Time to Wean After Tracheotomy Differs Among Subgroups of Critically Ill Patients: Retrospective Analysis in a Mixed Medical/Surgical Intensive Care Unit

Ary-Jan WJ van der Lely MD, Denise P Veelo MD, Dave A Dongelmans MD, Johanna C Korevaar PhD, Margreeth B Vroom MD PhD, and Marcus J Schultz MD PhD

OBJECTIVE: To determine the time to wean from mechanical ventilation and time spent off the ventilator per day after tracheotomy in critically ill patients in a 28-bed mixed medical and surgical intensive care unit (ICU) in Amsterdam, Netherlands. METHODS: We conducted a retrospective analysis of consecutive patients during the 14-month period from November 1, 2003, through January 1, 2005. Included were translaryngeally intubated mechanically ventilated patients who received a tracheotomy during their ICU stay. RESULTS: Of all the patients admitted to the ICU, 129 (7%) received a tracheotomy. Significantly more tracheotomies were performed in neurosurgery/neurology patients and in those admitted for acute conditions (16% and 12%, respectively). Tracheotomy was performed a median 8 days (interquartile range 4–13 d) after ICU admission. For all the patients, the median time to wean after tracheotomy was 5 days (interquartile range 2–11 d). Neurosurgery/neurology patients and patients in the cardiology subgroup needed significantly less time to wean from mechanical ventilation than did patients in other subgroups (3 d, interquartile range 2–7 d, and 3 d, interquartile range 2–5 d, respectively, $p < 0.05$). There was a significant association between admission group and neurological status at the time of tracheotomy. A low Glasgow coma scale score was associated with shorter time to wean. Within 1 week after tracheotomy, the probability of the patient having breathed spontaneously, without ventilator assistance, for > 4 h/d was 89%, 78% for > 8 h/d, and 72% for > 12 h/d. By day 28, the probability of the patient having breathed spontaneously for > 4 h/d was 98%, 97% for > 8 h/d, and 94% for > 12 h/d. CONCLUSION: Time to wean from after tracheotomy differed among the subgroups in our ICU. After tracheotomy, the majority of patients were quickly able to breathe spontaneously without assistance of the mechanical ventilator for several hours per day. Patients who require tracheotomy only for airway protection wean sooner than other patients. *Key words: artificial respiration, tracheotomy, respiratory failure, ventilator weaning*. [Respir Care 2006;51(12):1408–1415.

Introduction

Percutaneous tracheotomy is commonly performed in mechanically ventilated intensive care unit (ICU) patients.[1–4] A tracheotomy is a relatively stable, well-tolerated, and safe artificial airway. It has been suggested that

Ary-Jan WJ van der Lely MD, Denise P Veelo MD, Dave A Dongelmans MD, Margreeth B Vroom MD PhD, and Marcus J Schultz MD PhD are affiliated with the Department of Intensive Care Medicine; Johanna C Korevaar PhD is affiliated with the Departments of Clinical Epidemiology and Biostatistics; Academic Medical Center, University of Amsterdam, Amsterdam, Netherlands. Denise P Veelo MD is also affiliated with the Department of Anesthesiology; Marcus J Schultz MD PhD is also affiliated with the Laboratory of Experimental Intensive Care and Anesthesiology at the same institution.

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Correspondence: Marcus J Schultz MD PhD, Department of Intensive Care Medicine, C3-329, Academic Medical Center, University of Amsterdam, Meibergdreef 9, 1105 AZ Amsterdam, Netherlands. E-mail: m.j.schultz@amc.uva.nl.

tracheotomy enhances communication, permits earlier mobilization, and facilitates oral feeding, but robust data are lacking.[5–9] In addition, a tracheotomy allows the patient to breathe spontaneously for several hours per day, then the patient is reconnected to the ventilator before becoming exhausted. Prolonged translaryngeal intubation has several disadvantages, such as the danger of self-extubation/malposition and physical discomfort, for which increased sedation is necessary.[10–14] A recent meta-analysis suggested that performing tracheotomy at an earlier stage than is currently practiced may shorten the duration of artificial ventilation and ICU stay in adult patients who require prolonged mechanical ventilation.[15]

Information is scarce on how much time tracheotomized patients need to wean from mechanical ventilation. Determining the time to wean after tracheotomy is important because that information can be used for scheduling: knowing the probable duration of mechanical ventilation and how much time a patient will probably need until discharge is important for the referring ICU, for the step-down facility that receives the patient after ICU discharge, and for the patient and/or family.

