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Tracheostomy risk factors and outcomes after severe traumatic brain injury

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Abstract

Objective—To determine risk factors associated with tracheostomy placement after severe traumatic brain injury (TBI) and subsequent outcomes among those who did and did not receive a tracheostomy.

Methods—This retrospective cohort study compared adult trauma patients with severe TBI (n=583) who did and did not receive tracheostomy. A multivariable logistic regression model assessed the associations between age, sex, race, insurance status, admission GCS, AIS (Head, Face, Chest), and tracheostomy placement. Ordinal logistic regression models assessed tracheostomy's influence on ventilator days and ICU LOS. To limit immortal time bias, Cox proportional hazards models assessed mortality at 1, 3, and 12-months.

Results—In our multivariable model, younger age and private insurance were associated with increased probability of tracheostomy. AIS, ISS, GCS, race, and sex were not risk factors for

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tracheostomy placement. Age showed a non-linear relationship with tracheostomy placement; likelihood peaked in the fourth decade and declined with age. Compared to uninsured patients, privately insured patients had an increased probability of receiving a tracheostomy (OR=1.89[95%CI:1.09–3.23]). Mortality was higher in those without tracheostomy placement (HR=4.92[95%CI:3.49–6.93]). Abbreviated injury scale - Head was an independent factor for time to death (HR=2.53[95%CI: 2.00–3.19]), but age, gender, and insurance were not.

Conclusions—Age and insurance status are independently associated with tracheostomy placement but not with mortality after severe TBI. Tracheostomy placement is associated with increased survival after severe TBI.

Keywords

traumatic brain injury; outcome; trauma; tracheostomy; insurance

In the United States, traumatic brain injury (TBI) affects more than 2 million individuals annually, with an economic impact of $76.5 billion, and hospitalized patients with severe TBI account for 90% of this cost [1–3]. Patients with severe TBI remain intubated for prolonged periods of time, and tracheostomy is frequently performed in the intensive care unit (ICU) setting for patients requiring prolonged ventilator support. Tracheostomy placement improves patient comfort, reduces sedation requirements, improves pulmonary toilet, reduces dead-space ventilation, and may improve weaning from mechanical ventilation, in addition to preventing the complications associated with prolonged placement of an endotracheal tube [4–15].

Accurately determining which critically-ill patients need prolonged mechanical ventilation represents the major dilemma surrounding tracheostomy placement [8, 9, 12, 13, 16]. Possible explanations for the absence of objective criteria for tracheostomy placement, evidenced by a lack of consensus among previous studies, are variations in technical tracheostomy protocol and inclusion of heterogeneous critically-ill patient populations affected by a wide array of pathophysiologic states. Predicting the need for prolonged mechanical ventilation and determining the optimal timing of tracheostomy placement have been the subjects of numerous studies comparing early and late tracheostomy placement with patient characteristics and clinical outcomes [5, 9, 12–21]. However, despite numerous studies, definitive criteria for indications and timing of tracheostomy post-TBI remain absent, and the decision to place a tracheostomy remains dependent on the attending physician’s interpretation of the patient’s clinical status [5, 13, 22].

A few smaller studies, often lacking an appropriate control group, have investigated tracheostomy exclusively in patients with severe traumatic brain injury (TBI), a unique and specific population in which airway management is a necessity, and prolonged mechanical ventilation is common [9, 10, 17] Given the unpredictable nature of coma recovery amidst multisystem injuries, patients with severe TBI often have tracheostomy placement during their ICU stay [5, 9, 10, 12, 17] The purpose of this retrospective cohort study was to describe factors associated with tracheostomy placement after severe TBI and factors with associated clinical outcomes, including days of mechanical ventilation, ICU length of stay (LOS), and mortality.

Methods

The patient population for this retrospective cohort study consisted of adults admitted to our Level 1 trauma center ICU between 2000 and 2011 who sustained severe TBI and required mechanical ventilation for at least 96 hours. We defined adult patients as age 18 years and older; severe TBI was defined as admission Glasgow Coma Scale (GCS) score less than or equal to 8, Abbreviated Injury Scale (AIS) - Head score greater than or equal to 3, and intracranial hemorrhage observed on head CT. We excluded subjects with confounding events (i.e. mortality, discharge, extubation, urgent tracheostomy placement) occurring before 96 hours. Utilizing this time point allowed for exclusion of patients with acutely non-survivable injury, those with less severe injury whose admission GCS may have been falsely reduced secondary to intoxication or pre-hospital sedation, as well as those with non-neurological injuries requiring tracheostomy, such as patients with severe maxillofacial injury preventing placement of an endotracheal tube. Furthermore, in the TBI population, intracranial pressure generally peaks by 96 hours [22–26]. Thus, the 96-hour exclusion provided a clinically stable patient population that required an evaluation and decision about airway management based on the patient’s likely clinical course.

