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Early tracheostomy in patients with cervical spine injury reduces morbidity and improves resource utilization

Muhammad Khan [a], Kartik Prabhakaran [b, *], Faisal Jehan [a], Patrice Anderson [b], Jorge Con [b], Gary Lombardo [b], Peter Rhee [b], Rifat Latifi [b]

[a] Department of Surgery, Westchester Medical Center-New York Medical College Valhalla New York, USA
[b] Section of Trauma and Acute Care Surgery, Department of Surgery, Westchester Medical Center-New York Medical College Valhalla New York, USA

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ABSTRACT

Background: Aim of our study is to analyze the impact of Early Tracheostomy (ET) in patients with cervical-spine (C-spine) injuries.
Methods: We analyzed seven-year (2010–2016) ACS-TQIP databank and included all non-TBI trauma patients diagnosed with c-spine injuries. Patients were stratified into two groups based on the timing of tracheostomy (Early; ≤7days: Late; >7days). Outcomes were complications, hospital and ICU stay. Regression analysis was performed.
Results: We included 1139 patients. Mean age was 47 ± 12, median ISS was 18 [12–28], and median C-spine AIS was 4 [3–5]. 24.5% of the patients received ET. On regression analysis, patients who received ET had lower overall-complications (OR:0.57) and ventilator-associated pneumonia (OR:0.61). ET was associated with shorter duration of mechanical ventilation, and hospital and ICU stay. There was no difference in mortality rate.
Conclusions: Early tracheostomy in patients with C-spine injuries was associated with lower rates of ventilator-associated-pneumonia, shorter duration of mechanical ventilation, and ICU and hospital stay.

Introduction

Trauma remains one of the leading causes of morbidity, disability, and mortality among the adult population in the United States.[1] According to the National Spinal Cord Injury statistics central, the incidence of spinal cord injury (SCI) is about 17,730 cases each year excluding those who die on scene with most common site of injury being the cervical and thoracic spine.[2] Patients with cervical spinal cord (C-spine) injury can have variable presentation depending on the level of injury and the extent of injury. Patients with injury above C4 usually have severe respiratory distress due to phrenic nerve compromise requiring intubation and prolonged mechanical ventilation.[3] Based on the literature the need for mechanical ventilation can be as high as 100% depending on the severity of injury.[4,5]

According to statistics from the national trauma databank, it is estimated that one out of every fifth patient with cervical spine injury will need tracheostomy (NTDB).[6] Studies have demonstrated the predictors associated with the need for tracheostomy in patients with cervical spinal cord injuries. These factors include anatomic level of spinal cord injuries, complete spinal cord injuries, higher injury severity score, lower Glasgow coma scale, facial fractures and thoracic injuries.[6–8] Tracheostomy is a low-risk procedure that can be performed at bedside. Single-center studies have demonstrated certain benefits of early tracheostomy if done within 7 days of injury or intubation. Early tracheostomy has been shown to decrease hospital length of stay, decrease intensive care unit (ICU) length of stay and improve weaning from mechanical ventilation.[9,10] However, potential benefits of early tracheostomy in terms of reducing respiratory complications, and decreasing mortality and readmission rate has not yet been demonstrated.

Most of the previous literature on early tracheostomy after cervical spinal cord injury is from single-institutional studies, and failed to demonstrate a benefit in terms of reducing respiratory

* Corresponding author. Westchester Medical Center, New York Medical College, E150 Taylor Pavilion, 100 Woods Road, Valhalla, NY, 10595, USA.
E-mail addresses: Muhammad.khan@wmchealth.org (M. Khan), Kartik.Prabhakaran@wmchealth.org (K. Prabhakaran), Faisal.Jehan@wmchealth.org (F. Jehan), PatriceLynn.Anderson@wmchealth.org (P. Anderson), Jorge.Con@wmchealth.org (J. Con), Gary.Lombardo@wmchealth.org (G. Lombardo), Peter.Rhee@wmchealth.org (P. Rhee), Rifat.Latifi@wmchealth.org (R. Latifi).