In this single-center observational study we determined (1) time to wean in all tracheotomized ICU patients and in certain subgroups (because weaning after tracheotomy can be influenced by the presence or absence of muscle weakness, the pulmonary condition, and the level of consciousness), and (2) how many hours per day these patients breathed spontaneously without help of the mechanical ventilator after tracheotomy.

Methods

We collected data from consecutive patients who received a tracheotomy in our ICU, during the 14-month period of November 1, 2003, through January 1, 2005. We obtained demographic data and data on admission type and reason for admission from the National Intensive Care Evaluation database.[16] Data on weaning and Glasgow coma scale scores (Glasgow scores) at the time of tracheotomy were obtained from our patient data management system (Metavision, iMDsoft, Sassenheim, Netherlands). Our institution's ethics committee approved the study.

Study Location

The study was performed in the academic mixed medical and surgical ICU at the Academic Medical Center, University of Amsterdam, Amsterdam, Netherlands, which is a 28-bed "closed format" department in which medical and surgical patients (including cardiothoracic surgery and neurosurgery/neurology patients) are under the direct care of the ICU team, which has 8 full-time ICU physicians, 8 subspecialty fellows, 12 residents, and occasionally 1 intern.

Weaning Protocol, Indications for Tracheotomy, and Tracheotomy Procedure

A mechanical ventilation protocol was available for all ICU members, both on our intranet and in printed form. The protocol advises pressure-controlled or pressure-support ventilation in all patients. Pressure-support ventilation was started as early as possible. Tidal volume was kept at 6–8 mL/kg predicted body weight in all patients, and maximum airway pressure was kept below 35 cm H_2O. Positive end-expiratory pressure was initially set at 5 cm H_2O, and was then adjusted, along with the fraction of inspired oxygen (F_{IO_2}) to achieve a P_{aO_2} of 75 mm Hg. In pressure-support ventilation the support level was set to reach a respiratory rate at which the patient was breathing comfortably. In our ICU, like many ICUs in the Netherlands, we did not use spontaneous breathing trials as a weaning method (before tracheotomy).

If it was anticipated that the artificial airway would be needed for < 10 days, translaryngeal endotracheal intubation was preferred. Other than suspected need for ventilation > 10 days, indications for tracheotomy were upper airway obstruction (eg, after upper airway surgery or trauma) and the need for frequent airway suctioning (ie, $> 10–12$ suctionings per day). Patients were reassessed daily to determine whether tracheotomy was required under the aforementioned criteria. In addition, patients who were extubated and failed to maintain airway control, due to lack of cough, unanticipated airway obstruction, or fatigue, were candidates for tracheotomy. The main contraindications for percutaneous tracheotomy were: hemodynamic or pulmonary instability; impalpable trachea (eg, due to adiposity); palpable vascular structures or overlying thyroid gland; abnormal anatomy of the neck (eg, after surgery or radiation); and skin infection over the trachea. The decision to proceed with tracheotomy was made by ICU physicians. Percutaneous tracheotomy (Ciaglia Blue Rhino, Cook Medical, Netherlands) was the method of choice unless technical considerations required a formal surgical approach.

