Timing of tracheostomy placement among children with severe traumatic brain injury: A propensity-matched analysis

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BACKGROUND: Early tracheostomy has been associated with shorter hospital stay and fewer complications in adult trauma patients. Guidelines for tracheostomy have not been established for children with severe traumatic brain injury (TBI). The purpose of this study was to (1) define nationwide trends in time to extubation and time to tracheostomy and (2) determine if early tracheostomy is associated with decreased length of stay and fewer complications in children with severe TBI.

METHODS: Records of children (<15 years) with severe TBI (head Abbreviated Injury Severity [AIS] score ≥3) who were mechanically ventilated (>48 hours) were obtained from the National Trauma Data Bank (2007–2015). Outcomes after early (≤14 days) and late (≥15 days) tracheostomy placement were compared using 1:1 propensity score matching to control for potential confounding by indication. Propensity scores were calculated based on age, race, pulse, blood pressure, Glasgow Coma Scale motor score, injury mechanism, associated injury Abbreviated Injury Severity scores, TBI subtype, craniotomy, and intracranial pressure monitor placement.

RESULTS: Among 6,101 children with severe TBI, 5,740 (94%) were extubated or died without tracheostomy, 95% of the time within 18 days. Tracheostomy was performed in 361 children (6%) at a median [interquartile range] of 15 [10, 22] days. Using propensity score matching, we compared 121 matched pairs with early or late tracheostomy. Early tracheostomy was associated with fewer ventilator days (14 [9, 19] vs. 25 [19, 35]), intensive care unit days (19 [14, 25] vs. 31 [24, 43]), and hospital days (26 [19, 41] vs. 39 [31, 54], all $p < 0.05$). Pneumonia (24% vs. 41%), venous thromboembolism (3% vs. 13%), and decubitus ulcer (4% vs. 13%) occurred less frequently with early tracheostomy ($p < 0.05$).

CONCLUSIONS: Early tracheostomy is associated with shorter hospital stay and fewer complications among children with severe TBI. Extubation without tracheostomy is rare beyond 18 days after injury. (*J Trauma Acute Care Surg.* 2019;87: 818–826. Copyright © 2019 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Prognostic and epidemiological, retrospective comparative study, level III.

KEY WORDS: Pediatric; timing; tracheostomy; traumatic brain injury.

Tracheostomy may be required for injured patients requiring prolonged mechanical ventilation or those with a severe neurologic injury associated with an impaired ability to maintain airway patency. Earlier timing of tracheostomy has been associated with decreased ventilator days, hospital length of stay, intensive care unit (ICU) length of stay, and lower mortality in both adults and children.[1–8] The decision to proceed with tracheostomy must be balanced against the known risks of the procedure, tracheostomy-related complications, and the likelihood of successful extubation without tracheostomy. Although procedure-related mortality is less than 1%, all-cause mortality has been estimated at 22% in adults and 17% in children who undergo a tracheostomy.[9,10] Two-year tracheostomy-related complications have been reported as high as 39% in children.[11]

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Children with severe traumatic brain injury (TBI) are at high risk for requiring tracheostomy, but tracheostomy is less commonly performed for injured children than for adults.[9,12] The decision to proceed with tracheostomy in children with severe TBI presents a challenge, and consensus indications to proceed with tracheostomy in this population have not been established. Barriers to developing guidelines for tracheostomy indication and timing in the pediatric severe TBI population include (1) the unknown natural history of ventilator dependency and time to extubation and (2) poorly defined national trends in the frequency and timing of tracheostomy in these children. While previous data from mixed pediatric ICU cohorts suggest that early tracheostomy is associated with fewer ventilator days, hospital days, and frequency of complications,[1,5–7] the generalizability of these findings specifically to the pediatric severe TBI population is unclear. The purpose of this study was to (1) define nationwide trends in time to extubation and time to tracheostomy and (2) determine if early tracheostomy is associated with decreased length of stay and fewer complications in children with severe TBI.

METHODS

Cohort and Confounding Covariate Definitions

We examined a retrospective cohort of children (<15 years) obtained from the National Trauma Data Bank Research Dataset (NTDB, 2007–2015). Patients were included if they had a severe TBI (head Abbreviated Injury Severity [AIS] score ≥3) and received mechanical ventilation for more than 48 hours. To reduce potential confounding by indication for tracheostomy, we excluded patients with severe injuries (AIS ≥3) to the face, neck, or chest. Patients were also excluded who were injured by drowning, hanging, burn, or military-related injury to compare a more homogeneous cohort. Human subjects approval was obtained from Children's Hospital of Los Angeles Institutional Review Board.

