those who received a tracheostomy later in their hospital course (Table 4).^{20–30} In some of these investigations, patients who received tracheostomy within 7 days of ICU admission were considered to have had “early” tracheostomy.^{25,31} Since there is no validated method to accurately predict the duration of mechanical ventilation at admission, the early-tracheostomy approach will probably lead to the procedure being performed in some patients who would have died or would have not required the procedure if a more conservative approach had been adopted. For example, in the trial reported by Rumbak and colleagues, 35% of survivors in the late-tracheostomy arm did not need a tracheostomy by the time the procedure was indicated per protocol.²⁵

Brook and co-workers²⁴ performed a prospective cohort study of patients who required prolonged mechanical ventilation and reported that “early” tracheostomy (performed within 10 d of intubation) was associated with significant reductions in duration of mechanical ventilation, ICU length of stay, and hospital costs. In contrast, Blot and associates²³ reported that neutropenic patients who developed acute respiratory failure and underwent “early” tracheostomy (within 48 h of intubation) had longer duration of mechanical ventilation and longer hospital length of stay than did patients who either underwent tracheostomy after 7 days or not at all. More recent literature has not settled this controversy. Sugeran and colleagues²⁶ conducted a prospective randomized multicenter study to evaluate the effect of early tracheostomy. Eligible patients, most of them trauma victims, were randomized on days 3–5 to receive tracheostomy or to continue translaryngeal intubation.²⁶ Patients who remained intubated were randomized again to tracheostomy or continued intubation on days 10–14. These investigators found no differences in length of ICU stay or frequency of pneumonia between the 2 groups.²⁶ However, the limitations included the fact that

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Table 4. Effect of Tracheostomy Timing on Outcomes of Critically Ill Patients

First Author	Design	Population	Tracheostomy Timing	Outcome
Rodriguez et al ²⁰	Prospective nonrandomized	Multiple trauma (<i>n</i> = 106)	< 7 d vs > 8 d after ICU admission	Trend towards decreased incidence of pneumonia. Decreased duration of MV, ICU LOS, hospital LOS.
Lesnik et al ²¹	Retrospective	Multiple trauma (<i>n</i> = 111)	< 4 d vs > 4 d after ICU admission	Trend towards decreased incidence of pneumonia. Decreased duration of MV.
Dunham and LaMonica ²²	Prospective randomized	Multiple trauma (<i>n</i> = 74)	< 4 d vs > 14 d after initiation of MV or no tracheostomy	No difference in incidence of laryngotracheal trauma or infectious complications
Blot et al ²³	Retrospective	Neutropenia (<i>n</i> = 53)	< 2 d vs > 7 d after initiation of MV or not at all	No difference in incidence of pneumonia or death. Increased duration of MV and hospital LOS in early tracheostomy group.
Brook et al ²⁴	Prospective observational	Medical ICU (<i>n</i> = 90)	< 10 d vs > 10 d after initiation of MV	Decreased duration of MV and ICU LOS in early tracheostomy group
Rumbak et al ²⁵	Prospective randomized	Medical ICU (<i>n</i> = 120)	PDT performed < 48 h vs 14–16 d after initiating MV	Decreased mortality, pneumonia, and accidental extubation in tracheostomy patients. Reduced duration of MV and ICU LOS.
Sugerman et al ²⁶	Randomized prospective	Trauma centers (<i>n</i> = 157)	Early (day 3–5) versus late (day 10–14) tracheostomy	No differences in ICU LOS, pneumonia, or death between the 2 groups. Significant physician bias in patient enrollment.
Arabi et al ²⁷	Prospective database	Trauma ICU (<i>n</i> = 136)	Early tracheostomy, within 7 d, versus later	Reduced duration of MV and ICU LOS in early-tracheostomy patients
Freeman et al ²⁸	Retrospective analysis of Project Impact data	Patients in 130 ICUs in several institutions (<i>n</i> = 43,916)	Tracheostomy performed in 5.6% of patients; median of 9 d following initiation of MV	Tracheostomy timing correlated with duration of MV, ICU LOS, and hospital LOS
Boynton et al ²⁹	Prospective observational	Surgical patients > 72 h of MV (<i>n</i> = 74)	Tracheostomy performed before active weaning (early) vs tracheostomy performed after initial weaning attempts with endotracheal tube (selective)	Median duration of weaning was reduced in early-tracheostomy group, but total duration of MV was similar in the 2 groups
Flaaten et al ³⁰	ICU database	Mixed medical and surgical ICU (<i>n</i> = 2,851)	Tracheostomy versus no tracheostomy	Reduced ICU, hospital, and 1-year mortality in tracheostomy patients vs patients who received MV without tracheostomy

ICU = intensive care unit

LOS = length of stay

MV = mechanical ventilation

PDT = percutaneous dilational tracheostomy

only one of 5 participating centers, and only 112 of 157 eligible patients completed the study.²⁶

Another group of investigators conducted a prospective study in 128 patients who were expected to require mechanical ventilation for more than 14 days.²⁵ Patients

were randomized to early percutaneous tracheostomy (within 48 h of ICU admission) or late tracheostomy (days 14–16). The early-tracheostomy group had a shorter ICU stay (mean 4.8 d vs 16.2 d), shorter duration of mechanical ventilation (mean 7.6 d vs 17.4 d),

and lower mortality (31.7% vs 61.7%) than the late-tracheostomy group.²⁵

A systematic review of the literature up until 2004 found only 5 randomized or quasi-randomized clinical trials, with a combined total of 406 patients, that were suitable for analysis.³² Meta-analysis of these studies showed that early tracheostomy did not influence mortality or risk of pneumonia. However, early tracheostomy did reduce duration of artificial ventilation and length of stay in the ICU.³² Likewise, among 136 trauma patients who required tracheostomy over a 5-year period, Arabi and colleagues²⁷ found that those who had tracheostomy within 7 days of mechanical ventilation had a significantly shorter ICU stay and duration of mechanical ventilation, compared to patients who received tracheostomy later in the course of mechanical ventilation, but ICU and hospital mortality rates were similar in the 2 groups of patients.

Other investigators found that early placement of tracheostomy reduced in-hospital mortality, compared to later placement, after adjustment for age, Charlson score, sex, and trauma status.³³ Freeman and colleagues²⁸ conducted a review of a multi-institutional critical-care administrative database (Project Impact) of approximately 44,000 patients. They found that tracheostomy patients had a higher survival rate (78.1%) than nontracheostomy patients (71.7%, $p < 0.001$). Moreover, the timing of tracheostomy was significantly associated with duration of mechanical ventilation, ICU length of stay, and hospital length of stay.²⁸

A group of investigators from Norway reported on long-term outcomes following tracheostomy in patients admitted to a closed ICU with a mixed population of medical and surgical patients.³⁰ Tracheostomy was performed in 16.2% of 2,844 admissions between 1997 and 2003. The median time to tracheostomy was 6 days after ICU admission, and the median duration of tracheostomy was 14 days. The ICU mortality, hospital mortality, and 1-year mortality were lower in the patients receiving tracheostomy, compared to a group of patients who received mechanical ventilation for more than 24 hours but did not undergo tracheostomy.³⁰ Moreover, patients who underwent tracheostomy before day 6 of ICU admission had shorter ICU length of stay and fewer ventilator days than did a group who received tracheostomy later in their course.³⁰ However, it is possible that the physicians were biased toward performing early tracheostomy in younger, less severely ill patients.

Early tracheostomy may also reduce the amount of time that patients remain sedated in the ICU.²⁵ A retrospective study of mechanically-ventilated patients assessed the effect of tracheostomy on sedation requirements and patient comfort.³⁴ Tracheostomy was performed in 72/312 patients (23% of total) undergoing mechanical ventilation for ≥ 48 hours. Sedation requirements were significantly reduced after tracheostomy, and the median time spent heavily

sedated was shorter.³⁴ Although weaning from mechanical ventilation was conducted per protocol, sedation requirements may have been reduced because weaning attempts were more aggressive after tracheostomy.

