The American Journal of Surgery 220 (2020) 495–498

Contents lists available at ScienceDirect

The American Journal of Surgery

journal homepage: www.americanjournalofsurgery.com

Predicting the need for tracheostomy in trauma patients without severe head injury

Kartik Prabhakaran [a, *], Asad Azim [b], Muhammad Khan [b], Faisal Jehan [b], James Feeney [c, **], Patrice Anderson [d], Anthony Policastro [e], Rifat Latifi [f]

[a] Westchester Medical Center, New York Medical College, 100 Woods Road, Taylor Pavilion, Office E15, Department of Surgery, Valhalla, NY, 10595, USA
[b] Westchester Medical Center, Department of Surgery, Taylor Pavilion, Room E-130, Center100 Woods Road, Valhalla, NY, 10595, USA
[c] MidHudson Regional Hospital, Westchester Medical Center, 241 North Road, Poughkeepsie, NY, 12601, USA
[d] Trauma Intensive Care Unit, Surgical Critical Care Fellowship, 100 Woods Road, Taylor Pavilion, Office E145, Westchester Medical Center, Department of Surgery, Valhalla, NY, 10595, USA
[e] Trauma Intensive Care Unit, Surgical Critical Care Fellowship, 100 Woods Road, Taylor Pavilion, Office E136, Westchester Medical Center, Department of Surgery, Valhalla, NY, 10595, USA
[f] Department of Surgery, Westchester Medical Center, New York Medical College, 100 Woods Road, Taylor Pavilion, Office Suite #353, Valhalla, NY, 10595, USA

A R T I C L E I N F O

Article history:
Received 28 September 2019
Received in revised form
10 December 2019
Accepted 13 December 2019

Keywords:
Tracheostomy
Traumatic brain injury
TQIP
Trauma
Scoring system

A B S T R A C T

Background: Early tracheostomy is recommended in patients with severe traumatic brain injury (TBI); however, predicting the timing of tracheostomy in trauma patients without severe TBI can be challenging.
Methods: A one year retrospective analysis of all trauma patients who were admitted to intensive Care Unit for > 7 days was performed, using the ACS-TQIP database. Univariate and Multivariate regression analyses were performed to assess the appropriate weight of each factor in determining the eventual need for early tracheostomy.
Results: A total of 21,663 trauma patients who met inclusion and exclusion criteria were identified. Overall, tracheostomy was performed in 18.3% of patients. On multivariate regression analysis age >70, flail chest, major operative intervention, ventilator days >5 days and underlying COPD were independently associated with need of tracheostomy. Based on these data, we developed a scoring system to predict risk for requiring tracheostomy.
Conclusion: Age >70, presence of flail chest, need for major operative intervention, ventilator days >5 and underlying COPD are independent predictors of need for tracheostomy in trauma patients without severe TBI.

Introduction

Mechanical ventilation is often required for severely injured trauma patients due to depressed neurologic function, the need for airway protection, respiratory compromise secondary to chest wall and intrathoracic trauma, the need for resuscitation, and for provision of anesthesia for operative procedures. The duration of mechanical ventilation varies based on the severity of the aforementioned admission variables as well as factors which develop after the initial presentation such as degree of neurologic recovery, hypoxemia, inadequacy of spontaneous ventilation, failed trial of extubation, and evolution of pulmonary injury.[1,2] The duration of mechanical ventilation has significant implications related to morbidity, resource utilization, quality of life and costs.[3,4] A proportion of trauma patients requiring prolonged mechanical ventilation ultimately require tracheostomy, as part of airway management and overall provision of critical care. However, assessment of the need for tracheostomy and determination of optimal timing remain unclear.[5,6] When examining critically ill patients at large, some studies have shown that early tracheostomy was associated with significant reductions in duration of

* Corresponding author.
** Corresponding author.
E-mail addresses: Kartik.prabhakaran@wmchealth.org (K. Prabhakaran), Asad.Azim@wmchealth.org (A. Azim), Muhammad.Khan@wmchealth.org (M. Khan), Faisal.Jehan@wmchealth.org (F. Jehan), James.Feeney@wmchealth.org (J. Feeney), PatriceLynn.Anderson@wmchealth.org (P. Anderson), Anthony.Policastro@wmchealth.org (A. Policastro), Rifat.Latifi@wmchealth.org (R. Latifi).