Demographic and clinical variables of interest were defined a priori and included age, gender, race, ethnicity, injury mechanism, transfer status, initial Glasgow Coma Scale (GCS) motor score, initial bradycardia, initial tachycardia, initial hypotension, AIS post dot severity scores (abdomen, spine, lower extremity, upper extremity, and external), TBI subtype[2] (epidural hematoma, subdural hematoma, cerebral vascular injury, intracerebral [parenchymal] lesion, compressed/absent basal cisterns, brainstem/cerebellar lesion, diffuse axonal injury, subarachnoid hemorrhage, subpial or other extra-axial hemorrhage, infarction or hypoxic/ischemic injury, intraventricular hemorrhage, and penetrating brain injury), craniotomy, and intracranial pressure (ICP) monitor placement (defined by *International Classification of Diseases, Ninth Revision* [*ICD-9*] procedure codes). Systolic blood pressure and heart rate were adjusted for age by using Pediatric Advanced Life Support normative threshold values to define dichotomous variables to indicate hypotension, tachycardia, and bradycardia.[13] Age was categorized into the pediatric strata defined by the Centers for Disease Control and Prevention[14]: less than 1 year, 1 to 4 years, 5 to 9 years, and 10 to 14 years. Abbreviated Injury Severity scores were dichotomized into severe (≥3) and not severe (<3). If a severity score was not reported for an AIS category, we assumed that no injury in body region occurred and categorized severity as "not severe." Race was categorized as white, African American, or other. Injury mechanism was determined using *ICD-9* external cause codes ("E codes"), and they were not treated as mutually exclusive (allowing a patient to have more than one mechanism). The type of TBI was determined using diagnostic coding (AIS and *ICD-9* codes, Supplemental Digital Content 1, Appendix 1, http://links.lww.com/TA/B304). Patients receiving tracheostomy were identified by *ICD-9* procedure codes.

Tracheostomy Timing

Time of tracheostomy was determined by the number of days or number of hours to procedure ("daytopro" or "hourtopro" variables), using the earliest time if multiple times were reported. We planned to divide the cohort equally around the median time to tracheostomy to maximize statistical power and external validity. An exploratory analysis was performed to determine the median time to tracheostomy in the overall cohort. We also performed an exploratory analysis of the natural history of timing of successful extubation (ventilator days of children not requiring tracheostomy) as a surrogate for avoiding "unnecessary" early tracheostomy in children that would otherwise liberate from the ventilator without a tracheostomy prior to discharge. Patients were then dichotomized into early (≤14 days) or late (≥15 days) cohorts around the median time point for the cohort. Patients with missing tracheostomy procedure times were excluded from this portion of the analysis.

Outcome Variables

The primary outcome variable for this study was hospital length of stay. Secondary outcomes included the number of ventilator days, number of ICU days, need for gastrostomy tube placement and hospital days before placement, complications (blood stream infection, urinary tract infection, pneumonia, sepsis, venous thromboembolism, acute respiratory distress syndrome, acute kidney injury, and decubitus ulcer), mortality, discharge to home, and ventilator dependency at discharge. Complication reporting guidelines are outlined in the publicly available NTDB data dictionary.[15] Due to known bias in complication reporting in the NTDB,[16] we categorized patients as "missing" for complication data if they were treated at a hospital that did not report any complications. Patients were categorized as ventilator-dependent at discharge if they had an equal number of reported hospital days, ICU days, and ventilator days.

Statistical Analysis

Frequency counts and percentages were obtained for categorical variables. Median and interquartile ranges (IQRs) were calculated for continuous data that were not normally distributed. A χ^2 or Fisher exact test (for expected counts <5) was used to test association between categorical variables. The Wilcoxon-Mann-Whitney test was used for continuous, nonparametric data.

Because of missing physiologic data in the NTDB, we used multiple imputation for managing missing data for systolic blood pressure, pulse, and GCS motor score. The multiple imputation model included age, gender, race, transfer status, severe AIS (spine, abdomen, lower extremity, and upper extremity), and injury mechanism (fall, firearm, motor vehicle traffic motorcyclist, motor vehicle traffic occupant, pedestrian, struck, and other mechanism) by vital interactions. Five imputed data sets were produced, and the median of the five imputed values for each variable was later used for propensity score calculation and matching.