Boynton and colleagues²⁹ performed an observational prospective cohort study with surgical patients who required ≥ 72 hours of mechanical ventilation. One group of patients received tracheostomy before any active weaning attempts, whereas a second group had initial weaning attempts with the endotracheal tube in place, and 47% of these patients eventually underwent tracheostomy. The median duration of weaning was shorter in the group that received early tracheostomy (3 d vs 6 d), but the duration of mechanical ventilation did not differ between the 2 groups of patients.²⁹

In summary, the timing of tracheostomy in critically ill patients remains a controversial issue, with several factors influencing this decision. Several recent studies indicate that some benefits may accrue from deciding to do a tracheostomy after 1 week rather than later, if prolonged mechanical ventilation (> 3 wk) is likely (see Table 4).

The risk of complications may increase after continued translaryngeal intubation with an endotracheal tube for more than 10 days,^{17,35} although this has not been a uniform finding.³⁶ If the patient is anticipated to require prolonged mechanical ventilation, stabilizing the patient and performing a tracheostomy in the first 7 days after ICU admission improves some outcomes, without significant improvement in overall mortality. The difficulty with this approach is that there are as yet no validated measures to predict the need for prolonged mechanical ventilation in a heterogeneous population of ICU patients. Performing a tracheostomy earlier during the course of the ICU stay also facilitates transfer of patients to a long-term care unit, if necessary. These advantages have to be balanced against the cost and risks of the procedure. In addition to the costs of the procedure, there could be a vested interest for hospitals to perform "early" tracheostomies, because hospital reimbursement is higher for tracheostomy placement for prolonged mechanical ventilation, via Diagnosis-Related Group 483.³⁷ Moreover, some patients who undergo early tracheostomy may not have needed the procedure, because they could have been weaned from mechanical ventilation within 3–4 weeks of ICU admission. Currently, several randomized controlled clinical trials are being conducted in the United Kingdom and other centers in Europe, which should provide more definitive data on this issue.³⁸ At the present time, most centers follow the recommendations proposed by Heffner.¹⁵ After a period of initial stabilization, the patient is assessed for the risks and benefits of undergoing tracheostomy, and the following decision tree is adopted:

Table 5. Indications for Tracheostomy in Patients With Chronic Neuromuscular Disease

Patient preference
Ventilatory failure
Inability to tolerate noninvasive positive-pressure ventilation
Failure of noninvasive means to support ventilation
Bulbar involvement
Aspiration
Frequent pneumonias
Inadequate cough
Excessive secretions
Mucus plugging
Recurrent atelectasis
Cough peak flow < 160 L/min
Need for around-the-clock ventilation*

*A minority of patients have successfully employed noninvasive ventilation for more than 16 h/d.

- Translaryngeal intubation is preferred for patients in whom the need for ventilatory support is anticipated to be less than 14 days.
- Tracheostomy is preferred if the need for ventilatory support is anticipated to exceed 21 days.
- When the anticipated need for mechanical ventilation is unclear, daily assessment is required to determine when conversion to tracheostomy is indicated.

In critically ill patients with neuromuscular disease, as in other ICU patients, the decision to perform a tracheostomy must be individualized. Unless there is the potential for rapid recovery, tracheostomy within the first 7 days of ICU admission should be considered in patients with profound neuromuscular weakness, because they would be reasonably expected to need prolonged mechanical ventilation. In addition, critically ill patients with severe brainstem involvement and bulbar weakness or those with inability to cough up secretions effectively (see below) should also be considered for early tracheostomy. On the other hand, tracheostomy may be delayed in comatose patients or in those who have suffered anoxic brain injury, until their chances of recovery have been better defined.

Patients With Neuromuscular Disease and Chronic Ventilatory Failure

The second group of patients with neuromuscular disease who receive a tracheostomy are those who have progressive neuromuscular weakness and eventually develop respiratory distress, orthopnea, daytime hypercapnia, and/or hypoxemia. The indications for performing a tracheostomy in such patients have not been clearly de-

Table 6. Factors That Influence the Decision to Perform Tracheostomy in Patients with Chronic Neuromuscular Disease

Complications of procedure
Short-term
Long-term
Need for resources to manage tracheostomy and ventilator
Quality of Life
Ethical issues
Cosmetic issues
Cost

defined,^{39,40} and the consensus is that tracheostomy is performed in only a minority of such patients. In one large survey conducted in Europe, however, as many as 24% of patients with neurological disease received tracheostomy for home mechanical ventilation.⁴¹ Table 5 shows the currently accepted indications for performing a tracheostomy in such patients.

In patients with inspiratory-muscle weakness, the expert consensus is that tracheostomy should be delayed, and ventilation supported noninvasively for as long as possible.^{42,43} In current practice, no level of pulmonary function or level of blood-gas abnormality absolutely mandates tracheostomy over noninvasive ventilation. However, presence of severe bulbar weakness and aspiration make the patient vulnerable to pneumonia, and such patients need tracheostomy for airway protection. Likewise, the inability to cough effectively and retention of secretions in the lung despite assisted cough and the use of mechanical aids for secretion clearance suggest the need for a tracheostomy. At this point in the patient's course, the patient or their care providers may elect to undergo tracheostomy or they may opt against having the procedure. Many patients select the latter approach. A tracheostomy is contraindicated in patients who have clearly stated their wishes against having the procedure.

Several factors that influence the decision whether to have a tracheostomy are listed in Table 6. Many patients decline to have a tracheostomy because they believe that it is an aggressive procedure and that invasive mechanical ventilation merely prolongs the process of dying. Importantly, such a negative view is not held about noninvasive ventilation with a mask. Physicians may also contribute to negative perceptions about invasive mechanical ventilation in patients with incurable illness. While the patient's and family's wishes must be respected, a negative bias toward tracheostomy and invasive mechanical ventilation is not consistent with current data. In the following sections we will discuss each of the factors that influence the complex medical decision about tracheostomy in patients with chronic, progressive neuromuscular disease.

Table 7. Complications of Tracheostomy in 1,130 Patients

Complications	Number of Cases	Outcome		
		Resolved	Surgery	Death
Tracheal stenosis	21	10	11*	0
Hemorrhage	9	0	7	2
Tracheocutaneous fistula	6	0	6	0
Infection	5	5	0	0
Tube decannulation/obstruction	4	0	0	4
Subcutaneous emphysema	1	1	0	0
Pneumothorax	3	1	0	2
Tracheoesophageal fistula	1	0	1	0

*4 patients treated with end-to-end anastomosis, 7 patients treated with CO₂ laser.
Data from Reference 48

Complications. A high rate of complications related to tracheostomy is often cited as a reason against undergoing the procedure. These high complication rates were reported in studies conducted 25 years ago,¹⁴ with much higher complication rates in emergency procedures than in elective ones.⁴⁴ In order to make the best informed decision, patients and their families need to know the most current risks and complications related to *elective* tracheostomy. The incidence of important complications after tracheostomy has been reported to be in the range of 5% to 40%.^{45,46} An average number for tracheostomy complications may be closer to 15%.^{47,48} In the past, hemorrhage has been the most common complication, occurring in about 4% of patients, whereas tube obstruction and tube displacement have been reported in 2.7% and 1.5% of patients, respectively. Other complications, such as pneumothorax, tracheal stenosis, and tracheoesophageal fistula, are less frequent (< 1%). Fatalities due to tracheostomy are most often related to hemorrhage or tube displacement and occur in 0.5–1.6% of patients.

A prospective study by Stock and co-workers⁴⁹ found that performance of a tracheostomy by surgeons who are skilled in airway placement could significantly reduce the complication rate associated with tracheostomy. Another retrospective investigation of tracheostomy complications studied 1,130 consecutive procedures performed at a single institution between 1987 and 1997 in a mixed population of patients, but mostly (76%) in patients who required long-term ventilation.⁴⁸ Only 3 (0.26%) were performed as an emergency after failed intubation or cricothyrotomy. All 1,130 tracheostomies were surgical, and no percutaneous tracheostomies were performed. Major complications occurred in only 49 (4.3%) tracheostomies and contributed to 8 deaths that were directly related to the tracheostomy (Table 7). This 4.3% of major complications, including all intraoperative, early postoperative, and late postoperative complications, and 0.7% death rate, represent a significant decrease in complications and mortal-

ity rate, compared with previous numbers from prior large series.¹⁴ An additional important finding in this study was that tracheal stenosis was the most common complication, whereas hemorrhage had always been the most common in previous studies. The authors of that study⁴⁸ noted as well that the complication of tracheal stenosis may also be more related to how long the patient was endotracheally intubated prior to tracheostomy. Clearly, tracheostomy complications could be minimized if skilled surgeons performed the procedure, and by careful postoperative and long-term tracheostomy-tube management.^{48,49} Moreover, refinement of the technique has led to a decline in complication rate from tracheostomy.⁵⁰

Complications of tracheostomy can be divided into those that are immediate (intraoperative), intermediate (early postoperative), and late (late postoperative). Early and intermediate complications could be reduced by careful surgical technique and expert postoperative care. We will focus on some of the more frequent long-term complications in tracheostomy care.