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complications, due to sampling size. Moreover, the benefit that was reported in such studies may be attributable to sample bias. Therefore, we aimed to analyze the impact of early tracheostomy in patients with C-spine injury utilizing a national database. We hypothesized that early tracheostomy in patients with C-spine injury, and without traumatic brain injury, is associated with improved outcomes.

Methods

Study design and population

We performed a seven-year analysis of the American College of Surgeons Trauma Quality Improvement Program (ACS-TQIP) database. We identified patients who were diagnosed with cervical spinal cord injuries using the ICD-9 and ICD-10 diagnosis codes. The ACS-TQIP is one of the largest national trauma databases. Over 800 trauma centers across the United States (U.S.) participate in providing the data.[11] Trained personnel abstract over 100 patient and institutional variables, including patient demographics (age, gender, race); comorbidities; injury parameters [type and mechanism of injury; injury severity score (ISS); abbreviated injury scale (AIS)], prehospital and emergency department (ED) vitals; in-hospital procedures, transfusions, complications & mortality and discharge disposition. Complications were defined as acute kidney injury (AKI), acute respiratory distress syndrome (ARDS), deep vein thrombosis (DVT), pulmonary embolus (PE), unplanned intubation, and severe sepsis.

TQIP provides standardized data collection and risk-adjusted reports that compare hospitals to other Level I and Level II trauma centers.[11] While TQIP is administered by the American College of Surgeons, the authors of this paper are solely responsible for the analysis and conclusions presented herein.

Inclusion and exclusion criteria

We included all adult trauma patients (age $\geq$ 18 years), with a blunt mechanism of injury who were diagnosed with cervical spinal cord injury and underwent tracheostomy. We excluded patients who were transferred from other facilities, had traumatic brain injury or major thoracic injury (Chest AIS$\geq$3), spinal cord injury below cervical level, facial fractures, vocal cord injury, tracheal injury, and burns.

Data points

We abstracted the following variables for each patient: demographics (age, gender, race and ethnicity); injury parameters (mechanism of injury, injury severity score [ISS], other body regions abbreviated injury scale score [AIS], level of cervical spinal cord injury); emergency department (ED) vitals (systolic blood pressure [SBP], heart rate [HR], and Glasgow coma scale [GCS]); comorbidities; tracheostomy procedure; operative fixation; hospital and ICU length of stay (LOS); in-hospital complications; and discharge disposition.

Patient stratification

Patients were stratified into two groups based on the timing of tracheostomy (early vs late tracheostomy). Early tracheostomy (ET) was defined at tracheostomy performed within 7 days ($\leq$7) of injury based on previous literature. Late tracheostomy (LT) was defined as tracheostomy performed after 7 days (>7) of injury.

Outcomes

Primary outcome measures were in-hospital mortality rates and complications. Secondary outcomes measures were ventilator days, hospital LOS, and ICU LOS.

Statistical analysis

We performed univariate regression analysis to assess the association between each variable and the outcome. Independent variables with p value of <0.2 was included in the multivariate regression model to evaluate the independent predictability for complications and mortality. On multivariate regression analysis, p value of <0.05 was considered statistically significant for independent association between the variables and outcomes. Furthermore, we assessed the fitness of model by the Hosmer-Lemeshow test. The Hosmer-Lemeshow test exceeded 0.05 and the tolerance was >0.1 for all independent variables with a variance inflation factor <10.0.

We reported all categorical variables as proportions, continuous parametric variables as mean (with standard deviation) and continuous non-parametric variables as median [with interquartile range]. For statistical comparison, we used Pearson's chi-square (X^2) test to compare categorical variables, while the Student's t-test and the Mann-Whitney U test were used to compare the continuous data. In our analysis, the alpha was set at 5% and a p-value of less than 0.05 ($p < 0.05$) was considered statistically significant. All the statistical analyses were performed using the Statistical Package for Social Services (SPSS, version 24; SPSS, Inc., Armonk, NY).