Following IRB approval, the criteria outlined above were provided for data retrieval from the Trauma Registry of the American College of Surgeons (TRACS). From TRACS, we obtained patient demographics (i.e. age, sex, race, insurance status), variables specific to injury severity (i.e. GCS score, AIS-Head score, AIS-Face score, AIS-Chest score, Injury Severity Score [ISS]), ventilator days, ICU LOS, and mortality up to one-year. Mortality was additionally cross-referenced with the Social Security Death Index and our hospital's Death Master File. We then identified which patients had a tracheostomy placement during their admission. Data obtained from TRACS was complete and no imputation was required. To verify accuracy of data of the tracheostomy procedure reported to the TRACS one hundred medical record numbers were selected from our severe TBI database at beginning, middle, and end time intervals over the study period. Data were validated against our institution’s electronic medical record system and found to be 100% accurate. Data were maintained using REDCap, a secure database hosted at Vanderbilt University [27].

To determine the factors associated with tracheostomy placement, a logistic regression model was constructed that utilized covariates of age, sex, race, insurance status, GCS score, and AIS (Head, Face, Chest) scores. Ordinal logistic regression models were fit for outcomes of ICU LOS and total ventilator days. Comparison was made between those who received tracheostomy and those who did not, while controlling for age, sex, race, insurance status, GCS score, and AIS (Head, Face, Chest) scores. These covariates were chosen due to their associations between both the independent variable (tracheostomy placement) and the outcomes of interest. To assess differences in survival time between our two cohorts, time to death was analyzed using both unadjusted and adjusted models. Unadjusted analyses included Kaplan-Meier survival curves and log-rank tests, while adjusted analysis was performed by logistic regression. To limit immortal time bias, a Cox proportional hazards model was fit to adjust for the previously mentioned covariates and included mortality. We also performed a sensitivity analysis in which we ran all the previously mentioned models, substituting ISS instead of our AIS sub-category scores. Given the collinearity of these variables identified in the sensitivity analysis and to avoid model over-fitting, we selected the AIS sub-category scores for inclusion in our main analyses, in particular due to the face validity that severe head, face, and chest injuries may predispose to tracheostomy placement, more so than abdominal or extremity injuries that can impact ISS.

Results

Using our inclusion criteria, we found 2,929 patients with severe TBI who were admitted to our institution's trauma ICU between the years 2000 and 2011. After applying exclusion criteria, the cohort (n=583) was sorted by tracheostomy (n=350) vs. no tracheostomy (n=233). As illustrated in Table 1, our groups were similar with respect to age, sex, race, and insurance status and almost identical with respect to injury severity.

After controlling for covariates, age was a significant factor (Table 2) associated with tracheostomy placement. Figure 1 illustrates the non-linear relationship between age and tracheostomy placement, such that the likelihood of tracheostomy in a patient with severe TBI increases from age 18 to 40, followed by a decreasing likelihood as age increases beyond 40. For example, compared to a 20-year-old patient, a 30-year-old patient is 39% more likely to receive a tracheostomy (OR=1.39 [95% CI: 1.05–1.84]), but a 60-year-old patient has a 24% decreased probability of tracheostomy placement when compared to a 50-year-old patient (OR=0.76 [95% CI: 0.62 – 0.92]). Additionally, we found insurance status to be associated with tracheostomy placement. Patients with severe TBI who have private insurance are more likely to have received a tracheostomy compared to those without insurance (OR=1.89 [95%CI: 1.09–3.23]).

While controlling for covariates, including death during hospitalization, patients with severe TBI without tracheostomy were more likely to have a shorter ICU LOS (OR=0.19 [95%CI: 0.13–0.27]) and fewer days of mechanical ventilation (OR=0.10 [95%CI: 0.07–0.14]) compared to those who received a tracheostomy. As AIS-Chest scores increased from zero to four, the probability of having more mechanical ventilation days increased (OR=1.52 [95% CI: 1.05–2.20]).