Tracheoarterial Fistula. Tracheoarterial fistula is a dreaded complication that mostly occurs in the late postoperative period and can lead to massive hemorrhage. It results from pressure necrosis or injury to the trachea adjacent to the course of the innominate artery. Several factors related to the tracheostomy tube (excessive tube movement, excessively long or curved tube, low tube placement), aberrant innominate artery position, tracheal infection, and corticosteroid therapy predispose to development of a tracheoarterial fistula. The incidence of this complication has been reported to be between 0.6% and 0.7% in 2 large studies.^{51,52} Most of the 15 patients out of 2,295 patients in these studies had their tracheostomy tubes for less than 2 weeks. Scalise et al retrospectively looked at the incidence of tracheoarterial fistula in patients with chronic tracheostomy tubes.⁵³ Out of 544 patients with long-term tracheostomy tubes at their facility between 1981 and 2003, they identified 5 patients (0.7%) who had sudden, massive hemoptysis that caused death from respiratory failure and/or exsanguination ($n = 1$) or had autopsy-proven tracheoarterial fistula ($n = 4$). The 5 patients were younger (mean age 31 y vs 68 y). This recent study suggests that risk of massive hemorrhage due to a tracheoarterial fistula in a patient with a chronic tracheostomy tube is not different than the small risk associated in patients with tracheostomies placed recently.

Tracheoesophageal Fistula. Injury to the posterior tracheal wall and esophagus leads to this complication in < 1% of patients.^{54,55} The position and angulation of the tube, high cuff pressure, and presence of a nasogastric tube are important risk factors. The occurrence of a tracheoesophageal fistula may be difficult to recognize in criti-

Table 8. Acute Postoperative Complications of Tracheostomy Tubes

Complication	First Author, Year of Publication, Journal, Year-Range Studied			
	Stauffer et al ¹⁴ 1981 <i>Am J Med</i> pre-1980 (%)	Dulguerov et al ⁵⁸ 1999 <i>Crit Care Med</i> 1960–1984 (%)	Dulguerov et al ⁵⁸ 1999 <i>Crit Care Med</i> 1985–1996 (%)	Goldenberg et al ⁴⁸ 2000 <i>Otol Head Neck Surg</i> 1987–1996 (%)
Death	NA	0.38	0.03	NA
Cardiopulmonary arrest	4	0.60	0.06	NA
Pneumothorax	4	1.10	0.74	0.26
Pneumomediastinum	4	0.31	0.03	0.18
Desaturation/hypotension	NA	0	0.23	NA
Posterior tracheal wall lesion	NA	0.5	0.06	NA
Cannula misplacement	2	0.55	0.17	NA
Aspiration	8	0.24	0	NA
Hemorrhage	2	1.70	1.42	0.62
Difficult tube placement	6	0	0.06	NA
False passage	NA	0.12	0.11	NA
Subcutaneous emphysema	9	3.49	0.20	0.08
Total perioperative complications	38	8.54	3.11	1.15

NA = data not available

cally ill patients. It should be suspected in patients with increased tracheal secretions, cough, and recurrent aspiration pneumonia. Endoscopic studies (both trachea and esophagus) are helpful to establish the diagnosis.⁵⁵ Surgical repair is needed for definitive treatment of a tracheo-esophageal fistula,⁵⁵ but a variety of stenting procedures can also be employed as an alternative.⁵⁶

Tracheal Stenosis. Previous endotracheal intubation, high tracheostomy or cricothyroidotomy, and airway trauma predispose to development of tracheal or subglottic stenosis. Most patients with tracheal stenosis remain asymptomatic. Symptoms appear when the tracheal lumen is reduced by 75% or to < 6 mm in diameter. Stenosis may develop at the level of the stoma or at the level of the cuff, due to direct pressure damage. Mucosal injury and stenosis from the cuff have become relatively rare since the availability of the high-volume, low-pressure cuffs.¹⁹

Granulation Tissue. This late complication of tracheostomy could result in bleeding, difficulty in replacing a dislodged tracheostomy, or interference with the function of a tracheostomy, and granulation tissue frequently leads to delayed decannulation. Yaremchuk observed a significant decrease in patients who required surgical interventions due to granulation tissue after implementing a policy that required routine tracheostomy-tube changes every 2 weeks in combination with a detailed evaluation of the tracheostomy stoma site.⁵⁷

There has been a steady decline in complication rates from surgical tracheostomy over the past 20 years (Tables 8 and 9). Moreover, the complication rate with percutane-

ous dilational tracheostomy may be even lower than that with surgical tracheostomy (Fig. 1).⁵⁰ With expert care, tracheostomy tubes could be safely employed for prolonged mechanical ventilation in patients with chronic neuromuscular disease.

Need for Resources to Manage Tracheostomy and Long-Term Mechanical Ventilation.

A tracheostomy is performed to allow long-term mechanical ventilation. In the United States, most long-term ventilation has now shifted to the home environment. When transfer to the home is not possible, options for institutional care are, unfortunately, very limited. Mechanical ventilation outside the hospital may be continued in a long-term acute-care facility, provided there is some potential for the patient to wean from the ventilator. Transfer to long-term care in a skilled-nursing home is another option. However, there are very few skilled-nursing facilities for ventilator-dependent patients. Transfer to a skilled-nursing facility may require that patients are separated from their families and suffer isolation and loneliness in unfamiliar surroundings. Disposition of such patients can be a frustrating and challenging problem that may take several months to accomplish.⁵⁹ Such patients may languish in acute-care hospitals for extended periods because of the unavailability of suitable care outside the hospital.

Providing long-term ventilation at home not only affects the patient, it influences the entire family and support system. These patients require 24-hour-a-day care, and the patient's family, hired care, or state services may be needed for providing such coverage. Caregivers need to be proficient in the care of the tracheostomy and the ventilator.

Table 9. Long-Term Postoperative Complications of Tracheostomy Tubes

Complication	First Author, Year of Publication, Journal, Year-Range Studied			
	Stauffer et al ¹⁴ 1981 <i>Am J Med</i> pre-1980 (%)	Dulguero et al ⁵⁸ 1991 <i>Crit Care Med</i> 1960–1984 (%)	Dulguero et al ⁵⁸ 1999 <i>Crit Care Med</i> 1985–1996 (%)	Goldenberg et al ⁴⁸ 2000 <i>Otol Head Neck Surg</i> 1987–1996 (%)
Death	6	1.24	0.14	0.70
Tracheoesophageal fistula	NA	0.31	0.0	0.08
Mediastinitis	4	0.12	0.0	0.18
Sepsis	4	0.24	0.06	NA
Hemorrhage, intratracheal (severe)	2	0.88	0.71	0.18
Pneumothorax	4	0.07	0.0	NA
Cannula displacement/obstruction	6	3.99	1.39	0.35
Tracheal stenosis	65	1.60	0.26	1.86
Pneumonia	NA	6.50	1.31	2.04
Atelectasis	NA	2.63	0.03	NA
Aspiration	8	0.74	0.09	NA
Tracheal cartilage lesion	91	0.76	0.03	NA
Hemorrhage, external	36	2.37	2.53	NA
Stomal/Wound infections	36	10.39	2.94	NA
Severe stomal/wound infections	NA	NA	NA	0.27
Delayed cutaneous closure	NA	0.38	0.0	0.53
Stomal erosion or breakdown	9	NA	NA	NA
Keloid and/or unaesthetic scar	22	0.58	0.14	NA
Excessive cuff pressure required	23	NA	NA	NA
Total postoperative complications	66	32.80	9.63	6.19