Missing data analysis

Missing data were treated as missing completely at random (MCAR). Multiple imputations using a missing value analysis technique to account for the missing values was performed. For multiple imputations, the original dataset was analyzed for random missing data points using Little's MCAR test. Then the Markov Chain Monte Carlo method was utilized for multiple imputations. This method refers to a collection of methods for simulating random draws from non-standard distributions.

Results

We analyzed a total of 1139 patients who had blunt cervical spinal cord injury and underwent tracheostomy. The mean age was 47 ± 12, 75% were male and 72.7% were caucasian. Median ISS was 18 [12–28], and median cervical spine AIS was 4 [3–5]. The most common mechanism of injury was falls from height (32.5%), followed by motor vehicle collision 29.4%. Overall 10.7% were intubated in the ED or on scene.

Of 1139 patients, 24.5% of the patients received tracheostomy within 7 days (Early Tracheostomy $\leq$ 7). The median time to tracheostomy in patients within the early group was 5 days [3–6]. Table 1. Demonstrates the demographics of the study population. Patients who received early tracheostomy were more likely to have higher systolic blood pressure ($p = 0.002$), higher injury severity score ($p = 0.04$), and were more likely to be intubated in ED or on the scene ($p < 0.001$). There was no difference in age ($p = 0.79$), gender ($p = 0.30$), race ($p = 0.10$), ED systolic blood pressure ($p = 0.06$), GCS ($p = 0.76$) and O2 saturation ($p = 0.76$). Similarly, there was no difference in chest ($p = 0.09$), thorax ($p = 0.88$), neck ($p = 0.98$), and face abbreviated injury scale score ($p = 0.99$).

Of 1139 patients, 35% of the patient has high cervical cord spine injuries, while 9.5% had multiple levels of injury. Furthermore, 5.7%

Table 1
Basic demographics of the study population.

Variable	Late Tracheostomy (859)	Early Tracheostomy (280)	*P-value*
Age, years, mean ± SD	49.4 ± 11	42.3 ± 13	0.79
Male, (%)	76%	73%	0.30
White, (%)	74%	69%	0.10
Vital Parameters			
ED SBP, mm of Hg, mean ± SD	108 ± 23	105 ± 26	0.06
ED HR, bpm, mean ± SD	88 ± 14	91 ± 13	0.002
ED GCS, median [IQR]	14 [13–15]	14 [12–15]	0.76
ED O2 Sat, %, mean ± SD	91 ± 8	92 ± 6	0.09
Injury Parameters, median [IQR]			
Cervical-Spine AIS	4 [3–5]	4 [4–5]	0.09
Thorax AIS	1 [1–2]	1 [1–2]	0.88
Neck AIS	0 [0-0]	0 [0-0]	0.98
Face AIS	0 [0–1]	0 [0–1]	0.99
ISS	17 [11–28]	19 [15–29]	0.04
Mechanism of injury, %			
Fall from height	32%	34%	0.55
Fall from standing	19%	18%	
MVC	29%	31%	
Others	20%	17%	
Intubated on arrival or in ED, %	9%	16%	<0.001

SD: Standard Deviation, ED: Emergency Department, SBP: Systolic Blood Pressure, HR: Heart Rate, GCS: Glasgow Coma Scale, O2; Oxygen, Sat; Saturation, AIS: Abbreviated Injury Scale Score, ISS; Injury Severity Scale Score, MVC: Motor Vehicle Collision.

Table 2
Cervical Spine Injury Characteristics of the study population.

