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The impact of time to tracheostomy on mechanical ventilation duration, length of stay, and mortality in intensive care unit patients

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Abstract

Introduction: This study examined the potential effects of time to tracheostomy on mechanical ventilation duration, intensive care unit (ICU), and hospital length of stay (LOS), and ICU and hospital mortality.

Methods: Cohort observational study was conducted in a tertiary care medical-surgical ICU based on a prospectively collected ICU database. We included 531 consecutive patients who were admitted between March 1999 and February 2005, and underwent tracheostomy during their ICU stay. The effect of time to tracheostomy on the different outcomes assessed was estimated using multivariate regression analyses (linear or logistic, based on the type of variables). Other independent variables that were included in the analyses included selected admission characteristics.

Results: Mean ± SD was 12.0 ± 7.3 days for time to tracheostomy, and 23.1 ± 18.9 days for ICU LOS. Time to tracheostomy was associated with an increased duration of mechanical ventilation (β-coefficient = 1.31 for each day; 95% confidence interval [CI], 1.14-1.48), ICU LOS (β-coefficient = 1.31 for each day; 95% CI, 1.13-1.48), and hospital LOS (β-coefficient = 1.80 for each day; 95% CI, 0.65-2.94). On the other hand, time to tracheostomy was not associated with increased ICU or hospital mortality.

Conclusions: Time to tracheostomy was independently associated with increased mechanical ventilation duration, ICU LOS, and hospital LOS, but was not associated with increased mortality. Performing tracheostomy earlier in the course of ICU stay may have an effect on ICU resources and could entail significant cost-savings without adversely affecting patient mortality.

Abbreviations: ICU, intensive care unit; LOS, length of stay; APACHE, Acute Physiology and Chronic Health Evaluation; CI, confidence interval.

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1. Introduction

Tracheostomy is performed in 11% of mechanically ventilated patients and 6% of intensive care unit (ICU) patients in general [1,2]. Although these proportions are small, patients with tracheostomy use substantial ICU resources, as they accounted for 26.2%, 21.0%, and 13.5% of all ventilator, ICU, and hospital days in the Project Impact database [2], respectively, and constituted 59% of patients staying in the ICU for more than 14 days in a study from our center [3]. Therefore, interventions that would decrease ICU length of stay (LOS) without adversely affecting outcome in this group of patients would likely result in significant cost-savings and improve resource utilization in the ICU.

Several studies have demonstrated that early tracheostomy is associated with decreased time to liberation from mechanical ventilation and decreased ICU LOS [4-11]; however, there is still lack of consensus on what constitutes early vs late tracheostomy. This is evident from the fact that different cut-off points, ranging from 2 to 28 days, have been used for this definition [4-8,12]. The purpose of this study was to assess the effect of time to tracheostomy on ICU LOS as well as on ICU and hospital mortality.

2. Materials and methods

This study was performed as a cohort observational study at a 21-bed medical-surgical ICU located at King Abdulaziz Medical City, an 850-bed tertiary care teaching center in Riyadh, Saudi Arabia. Data were extracted retrospectively from a prospectively collected ICU database for patients admitted between March 1, 1999, and February 28, 2005. Patients were included in the study if they were aged 18 years or older and had tracheostomy performed during their ICU stay. Patients were excluded from the study if they were (*a*) readmitted to ICU within their current hospital stay, (*b*) referred from another institution, and/or (*c*) admitted for burn management. The study was approved by the institutional review board.

The decision to perform tracheostomy and when to perform the procedure was at the discretion of the treating intensivists and was typically based on clinical assessment, including the failure to wean, the inability to "protect the airway," and the inability to cough spontaneously. Tracheostomy was performed in certain patients without an attempt to extubate if the intensivist judged that the chance for successful extubation was low. In other patients, tracheostomy was performed after one or more failed attempts to extubate. Since the data were extracted retrospectively from the general ICU database, the decision to perform tracheostomy was not influenced by the study. Tracheostomy was performed percutaneosuly unless the treating intensivist felt that it should be performed surgically because of difficult anatomy (such as short neck, obesity, cervical spine immobilization) or because of coagulopathy.