NA = data not available

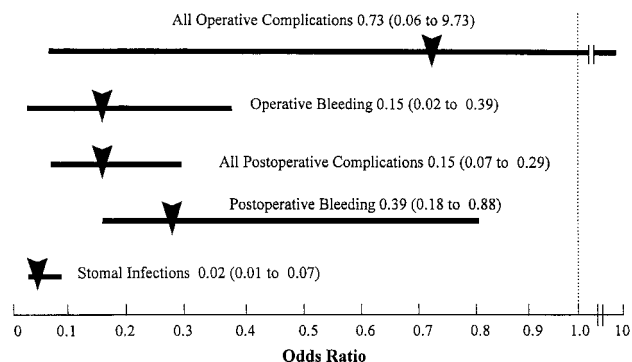


Fig. 1. Comparison of operative and postoperative complications after surgical tracheostomy and percutaneous dilational tracheostomy. Odds ratios (OR, arrowheads) and 95% confidence intervals (CI, horizontal bars) are shown for various complications. An OR of 1.0 (indicated by the dashed line) indicates no difference between the 2 procedures. There was no difference between surgical tracheostomy and percutaneous dilational tracheostomy with respect to overall operative complication rate (OR = 0.73, 95% CI = 0.06–9.37). However, relative to surgical tracheostomy, percutaneous dilational tracheostomy was associated with less perioperative bleeding (OR = 0.15, 95% CI = 0.02–0.39), a lower overall postoperative complication rate (OR = 0.15, 95% CI = 0.07–0.29), and a lower postoperative incidence of bleeding (OR = 0.39, 95% CI = 0.18–0.88) and stomal infection (OR = 0.02, 95% CI = 0.01–0.07). (From Reference 50, with permission.)

They also need training as first-responders so that they can display sound judgment and good decision-making ability in an emergency.

Quality of Life. The belief that patients with chronic neuromuscular disease have a poor quality of life is one that is commonly held by physicians and society in general. A physician’s assessment of a patient’s quality of life and the relative desirability of their existence may influence the likelihood of a patient receiving a therapeutic intervention.⁶⁰ Thus, a major reason for withholding mechanical ventilation in patients with chronic respiratory failure due to neuromuscular weakness may be the physician’s perception of a patient’s poor quality of life.⁶¹ Although only a few investigators have studied the quality of life in patients receiving long-term ventilatory assistance, their findings uniformly show that such patients express a high level of satisfaction with their lives. Bach and co-workers⁶² determined the life satisfaction among patients with Duchenne muscular dystrophy receiving mechanical ventilation. They found that the majority of patients were satisfied with life. In contrast, health-care professionals significantly underestimated the patients’ life satisfaction and overestimated their degree of hardship due to chronic ventilator dependence. Likewise, more than two thirds of

patients receiving long-term ventilatory assistance via tracheostomy were satisfied with their lives and 84% thought they had made the right choice.⁶³ All but one of 19 patients responded that they would repeat the experience if they had another chance.

Another group of Swedish investigators compared quality of life in patients with neuromuscular and skeletal disease receiving home mechanical ventilation.⁶⁴ They compared the Sickness Impact Profile, Health Index, and Sense of Coherence in 60 patients receiving noninvasive ventilation versus 31 patients who had tracheostomy. Similar to previous studies, patients on home mechanical ventilation reported good perceived health, despite severe physical limitations.⁶⁴ Somewhat surprisingly, patients with tracheostomy perceived better overall health, felt less fatigued, and had better sleep than patients receiving noninvasive ventilation.⁶⁴ However, this study was conducted at a specialized center where the tracheostomy patients received regular, expert follow-up care. Further studies are needed to determine if these findings would apply to a general population of patients receiving long-term ventilation.

Patients with different types of neuromuscular weakness may have different perceptions of quality of life. In general, patients adapt better to slowly progressing muscular dystrophies that begin in childhood (eg, Duchenne muscular dystrophy), as compared to adult-onset disorders with a more rapidly progressive course (eg, amyotrophic lateral sclerosis [ALS]).⁶³ Likewise, Markström and investigators⁶⁴ found that patients with scoliosis receiving home ventilation had little or no dysfunction in Sickness Impact Profile scores. Post-polio patients with tracheostomy had significantly lower Sickness Impact Profile scores than patients treated with noninvasive ventilation, whereas patients with neuromuscular disease who had undergone tracheostomy had higher Sickness Impact Profile scores than those receiving noninvasive ventilation. Further studies are needed to determine quality of life during home mechanical ventilation in patients with various categories of neuromuscular disorders.

In summary, patients with neuromuscular disease who are receiving mechanical ventilation outside an acute care facility appear to have a reasonable quality of life, despite severe physical limitations and handicaps. The underlying disease state also needs consideration while deciding various treatment options; however, more data are needed in this respect. The theme that emerges from all these studies is that health-care professionals tend to focus on the patient's disabilities but underestimate the value of the patient's self respect, control of their environment, and social contacts.⁶⁵

Certainly, physician-perceived poor quality of life should not be a reason to withhold tracheostomy and mechanical ventilation in patients with neuromuscular disease and ventilatory failure.

Ethical Issues. Patients with progressive neuromuscular illness have a limited life span. Most patients with Duchenne muscular dystrophy and ALS die due to complications of hypercapnic respiratory failure.^{66,67} In a retrospective analysis, patients with ALS who were unable to tolerate noninvasive ventilation and declined tracheostomy were compared with a group of patients with bulbar involvement who received noninvasive ventilation.⁶⁸ There was high early mortality in the patients who were not treated, especially for those patients with a P_{aCO_2} level of > 45 mm Hg.⁶⁸ In a prospective randomized trial of patients with ALS who had orthopnea and maximum inspiratory pressure $< 60\%$ of predicted or symptomatic daytime hypercapnia, Bourke and co-workers⁶⁹ found that 6 of 19 patients who were randomized to the control group (no ventilatory support) died within 2 weeks of randomization. Noninvasive ventilation improved survival in patients with normal or moderate bulbar dysfunction, but not in those with severe bulbar dysfunction.⁶⁹ Providing mechanical ventilation in such patients could add meaningful years to their lives.⁷⁰ In one series of patients with motor-neuron disease, Oppenheimer⁷¹ reported up to 85% 1-year survival and $> 50\%$ survival for ≥ 3 years. Although large controlled trials are lacking, patients with slow and nonprogressive disorders, such as poliomyelitis, muscular dystrophies, and myopathies, have $> 80\%$ actuarial probability of continuing noninvasive ventilatory support for 5 years.⁷² Ventilated patients with slower progression of neuromuscular weakness could become productive members of society.⁷³ After institution of mechanical ventilation, patients are thought to spend most of their lives in long-term acute care or in acute-care hospitals. Recent data show no reduction in the observed versus expected life span among patients with neuromuscular disease who survived at least 4 years after a tracheostomy.⁷⁴ These patients spent $< 4\%$ of their time in the hospital.⁷⁴ However, these results were achieved in a setting where patients received regular and expert care over a course of several years. The disease state and available resources must be carefully considered before denying the benefits of long-term mechanical ventilation to a patient with neuromuscular disease and chronic respiratory failure.⁷⁵

Cosmetic Issues. Tracheostomy leaves a scar after decannulation. Usually this is a linear scar about one inch in length. However, a substantial proportion of patients may be left with a disfiguring scar.⁷⁶ This may be a special concern for young women with potentially reversible acute neuromuscular weakness. Several plastic surgical techniques have been described to improve the cosmetic appearance of post-tracheostomy scars.⁷⁷⁻⁷⁹ Moreover, cosmetic results may be better after percutaneous tracheostomy than after surgical tracheostomy.^{80,81}

Cost. The cost of long-term ventilation at home is estimated to be approximately \$10,000 per month.^{82,83} The cost of nursing care is a major contributor to the overall costs of care. The provision of long-term mechanical ventilation is generally covered by private insurance companies or other state and federal agencies. Additional expenditures are incurred for modifications in the home and transportation needed to provide long-term mechanical ventilation. Ventilators adapted for use with motorized wheelchairs have allowed much greater mobility for patients receiving home ventilation.⁸⁴ Unfortunately, full insurance coverage is rare. For example, expert caregivers are needed around the clock, and some insurers may not provide such coverage. Insurance coverage for the amount of supplies (tracheostomy tubes, suction catheters, gauze) may also be limited.