Variable	Late Tracheostomy (859)	Early Tracheostomy (280)	*P-value*
C-Spine Injury Level, (%)			
High (C1–C4)	33%	41%	0.01
Low (C5–C7)	58%	48%	
Multiple level	9%	11%	
Anterior Cord Syndrome, %	5%	8%	0.07
Central cord syndrome, %	9%	13%	0.06
Complete cord injury, %	19%	25%	0.03
Operative Fixation of spine, %			
Anterior	12.6%	11.5%	0.67
Posterior	11.3%	9.7%	
Both	9.7%	7.8%	
Time to fixation, days, median [IQR]	3 [2–5]	2 [2–4]	0.11

IQR: Interquartile range.

of patients had anterior cord syndrome, 10% had central cord syndrome, and 20.4% had complete cord injury. One-third of patients underwent spine fixation with most common approach being anterior fixation (12.3%). The median time to tracheostomy after instrumentation was 4 days [3-11]. Table 2. Demonstrates the basic characteristics of c spine injuries. The patient who underwent early tracheostomy were more likely to have high level of C spine injury ($p = 0.01$), and complete cord injury ($p = 0.03$). There was no difference in anterior ($p = 0.07$) and central cord syndrome ($p = 0.06$) as well as operative fixation rates ($p = 0.67$).

The overall complication rate was 23.7% and the mortality rate was 5.3%. The most common complication was ventilator-associated pneumonia which was 14% followed by unplanned intubation (9.5%). Table 3 Demonstrates the outcomes of the study. Patients who received early tracheostomy had lower rates of overall complications ($p = 0.01$) and ventilator-associated pneumonia ($p < 0.01$)

Table 3
Outcomes of the study.

Outcomes	Late Tracheostomy (859)	Early Tracheostomy (280)	*p-value*
Overall Complications, %	25.6%	18.1%	0.01
AKI	7.3%	5.2%	0.27
ARDS	10.7%	7.3%	0.12
DVT	5.9%	4.3%	0.36
PE	2.7%	1.7%	0.50
Unplanned intubation	10.1%	7.8%	0.38
Severe sepsis	4.9%	2.4%	0.09
VAP	16.1%	9.5%	<0.01
LOS, days, median [IQR]	28 [22–38]	18 [13–25]	<0.001
ICU days, day, median [IQR]	23 [16–30]	14 [8–23]	<0.001
Ventilator days, days, median [IQR]	19.5 [12–25]	15 [4–21]	<0.001
Mortality, %	5.7%	4.3%	0.44

AKI: Acute Kidney Injury, ARDS: Acute Respiratory Distress Syndrome, DVT: Deep Venous Thrombosis, PE: Pulmonary Embolism, VAP: Ventilator associated pneumonia, LOS: Length of stay, ICU: Intensive Care Unit, IQR: Interquartile range.

Table 4
Multivariate Regression analysis.

Outcomes	OR	95% CI	*p-value*
Overall Complications	0.57	0.33–0.87	<0.001
VAP	0.61	0.42–0.83	<0.001
In-Hospital Mortality	0.91	0.75–1.34	0.35

OR: Odds Ratio, VAP: Ventilator Associated Pneumonia.

compared to those who received late tracheostomy. Moreover, they had lower ventilator days ($p < 0.001$), hospital ($p < 0.001$) and ICU ($p < 0.001$) LOS. There was no difference in all-cause mortality rate ($p = 0.44$). Table 4. Demonstrates multivariate regression analysis for outcomes. After controlling for race, ED SBP, O2 saturations, C-Spine AIS, ISS, intubation status, level of C-spine injury, cord syndrome, and time to operative fixation, patients who received early tracheostomy was associated with a lower rate of complications (OR: 0.57) and ventilator-associated pneumonia (OR: 0.61).

Sub analysis was performed based on the level of c-spine injury. Of 1139, patients 398 (35%) patients had a high level of injury involving C1–C4 spine, while 632 (55.5) patients had low level of injury involving C5–C7. When patients with high levels of C-spine injury were analyzed, early tracheostomy was associated with lower overall complications ($p = 0.01$) and ventilator-associated pneumonia ($p = 0.04$) compared to late tracheostomy. Similarly, in patients with low levels of c spine injury, early tracheostomy was associated with lower rates of overall complications ($p = 0.03$) and ventilator-associated pneumonia ($p = 0.02$) compared to late tracheostomy. However, there was no difference in mortality rate in either group in both subgroups (Table 5).