For weaning and spontaneous breathing after tracheotomy, a local guideline was available for ICU nurses and ICU physicians, in which it is stated that patients start with spontaneous breathing trials when the pressure support level is < 15 cm H_2O and the positive end-expiratory pressure is $< 5–7$ cm H_2O. During spontaneous breathing trials, patients were connected to a T-piece without a positive-pressure valve, through which humidified air, with 50% oxygen, was applied. The duration of each session was chosen depending on the patient's condition. Patients who were expected to have normal muscle strength and

Table 1. Baseline Characteristics

	No Tracheotomy	Tracheotomy	p
Number of patients	1,788	129	NA
Age (median and IQ range y)	64 (51–73)	57 (45–71)	< 0.01
Male (*n* and %)	1,121 (63)	86 (67)	0.37
APACHE II score (median and IQ range)	15.0 (12.0–20.0)	21.0 (15.5–25.5)	< 0.01
SAPS II score (median and IQ range)	33.0 (25.5–43.0)	44.0 (34.5–56.0)	< 0.01
ICU mortality (*n* and %)	177 (9.9)	18 (14.0)	0.23
Hospital mortality (*n* and %)	235 (13.1)	41 (31.8)	< 0.01
ICU stay (median and IQ range d)	1.7 (0.9–3.3)	17.7 (11.2–28.4)	< 0.01
ARDS (*n* and %)	ND	33 (25.6)	ND
ALI (*n* and %)	ND	9 (7.0)	ND

Admission Diagnosis	No Tracheotomy (*n* and %)	Tracheotomy			< 0.01*
		n	% of total	% of this category	
Medical	250 (14.0)	25	19.4	10.0	
Surgical	357 (20.0)	39	30.2	10.9	
Neurosurgery/neurology	198 (11.1)	31	24.0	15.7	
Cardiopulmonary surgery	830 (46.4)	13	10.1	1.6	
Cardiology	115 (6.4)	16	12.4	13.9	
Other	43 (2.1)	5	3.8	10.0	

Admission Type	No Tracheotomy (*n* and %)	Tracheotomy			< 0.01†
		n	% of total	% of this category	
Acute admission (%)	831 (46.5)	115	89.1	12.2	
Planned admission (%)	957 (53.5)	14	10.9	10.1	
After cardiac arrest (%)‡	118 (6.6)	20	15.5	14.5	< 0.01‡

*Via chi-square test of whether the distribution of patients with or without a tracheotomy among the 6 admission diagnoses is similar.
†Via chi-square test of whether the distribution of patients with or without a tracheotomy among the 2 types of admission is similar.
‡Patients after cardiac arrest were among the acute admissions to the intensive care unit (ICU).
NA = not applicable
IQ = interquartile
APACHE = Acute Physiology and Chronic Health Evaluation
SAPS = Simplified Acute Physiology Score
ARDS = acute respiratory distress syndrome
ND = no data available
ALI = acute lung injury

pulmonary function started with as many hours as possible per day, or were kept off the ventilator directly. For other patients it was the policy to start with three 1-hour spontaneous breathing periods per day. In all patients, the number of hours per day was increased steadily (by doubling the number of hours over all sessions each day), until complete weaning was reached. Patients who showed desaturation, rapid shallow breathing, or signs of fatigue during spontaneous breathing sessions went through the protocol more slowly. Patients who showed hemodynamic instability were not allowed to breathe spontaneously.

Our ICU does not have a long-term weaning unit, so we remain responsible for all ventilated patients, and only fully weaned patients can be transferred to other wards. When patients are discharged from the ICU to a step-down facility, we often leave the tracheotomy cannula in situ to help the patient clear secretions while he or she is still too weak to cough adequately. In our hospital, decannulation is performed by the ICU physician, who visits the patient in the step-down facility twice a week until decannulation.