The following data were extracted: age, sex, body mass index, and Acute Physiology and Chronic Health Evaluation (APACHE) II score [13]. The main diagnostic categories for ICU admission were derived from the APACHE II system and were divided into the following groups: respiratory, cardiovascular, neurologic, trauma, postoperative non-trauma, and other medical (Appendix A) [13]. Severe chronic comorbidities were also classified using APACHE II definitions [13]. Shock was defined as systolic blood pressure of less than 90 mm Hg requiring vasoactive drugs; coma as Glasgow Coma Scale of 6 or lesser assessed in nonsedated or presedated condition or based on the best clinical judgment that reflects the true neurologic status rather than on the effect of sedatives; hypoxemia as PaO_2 of less than 60 mm Hg, renal impairment as creatinine of more than 176 μmol L^{-1}, and coagulopathy as international normalized ratio of more than 1.3. We documented the total number of ventilator days and the time to tracheostomy (defined as the number of ventilator days before tracheostomy). In addition, we documented the type of tracheostomy procedure (percutaneous vs surgical). We also documented whether the patient had a failed extubation before tracheostomy. Study end points were ICU and hospital mortality, ICU and hospital LOS, and mechanical ventilation duration.

2.1. Statistical analyses

Descriptive characteristics of the study sample were summarized using numbers and percents (for categorical variables) and means and standard deviations for continuous variables. Predictors of continuous outcomes (duration of mechanical ventilation, ICU LOS, hospital LOS) were assessed using multiple linear regression, with stepwise selection. Similarly, predictors of categorical outcomes (ICU mortality and hospital mortality) were assessed using multiple logistic regression, with stepwise selection. The following variables were entered in these models: age, sex, APACHE II score, main diagnostic category for admission, time to tracheostomy, type of tracheostomy, severe chronic comorbidities, the presence of shock, coma, hypoxemia, renal impairment, and/or coagulopathy and failed extubation, For selection purposes, a *P* value of .25 was selected for entry into the model, whereas a *P* value of .15 was selected for staying in the model. Regression diagnostics were performed on variables that remained in the final multivariable model to ensure that the model's assumptions were fulfilled. Statistical analyses were performed using SAS statistical software (SAS system for Windows, release 8, SAS Institute, Inc, Cary, NC, 1999).

3. Results

During the study period, 4862 adult patients were admitted to the ICU and 531 (11%) met the eligibility criteria. Baseline characteristics of the study cohort are shown in Table 1.

Table 1 Baseline characteristics

Variable	
Number	531
Age in years	49 ± 22
Male sex	386 (73)
APACHE II score	22 ± 8
Main reason for ICU admission	
Respiratory	129 (24)
Cardiovascular	122 (23)
Neurologic	47 (9)
Other medical	5 (1)
Nontrauma postoperative	137 (26)
Trauma	91 (17)
Characteristics at the first 24 h of ICU admission	
Coma	297 (56)
Shock	298 (56)
Hypoxemia	66 (12)
Renal impairment	92 (17)
Coagulopathy	205 (39)
Chronic underlying illnesses	
Chronic respiratory disease	45 (8)
Chronic renal disease	25 (5)
Chronic immunosuppression	24 (5)
Chronic cardiovascular disease	16 (3)
Chronic liver disease	15 (3)
Other	
Reintubation	116 (22)

Values are expressed as number, mean ± SD, or numbers (percentages) where appropriate.

Surgical tracheostomy was performed in 173 (33%) patients; the rest underwent a bedside percutaneous tracheostomy. The mean time to tracheostomy was 12.0 ± 7.3 days and posttracheostomy mechanical ventilation duration was 8.8 ± 16.4 days. Mean mechanical ventilation duration among this cohort was 20.6 ± 18.3 days, and mean ICU and hospital LOS were 23.1 ± 18.9 and 101.4 ± 97.6 days, respectively. Tracheostomy was performed in 116 (22%) after failed extubation. Among all patients, 343 (65%) remained in the ICU longer than 14 days, 53 (10%) died in the ICU, and 190 (36%) died during their hospitalization.

Fig. 1 shows the mean mechanical ventilation duration, ICU LOS, and hospital LOS plotted by time to tracheostomy. Table 2 shows the independent predictors of mechanical ventilation duration, ICU LOS, and hospital LOS. Time to tracheostomy was an independent predictor of the 3 variables. For each 1-day increase in time to tracheostomy, there was a 1.31-day increase in mechanical ventilation duration (95% confidence interval [CI], 1.14-1.48; $P < .0001$), 1.31-day increase in ICU LOS (95% CI, 1.13-1.48; $P < .0001$), and 1.80-day increase in hospital LOS (95% CI, 0.65-2.94; $P = .002$).

Table 3 shows the independent predictors of ICU and hospital mortality. Interestingly, time to tracheostomy was not significantly associated with any one of them.