The absolute standardized difference was used to assess balance in demographic and clinical data among early and late tracheostomy groups.[17] Propensity score matching without replacement was used to account for potential treatment bias. Logistic regression was used to estimate a propensity score for early tracheostomy exposure. Independent variables in the model included age, race, penetrating mechanism, nonaccidental trauma, bradycardia, tachycardia, hypotension, GCS motor score, AIS post dot score ≥3 (spine, abdomen, lower extremity, and upper extremity), TBI subtype, craniotomy, and ICP monitor placement. Patients were caliper matched with a bandwidth of 0.2 times the SD of the logit propensity score distribution. A 1-to-1 matching technique was used for the early versus late tracheostomy exposure subset.[18] Covariate balance after matching was assessed by calculating the absolute difference of the means or proportion of the covariates divided by the standard error. For continuous variables that were skewed, the absolute difference of the mean rankings was used. A standardized difference cutoff of less than 0.1 was considered sufficient balance.[19] A generalized estimating equation for logistic regression was used for binary outcomes and complications, and negative binomial for count data to account for overdispersion. An unstructured correlation structure was used to account for matched data. The rate ratio (RR) and the 95% confidence interval (CI) was estimated assuming a negative binomial distribution for days to tracheostomy, ventilator days, hospital length of stay, ICU length of stay, and days to gastrostomy.

A sensitivity analysis was performed to determine if patients without AIS scores were statistically different from those with reported AIS scores of less than 3 ("not severe") in the same injury category. We found no statistically significant difference for AIS categories of abdomen, spine, lower extremity, and upper extremity. We therefore combined patients without AIS scores and with AIS of less than 3 into "not severe" for these aforementioned injury categories. For variables with standardized difference of greater than 0.1, McNemar test was used to compare early and late tracheostomy cohorts. A sensitivity analysis was performed to determine if further adjusting for these variables affected the association between tracheostomy timing and outcomes or complications. A propensity score weight (inverse probability of treatment weights) was also performed to determine the association between the exposure groups and outcomes. Results were compared with the propensity score–matched results for consistency. All significance tests were two-tailed, with $\alpha = 0.05$. All analyses were performed using SAS software version 9.4 (SAS Institute Inc, Cary, NC).

RESULTS

The overall cohort of children with severe TBI requiring more than 48 hours of mechanical ventilation included 6,101 patients, of which 361 (5.9%) underwent tracheostomy (Fig. 1). Extubation or death occurred by 18 days in 95% of children not undergoing tracheostomy (Fig. 2). Tracheostomy was performed at a median (IQR) of 15 (10, 22) days, with 43% before 14 days and 28% after 20 days in (Fig. 3). Infants (<1 year) had the longest time to tracheostomy (19 [13, 30] days, Fig. 4). Patients who underwent tracheostomy were older, more frequently were injured by a penetrating mechanism, were hypotensive, and had a lower GCS motor score at presentation (Supplemental Digital Content 2, Table 1, http://links.lww.com/TA/B305). Tracheostomy was also associated with more frequent severe spine injury, severe upper extremity injury, and brainstem or cerebellar lesion.

Unadjusted comparisons between early (n = 168) and late (n = 190) tracheostomy cohorts revealed several statistically significant differences (Table 1). The early tracheostomy group had a higher frequency of older (10–14 years) patients, higher frequency of penetrating mechanism, lower frequency of nonaccidental trauma, lower frequency of ICP monitor placement, and lower frequency of compressed or absent basal cisterns.

Propensity score matching resulted in 121 matched pairs with early and late tracheostomy. All standardized differences were reduced to less than 0.1 after matching except for age, craniotomy, and severe lower extremity injury (Supplemental Digital Content 3, Table 2, http://links.lww.com/TA/B306). Early tracheostomy was associated with fewer ventilator days (RR [95% CI], 0.55 [0.46–0.65]), a shorter ICU length of stay (0.77 [0.63–0.93]), a shorter hospital length of stay (0.62 [0.53–0.72]), less frequent gastrostomy placement (odds ratio [OR], 0.55 [0.31–0.97]), and shorter time to gastrostomy placement (RR, 0.33 [0.26–0.43], Table 2). Early tracheostomy was also associated with less frequent pneumonia (OR, 0.44 [0.26–0.76]), venous thromboembolism (0.20 [0.07–0.57]), and decubitus ulcer (0.25 [0.08–0.80]). No significant differences in mortality (1.26 [0.46–3.49]) or ventilator dependency at discharge (0.64 [0.25–1.64]) were observed, but early tracheostomy was associated with higher odds of discharge to home (2.42 (1.28–4.60). All statistically significant