What Is Needed? Clearly, noninvasive ventilation has had a profound impact on the care of patients with respiratory failure due to neuromuscular disease. Yet some patients with neuromuscular weakness may be unable to tolerate noninvasive ventilation, whereas others may develop complications (eg, severe bulbar involvement) that cannot be treated by noninvasive ventilation alone. Such patients have a high early mortality if they are denied any further treatment. Judicious use of tracheostomy and long-term ventilation can prolong the patient's life. Tracheostomy, however, is not an unmixed blessing. There is potential for serious and sometimes fatal complications. Moreover, major adjustments in lifestyle are needed, and education about the pros and cons of tracheostomy should start much before the procedure is actually performed.⁸³ Prospective, multicenter studies are needed to determine the precise value of tracheostomy and long-term mechanical ventilation in a variety of neuromuscular diseases. Performance of tracheostomy as an elective procedure by skilled surgeons and follow-up care in specialized centers could go a long way in reducing complications. Greater education for patients, families, and health-care providers, and a more active role by home-care companies in providing care to these patients are other important considerations. Health-care professionals need to be aware that patients can lead satisfactory and productive lives while receiving long-term ventilation via a tracheostomy. In addition, insurers and social-service agencies need to intervene and find suitable placement for those unfortunate patients who are unable to receive long-term ventilation at home. In the absence of good scientific evidence, there may be several constraints on the type and amount of insurance coverage for patients receiving home ventilation, and this may vary in different geographic locations. Patients should not be denied tracheostomy and long-term ventilation without careful consideration of these factors.

Types of Tracheostomy Tubes

The various types and designs of tracheostomy tubes that are available have been reviewed in detail by Hess.⁸⁵ Most tracheostomy tubes are manufactured from metal, polyvinyl chloride, silicone, or a combination of these materials. Metal tubes are uncommonly employed nowadays, because they are rigid and they cannot be connected in a ventilator circuit. Moreover, they lack a cuff, so it is almost impossible to provide mechanical ventilation with them.

Tracheostomy tubes (Fig. 2) are available in a variety of sizes (Tables 10 and 11). The dimensions of tracheostomy tubes consist of inner diameter, outer diameter, length, and curvature. Tube sizes are mainly given by either Jackson size or by the ISO [International Standards Organization] method of sizing. Jackson size was initially used to give the size of metal tubes, but is still used for sizing the Shiley brand. The size is based on the length and the taper of the outer diameter of the tube from the proximal to the distal tip. The ISO method of sizing is used for single-cannula and dual-cannula (with one or more shaft sections that are straight) tracheostomy tubes, and the size is determined by the inner diameter of the outer cannula at its smallest dimension.

Both the inner diameter and the outer diameter have to be considered when selecting a tracheostomy tube. The inner diameter can affect the airflow resistance, and the outer diameter will affect airflow when the cuff is deflated, based on the space between the tracheal wall and the tube when the cuff is down. If the inner diameter is too small, not only will the resistance be increased and airway clearance be more difficult, greater cuff pressure will also be required to create a seal and secure the tube in the trachea. On the contrary, if the outer diameter is too large, it will be difficult for air to pass and the patient to breathe when the cuff is deflated. Clinicians need to be familiar with the commonly employed tracheostomy tubes and their features. This is important because even tracheostomy tubes with the same inner diameter that are made by different manufacturers can have clinically important differences in tube length.

Single-lumen tubes do not have a removable inner cannula. Because silicone is relatively secretion-resistant, tubes manufactured from this material frequently do not have an inner cannula. Dual-cannula tracheostomy tubes have an inner cannula, which may or may not be disposable. The removable inner cannula in dual-lumen tubes facilitates cleaning of inspissated secretions that would otherwise cause tube occlusion.⁸⁶ Although cleaning the inner cannula may decrease biofilm formation and ventilator-associated pneumonia, this has never been proven. The inner cannula may also be removed to restore the airway in the event of tube occlusion. This is very important in sub-

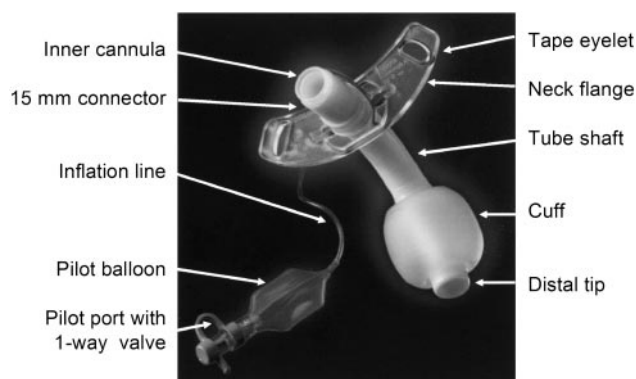


Fig. 2. Components of a cuffed tracheostomy tube. The cuff can be inflated or deflated by injecting air through the line connected to the pilot balloon. The pilot balloon indicates whether the cuff is inflated. The inner cannula can be removed for cleaning. The tube is secured by tape that is passed through the eyelets in the neck flange. (From Reference 85, with permission, and courtesy of Smiths Medical, Keene, New Hampshire.)

Table 10. Inner and Outer Diameter and Length of Shiley Disposable-Cannula, Low-Pressure, Cuffed Tracheostomy Tube

Jackon Size	Inner Diameter With Inner Cannula (mm)	Inner Diameter Without Inner Cannula (mm)	Outer Diameter (mm)	Length (mm)
4	5.0	6.7	9.4	62
6	6.4	8.1	10.8	74
8	7.6	9.1	12.2	79
10	8.9	10.7	13.8	79

acute-care facilities and in long-term ventilator rehabilitation units, where staff may not have the expertise to replace an occluded tracheostomy tube. As shown in Tables 10 and 11, an inner cannula decreases the inner diameter of the tracheostomy tube, and increases work of breathing in the spontaneously breathing patient.

Tracheostomy tubes are available with and without cuffs. The most common type of cuff used is a high-volume low-pressure cuff. The purpose of the cuff is to maintain a seal between the tube and the trachea sufficient to prevent escape of air from around the tracheostomy tube during mechanical ventilation. Moreover, the cuff minimizes the risk of aspiration. Other types of cuffs used less often on tracheostomy tubes are tight-to-shaft cuffs and foam cuffs. Tracheostomy tubes with foam cuffs conform to a patient's trachea and remain consistently inflated at low pressure. Foam-cuffed tubes are indicated in patients who have sustained damage from excessive cuff pressure (eg, tracheomalacia).

Fenestrated tubes are used to promote speech and are generally used in individuals who tolerate liberation from mechanical ventilation for varying periods. Fenestrated

Table 11. Inner and Outer Diameter and Length of Portex Flex DIC (Flexible Disposable Inner Cannula) Tracheostomy Tube

International Standards Organization Size	Inner Diameter (mm)	Inner Diameter With Inner Cannula (mm)	Outer Diameter (mm)	Length (mm)
6 (orange)	6	5	8.2	64
7 (green)	7	6	9.6	70
8 (white)	8	7	10.9	74
9 (blue)	9	8	12.3	80
10 (yellow)	10	9	13.7	80

tubes have an opening or openings on their superior aspect, such that when the inner cannula is removed, the cuff deflated, and the external orifice occluded (eg, with a Passy-Muir type valve), air can pass through the vocal cords and the patient is able to speak. A fenestrated tube also promotes decreased work of breathing for the patient by not having a cuff in the airway, and improves patient comfort during the process of decannulation. Obstruction of the fenestrations against the tracheal mucosa or by granulation tissue has been cited as one drawback of such tubes.⁸⁷

Another important factor in choosing a type a tracheostomy tube is selecting a shape that will correspond closely to the anatomy of the trachea. Various differences among tubes include angled versus curved, standard length versus extra length, and tubes with flexible shafts, including some that have a spiral-wire-reinforced flexible design. If the tracheostomy tube does not fit appropriately in the center of the trachea, it can lead to several problems, including trauma to the anterior or posterior tracheal wall, obstruction of the distal opening of the tube due to compression against the tracheal wall, and pressure at the stoma.⁸⁸ Angled tubes that are extra length may have either extra proximal length (horizontal) or extra distal length (vertical). In obese patients with large necks, extra proximal length may benefit in proper tube placement, whereas in patients with tracheomalacia, other tracheal anomalies, or problems with obstruction of the tube against the posterior tracheal wall, extra distal length may assist in proper tube placement (Fig. 3).