Subgroup Analysis

Medical patients, surgical patients, cardiopulmonary surgery patients, cardiology patients, and neurosurgery/neurology patients were analyzed separately. In addition, patients who were admitted after cardiac arrest were analyzed separately from those who were admitted for other rea-

Table 2. Reasons for Initiation of Mechanical Ventilation in 129 Tracheotomized Patients

Reason	*n*	%
COPD	1	0.8
Coma	18	14.0
Neuromuscular disease	2	1.6
Chronic pulmonary disease	4	3.1
ARF*	104	80.6
ARDS/ALI	35	33.7
Postoperative	27	26.0
Aspiration	1	1.0
Pneumonia	16	15.4
Sepsis/SIRS	19	18.3
Trauma	21	20.2
Cardiac arrest	15	14.4
Lung bleeding	2	1.9

*ARF (acute respiratory failure) could have more than one cause, so the number of ARF diagnoses (104) is less than the number of ARF causes (136).
COPD = chronic obstructive pulmonary disease
ARDS = acute respiratory distress syndrome
ALI = acute lung injury
SIRS = systemic inflammatory response syndrome

sons, as were patients with or without acute lung injury (ALI),[17] and patients after acute ICU admission or planned ICU admission. We also studied the influence of Glasgow score at the time of tracheotomy on time to wean.

Definitions

We defined "time until tracheotomy" as the time from ICU admission until the day of tracheotomy. "Time to wean after tracheotomy" was defined as the time from day of tracheotomy until the day on which the patient breathed spontaneously without help of the mechanical ventilator for > 24 hours and had no need for mechanical ventilation for at least 7 days thereafter. "Time until > 4 h/d, > 8 h/d, or > 12 h/d disconnected from the ventilator" was the time from the day of the tracheotomy until the day on which the patient breathed spontaneously without help of the ventilator for at least 4 h/d, 8 h/d, or 12 h/d. The Glasgow score we recorded was the last available score on the eye and motor components of the Glascow test before tracheotomy. Then the derived verbal score was predicted by using the eye and motor component in a regression model.[18]

Statistical Analysis

The data were analyzed with statistics software (SPSS 12.0, SPSS, Chicago, Illinois). Continuous (not normally distributed) data are expressed as median and interquartile range. Categorical data are expressed as percentages. Comparisons were made using the Kruskal-Wallis test and the Mann-Whitney U test for continuous data. The chi-square test was used for categorical data. Multivariate linear regression analysis was applied to further determine the influence of admission diagnosis, Glasgow score, Acute Physiology and Chronic Health Evaluation (APACHE II) score, cardiac arrest, and presence of lung injury on time to wean. Log transformation for time to wean was performed because it was not normally distributed. We applied a backward procedure in the multivariate linear regression; variables with a $p < 0.05$ were removed from the model. For the survival analysis we used a log rank test. When more than 2 subgroups were compared, a correction was done for multiple testing (false discovery rate, with an accepted level of 0.05). All tests were 2-tailed, and differences with a p value < 0.05 were considered significant.

Results

Patient Characteristics

Seven percent of a total of 1,917 admitted ICU patients required tracheotomy. Table 1 shows the demographic data. Table 2 shows the reasons for initiation of mechanical ventilation in tracheotomized patients. Compared to the other subgroups, significantly more tracheotomies were performed in patients admitted for neurosurgical/neurological and cardiologic problems and after cardiac arrest. The majority of patients who required tracheotomy were acutely admitted to the ICU. There was no significant difference in ICU mortality, though hospital mortality of patients who had a tracheotomy was higher than that of patients who did not have tracheotomy.

Time Until Tracheotomy

Tracheotomy was performed a median 8 days (interquartile range 4–13 d) after ICU admission (Table 3). Time until tracheotomy was significantly shorter in the neurosurgery/neurology and cardiology subgroup than in the other subgroups. Time until tracheotomy was also significantly shorter among patients who did not have ALI/ARDS than among those who did. There was no significant difference in time until tracheotomy between patients with and without cardiac arrest prior to ICU admission. Similarly, there were no differences between the predefined APACHE-score subgroups.