https://doi.org/10.1016/j.amjsurg.2019.12.018
0002-9610/

mechanical ventilation, hospital length of stay and cost of hospitalization, albeit with no effect on mortality.[7] Moreover, studies have also demonstrated a correlation between tracheostomy and a reduction in the requirement for sedation as well as an increase in mobilization of critically ill patients.[8] However, randomized controlled trials of critically ill mechanically ventilated patients failed to show a benefit of tracheostomy with respect to mortality, ventilator-associated pneumonia, or hospital and ICU length of stay.[9,10]

Given the inherent heterogeneity of the critically ill patient population, the question of timing and potential benefit with respect to tracheostomy merits specific consideration amongst trauma patients. The identification of those patients that would benefit from tracheostomy begins with predicting the need for long-term ventilator support. The aim of this retrospective study was to better elucidate whether there are early predictors of who might benefit from tracheostomy in patients without severe head injury.

Methods

We performed a 1-year retrospective analysis of the American College of Surgeons, Trauma Quality Improvement Program (ACS-TQIP) database from 2016. We analyzed all trauma patients in ACS-TQIP who were admitted to Intensive Care Unit (ICU) during the study period age >18) for greater than 7 days. We excluded all patients who had Head AIS ≥3 or those who died within 2 weeks of ICU admission.

We collected the following data points from the TQIP dataset: patients demographic characteristics, including age, sex, and race; pre-hospital and ED vital parameters, including systolic blood pressure (SBP), heart rate (HR) and Glasgow Coma Scale (GCS); Injury parameters, including mechanism of injury, ISS and body region specific AIS; Complications, including, Acute Respiratory Distress Syndrome (ARDS), Acute Kidney Injury (AKI), Deep Venous Thrombosis (DVT), Pulmonary Embolism (PE), Pneumonia and Cerebrovascular Accident (CVA); need for Intervention, including laparotomy, thoracotomy; ventilator days; intensive care unit (ICU) and Hospital lengths of stay; disposition to home, rehab, or skilled nursing facility (SNF).

We reported data as a mean ± standard deviation (SD) for continuous variables, as frequency and proportions for categorical variables, and as median with interquartile range for ordinal variables. We performed chi-square test to explore the differences in categorical variables between the two groups. In addition, we used the independent student's t-test for continuous parametric data and the Mann-Whitney *U* test for continuous non-parametric data. We considered $p < 0.05$ as statistically significant for our study.

We used univariate logistic regression models to identify variables for further analysis. Independent associations between risk factors and tracheostomy were assessed using forward stepwise logistic regression, including variables with a $p < 0.1$ in the unadjusted analysis. To improve applicability, we excluded individual variables in turn and checked the concordance statistic of each model in order to find the best-fit model with the fewest clinical variables.

Odds ratio was calculated for each factor associated with tracheostomy in a multivariate regression model. The weight of each factor was then calculated by converting the odds ratio to a point based system using natural logarithm of odds ratio. The weight was then rounded off to the nearest integer. An equation to calculate a **TRACH** (**TRA**cheostomy for patients without intra-**C**ranial **H**emorrhage) score for each patient was created using these weights, and the risk of tracheostomy was assigned to each score based on the actual rate of tracheostomy in this cohort. The model's discrimination was evaluated using the area under the Receiver Operator Characteristic (AUROC) curve. For our study, we considered a p value < 0.05 as statistically significant. All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS, Version 24; SPSS, Inc., Armonk, NY).

Results

A total of 21,663 trauma patient who were admitted ICU for >7 days without severe head injury were identified. Mean age was 44.5 ± 34, 72.2% were white, 67.9% were male, mean ISS was 18.82 ± 31, mean SBP on admission was 102 ± 36.3, and mean HR was 110.7 ± 28.2. The overall tracheostomy rate was 18.3%. Table 1 summarizes demographics and injury characteristics in patients who received tracheostomy as compared to those who did not.

Table 2 demonstrates the factors significant for tracheostomy in the risk adjusted analysis and natural logarithm (ln) of respective

Table 1
Demographics and Injury characteristics.