4. Discussion

In our study, we found that time to tracheostomy was an independent predictor of mechanical ventilation duration, ICU LOS, and hospital LOS among patients who underwent tracheostomy in the ICU. However, time to tracheostomy was not associated with increased ICU or hospital mortality.

Most previous studies categorized time to tracheostomy in a dichotomous model to early and late, with variable definitions and substantial debate [4-11]. Rumbak et al

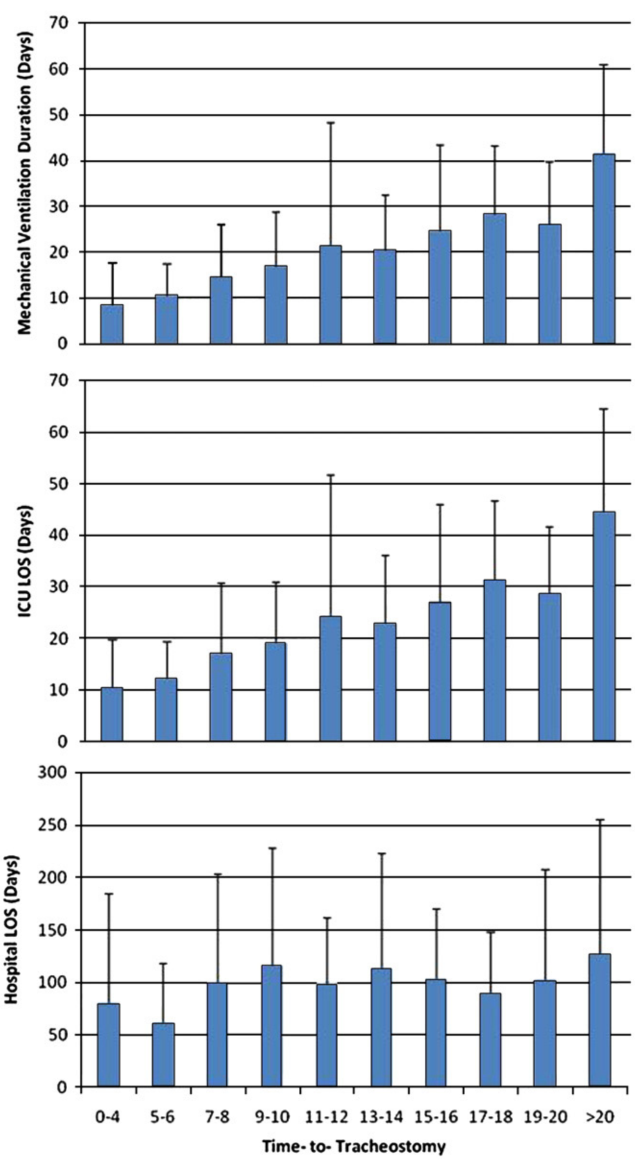

Fig. 1 Mean ± SD of mechanical ventilation duration, ICU LOS, and hospital LOS plotted in relation to time to tracheostomy.

Table 2 Predictors of duration of mechanical ventilation duration, ICU LOS, and hospital LOS using multivariate analyses (multiple linear regression)

Parameter	Coefficient	95% CI	*P* value
For mechanical ventilation duration			
Time to tracheostomy (for each 1-d increment)	1.31	1.14 to 1.48	<.0001
Surgical tracheostomy	2.04	−0.66 to 4.73	.1
24 h postadmission: coma	−6.23	−8.85 to −3.62	<.0001
Chronic cardiovascular disease	21.11	14.01 to 28.22	<.0001
Chronic respiratory disease	7.54	3.07 to 12.02	.001
Reintubation	−2.66	−5.68 to 0.36	.08
For ICU LOS			
Time to tracheostomy (for each 1-d increment)	1.31	1.13 to 1.48	<.0001
Coma	−7.08	−9.70 to −4.46	<.00001
Hypoxemia	4.05	0.17 to 7.93	.04
Chronic cardiovascular disease	20.88	13.60 to 28.17	<.0001
Chronic respiratory disease	7.77	3.16 to 12.39	.001
For hospital LOS			
Time to tracheostomy (for each 1-d increment)	1.80	0.65 to 2.94	.002
Age (for each 1-y increment)	−0.36	−0.75 to 0.028	.07
Surgical tracheostomy	13.09	−4.66 to 30.84	.1
Renal impairment	−24.15	−47.28 to −1.02	.04
Chronic liver disease	−42.81	−92.48 to 6.86	.09