Discussion

The purpose of our study was to determine whether early tracheostomy (within 7 days of injury) amongst patients sustaining a blunt injury to the cervical spinal cord conferred a benefit. The results of our study suggest early tracheostomy is associated with lower rates of overall complications and in particular ventilator-associated pneumonia in patients with C-spine injury and without traumatic brain injury. This association was not significant for mortality. Furthermore, early tracheostomy was associated with a reduction in hospital and ICU length of stay as well as ventilator days. Our results were obtained after controlling for confounding factors including demographics, injury parameters, admission vitals, and operative fixation.

One in every fifth trauma patient with cervical spinal cord injury requires prolonged mechanical ventilation.[6] Complications associated with mechanical ventilation have been well studied. Ventilator-associated pneumonia is one of the most serious complications associated with prolonged mechanical ventilation, which can further increase morbidity and mortality. In the past couple of decades, early tracheostomy has been introduced as an alternative to prolonged endotracheal intubation. Tracheostomy itself reduces patient discomfort, airway trauma or pressure ulcers, management of secretions and facilitates weaning from mechanical ventilation.[12]

The utilization of early tracheostomy has been studied extensively in critically ill non-trauma patients. In a recent Cochrane systematic review and meta-analysis, Andriolo et al. demonstrated the survival benefit of early tracheostomy within 10 days in 1977 critically ill patients.[13] However, this study did not demonstrate an effect of early tracheostomy in lowering ventilator-associated pneumonia. In contrast, Adly et al. in a meta-analysis of 222,501 adult patients and 140 pediatric patients demonstrated a benefit early tracheostomy in reducing the incidence of ventilator-associated pneumonia, as well as mortality and ICU length of stay.[14] In the trauma patient population, recommendations regarding early tracheostomy have been more conclusive for some patients such as head trauma as these patients are often unable to protect their airway. The Eastern Association for the Surgery of Trauma (EAST) guidelines recommends early tracheostomy in patients with traumatic brain injury (Level II evidence).[15] Furthermore, EAST guidelines also recommend early tracheostomy in all critically ill trauma patients without head trauma (Level III evidence). Patient with C-spine injuries represents a group of high risk of patients that are unable to sneeze or cough and can exhaust their diaphragm muscle and may need prolonged mechanical ventilation. In thus study, we excluded patients with traumatic brain injury in order to further define the specific potential benefit of early tracheostomy in the specific patient population studied.

In our analysis one in every four patients who underwent tracheostomy, did so within 7 days (early). Patients who received early tracheostomy did have a selection bias in that these patients had a higher level of c-spine injury and were more likely to be intubated in scene or in ED. This can potentially explain the preferential use of early utilization of tracheostomy during hospital course for these patients. Previous literature regarding tracheostomy in cervical spine injury included patients with concomitant thoracic injury in over 30% of the patients. As such, we have tried to minimize the implicit bias by excluding patients with major thoracic injury which can further increase the incidence of pneumonia and ARDS.[9] In our unadjusted analysis, early tracheostomy within 7 days was associated with lower rates of overall complications and ventilator-associated pneumonia. The results were replicated in a regression analysis after controlling for race, ED SBP, O2 saturations, C-Spine AIS, ISS, intubation status, level of C-spine injury, cord syndrome, and time to operative fixation, Moreover, there was a trend towards lower rates of ARDS, thromboembolic events, and sepsis. Similar to our reports, Adly et al. also demonstrated that early tracheostomy was associated with reduction in pneumonia rates.[14] In contrast, Flanagan et al. failed to demonstrate any statistical difference in pneumonia rates in either group; however in that study, there was a trend towards lower rates of pneumonia in the early tracheostomy group.[9] This can potentially be attributed to low sample size. Furthermore, they reported that only significant predictor of

Table 5
Sub-analysis based on level of injury.