Unadjusted survival analysis showed significantly higher survival in the tracheostomy group (Figure 2). Adjusted survival analysis using logistic regression demonstrated patients with severe TBI who received a tracheostomy had increased survival at 1, 3, and 12 months compared to those who did not (Table 3). Adjusting for covariates in a Cox proportional hazard model, the hazard ratio for time to death in those without a tracheostomy is 4.92 [95%CI: 3.49–6.93]. AIS-Head was another independent factor for time to death (hazard ratio 2.53 [95%CI: 2.00–3.19]). All models had similar results when reconstructed using ISS instead of our selected AIS sub-category scores. Age, gender, and insurance status were not consistently associated with time to death.

Discussion

In our population of patients with severe TBI, age and lack of insurance were the only significant factors associated with tracheostomy placement, and tracheostomy placement was independently associated with increased ICU LOS, increased duration of mechanical ventilation, and increased survival. Although tracheostomy placement has been investigated extensively, studies for comparison are limited, as few are specific to patients with severe TBI and often lack an appropriate control group. Furthermore, the majority of studies evaluate optimal tracheostomy timing in smaller populations, rather than investigating factors associated with tracheostomy placement among a large cohort over time.

Our study is further strengthened by the consistency of bedside tracheostomy technique by a single protocol-driven service over the study period, which is similarly and safely performed at many institutions [28–30]. Our institution's tracheostomy team utilizes a standardized process to perform bedside percutaneous tracheostomies for patients in both the trauma and surgical ICUs and functions as a consultation service for patients in other ICUs. This team consists of two physicians and a specifically trained procedural support nurse from the Division of Trauma and Surgical Critical Care, and each team member has a dedicated, well-defined role for every tracheostomy. In addition to a dedicated team, this standardized process also includes use of a commercial percutaneous tracheostomy kit, a pre-procedural checklist, a pre-procedural timeout, as well as extra-long tracheostomy tubes for patients with a body mass index greater than 35 [31].

Our findings show a non-linear relationship between age and tracheostomy, illustrated in Figure 1, which may be related to the prognostic value age has on clinical outcomes after severe TBI. Younger patients have better clinical outcomes and a higher probability of recovery after TBI, as seen in the prognostic IMPACT model [33]. The decreased likelihood of tracheostomy in elderly patients might be explained by perceived futility with escalating co-morbidities and deteriorating baseline functional status and by improved prognosis in the younger patients. Given the interplay between age, anatomic TBI severity (i.e. AIS-Head) and clinical TBI severity (i.e. GCS), a strength of our model is that it incorporates these key covariates [32]. Although our study seems to imply a provider-based survivorship bias influencing tracheostomy placement decisions, our ability to evaluate motivations surrounding tracheostomy placement is limited by the lack of baseline cognitive and functional status in this retrospective population analysis.

The association of insurance status with tracheostomy placement was unexpected. The observation that patients holding private insurance are more likely to receive a tracheostomy than uninsured patients might reflect unmeasured baseline differences in comorbid disease and socio-demographic factors that may impact outcome after TBI. A prior five-year single-center all-comer TBI cohort did not show this association [34], and the observed difference in the present study may relate to our strict eligibility criteria focusing on critically-ill severe TBI subjects, who are at highest risk for prolonged respiratory failure. Interestingly, Scales and Ferguson [13] have previously suggested a compensation-based incentive for tracheostomy placement, given the high-paying coding group to which these patients are often assigned.

Those without insurance are not universally poor or unemployed. The uninsured represent people from a variety of backgrounds but may include those with less family support, decreased health literacy, pre-existing illness, and youth who elect to be uninsured [35,36]. Elements not measured in this study related to insurance status (e.g. educational level, employment, socioeconomic status, income, co-morbidities, social support) may steer surrogate decision-making regarding ventilator dependence, tracheostomy placement, and long-term planning. Insurance status may also impact long-term functional and quality of life outcomes [37]. The relationship between insurance status and tracheostomy placement likely reflects multiple factors. This limitation represents a potential future direction for study.

We found no correlation between injury severity (GCS score, AIS sub-scores, or ISS in sensitivity analysis) and probability of tracheostomy placement, although the AIS-chest score was unsurprisingly a statistically significant predictor of prolonged mechanical ventilation. The lack of significant association between injury severity and tracheostomy placement is likely a function of utilizing admission severity scores for a population defined by tracheostomy placement on or after 96 hours. Our lack of data for physiologic or organ-specific severity scores on subsequent hospital days, particularly at the 96-hour time point is due to the ICU's incomplete transition from paper to electronic medical records over the study period and represents a significant limitation of this study.