	Tracheostomy (n = 3898)	No Tracheostomy (n = 17765)	*p-value*
Age, y, mean ± SD	51 ± 34	46 ± 27	0.011
Male, %	60.5%	65.5%	0.34
White, %	76%	74.5%	0.42
Hispanic, %	7.8%	6.7%	0.75
ED Vitals			
SBP, mean ± SD	92 ± 22	105 ± 15	0.02
HR, mean ± SD	118 ± 17	108 ± 16	0.11
GCS, median [IQR]	14 [13–15]	15 [14–15]	0.12
Injury Parameters			
Blunt Injury, %	76%	74%	0.16
ISS, median [IQR]	28 [21–33]	21 [15–25]	**<0.001**
Head-AIS, median [IQR]	1 [1–2]	1 [1–2]	0.79
Thorax-AIS	5 [4–7]	3 [3–5]	**0.01**
Abdomen AIS	5 [4–6]	4 [3–5]	0.07
Rib Fractures >6	38%	14%	**0.001**
Major Procedure			
Thoracotomy	16%	8%	**0.01**
Laparotomy	36%	15%	**0.001**
Comorbidities			
COPD	26%	15%	**<0.001**
CHF	15%	9%	0.22
CKD	9%	11%	0.21
CAD	7%	10%	0.09

Table 2
Multivariate regression analysis.

Variables	Odds Ratio (95% CI)	ln (OR)
Age >70	2.1 [1.5–2.7]	0.74
Chest/Abdominal AIS>5	3.4 [2.3–4.5]	1.24
Flail Chest	1.3 [0.87–2.6]	–
Rib fractures > 6	2.3 [1.8–3.1]	0.83
Major Procedure	5.3 [3.8–7.7]	1.71
COPD	2.8 [2.1–4.2]	1.02
CHF	1.3 [0.91–2.1]	–

ln = natural logarithm.

Table 4
Risk of Tracheostomy based on TRACH score with Fig. 1 ROC curve below.

TRACH SCORE	Number of patients	No of patient underwent tracheostomy	*Level of risk*
0	7444	0%	**LOW**
1	4906	3% (147)	
2	3934	11% (432)	
3	2166	42% (909)	**MODERATE**
4	1765	78% (1376)	
5	922	100% (922)	**HIGH**
6	526	100% (526)	

odds ratios. Age >65, Major procedure, Rib fractures >6, Chest/Abdominal AIS ≥5 and COPD were significant factors associated with tracheostomy. Table 3 summarizes the parameters of TRACH Score and their respective weights based on ln (odds ratio) based on which Major procedure received the maximum weight of 2 other factors including Age >70, Rib fracture >6, Abdominal and Chest AIS ≥5 and COPD received a weight of 1.

Table 4 summarizes the risk of tracheostomy associated with TRACH Score: A TRACH score 0–2 was associated with low risk, 3–4 with moderate risk and ≥5 was associated with high risk of tracheostomy. AUROC was utilized to assess discrimination power of TRACH Score to identify patient at increased risk of receiving a tracheostomy. The AUROC (Fig. 1) for the TRACH score was 0.792, (95% CI = 0.683–0.818).

Discussion

Earlier studies aimed at predicting the need for prolonged durations of mechanical ventilation amongst trauma patients demonstrated a significant correlation between Glasgow coma scores of ≤8 (severe traumatic brain injury) age, and intracranial hypertension and the need for tracheostomy.[1,6] More recently, studies examining patients with severe traumatic brain injury demonstrated that early tracheostomy (<8 days after intubation) was associated with a shorter duration of mechanical ventilation, reduction in ventilator associated pneumonia, as well as intensive care unit and hospital lengths of stay, albeit with no effect on mortality.[11,12] Moreover, in addition to benefits with respect to infectious complications and resource utilization, one study demonstrated a correlation between early tracheostomy and long-term neurologic outcoumes.[13] Based on these and several similar studies demonstrating a benefit to early tracheostomy in the setting of head injury, the Brain Trauma Foundation Guidelines have incorporated a level IIA recommendation for early tracheostomy in the setting of severe traumatic brain injury.[14]

Based on the growing body of literature and with widespread incorporation of the Brain Trauma Foundation guidelines, early tracheostomy has become standard practice in many trauma centers and institutions in the setting of severe traumatic brain injury. However, a significant number of trauma patients without severe head injury continue to require prolonged durations of mechanical ventilation and ultimately require tracheostomy. Given the impact of prolonged mechanical ventilation on the need for heavy sedation, resource allocation, hospital costs, nosocomial infections, and patient mobilization, it is important to identify those factors amongst trauma patients without severe head injury that foreshadow the need for tracheostomy. As such, our study was designed to identify risk factors for requiring tracheostomy amongst trauma patients without severe traumatic brain injury.