In summary, selecting the appropriate tracheostomy tube requires some expertise. An appropriately fitting tube should extend at least 2–3 cm beyond the stoma and lie in the center of the trachea, at least 2 cm above the carina. The curvature of the tube should be selected to allow the tube to be linearly aligned with the center of the trachea. The selection of a tracheostomy tube should be individualized, and if a suitable tube is not commercially available, then it may need to be custom made. Ultimately, the best-fitting tracheostomy tube will lead to success in managing

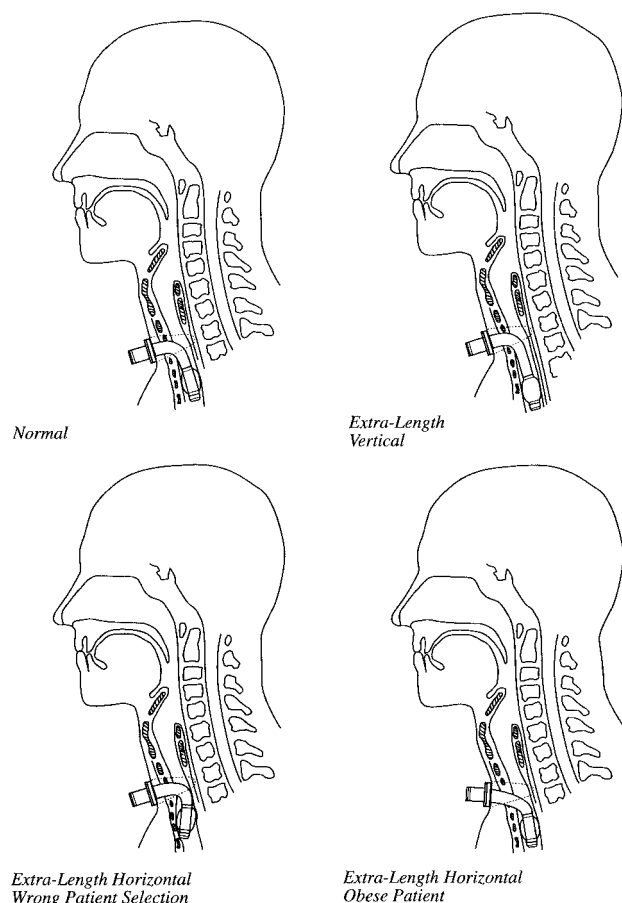


Fig. 3. Position of extra-length tracheostomy tubes in the trachea. The tube should lie in the center of the trachea and be linear with the center of the trachea. Inappropriate use of an extra-length tube could lead to obstruction of the tube against the posterior tracheal wall. (From Reference 88, with permission.)

the patient's airway, provide ventilation, promote patient comfort, and minimize complications.

Care of the Long-Term Tracheostomy

Patients who require long-term mechanical ventilation through a tracheostomy need specialized care to prevent complications. Some special areas of concern are discussed below.

Cuff Pressure

Tracheostomy tube cuffs provide a seal in the upper airway to allow positive-pressure ventilation. In addition, the presence of a cuff protects from aspiration of oral contents. The recommended inflation pressure in the cuff is 20–25 mm Hg. Higher pressure can cause mucosal ischemia by compressing mucosal capillaries, and predispose to subsequent development of tracheomalacia and tracheal

stenosis. Indirect assessments by palpation of the pilot balloon or determination of minimal leak are inaccurate.⁸⁹ In patients with stiff lungs, high inflation pressure can be transmitted to the cuff, and this pressure is transmitted to the airway mucosa at the level of the cuff.⁹⁰ Careful monitoring of cuff pressure is recommended to detect such occurrences.

Cuff Leak

Leakage of a tracheostomy cuff prevents successful positive-pressure ventilation because of leakage of air around the cuff, and also predisposes to aspiration. If there is an audible air leak, the cuff is checked to ensure that it does not leak air when inflated. If the cuff is leaking, the tracheostomy tube needs to be changed. If the problem is not with the cuff, then tracheomalacia should be suspected. Tracheomalacia is not uncommon in patients receiving long-term mechanical ventilation. If the cuff leak is well tolerated, the tracheostomy tube can be left in place and the cuff pressure maintained at 20–25 mm Hg. Alternatively, a larger tube or one with a large-volume low-pressure cuff (eg, a foam-cuff) could be employed. Increasing the pressure in the cuff to get a seal should be avoided, because it could cause further ischemia and tracheal mucosal injury.

Tube Dislodgement

A tracheostomy tube could get dislodged at any time; however, the problem appears to be much less frequent with percutaneous dilational tracheostomy than after surgical tracheostomy. Dislodgement during the first postoperative week can be particularly problematic, because the tract has not yet matured and the tube may be difficult to reinsert. Such patients may need immediate translaryngeal intubation to secure the airway, followed by insertion of the tracheostomy tube under more controlled conditions in an operating room. A tube that becomes dislodged after the tract has matured can be replaced at the bedside without much difficulty. Fiberoptic bronchoscopy helps to verify correct positioning of the tube in the airway.

Tube Occlusion

Inspissated secretions frequently cause occlusion of a tracheostomy tube. If the tube has an inner cannula, it can be removed and cleaned. After percutaneous dilational tracheostomy, obstruction of the tracheal cannula by hematoma and swelling of the posterior tracheal wall was recently reported to cause episodic respiratory difficulties in ICU patients.⁹¹ Tubes can also become occluded if the tip migrates anteriorly into the pretracheal tissues or posteriorly against the wall of the trachea.^{92,93} Such patients have

respiratory difficulty or cough, and it becomes difficult to pass a suction catheter through the tube. Either the same tube can be replaced or a different size and length of tube may be needed. Patients should always have a spare tube, preferably one that is of a smaller size than the one in regular use.

Infection

Infection at the site of the stoma is common.¹⁴ A minor infection at this site can be managed by local treatment. However, if the infection spreads into the mediastinum, broad-spectrum antibiotics and even surgical intervention may be required.⁹⁴

Patients with long-term tracheostomy have an increased risk of clinically important aspiration of gastric contents.⁹⁵ It is almost unavoidable to have some degree of tracheitis manifested by an increase in purulent secretions. Colonization of the trachea with *Pseudomonas* and other enteric Gram-negative organisms occurs⁹⁶ and predisposes patients to development of nosocomial pneumonia.

Changing Tracheostomy Tubes

The recommended frequency of changing tracheostomy tubes varies widely^{97,98} and is based on local practice and individual preferences. In general, we recommend changing the tube only if there is a need to do so, as routine changing of the tube has no proven benefit. Suggested advantages of frequent changing are that such a practice prevents airway infection, reduces the chance of tube occlusion by inspissated secretions, and reduces the incidence of airway granuloma formation.⁵⁷ However, changing a tube can be uncomfortable for the patient, and the stoma is stretched when a cuffed tube is replaced. Moreover, there is a risk of creating a false passage in the pretracheal space while replacing the tube. Polyvinyl-chloride tubes stiffen after 3–4 months, whereas silicone tubes can be employed for longer intervals. All types of tracheostomy tubes should be replaced if they develop cracks or if the pilot balloon ruptures.