Time to Wean After Tracheotomy

The median time to wean from mechanical ventilation for all patients was 5 days (interquartile range 2–11 d). Time to wean was significantly different among the subgroups: neurosurgery/neurology and cardiology patients

Table 3. Time Until Tracheotomy, Time Until Weaned, and ICU Stay After Tracheotomy*

	Time Until Tracheotomy (median and IQ range d)	Time Until Weaned (median and IQ range d)	ICU Stay After Tracheotomy (median and IQ range d)
Admission Diagnosis†			
Medical (*n* = 20)	7 (4–14)	9 (5–13)	11 (7–16)
Surgical (*n* = 35)	11 (8–16)	8 (3–12)	12 (6–18)
Neurosurgery/neurology (*n* = 30)	6 (4–12)‡	3 (2–7)§	4 (3–10)§
Cardiopulmonary surgery (*n* = 10)	12 (7–17)	7 (3–16)	12 (5–26)
Cardiology (*n* = 12)	5 (3–7)‡	3 (2–5)§	4 (2–6)§
Cardiac Arrest as a Reason for Present ICU Admission			
Yes (*n* = 16)	6 (4–11)	4 (1–8)	6 (3–14)
No (*n* = 95)	9 (4–13)	6 (2–12)	9 (4–15)
Presence of Lung Injury			
ARDS (*n* = 27)	10 (6–16)	9 (2–15)	11 (5–19)
ALI (*n* = 8)	14 (6–20)	8 (3–13)	13 (7–17)
No lung injury (*n* = 76)	7 (4–12)‖	4 (2–10)	7 (3–13)
APACHE II Score			
0–10 (*n* = 8)	4 (0–7)	7 (1–24)	9 (3–23)
11–20 (*n* = 50)	9 (5–12)	8 (3–11)	11 (4–15)
> 21 (*n* = 53)	9 (4–15)	4 (2–9)	6 (4–12)
All patients (*n* = 111)	8 (4–13)	5 (2–11)	9 (4–14)

*Only patients who survived to ICU discharge are included in this table.
†For the 5 patients without a diagnostic category, no data are presented.
‡p < 0.05 for the neurosurgery/neurology and cardiology patients versus surgical and cardiopulmonary surgery patients.
§p < 0.05 for neurosurgery/neurology and cardiology patients versus all other subgroups.
‖p < 0.05 for patients with no lung injury versus patients with ARDS and patients with ALI.
ICU = intensive care unit
IQ = interquartile
ARDS = acute respiratory distress syndrome
ALI = acute lung injury
APACHE II = Acute Physiology and Chronic Health Evaluation II

needed significantly less time to fully wean from mechanical ventilation than did the patients in the other subgroups.

At day 7, 77% of the neurosurgery/neurology patients, 66% of the cardiopulmonary surgery patients, and 63% of the cardiology patients had weaned completely, compared to 34% of the medical patients and 41% of the surgical patients (Fig. 1). By day 28, the probability of having weaned completely from mechanical ventilation was 90% for medical patients, 89% for surgical patients, 96% for neurosurgery/neurology patients, 89% for cardiopulmonary surgery patients, and 86% for cardiology patients ($p = 0.17$). Differences in time to wean after tracheotomy were not statistically significant between patients with ALI/ARDS and patients without pulmonary disease, nor between patients admitted because of cardiac arrest and other patients.

Multivariate linear regression analysis showed similar results: only within admission-diagnosis groups was there significant influence on time to wean: cardiology ($p = 0.05$) and neurology/neurosurgery ($p = 0.04$) patients had a significantly shorter time to wean (3.5 d and 3.1 d shorter, respectively) than medical patients. Moreover, the cardiology and neurology/neurosurgery patients had a significantly shorter time to wean (3.4 d, $p = 0.04$, and 3.0 d, $p = 0.02$, respectively) than the surgical patients. There was no significant difference between cardiopulmonary surgery patients and cardiology patients ($p = 0.13$, $r^2 = 0.09$). There was no difference in time to wean between medical and surgical patients.