The proposed benefits of tracheostomy, aside from reducing the complications of prolonged intubation, suggest an expected decrease in ICU LOS and ventilator time. However, we observed increased time intervals for these variables in the tracheostomy cohort, and variations among individual patients, their baseline illnesses, and in-hospital course are likely too numerous and diverse to produce the observed effect. These findings might suggest accurate clinical prediction of those requiring prolonged ventilation, given the primary indication for tracheostomy placement in the TBI population is prolonged mechanical ventilation. Furthermore, with competing risks of time and mortality, increased mortality in the cohort not receiving a tracheostomy would produce artificially decreased ICU LOS and ventilator time. However, immortal time bias and death during hospital stay was controlled for in our adjusted Cox proportional hazard analysis [38]. Based on this analysis, the common assumption that patients in the cohort not receiving a tracheostomy were deemed to have a non-survivable injury, did not receive a tracheostomy, and died quickly in the ICU may not entirely explain the observed relationship. Decreased ICU LOS and decreased ventilator days in the no tracheostomy cohort could also be a function of a subgroup of survivors.

Our findings demonstrate a survival benefit for patients with severe TBI that receive a tracheostomy. While tracheostomy has been suggested to provide multiple benefits over prolonged intubation [5,8–15], our study does not quantify these benefits. Although our two cohorts were quite similar with respect to baseline demographics and injury severity, it remains unclear whether or not tracheostomy independently improves survival outcomes in patients with severe TBI, or whether both groups were at equal risk for prolonged mechanical ventilation, as opposed to unmeasured use of palliation, code status, and/or withdrawal of care.

The major limitations of this study reflect its retrospective design. Inherent bias exists in the clinical decisions surrounding tracheostomy placement, with respect to injury severity, previous and predicted future days of mechanical ventilation, survival, and futility of care;

we attempted to adjust for many of these factors in our regression models. Furthermore, excluding adult patients with severe TBI who experienced confounding events before 96 hours potentially introduced selection bias to our study population.

In summary, age and lack of insurance are independent factors associated with tracheostomy placement after TBI but are not associated with mortality. Tracheostomy placement is associated with prolonged mechanical ventilation and longer ICU LOS, but also increased survival. Further investigations incorporating pre-hospitalization co-morbidities, baseline cognitive and functional status, time-varying covariates, and state-transition models will allow improved modeling of TBI outcomes important for patients, family members, care providers, and health care organizations.

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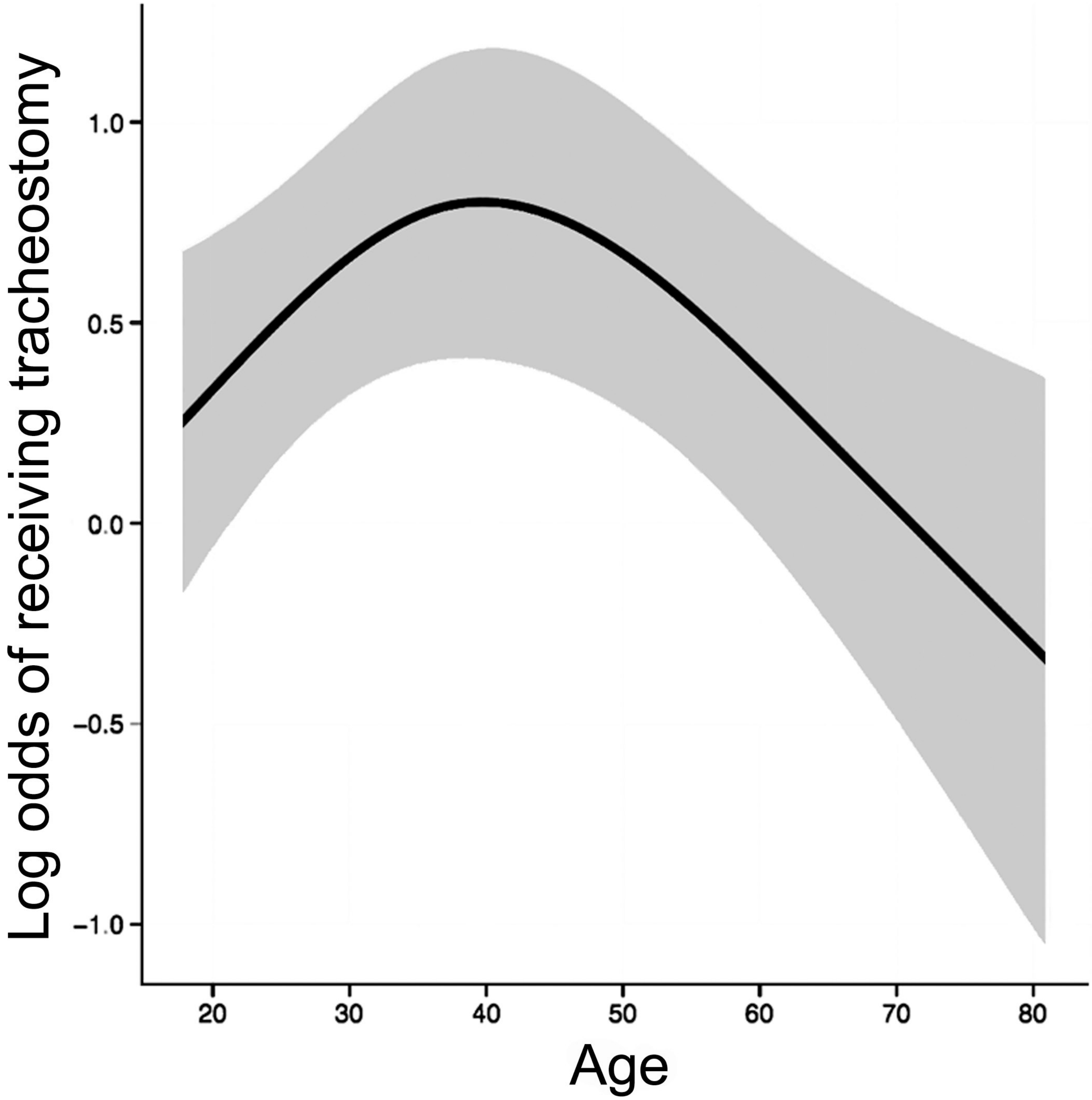