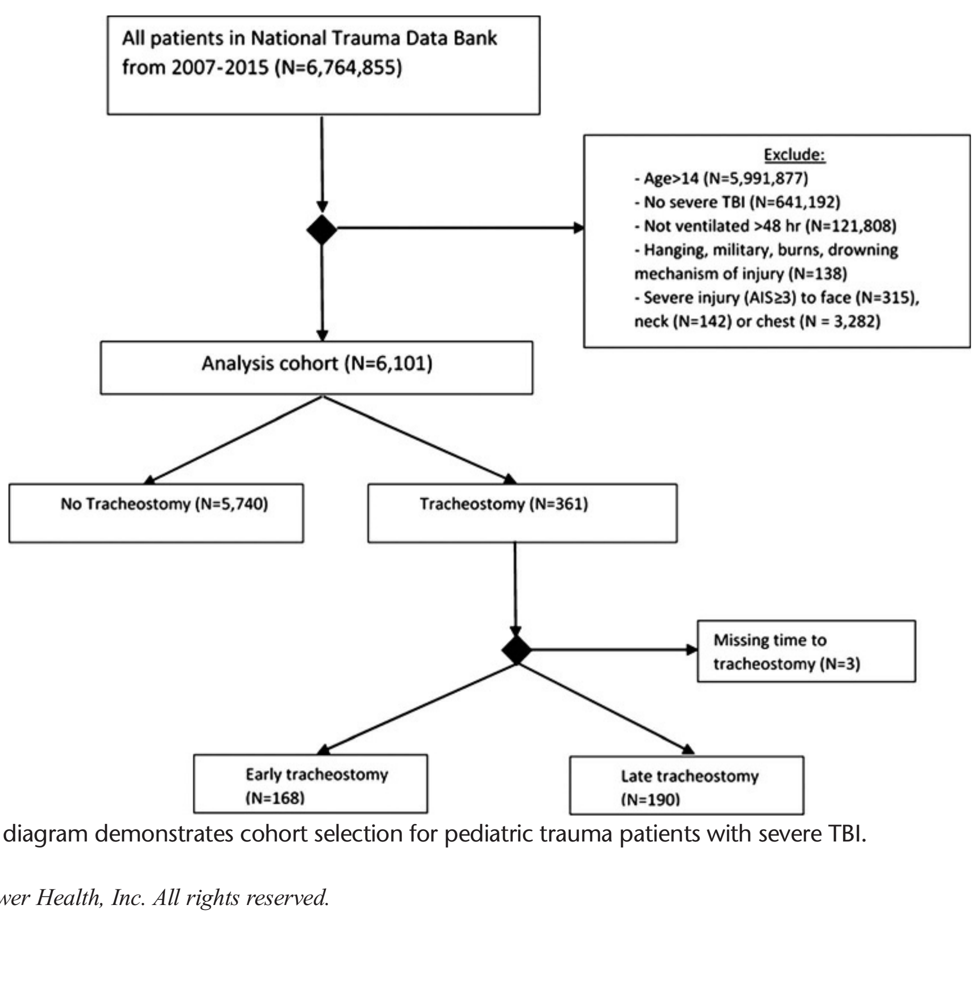

Figure 1. STROBE diagram demonstrates cohort selection for pediatric trauma patients with severe TBI.

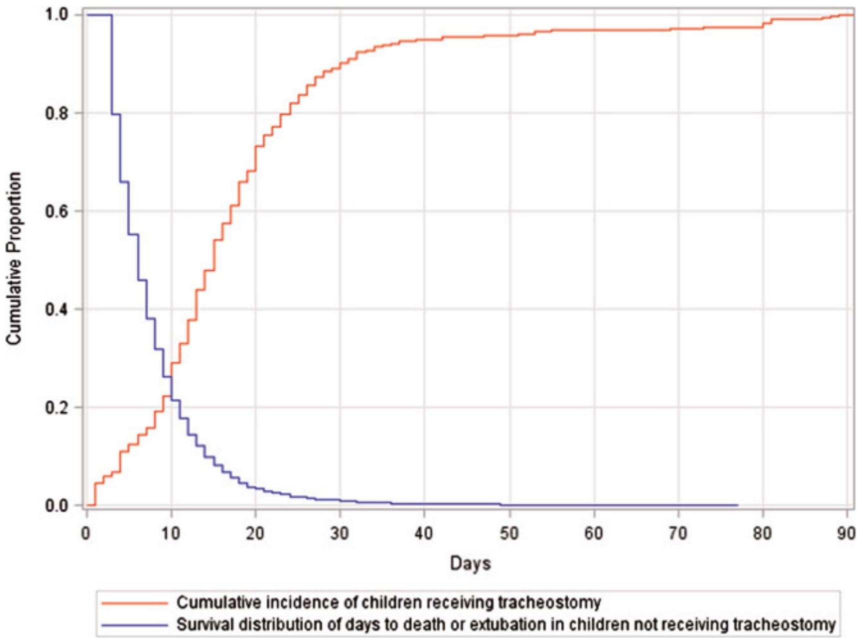

Figure 2. Comparison of time to extubation versus time to tracheostomy among children with severe TBI who required more than 2 days of mechanical ventilation.

associations were similar after adjusting for unbalanced covariates (data not shown).