Glasgow score was significantly associated with admission diagnosis and consequently was not included in the multivariate linear regression analysis; cardiology patients and neurology/neurosurgery patients had a significantly ($p < 0.01$) lower Glasgow score than patients in other subgroups (Table 4). When we replaced admission diagnosis by Glasgow score in the linear regression analysis, Glasgow score was also significantly associated with time to wean ($r^2 = 0.12$). With lower Glasgow score, time to wean was shorter ($p < 0.01$). In patients with a lower Glasgow score, time to wean was 4.5 days shorter than patients with a higher Glasgow score.

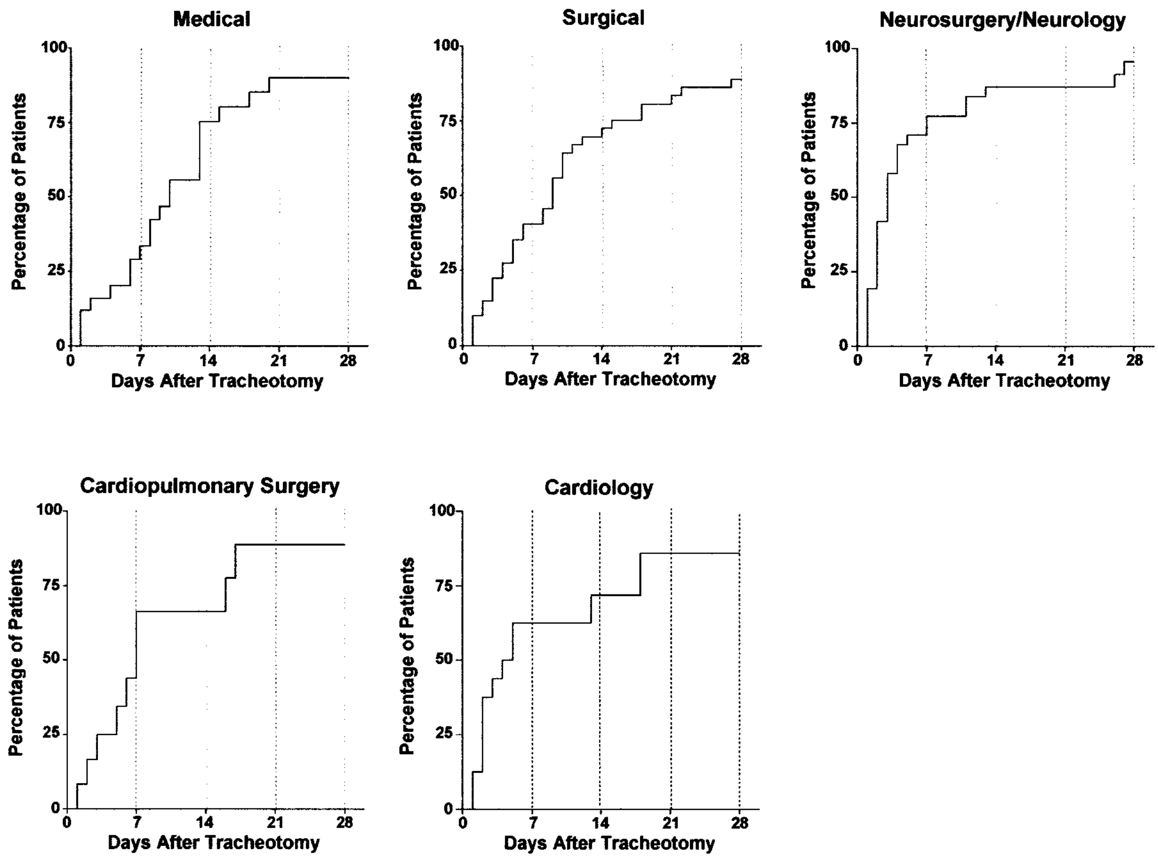

Fig. 1. Kaplan-Meier curves of the probability of complete weaning from the ventilator for the 5 subgroups. Via the log rank test, $p = 0.03$ for the neurology/neurosurgery versus medical and surgical subgroups. When corrected for multiple testing, $p = 0.17$.