Figure 1.

Non-linear relationship between age and log odds of tracheostomy after severe TBI. Gray area represents the 95% confidence interval.

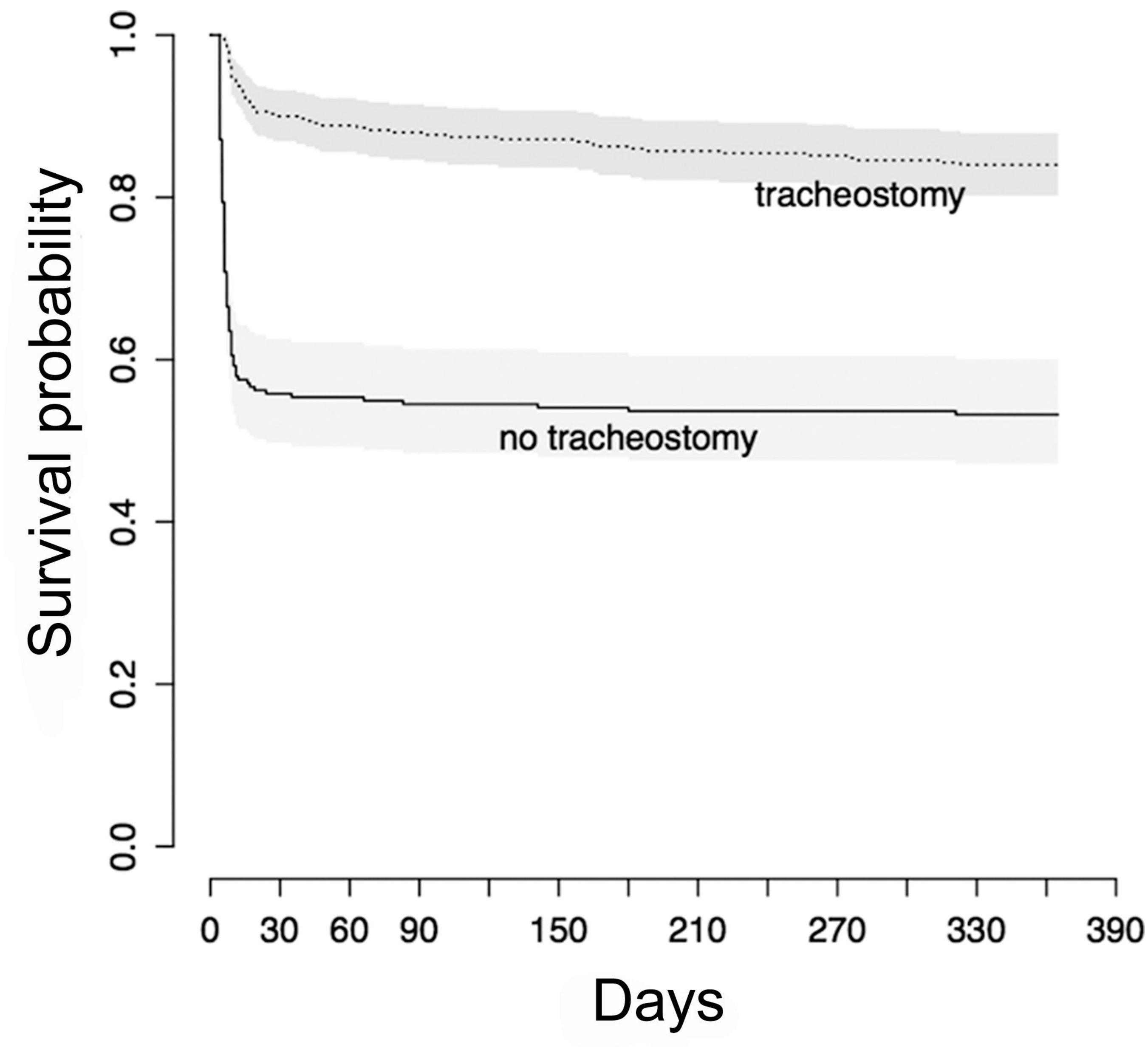

Figure 2.
Unadjusted Kaplan-Meier survival curve with and without tracheostomy after severe TBI

Table 1

Descriptive statistics of no tracheostomy and tracheostomy groups on admission after severe TBI

Variable	No tracheostomy (n=233)	Tracheostomy (n=350)
Age	36 (IQR: 24–53)	37 (IQR: 24–51)
Gender	76% Male	73% Male
Race	86% White 8% Black 5% Hispanic <1% Other	86% White 7% Black 6% Hispanic 1% Other
Insurance	48% Private 30% Public 16% Uninsured 4% Workers' Compensation 1% Other	53% Private 34% Public 10% Uninsured 3% Workers' Compensation 1% Other
GCS Score	3 (IQR: 3–4)	3 (IQR: 3–4)
AIS-Head Score	4 (IQR: 4–5)	4 (IQR: 4–5)
AIS-Face Score	0 (IQR: 0–2)	0 (IQR: 0–2)
AIS-Chest score	3 (IQR: 0–4)	3 (IQR: 0.25–4)
ISS	34 (IQR: 26–41)	34 (IQR: 27–41)

Descriptors are either Percent (%) or Median (Interquartile Range: 25–75%)

Table 2

Risk factors for tracheostomy after severe TBI