Table 3
Parameters and calculated weights of TRACH Score.

Variables	ln (OR)	Weights
Age >70	0.74	1
Chest or Abdominal AIS ≥5	1.24	1
Rib fractures > 6	0.83	1
Major Procedure	1.71	2
COPD	1.02	1

ln = natural logarithm.

We used the TQIP dataset to examine national data from trauma centers across the country. TQIP is a dataset administered by the American College of Surgeons (ACS) that can be used to compare risk-adjusted outcomes in the trauma centers across the US. More than 700 trauma centers across the US report data to the TQIP. This dataset is collected by specialized data abstractors at each institution; they record more than 100 variables, including patient demographics, pre-hospital EMS vital, re-hospital interventions, emergency department (ED) vitals, ED disposition, injury parameters (mechanism and mode of injury), objective injury severity score (ISS), abbreviated injury scale (AIS), in-hospital interventions (blood transfusion, surgical intervention and interventional radiology (IR) procedures), and outcomes (complications, in-hospital mortality and discharge disposition).

Correctly predicting the eventual need for tracheostomy in non-head injured trauma patients is important in the planning of the patient's care, setting family expectations, discussing end of life concerns, and may improve hospital and ICU lengths of stay. In an increasingly cost conscious environment of care, the importance of decreasing lengths of stay is difficult to overstate. However, just as important, reducing sedation, opiate use, improving mobilization, reducing resource utilization and possibly improving complication rates, as was described for head injured patients, may be expected to lead to improvements in measurable quality indices, as well as patient satisfaction. Families with loved ones requiring ICU care want answers, and without predictive models, the answers given are little more than educated guesswork. This is the use for which our massive TQIP dataset was initially envisioned: allowing physicians to respond to families' questions about the future with data driven answers.

One benefit of utilizing the TQIP dataset is that it ostensibly corrects for individual variables in care at single institutions that may otherwise impact lengths of stay or outcomes. With a large sample size, and prospective data from several participating trauma centers, this study has the statistical power to glean which factors are significant contributors to the need for tracheostomy. Our dataset described major procedure, age >70, rib fractures>6, abdominal or chest AIS >3, or preexisting COPD as independent predictors of the need for tracheostomy. The AUROC was very good at 0.792, meaning that this simple, easy to remember, straightforward scoring system should be easily applied with good concordance.

As with any study, ours has its limitations. As good as the concordance is at AUROC = 0.792, it could, perhaps, be higher. Other, currently unknown factors that may affect the AUROC may simply not be collected by TQIP registrars. Identifying these factors would take further study outside the limits of this excellent dataset. Several factors come to mind as possibilities, and targets of further

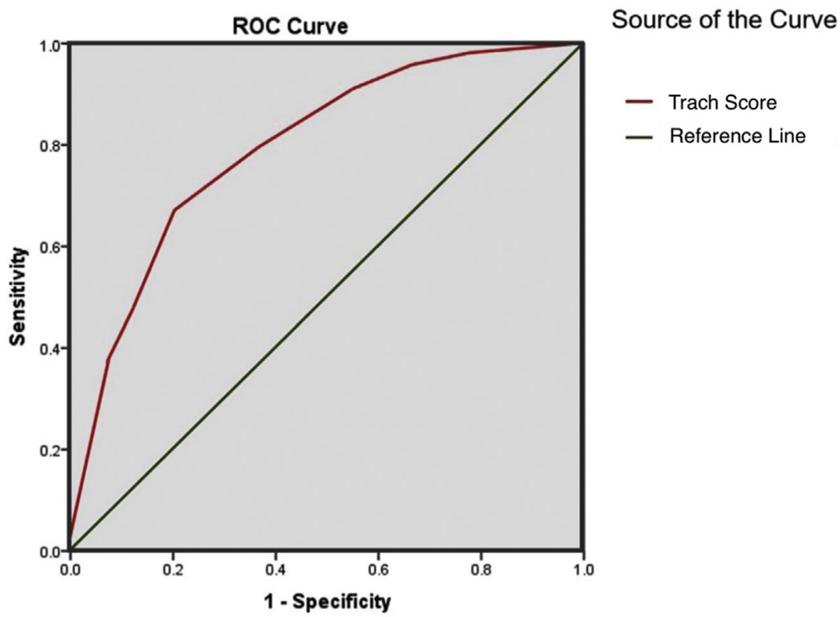

Fig. 1. AUROC for TRACH score with reference line

research, including measured muscle mass, nutrition parameters, signs or symptoms of dementia, preexisting drug or medication use, or any combination of other biochemical abnormalities, derangements, or comorbidities. Further study is indicated.