A descriptive analysis of patients unable to be matched using propensity scores is shown in Supplemental Digital Content 4, Table 3, http://links.lww.com/TA/B307. Unmatched infants with abusive head trauma were more likely to undergo late tracheostomy, whereas adolescents with penetrating mechanism were more likely to undergo early tracheostomy. Unmatched patients in the late tracheostomy group more frequently had associated severe abdominal and spine injures, more frequent hypotension, lower GCS, more frequent ICP monitor placement, and more anatomic TBI diagnoses.

DISCUSSION

This retrospective, propensity-matched cohort study of tracheostomy timing in children with severe TBI showed several important findings. Ninety-five percent of patients not receiving a tracheostomy either died or were extubated within 18 days. A tracheostomy was performed at a median of 15 days, but 28% of

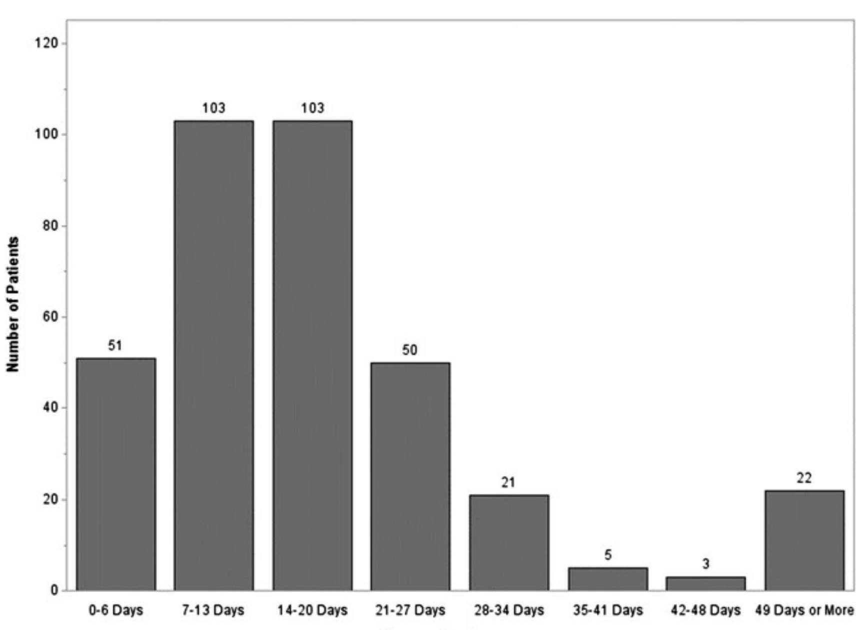

Figure 3. Timing of tracheostomy for children with severe TBI.

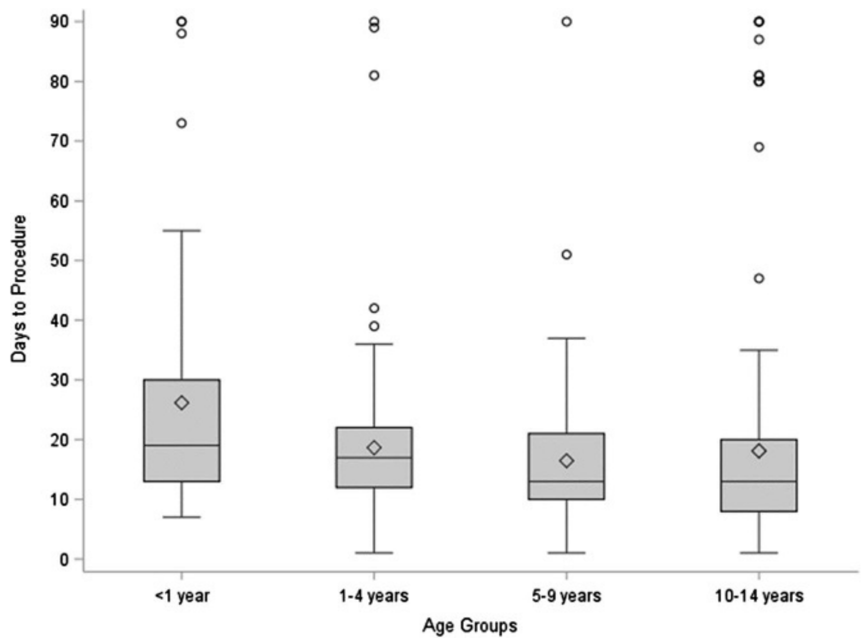

Figure 4. Timing of tracheostomy by age strata for children with severe TBI. $p < 0.01$ comparing all age groups using Kruskal-Wallis test.