Patient Characteristic	Odds Ratio for Tracheostomy
Age (Years)	
20 vs. 30	1.39 [95% CI: 1.05 – 1.84]
30 vs. 40	1.16 [95% CI: 0.98 – 1.36]
40 vs. 50	0.89 [95% CI: 0.79 – 1.00]
50 vs. 60	0.76 [95% CI: 0.62 – 0.92]
60 vs. 70	0.72 [95% CI: 0.57 – 0.90]
70 vs. 80	0.72 [95% CI: 0.57 – 0.90]
Gender	
Female vs. Male	1.15 [95% CI: 0.76 – 1.73]
Race	
Black vs. White	1.00 [95% CI: 0.52 – 1.92]
Hispanic vs. White	1.31 [95% CI: 0.62 – 2.77]
Insurance Status	
Public vs. Private	0.90 [95% CI: 0.61 – 1.33]
Workers' Compensation vs. Private	1.79 [95% CI: 0.69 – 4.55]
None vs. Private	1.89 [95% CI: 1.09 – 3.23]
Other vs. Private	1.64 [95% CI: 0.32 – 8.33]
GCS	1.00 [95% CI: 0.89 – 1.12]
AIS-Head & Neck	1.08 [95% CI: 0.86 – 1.35]
AIS-Face	0.97 [95% CI: 0.71 – 1.33]

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Table 3

Adjusted probability of mortality without tracheostomy after severe TBI

Time	Odds Ratio for Mortality
1 month	9.24 [95% CI: 5.62 – 15.18]
3 month	7.83 [95% CI: 4.88 – 12.56]
12 month	5.54 [95% CI: 3.58 – 8.60]