Spontaneous Breathing Trials

By day 7, the probability of the patient spontaneously breathing (ie, disconnected from the ventilator) for > 4 h/d was 89%, 78% for > 8 h/d, and 72% for > 12 h/d (Fig. 2). By day 28, most patients had reached the following targets: 98% > 4 h/d, 97% > 8 h/d, and 94% > 12 h/d. The probability of the patient spontaneously breathing for > 24 h was 60% at day 7, and 93% at day 28.

Discussion

We described a single center's experience with ventilator weaning after tracheotomy performed during ICU stay, and found that a large proportion of patients with tracheotomy were completely weaned from the ventilator within 1 week, in particular neurosurgery/neurology patients, cardiology patients, and those admitted to the ICU after cardiac arrest. Glasgow score was significantly associated with admission-diagnosis group, and time to wean was shorter with lower neurological status. The majority of patients breathed spontaneously without ventilator assistance for several hours per day soon after tracheotomy.

Our study has several important limitations. As with all retrospective analyses, inadequacy of the databases from which we collected our data could result in wrong or incomplete conclusions. Indeed, in the several databases we used, it was not easy to find important information, such as the specific reason for tracheotomy, data on baseline pulmonary function (such as history of chronic pulmonary disease), pulmonary compliance (in particular in those with ALI/ARDS), cardiac function, and neurological status (except for the Glasgow score). All those factors might have influenced the weaning process.

Second, this study was at only one ICU, and the ICU used a strict protocol on mechanical ventilation, as well as other protocols that might influence time to wean. This limits the wider applicability of our results, and more studies are needed before our results can be generalized. In addition, although we did have a formal protocol on weaning after tracheotomy, ICU nurses and physicians could still make certain decisions in the timing of disconnecting the patient from the ventilator. Our protocol indicated only that in case of (expected) normal or good muscle strength,

Table 4. Association of Glasgow Coma Scale Score With Admission Diagnosis

Admission Diagnosis	Glasgow Coma Scale Score (median and interquartile range d*)
Medical	14.75 (14.75–14.75)
Surgical	14.75 (14.75–14.75)
Neurology/neurosurgery	8.76 (6.61–12.14)
Cardiopulmonary surgery	14.75 (5.15–14.75)
Cardiology	7.11 (4.51–11.00)

*Only tracheotomized patients who survived to discharge from the intensive care unit are included in this table. The Kruskall-Wallis test showed that cardiology and neurology/neurosurgery patients had a significantly lower Glasgow come scale score than the other patient groups.

the patient had to be disconnected from the ventilator more often and for a longer period. Similarly, patients who showed subjective signs of fatigue were to be disconnected less often and for shorter periods. We did not intervene with this practice; rather, we just wanted to determine what happened in our institution, but no doubt this influenced time to wean.

Finally, we did not pre-calculate an ideal sample size, but instead merely took data from a 14-month period. We made multiple comparisons, but we chose not to adjust for this, because this was largely an exploratory presentation of data rather than hypothesis testing.[19]

The incidence and timing of tracheotomy in our study is comparable to that reported in other studies.[2,4] In our institution, 7% of all admitted patients received a tracheotomy, which is somewhat less than in other reports.[4] However, adjusting our results for case mix, by ignoring the cardiopulmonary surgery patients, the incidence of tracheotomy was 11%, which is in line with earlier reports.[2,4] When we considered only those patients who were admitted to the ICU for $\geq$ 2 days (thereby excluding both uncomplicated cardiopulmonary surgery and general surgery patients), the incidence of tracheotomy increased to 16%.