The scoring system has yet to be validated prospectively. Additionally, with different technologies, modes of ventilation, and improvements in systems of care, it is certainly possible that individual centers, as outliers, were lost in the statistical noise of the larger dataset. Certainly, it would be imaginable that the best performing trauma centers have technologies or practices that obviate the need for tracheostomy in multiply injured, postoperative septuagenarians with multiple rib fractures and a history of COPD. We were unable to tease out the individual centers from our dataset, and so we were unable to identify whether there were such outlier institutions in the sample. To that end, as technology advances, and critical care practices advance, these factors may play a less important role in the need for tracheostomy. These are all weaknesses of a retrospective study that might be solved by a randomized, controlled, multicenter trial.

In conclusion, we used the TQIP dataset to retrospectively analyze the factors associated with the need for tracheostomy in non-head injured patients, and produced a scoring system with very good concordance. Further evidence is needed to advocate for widespread use, and further study is indicated in order to validate and refine the score.

Source of funding

None.

Declaration of competing interest

None.

References

1. Ross BJ, Barker DE, Russell WL, Burns RP. Prediction of long-term ventilatory support in trauma patients. *Am Surg*. 1996;62:19–25.
2. Mahmood S, Alani M, Al-Thani H, et al. Predictors of reintubation in trauma intensive care unit: Qatar experience. *Oman Med J*. 2014 Jul;29(4):289–293. https://doi.org/10.5001/omj.2014.75.
3. Cox CE, Carson SS, Govert JA, et al. An economic evaluation of prolonged mechanical ventilation. *Crit Care Med*. 2007;35:1918–1927.
4. Unroe M, Kahn JM, Carson SS, et al. One-year trajectories of care and resource utilization for recipients of prolonged mechanical ventilation: a cohort study. *Ann Intern Med*. 2010;153:167–175.
5. Sugerman HJ, Wolfe L, Pasquale MD, et al. Multicenter, randomized, prospective trial of early tracheostomy. *J Trauma*. 1997;43:741–747.
6. Goettler C, Fugo JR, Bard MR, et al. Predicting the need for early tracheostomy: a multifactorial analysis of 992 intubated trauma patients. *J Trauma*. 2006 May;60(5):991–996.
7. Brook AD, Sherman G, Malen J, et al. Early versus late tracheostomy in patients who require prolonged mechanical ventilation. *Am J Crit Care*. 2000;9:352–359.
8. Nieszkowska A, Combes A, Luyt CE, et al. Impact of tracheotomy on sedative administration, sedation level, and comfort of mechanically ventilated intensive care unit patients. *Crit Care Med*. 2005;33:2527–2533.
9. Terragni PP, Antonelli M, Fumagalli R, et al. Early vs late tracheotomy for prevention of pneumonia in mechanically ventilated adult ICU patients: a randomized controlled trial. *J Am Med Assoc*. 2010;303:1483–1489.
10. Young D, Harrison DA, Cuthbertson BH, et al. Effect of early vs late tracheostomy placement on survival in patients receiving mechanical ventilation: the TracMan randomized trial. *J Am Med Assoc*. 2013;309:2121–2129.
11. Alali AS, Scales DC, Fowler RA, et al. Tracheostomy timing in traumatic brain injury: a propensity-matched cohort study. *J Trauma Acute Care Surg*. 2014 Jan;76(1):70–76. discussion 76-8.
12. Jeon YT, Hwang JW, Lim YJ, et al. Effect of tracheostomy timing on clinical outcome in neurosurgical patients: early versus late tracheostomy. *J Neurosurg Anesthesiol*. 2014 Jan;26(1):22–26. https://doi.org/10.1097/ANA.0b013e31829770a0.
13. Khalili H, Paydar S, Safari R, et al. Experience with traumatic brain injury: is early tracheostomy associated with better prognosis? *World Neurosurg*. 2017 Jul;103:88–93. https://doi.org/10.1016/j.wneu.2017.02.060.
14. Carney N, Totten AM, O'Reilly C, et al. *Guidelines for the Management of Severe Traumatic Brain Injury*. fourth ed. Brain Trauma Foundation; 2016.