Categorical variables were coded 1 for “yes” and 0 for “no.”
The final model for mechanical ventilation duration: Mechanical ventilation duration (days) = 6.96 + 1.31 (time to tracheostomy in days) + 2.04 (surgical tracheostomy) − 6.23 (coma) +21.11 (chronic cardiovascular disease) + 7.54 (chronic respiratory disease) − 2.66 (reintubation). $F = 60.99$, $P < .0001$, $R^2 = 0.4112$.
The final model: for ICU LOS (days) = 9.61 + 1.31 (time to tracheostomy in days) − 7.08 (coma) + 4.05 (hypoxemia) + 20.88 (heart failure) + 7.77 (chronic respiratory disease). $F = 74.17$, $P < .0001$, $R^2 = 0.414$.
The final model: for hospital LOS (days) = 98.8 + 1.80 (time to tracheostomy in days) − 0.36 (age in years) + 13.09 (surgical tracheostomy) − 24.15 (renal impairment) − 42.81 (chronic liver disease). $F = 5.60$, $P < .0001$, $R^2 = 0.0506$.

[10] conducted a study where they randomized 120 medical ICU patients to either early tracheotomy (within 48 hours) or delayed tracheotomy (at days 14-16). They found that the early tracheotomy group had shorter mechanical ventilation duration (7.6 ± 2.0 vs 17.4 ± 5.3 days) and ICU LOS (4.8 ± 1.4 vs 16.2 ± 3.8 days) as well as less mortality (31.7% vs 61.7%) [10]. The study used an APACHE II score of greater than 25 as an inclusion criterion, which limits the generalizability to patients who are less critically ill. Rodriquez et al [5] randomized 51 patients to early tracheostomy (within 7 days of intubation) and 55 patients to late tracheostomy (>7 days) and found that early tracheostomy was associated with a decrease in mechanical ventilation duration, ICU LOS, and hospital LOS. However, the analyses were not based on intention-to treat: patients who were assigned to the late tracheostomy group but weaned successfully before undergoing the procedure were not included in the analyses, which represented a significant limitation of this study. Lesnik et al [6] retrospectively studied 101 patients with blunt multiple trauma and found that early tracheostomy (performed within 4 days of intubation) was associated with shorter mechanical ventilation duration; the ICU LOS and the hospital LOS were not reported. Armstrong et al [7] performed a retrospective chart review of 157 patients with blunt trauma and found that early tracheostomy (≤6 days of intubation) was associated with a decrease in the ICU and hospital LOS. D’Amelio et al [8] studied 43 patients with trauma retrospectively, 31 of whom underwent tracheostomy. Patients who had tracheostomy done within the first 7 days of intubation had shorter mechanical ventilation duration as well as ICU and hospital LOS. In a study from our center [9], we examined the impact of early vs late tracheostomy on the outcome of 136 patients with trauma who underwent tracheostomy, 29 of whom had early tracheostomy (≤7 days of mechanical ventilation). We found that the duration of mechanical ventilation and ICU LOS was significantly shorter in the early tracheostomy group, but mortality rates were similar. Bouderka et al [4] prospectively studied 62 patients with trauma with isolated head injury who were randomized into 2 groups: early tracheostomy group (fifth-sixth day, n = 31) and late tracheostomy group (after the sixth day). The investigators found that the mechanical ventilation duration was shorter in the early tracheostomy group. There was no difference in the frequency of pneumonia or mortality between the 2 groups. Surgerman et al [14] conducted a prospective randomized multicenter study of 157 patients, all but 18 of whom were patients with trauma. Patients were randomized on days 3 to

Table 3 Factors associated with ICU and hospital mortality using multivariable analysis (logistic regression)

Parameter	OR	95% CI	*P*
For ICU mortality			
Time to tracheostomy (for each 1-d increment)	1.03	0.99-1.07	.1
APACHE II score	1.05	1.01-1.10	.02
Surgical tracheostomy	0.54	0.27-1.10	.09
Nontrauma postoperative admission	0.24	0.05-1.09	.06
Cardiovascular admission	2.53	1.30-4.97	.006
Chronic cardiovascular disease	3.12	0.91-10.68	.07
Chronic liver disease	5.78	1.80-18.55	.003
Chronic respiratory disease	2.31	0.97-5.54	.06
For hospital mortality			
Time to tracheostomy (for each 1-d increment)	1.00	0.97-1.02	.97
Age (for each 1-y increment)	1.03	1.02-1.04	<.0001
APACHE II score	1.04	1.00-1.07	.03
Nontrauma postoperative admission	0.50	0.27-0.91	.02
Renal impairment	2.48	1.40-4.39	.002
Hypoxemia	0.62	0.33-1.16	.1
Chronic liver disease	8.35	1.74-40.10	.008
Reintubation	0.65	0.38-1.10	.1

OR indicates odds ratio.
For the ICU mortality model, χ^2 likelihood ratio = 60.43, $P < .0001$.
For the hospital mortality model, χ^2 likelihood ratio = 129.12, $P < .0001$.