Relatively more neurology/neurosurgery patients received tracheotomy than other subgroups. This is in line with earlier reports. Our patients were tracheotomized relatively early, as compared to patients in other studies; in our institution tracheotomy was performed at a median 8 days, whereas the timing of tracheotomy was 11–12 days in earlier reports.[2,4] Randomized clinical trials published to date are insufficient to establish clear guidelines regarding the timing of tracheotomy.[20] It has been suggested that tracheotomy at an earlier stage than is currently practiced may shorten the duration of artificial ventilation and ICU stay among adult patients who require prolonged mechanical ventilation.[15] Several studies are underway to address this issue.[21]

Certain subgroups in our ICU weaned faster than other groups. Information on how much time tracheotomized

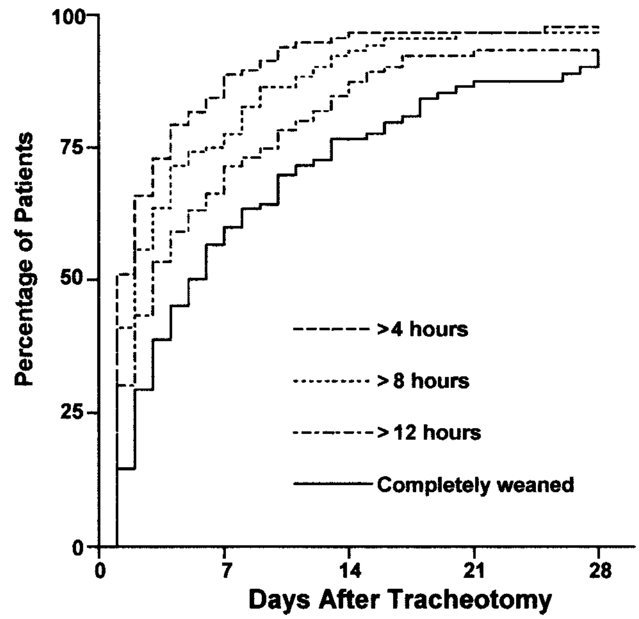

Fig. 2. Kaplan-Meier curve of the probability of breathing spontaneously without assistance from the mechanical ventilator for > 4 h/d, > 8 h/d, or > 12 h/d, and of being completely weaned, among all patients who received a tracheostomy in the ICU during the studied period.

patients need to wean from mechanical ventilation is important for scheduling reasons. Indeed, step-down facilities can better anticipate admissions when they are informed early about the presence of these patients in the ICU.

The differences in time to wean after tracheotomy between the subgroups might be explained by the fact that certain patient groups, such as neurology/neurosurgery patients and patients after cardiopulmonary resuscitation, need tracheotomy only for airway protection. Unfortunately, the indication for tracheotomy was not clearly indicated in the available databases. However, the analysis on Glasgow score showed that neurology/neurosurgery and cardiology patients had significantly lower Glasgow scores than the other subgroups. Furthermore, there was a significant relationship between Glasgow score and time to wean. Accordingly, we suggest that patients who need a tracheotomy only for airway protection wean faster. This emphasizes the fact that these patients should receive tracheotomy as soon as possible.

The majority of patients can breathe spontaneously, without mechanical support, for several hours per day, soon after tracheotomy. We assume this to be a potential advantage of tracheotomy for some of our patients, because of the lower work of breathing and lower intrinsic positive end-expiratory pressure in patients who require a lower level of ventilatory support.[22,23] However, only a minority of our patients suffered from chronic pulmonary disease. Weaning from mechanical ventilation with tracheotomy has also been known to reduce muscle atrophy and diaphragm muscle dysfunction, which is often induced by mechanical ventilation.[24–26] However, a comparative study is needed to determine whether this presumed advantage actually influences ventilation parameters and patient outcome.

Conclusions

Time to wean after tracheotomy differed among our ICU subgroups. A large proportion of patients with tracheotomy are completely weaned within 1 week, particularly neurosurgery/neurology patients and cardiology patients. Our data suggest that these patients need a tracheotomy merely for airway protection. In addition, most patients are quickly able to breathe spontaneously without mechanical assistance for several hours per day.

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Both Drs van der Lely and Veelo contributed equally to this manuscript.

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