Suctioning

Patients with a chronic tracheostomy generally have increased secretions and require frequent suctioning. Removal of secretions is important for maintaining tube patency; however, suctioning can be uncomfortable for the patient. For home care, use of a clean catheter and non-sterile disposable gloves, or freshly washed, clean hands is recommended.⁹⁷ Suctioning should be performed as needed, and a fixed schedule is not necessary.⁹⁹ The catheter tip should be inserted just beyond the tip of the tracheostomy tube, suction is applied, and the catheter is

rotated as it is pulled back. Deep suctioning should not be performed routinely, because it has the potential to cause airway injury.¹⁰⁰ The patient should receive some high-volume breaths with the ventilator and be well oxygenated before suctioning is performed. Closed suction systems are not only as effective as conventional suction catheters,¹⁰¹ they have the advantages of maintaining oxygenation during suctioning¹⁰² and a lesser chance of becoming contaminated from the environment.¹⁰³

Saline is instilled into the airway during suctioning to loosen secretions, stimulate cough, and to lubricate the catheter. However, the routine use of saline for suctioning is not recommended. Instillation of saline could lead to a decrease in oxygen saturation¹⁰⁴ and has the potential to dislodge microorganisms from the tube into the lower respiratory tract.¹⁰⁵ Saline instillation should therefore be used selectively to remove thick and tenacious secretions that are not removed by routine suctioning.

Promoting Communication

Being unable to speak is a major cause of frustration for patients with an endotracheal tube.¹⁰⁶ Therefore, the availability of speech aids with tracheostomy tubes is viewed as an important advantage over endotracheal tubes.^{107,108} Airflow through the upper airway and vocal cords is necessary for voice production. Initially, partial deflation of the tracheostomy tube cuff allows the patient to speak in a whisper during the inspiratory phase of the respiratory cycle.¹⁰⁹ Adding a small amount of positive end-expiratory pressure produces a continued air leak and permits audible speech throughout the breathing cycle.¹⁰⁹ Patients with neuromuscular weakness who have minimal ventilator requirements are often ventilated with cuffless tubes so that they may speak while receiving ventilator support.¹¹⁰

Patients who are able to breathe spontaneously while having a tracheostomy tube could benefit from the use of a fenestrated tube. When the external end of the tube is transiently occluded, air flows through the fenestrations into the upper airway during exhalation. Deflation of the tracheostomy-tube cuff during periods of spontaneous breathing can also facilitate speech by enhancing expiratory airflow through the vocal cords. Use of a one-way valve, such as a Passy-Muir valve, allows airflow through the tracheostomy tube during inspiration but does not permit air to exit the tracheostomy tube during exhalation. When the valve is employed with a cuffless or fenestrated tracheostomy tube, expiratory airflow is directed through the vocal cords and normal speech is facilitated.¹¹¹ A speaking valve is contraindicated in patients with upper-airway obstruction. Moreover, caution should be exercised when employing a speaking valve in patients who have thick secretions, are mentally obtunded, or have substantial aspiration.

Other devices are available for promoting speech in patients with tracheostomy tubes. Well-motivated patients could learn to communicate via “talking” tracheostomy tubes,^{112,113} tone generators,¹¹⁴ or an electrolarynx.¹¹⁵

Decannulation

When a tracheostomy is placed for mechanical ventilation and the patient recovers from the acute illness, the clinician should consider removal of the tracheostomy tube. An organized and stepwise approach is advocated for tube removal.^{116,117} Some patients with long-term tracheostomies have underlying cardiopulmonary disease, and ventilatory capacity is especially compromised in patients with neuromuscular weakness. Moreover, clinicians need to be prepared for unexpected problems with the airway during decannulation; otherwise, there could be catastrophic consequences for the patient.

Patients who are hemodynamically stable, are able to breathe comfortably and spontaneously without becoming fatigued, and have been off mechanical ventilation for 24–48 hours are candidates for decannulation. The patient should not have excessive airway secretions or require frequent suctioning. An effective cough with a peak cough flow > 160 L/min is ideal,¹¹⁸ and the patient should be able to protect the airway without substantial risk of aspiration. The steps in the decannulation process should be carefully explained to the patient and their family members.

Once the above criteria are met, the tracheostomy cuff is deflated and the patient observed for signs of aspiration.¹¹⁹ If aspiration is present, laryngoscopic examination should be performed to assess the structure and function of the glottis. Problems with vocal-cord function may become apparent at this time, and these should be addressed before proceeding with removal of the tracheostomy tube.¹²⁰

The next step is to briefly occlude the tracheostomy tube with a gloved finger and observe for any signs of respiratory distress or fall in oxygen saturation. If the patient can breathe around a size 8 or 7 tube that has been occluded with the cuff down, the airway is probably intact, and removal of the tracheostomy tube should be well tolerated. On the other hand, occurrence of respiratory distress, stridor, or diaphoresis indicates the presence of airway narrowing or a tube that is too large for the patient’s airway. Immediate breathing difficulty after tube occlusion should prompt a fiberoptic bronchoscopy to evaluate the patient’s airway.

If tube occlusion is tolerated, the tube is then capped. For safety reasons, we do not cap cuffed tracheostomy tubes at our institution. The tube could be removed in relatively healthier patients if the capping is well tolerated.¹²¹ For patients with poor cardiopulmonary function,

marginal ventilatory reserve, or other comorbidities, the tube may need to be downsized further, until the patient can tolerate a small, uncapped tracheostomy tube.¹¹⁷ Breathing difficulty occurring more than 30 min after capping the tube indicates a high likelihood of airway narrowing due to granulation tissue, tracheal strictures, or other airway lesions.¹²¹ A laryngoscopic examination is required to rule out tracheal narrowing. If airway problems are excluded, the tube can be capped intermittently for gradually lengthening periods. The tube can be occluded with either a cap or a one-way speaking valve; the latter has the advantage that it allows the patient to phonate and communicate better.

In patients with marginal status, it is advisable to wait 48 hours after the patient tolerates capping before removing the tracheostomy tube. During this time, occurrence of delayed muscle fatigue or occult aspiration would suggest the need for further evaluation before proceeding with decannulation.

In patients with very poor ventilatory reserve, the presence of the tracheostomy tube itself may increase airway resistance and impair clearance of secretions. In such patients, the use of a tracheal button or stoma stent may be helpful in preserving the stoma tract, while the removal of the tube allows the patient to breathe and clear secretions through the upper airway. Should the patient require reinsertion of the tracheostomy tube, this can be performed without difficulty, as the stoma tract is preserved by the tracheal button. Placement of the button requires careful fitting and observation.¹¹⁶

After removal of the tracheostomy tube, the stoma closes within a few days in the majority of patients. Once the stoma closes and the tract heals, the tracheostomy tube cannot be reinserted through it in the event that the patient fails decannulation or develops complications that require reinstitution of mechanical ventilation.

Summary

Tracheostomy is performed for a variety of indications in patients with neuromuscular disease. In critically ill patients, the evidence appears to favor performing the procedure early during the ICU course if mechanical ventilation is anticipated to continue for 3 weeks or more. More definitive evidence on this issue is awaited. In patients with chronic progressive neuromuscular weakness who develop ventilatory failure, the decision to perform a tracheostomy is complex and involves consideration of several factors. Clinicians caring for patients receiving tracheostomy tubes should be knowledgeable about the various types of tracheostomy tubes and attempt to provide an appropriate, well-fitting tube for their patients. Caregivers and patients need training in troubleshooting tracheostomy tubes outside the hospital. Decannulation from a trache-

ostomy could be a lengthy process and requires a planned approach. Overall, tracheostomy could be performed safely and the complications from the procedure could be minimized if it is performed by skilled and experienced personnel. Likewise, expert follow-up care could reduce complications and promote comfort and the quality of life of patients receiving long-term ventilation via tracheostomy.

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Discussion

Hess: I'd like to explore the issue of weaning from the tracheostomy. If the patient's off the ventilator and can clear the mucus and protect the airway, and you cap the tube for a day or two, why not just take it out?

Rajiv Dhand: Yes, but the point is that you don't take it out 30 minutes after you cap the tube. You have to give it a day or two to make sure that you're not going to end up with problems of subclinical aspiration. Once the patient is able to tolerate capping and breathe spontaneously on their own for a couple of days, that should be good enough.

Hess: I don't think we need to go through the downsizing, and the fenestrated tracheostomy tube, and all the things we used to do.

Rajiv Dhand: You know, there are situations where the patient's either very weak or you're not sure about their swallowing ability; many of these patients are recovering from neurological insults, either trauma or strokes or tumors, and in those situations, it is probably safer to downsize the tracheostomy tube and see how the patient does before capping it.