5 to receive tracheostomy or to continue with translaryngeal intubation. Patients who remained intubated were randomized again on days 10 to 14. They found that ICU LOS did not differ between the 2 groups. However, of 5 participating centers, only one completed the study and of 157 enrolled patients, only 112 completed the study.

Maziak et al [15] performed a systematic review of the effect of time to tracheostomy which included 5 studies. The authors found that there was insufficient evidence to support that early tracheostomy could result in shorter mechanical ventilation in critically ill patients. However, there were limitations to this systematic review including the retrospective nature of 2 of the studies and the significant limitations of the included randomized controlled trials. A recent systematic review included randomized and quasi-randomized controlled studies that compared early tracheostomy (as defined by the authors of the original studies) with either late tracheostomy or prolonged endotracheal intubation [11]. Five studies with 406 participants were analyzed. Early tracheostomy significantly reduced the mechanical ventilation duration (weighted mean difference, −8.5 days; 95% CI, −15.3 to −1.7) and ICU LOS (weighted mean difference, −15.3 days; 95% CI, −24.6 to −6.1) but did not significantly alter mortality (relative risk, 0.79; 95% CI, 0.45-1.39). In a cohort from Project Impact, Freeman et al [2] found that tracheostomy timing correlated significantly with mechanical ventilation duration (r = 0.69), ICU LOS (r = 0.61), and hospital LOS (r = 0.34, $P < .001$ for all).

Our study demonstrates that the relationship between time to tracheostomy and ICU LOS follows a continuum rather than a dichotomous model; the later the tracheostomy, the longer the mechanical ventilation duration, the ICU LOS, and the hospital LOS. We found no association between the time to tracheostomy and mortality. Therefore, in patients who are deemed to likely require tracheostomy, it might be preferred to perform tracheostomy earlier than later. These results suggest the need for a prospective protocolized strategy to identify the patients who are likely to require tracheostomy, so it can be performed earlier than later [16].

The results of our study should be interpreted in light of its strengths and limitations. Strengths included the large number of patients and the prospective data collection. Limitations included the fact that it was conducted in a single center and was generated from a general ICU database. These findings need to be validated in a properly powered intention-to-treat multicenter randomized controlled trial.

5. Conclusions

This study demonstrates that time to tracheostomy is an independent predictor of mechanical ventilation duration, ICU LOS, and hospital LOS, but is not associated with increased ICU or hospital mortality. This study suggests that in patients who appear likely to require tracheostomy, early tracheostomy might lead to significant resource saving without negatively affecting survival.

Appendix A. Reasons for ICU admission

Respiratory: Asthma/allergy, COPD exacerbation, noncardiogenic pulmonary edema, respiratory arrest, aspiration/poisoning/toxic, respiratory infection, pulmonary embolus, pulmonary neoplasm.

Cardiovascular: Hypertension, rhythm disturbance, congestive heart failure, hemorrhage/hypovolemic shock, coronary artery disease, sepsis, postcardiac arrest, dissecting thoracic/abdominal aneurysm, cardiogenic shock.

Neurologic: Seizure disorders, intracranial/subdural/subarachnoid hemorrhage.

Other medical: Drug overdose, diabetic ketoacidosis, gastrointestinal (GI) bleeding, other metabolic/renal, other respiratory, other neurologic, other cardiovascular, other gastrointestinal.

Trauma: Multiple trauma, nonoperative head trauma, postoperative multiple trauma, postoperative head trauma.

Nontrauma postoperative: Postoperative chronic cardiovascular disease, postoperative peripheral vascular surgery, postoperative heart valve surgery, postoperative craniotomy for neoplasm, postoperative renal surgery for neoplasm, postoperative renal transplant, postoperative thoracotomy for neoplasm, postoperative craniotomy for intracranial/subdural/subarachnoid hemorrhage, postoperative laminectomy and spinal cord surgery, postoperative with hemorrhagic shock, postoperative GI bleed, postoperative GI neoplasm, postoperative respiratory insufficiency, postoperative GI obstruction/perforation, postoperative other neurologic, postoperative other cardiovascular, postoperative other respiratory, postoperative other GI, postoperative other metabolic/renal.

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