tracheostomy placements were after 20 days—identifying a potential opportunity to improve care and outcomes with earlier tracheostomy. While tracheostomy within 14 days was not associated with lower mortality, it was associated with fewer ventilator days, shorter ICU length of stay, shorter hospital length of stay, fewer gastrostomy placements, a lower incidence of complications, and higher frequency of discharge to home. These findings suggest that optimal care of children with severe TBI may include (1) early identification of those children who will require tracheostomy and (2) early discussion with families about tracheostomy to allow for early timing of surgery.

Pediatric patients with severe TBI who require prolonged mechanical ventilation pose a management dilemma. The decision to place a tracheostomy requires estimating several variables, including short- and long-term recovery potential, discharge disposition, and likelihood that a child will be ventilator dependent. The appropriate time to initiate discussions with families about the need for tracheostomy is debatable. Our data showed that about 80% of extubation or mortality occurred by 10 days, and 95% by 18 days without tracheostomy. These findings are useful for counseling families about the likelihood of successful extubation and the potential need for tracheostomy.

Our study provides important epidemiologic data related to timing of extubation in children with severe TBI and insight into national practice patterns and outcomes related to tracheostomy timing in pediatric trauma patients. The associations we found between early tracheostomy and lower ventilator days, ICU days, and hospital days are consistent with previous pediatric studies[1,5–7] and with a similar analysis performed in adult TBI patients.[2] Our study also showed associations between early tracheostomy and lower rates of pneumonia, venous thromboembolism, and decubitus ulcer in a pediatric population. Earlier timing of tracheostomy may allow for earlier reduction or cessation of sedative medications, earlier ambulation, improved oral hygiene, and pulmonary toilet. These factors may account for the observed lower frequency of complications.

The main strength of this study was the use of a propensity-matched analysis that allowed for a balanced comparison of early versus late tracheostomy cohorts. This technique may most closely approximate a randomized study when using retrospective data. Sample size was also relatively large in our study, which limited potential type II error. We urge caution in the application of these results to populations that were largely unmatched in our analysis. Infants with abusive head trauma were often unmatched in this cohort and frequently underwent late tracheostomy. We suspect this relates to ongoing discussions of tracheostomy versus compassionate extubation and initiation of comfort care measures. We recognize this ethical dilemma and would not emphasize early tracheostomy in infants with abusive head trauma. Furthermore, adolescents with penetrating injuries were not well matched in our analysis and more frequently underwent early tracheostomy. These patients may more closely resemble the adult population in which tracheostomy within 8 days is preferred.[2] Finally, there were a number of unmatched late tracheostomy patients who presented with polytrauma (abdomen and spine injuries), hypotension, more anatomic brain lesions, and more frequent ICP monitor placements. We suspect these children were frequently deemed too unstable for early tracheostomy and thus represent a population distinctly different from the analysis cohort we report here.

Our results should still be interpreted with consideration of key limitations. First, our findings are limited by a retrospective design. While our propensity-matched analysis improved internal validity by addressing potential confounding by indication, there is always risk for unmeasured confounding with retrospective data. Second, our definitions of early versus late tracheostomy were later than those used in previous studies.[1–4] These definitions were based on two main considerations: (1) our exploratory analysis demonstrated that many

TABLE 1. Unadjusted and Propensity-Matched Comparison of Early (≤14 Days) Versus Late (15+ Days) Tracheostomy in Pediatric (<15 Years) Patients With Severe Traumatic Brain Injury