High C-spine injury (C1–C4)	Late Tracheostomy (283)	Early Tracheostomy (115)	*p-value*
Overall Complications, %	26.8%	18.2%	0.01
VAP	16.9%	9.5%	0.04
Mortality, %	4.9%	4.3%	096
Low C-spine injury (C5–C7)	**Late Tracheostomy (498)**	**Early Tracheostomy (134)**	***p-value***
Overall Complications, %	25.3%	16.4%	0.03
VAP	17%	8.9%	0.02
Mortality, %	5.4%	4.5%	0.82

VAP: Ventilator associated pneumonia.

pneumonia was chest trauma. Similarly, Romero et al. only reported reduction in laryngotracheal complications and not in pneumonia rates with early tracheostomy.[10] In our sub analysis of patients based on the level of c-spine injury, early tracheostomy was associated with lower rates of overall complications and ventilator associated pneumonia in both high or low cervical spine injury. Guirgis et al. reported similar findings; however they defined high level injury as C1–C2 and low C spine injury as C3–C7.[16] In our analysis, there was no difference in mortality rate between the two group. In contrast to our results, Guirgis et al. reported a higher mortality rate associated with early tracheostomy in patients with high c spine injury. Most of the studies have demonstrated the beneficial aspect of early tracheostomy in either critically ill trauma patients, or polytrauma or with associated traumatic brain injury.[17,18] In our analysis, we excluded patients with head trauma, major chest injury or facial fractures in order to reduce the bias. Multiple studies have attributed the beneficial aspect of early tracheostomy to improved pulmonary mechanics which can assist with ventilator weaning and pulmonary hygiene leading in turn to a reduction in ventilator associated pneumonia[19].

Improving health care quality, resource utilization and cost has been the focus of many studies and initiatives in the setting of trauma. One method to accomplish these goals is the reduction of hospital and ICU length of stay. Prolonged hospitalization may result in a significant increase in avoidable morbidity and an indirectly financial burden.[20] In our analysis, early tracheostomy is associated with shortened ventilator days, ICU and hospital length of stay. Similarly, Flanagan et al., and Romero et al. in their single-center retrospective analysis reported shortened ventilator days and ICU length of stay.[9,10] Flanagan et al. also analyzed the impact of early tracheostomy on in-hospital and 90-day mortality.[9] He could not demonstrate any difference in mortality rate between the two groups. Similarly, in our analysis, there was no difference in mortality between the two groups either. This finding was replicated by Romero et al. as well.[10]

Limitations and future research

The retrospective nature of our study is responsible for certain limitations. The TQIP database does not capture all trauma patients across the country. We were not able to control for additional confounding factors including, but not limited to, scoring of patients based on the American Spinal Injury Association Impairment (ASIA) scale and assessment of patients based upon improvement in neurological function. We could also not identify the hospital day on which the ventilator-associated pneumonia was diagnosed, and neither could we determine if patients received diaphragm pacemakers. Despite these limitations, our study has significant strength because of the nature of the database in representing the adult trauma population in the United States, and its strength of interrater reliability of data. Furthermore, our methodology allowed for minimizing the confounding effects of concomitant traumatic injuries, allowing for study of a specific patient population with a sufficiently large sample size. This study can be used to spur future prospective clinical trials to provide a stronger evidence-based recommendation for early tracheostomy in cervical spinal cord injury patients.

Conclusions

Early tracheostomy in patients with C-spine injuries was associated with a shorter duration of mechanical ventilation, intensive care unit stay, and hospital length of stay without any effect on mortality. Furthermore, patients had lower rates of overall complications in the early tracheostomy group. Early tracheostomy can be utilized to reduce morbidity and maximize resource utilization in this group of patients. Further prospective randomized controlled trials are required to delineate the appropriate timing of tracheostomy in patients with cervical spinal cord injuries.

Authors Contributions

M.K, K.P, F.J, G.L, J.C, A.P, P.R, and R.L participated in the design of this study.

M.K, K.P, J.C, A.P, G.L, P.R, F.J and R.L searched the literature.

M.K, K.P, J.C, A.P, G.L, and R.L collected the data.

M.K, K.P, J.C, A.P, G.L, and F.J analyzed the data.

All authors participated in data interpretation and manuscript preparation.

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Declaration of Competing interest

There are no identifiable conflicts of interest to report.

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