Panitch: Occasionally we have children who've required tracheostomies for long-term ventilation; they no longer require mechanical ventilatory support, but remain hypoxemic without supplemental oxygen. And we've taken out the tracheostomy tube, but put in a transtracheal oxygen catheter. Is that done in adult patients?

Rajiv Dhand: No, I haven't really had that experience, although in patients with COPD, sometimes we give them supplemental oxygen through a tracheostomy, with a catheter. That helps the dyspnea in some of these patients.

Hill: At the risk of sounding like a broken record, noninvasive ventilation can help in the decannulation process in selected patients. With regard to that data you showed from Goldenberg et al,¹ with very low rates of complications, was that during the acute hospitalization or were these long-term ventilated patients?

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Rajiv Dhand: I think they were a mixture of patients. But the point was that hemorrhage, which was originally considered a much more frequent complication, had become less frequent, and tracheal stenosis was now the major complication we were seeing as a long-term problem with the tracheostomy.

Hill: I think that's probably true, but the neuromuscular-disease patients I follow who have been receiving tracheostomy ventilation at home for years definitely have a lot of tracheostomy-associated complications. I don't see tracheal stenoses that often, but the most frequent problem is repeated respiratory infections. You had mentioned suctioning 4-5 times a day; but my patients are doing it at least twice that often. It can be a big problem for them.

Rajiv Dhand: One thing that I've found useful, although it's not—again—evidence-based, is that those patients often have tracheobronchitis, and there's very poor antibiotic penetration in the airways. The efficacy of antibiotics toward bacteria in intraluminal secretions is very poor. So one approach that I've found helpful in those instances is to give them aerosolized antibiotics for some time. No amount of systemic antibiotics helps in those instances, but aerosolized an-

tibiotics have often reduced the secretions, and many times helped us to decannulate the patient.

Hill: Yes, I use that not infrequently, but my results have been mixed. Sometimes it just doesn't seem to help much. I think tracheostomy tubes with inner cannulas and fenestrations sometimes cause more trouble than they're worth. Caregivers sometimes forget to insert the inner cannula, so the patient doesn't get ventilated. Also, I believe that fenestrations don't do any good and most of the time do harm, because the tracheostomy tube is not optimally positioned in the neck. The fenestration isn't in the lumen; it's in the stoma, granulation tissue grows into it and it causes irritation.

Rajiv Dhand: Yes, I completely agree with you. In fact, we've taken off the fenestrated tubes from the regular supply. They're kept in a separate area now, so no one gets a fenestrated tube unless specifically asked for. The inner cannula issue is a little more complicated. The Shiley tube, for example, cannot be used for mechanical ventilation without the inner cannula. The Portex tubes—if they require frequent cleaning because of secretions, or they're getting blocked by mucus, then I would advocate that the inner cannula be left in, because secretions could plug up the entire tracheostomy tube and cause problems for a patient at night. So, in that situation, it might be helpful to keep the inner cannula in. Otherwise, there isn't much role for having the inner cannula, in a stable patient, long-term.

Mehta: I want to make a comment about those patients who come to the ICU for acute respiratory failure, who you think will end-up getting decannulated. I had a rather cavalier attitude about the tracheostomy procedure, until the ARDS [acute respiratory distress syndrome] outcomes study by Herridge et al.¹ They followed 100 patients for up to 5 years after their

long ICU stays, and many of those people had tracheostomies and were decannulated. I think we underestimate the cosmetic consequences of tracheostomy. Many of these patients are very sensitive about their scars, hesitate to wear open-necked shirts, and have had revision surgery of the scar. In addition, there are complications of the surgery. Given the lack of evidence that tracheostomies offer any benefit in acute respiratory failure, I tend to wait a little bit longer now before making the decision to proceed with a tracheostomy.

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Rajiv Dhand: And, again, a lot of this is individually-based, depending on physician practice. I think that until we get more solid data to indicate one way or the other whether an early tracheostomy is beneficial or not, we really don't have a satisfactory way to address this question. But I do agree that the scar can be visible. Several people who have had thyroid surgery wear jewelry or something to cover that scar. So I think that tracheostomy scars can also be covered by some scarf or jewelry.

Pierson:* Just a follow-on to Geeta's comment about the still-controversial issue of whether we should tracheostomize people during critical illness. The Western Trauma Association Multi-Institutional Study Group attempted to do a multicenter study, randomizing patients who were judged to require long-term mechanical ventilation after trauma and

nontrauma surgical illness, to early versus late tracheostomy. That study went on for several years, and a report was finally published¹ that had the main conclusion that it is not really possible to do a study like that, because the participants at all of the various study sites wound up gaming the protocol by including and excluding different patients, because they were so certain that this particular patient needed a tracheostomy early, and that one didn't. The bottom line, which I think explains why we have such poor literature on this subject, is that, although there is no answer as to when patients with acute respiratory failure should undergo tracheostomy, every individual clinician has his or her own firm opinion about that, which means, in the absence of equipoise, a randomized controlled trial becomes exceedingly difficult to do.

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Rajiv Dhand: There are additional problems, because patients have opinions, their families have opinions, physicians have their own opinions, and patients have such a diversity of diseases when they are in the medical ICU or trauma ICU, that it is really difficult to conduct a study on this issue.

Hill: In the United States there are also factors unrelated to the patient that influence the tracheostomy decision. The DRG [diagnosis-related group] for tracheostomy is better-reimbursed than is the DRG for a trans-laryngeal tube. Also, we are under intense pressure to maximize "through-put" in our ICUs. If you tracheostomize patients promptly, then they're ready to go to a rehabilitation

facility earlier, and they have a shorter hospital stay. These factors also exert pressure on decision making.

Rajiv Dhand: Yes, that's true. And now we are being looked at on a national level and compared not only to university hospital consortiums; we are being compared in several databases. Every one of you is being compared. Believe me, there are data at the individual-physician level now to indicate what our kind of practice is. At some point we're going to have to reconcile these issues and see what is the best way to handle these patients, and also to move them out of the ICU quicker.

Panitch: In the pediatric world, the presence of a tracheostomy has huge ramifications. It may make it impossible for the child to go to school, because no one will take responsibility for the transportation to and from school. It may require that a nurse sit in school with the child. And it leads to all kinds of societal issues, beyond the health-care issues.

Brown: Continuing in the anecdotal mode with regard to fenestrated tracheostomy tubes, with which I've had as much difficulty as anyone, I had a patient with post-polio syndrome, severe kyphoscoliosis, and obstructive sleep apnea, who needed a tracheostomy, but his neck and tracheostomy area were so deformed that we couldn't put in a standard one that allowed him to breathe and speak very well. So I put in an un-fenestrated tracheostomy tube and with a bronchoscope I looked to see where I thought the hole should be. I took the tube out, marked it, and gave it to the dentists in the hospital, who, with their fine tools, created 3 fenestrated tracheostomy tubes, with the fenestrations in exactly the places I wanted. I inserted one of these tubes into the patient, did another bronchoscopy, found that the hole was in the right place, and it worked

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beautifully. So you can manage somehow.

With regard to the DRG issue, a year or so ago, 2 speech-language pathologists visited our hospital from Australia. They had conducted a program in their hospital in Australia,

in which a team of trained individuals went around the hospital visiting every single patient who had a tracheostomy. They had collected data for a year before they did this, and for a year after, and they had a huge decrease in the number of tra-

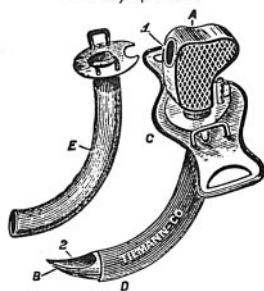
cheostomy complications, and a decrease in the length of stay. Well, the same thing is happening at Massachusetts General Hospital, and I think this kind of teamwork makes a big difference in length of stay and ought to be considered.

Fig. 21.—A NEW TRACHEOTOME.

By H. T. HANKS, M. D., New York.

American Journal of Obstetrics, January, 1877.

Price, \$9.00.



"A New Tracheotome"

From *The American Armamentarium Chirurgicum*

George Tiemann & Co, New York, 1878

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