			Unadjusted		Propensity Matched*
Characteristics	**Early Tracheostomy (n = 168)**	**Late Tracheostomy (n = 190)**	***p***	**Standardized Difference**	**Standardized Difference**
	n (%)	**n (%)**			
Age			<0.01	0.47	0.17
<1 y	17 (10.1)	38 (20.0)			
1–4 y	38 (22.6)	67 (35.3)			
5–9 y	35 (20.8)	29 (15.3)			
10–14 y	78 (46.4)	56 (29.5)			
Gender			0.55	—	—
Male	59 (35.3)	73 (38.4)			
Female	108 (64.7)	117 (61.6)			
Mechanism**					
Blunt	119 (70.8)	133 (70.0)	0.86	—	—
Penetrating	19 (11.3)	8 (4.2)	0.01	0.27	0.03
Nonaccidental trauma	20 (11.9)	42 (22.1)	0.01	0.27	0.07
Other	24 (14.3)	26 (13.7)	0.87	—	—
Race			0.05	0.27	0.04
Black or African American	33 (21.3)	41 (22.8)			
White	100 (64.5)	96 (53.3)			
Other	22 (14.2)	43 (23.9)			
Ethnicity			0.59	—	—
Hispanic or Latino	28 (16.7)	38 (20.0)			
Not Hispanic or Latino	90 (53.6)	103 (54.2)			
Ethnicity not specified	50 (29.8)	49 (25.8)			
Transfer	83 (49.4)	87 (46.0)	0.52	—	—
ED hypotension	10 (6.4)	22 (12.7)	0.05	0.22	0.06
ED tachycardia	65 (40.4)	65 (36.9)	0.52	0.07	0.03
ED bradycardia	20 (12.4)	24 (13.6)	0.74	0.04	0.05
	Median (IQR)	**Median (IQR)**			
ED GCS motor	1 (1, 4)	1 (1, 3)	0.41	0.09	0.05
	n (%)	**n (%)**			
Severe AIS score (≥3)**					
Abdomen	7 (4.2)	10 (5.3)	0.63	0.05	0.04
Spine	19 (11.3)	31 (16.3)	0.17	0.15	0.08
Lower extremity	6 (3.6)	1 (0.5)	0.05	0.22	0.13
Upper extremity	17 (10.1)	26 (13.7)	0.30	0.11	0.05
External	0 (0)	0 (0)	—	—	—
Type of TBI**					
Epidural hematoma	13 (7.7)	20 (10.5)	0.36	0.10	0.03
Subdural hematoma	96 (57.1)	124 (65.3)	0.12	0.17	0.09
Cerebral vascular injury	3 (1.8)	7 (3.7)	0.35	0.12	0.07
Intracerebral (parenchymal) lesion	59 (35.1)	61 (32.1)	0.55	0.06	0.02
Compressed/absent basal cisterns	16 (9.5)	39 (20.5)	<0.01	0.31	0.02
Brainstem/cerebellar lesion	22 (13.1)	37 (19.5)	0.10	0.17	0.10
Diffuse axonal injury NFS	18 (10.7)	27 (14.2)	0.32	0.11	0.03
Subarachnoid hemorrhage	51 (30.4)	73 (38.4)	0.11	0.17	0.03
Subpial or other extra-axial hemorrhage	53 (31.6)	70 (36.8)	0.29	0.11	<0.01
Infarction or hypoxic/ischemic injury	8 (4.8)	7 (3.7)	0.61	—	—
Intraventricular hemorrhage	15 (8.9)	27 (14.2)	0.12	0.17	<0.01
Penetrating injury not further specified	1 (0.6)	2 (1.1)	1.00	—	—

Continued next page

TABLE 1. *(Continued)*

			Unadjusted		Propensity Matched*
Characteristics	Early Tracheostomy (n = 168)	Late Tracheostomy (n = 190)	*p*	Standardized Difference	Standardized Difference
Craniotomy	86 (51.2)	94 (49.5)	0.75	0.03	0.12
ICP monitor placement	77 (45.8)	109 (57.4)	0.03	0.23	0.07

*n = 121 matched early/late tracheostomy pairs. Independent variables in the propensity score model: age, race, penetrating mechanism, nonaccidental trauma, bradycardia, tachycardia, hypotension, GCS motor, severe AIS (spine, abdomen, lower extremity, and upper extremity), type of TBI, craniotomy, and ICP monitor placement. Missing data: gender (n = 1), race (n = 23), transfer (n = 1), hypotension (n = 28), tachycardia (n = 21), bradycardia (n = 21), GCS motor (n = 27).

**Not mutually exclusive.

ED, emergency department.

children who never receive tracheostomy are extubated between 7 and 14 days (suggesting tracheostomy performed before day 7 may be too aggressive); (2) we aimed to maximize sample size and external validity by defining early versus late timing around the median time to procedure (15 days). Third, this study measured in-hospital outcomes but not long-term outcomes. Long-term ventilator dependence, neurodevelopmental outcomes, time to decannulation, and functional status are among many important outcomes we were unable to asses. We attempted to assess ventilator dependence at discharge, but the use of surrogate markers to define this variable likely resulted in underestimation. Third, complications are subject to reporting bias in the NTDB.[16] Only 13 patients in the matched analysis were treated at centers that never reported complications, suggesting that reporting bias may have had minimal impact. A final limitation is the inability of this study to discriminate association from causation. For example, the decreased frequency of pneumonia associated with early tracheostomy may be related to improved oral care and suctioning after the procedure. It is also plausible that patients with pneumonia had their tracheostomy delayed due to anesthetic risk. The lack of time stamping of complication codes relative to tracheostomy limited our ability to determine causality. We also found that patients were discharged home more frequently after an early tracheostomy. This finding may reflect a benefit from earlier timing of the procedure or a bias to offer tracheostomy earlier to children deemed good candidates for discharge to home without ventilator dependence.

In conclusion, early timing of tracheostomy in children with severe TBI is associated with improved outcomes. Although our study does not resolve the appropriate timing of

TABLE 2. Outcomes in Propensity-Matched Pediatric (<15 Years) Patients With Severe Traumatic Brain Injury, Comparing Early (≤14 Days) Versus Late (15+ Days) Tracheostomy

Outcomes	Early Tracheostomy (n = 121)	Late Tracheostomy (n = 121)	Propensity Matched
	Median (IQR)	**Median (IQR)**	**RR (95% CI)**
Days to tracheostomy	10 (6, 12)	20 (17, 31)	0.29 (0.24–0.35)
Ventilator days	14 (9, 19)	25 (19, 35)	0.55 (0.46–0.65)
ICU length of stay, d	19 (14, 25)	31 (24, 43)	0.77 (0.63–0.93)
Hospital length of stay, d	26 (19, 41)	39 (31, 54)	0.62 (0.53–0.72)
	n (%)	**n (%)**	**OR (95% CI)**
Gastrostomy	78 (64.5)	93 (76.9)	0.55 (0.31–0.97)
	Median (IQR)	**Median (IQR)**	**RR (95% CI)**
Days to gastrostomy	11 (8, 13)	20 (18, 31)	0.33 (0.26–0.43)
	n (%)	**n (%)**	**OR (95% CI)**
Complications			
Bloodstream infection	1 (0.9)	1 (0.9)	1.03 (0.06–6.79)
Urinary tract infection	4 (3.5)	7 (6.0)	0.57 (0.16–2.06)
Sepsis	5 (4.4)	4 (3.5)	1.30 (0.33–5.07)
Pneumonia	27 (23.9)	48 (41.4)	0.44 (0.26–0.76)
Deep vein thrombosis/pulmonary embolism	3 (2.7)	15 (12.9)	0.20 (0.07–0.57)
Acute kidney injury	0 (0)	2 (1.7)	—
Acute respiratory distress syndrome	20 (17.7)	13 (11.2)	1.74 (0.77–3.93)
Decubitus ulcer	4 (3.5)	15 (12.9)	0.25 (0.08–0.80)
Discharge to home	36 (29.8)	18 (14.9)	2.42 (1.28–4.60)
Ventilator dependent at discharge	6 (5.0)	9 (7.6)	0.64 (0.25–1.64)
Mortality	5 (4.1)	4 (3.3)	1.26 (0.46–3.49)

Missing data: ICU length of stay (n = 2), complications (n = 13), and ventilator dependence (n = 2).

tracheostomy, our data suggest that most children will extubate by 3 weeks, and those who are not extubated are likely to require tracheostomy. Early identification of these children at high risk for tracheostomy is needed to optimize airway management in children with severe TBI. We urge caution in applying these conclusions to infants with abusive head trauma, adolescents with penetrating mechanism, and unstable polytrauma patients, as they were not well matched in this study.

AUTHORSHIP

C.M., D.D., D.W.B., A.B., J.U., A.B.N., R.S.B., and A.R.J. designed the study. C.P., C.J.L., and W.J.M. collected and analyzed the data. C.P., C.J.L., W.J.M., C.M., D.D., A.B., and A.R.J. interpreted the data. C.M., D.D., and A.R.J. wrote the manuscript. C.P., C.J.L., W.J.M., A.B., J.U., A.B.N., and R.S.B. critically revised the manuscript. This work was supported by grants KL2TR001854, UL1TR001855, and UL1TR000130 from the National Center for Advancing Translational Science of the US National Institutes of Health. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

DISCLOSURE

The authors declare no conflicts of interest.

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