Neurocrit Care (2019) 30:546–554
https://doi.org/10.1007/s12028-019-00697-5

NEUROCRITICAL CARE SOCIETY

ORIGINAL WORK

Tracheostomy After Severe Acute Brain Injury: Trends and Variability in the USA

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Abstract

Background/Objective: Severe acute brain injury (SABI) is responsible for 12 million deaths annually, prolonged disability in survivors, and substantial resource utilization. Little guidance exists regarding indication or optimal timing of tracheostomy after SABI. Our aims were to determine national trends in tracheostomy utilization among mechanically ventilated patients with SABI in the USA, as well as to examine factors associated with tracheostomy utilization following SABI.

Methods: We conducted a population-based retrospective cohort study using the National Inpatient Sample from 2002 to 2011. We identified adult patients with SABI, defined as a primary diagnosis of stroke, traumatic brain injury or post-cardiac arrest who received mechanical ventilation for greater than 96 h. We analyzed trends in tracheostomy utilization over time and used multilevel mixed-effects logistic regression to analyze factors associated with tracheostomy utilization.

Results: There were 94,082 hospitalizations for SABI during the study period, with 30,455 (32%) resulting in tracheostomy utilization. The proportion of patients with SABI who received a tracheostomy increased during the study period, from 28.0% in 2002 to 32.1% in 2011 ($p < 0.001$). Variation in tracheostomy utilization was noted based on patient and facility characteristics, including higher odds of tracheostomy in large hospitals (OR 1.34, 95% CI 1.18–1.53, $p < 0.001$, compared to small hospitals), teaching hospitals (OR 1.15, 95% CI 1.06–1.25, $p = 0.001$, compared to non-teaching hospitals), and urban hospitals (OR 1.60, 95% CI 1.33–1.92, $p < 0.001$, compared to rural hospitals).

Conclusions: Tracheostomy utilization has increased in the USA among patients with SABI, with wide variation by patient and facility-level factors.

Keywords: Brain injury, Tracheostomy, Respiratory failure

Introduction

Severe acute brain injury (SABI) comprises a distinct group of diseases that render a patient acutely neurologically injured and includes ischemic/hemorrhagic stroke, traumatic brain injury (TBI) and hypoxic ischemic encephalopathy after cardiac arrest. SABI is responsible for 12 million deaths annually, prolonged disability in survivors, and substantial resource utilization [1–4]. Given the severity of initial brain injury and impairment of airway protective reflexes, patients with SABI require intubation and mechanical ventilation for support during their initial critical care. Some patients with SABI experience prolonged neurologic impairment and receive long-term airway support with a tracheostomy. The decision to undergo tracheostomy after SABI is typically made in the setting of significant prognostic uncertainty in order to give patients and surrogates time for a clearer prognosis to emerge ('time-limited trial') [5].

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Tracheostomy after SABI is a procedure that may prolong life, but may not always lead to improved patient- or family-centered outcomes. Additionally, little guidance exists regarding indication or optimal timing of tracheostomy after SABI [6]. It is likely that factors outside of clinical characteristics (such as the patients' culture, religion, ethnicity, socioeconomic status, or characteristics related to the hospital) contribute to tracheostomy utilization in SABI patients, as has been suggested for other treatment decisions and processes of care after SABI, including the use of feeding tubes or the withholding or withdrawing of life-sustaining treatments [7–11]. We aimed to determine national trends in tracheostomy utilization among mechanically ventilated patients with SABI in the USA, as well as to examine factors associated with tracheostomy utilization following SABI.

Methods

Nationwide Inpatient Sample

Our study used data from the United States Agency for Healthcare and Research Quality's Healthcare Cost and Utilization Project's Nationwide Inpatient Sample (NIS). The NIS is a 20% stratified probability sample of all non-federal hospitalizations for acute care in the USA and contains administrative claims data from up to 8 million discharges per year. The NIS data are fully de-identified and does not meet the regulatory definition of human subject research; therefore, our study was exempt from institutional review board approval.

Study Design and Population

We conducted a population-based retrospective cohort study using the NIS data for the years 2002–2011. We identified all adult patients (≥ 18 years) with SABI, which we defined as a primary diagnosis of stroke, TBI or post-cardiac arrest who received mechanical ventilation for greater than 96 h, in order to only include patients who would be "at risk" for receiving a tracheostomy. We identified our population using *International Classification of Disease, Ninth Revision, Clinical Modification* (ICD9-CM) codes for ischemic stroke (ICD9-CM codes 424.X1 and 436), subarachnoid hemorrhage (ICD9-CM code 430), intracerebral hemorrhage (ICD9-CM code 431), TBI (ICD9-CM codes 800, 801, 802, 803, 804, 852.0, 852.1, 852.2, 852.3, 852.4, 852.5, and 854), and cardiac arrest (427.5 and 427.41). We restricted our population to patients who required mechanical ventilation for greater than 96 h using ICD9-CM code 96.72. We identified tracheostomies using ICD9-CM codes 31.1x, 31.2, 31.21, and 31.29. We excluded patients less than 18 years and patients whose admission was classified as "elective." Lastly, to exclude patients who may have received tracheal intubation and mechanical ventilation for reasons other than SABI, we limited the study to patients with a single SABI diagnosis in the first five diagnosis fields.

Exposures, Outcomes, and Covariates

Among patients with an acute care hospitalization for SABI, exposures of interest included demographic, clinical, and facility characteristics contributing to tracheostomy placement including: age, sex, medical comorbidities, income, race, payer status, hospital size, hospital location (urban versus rural), hospital teaching status, and USA census region. In our primary analysis, the outcome of interest was the incidence of tracheostomy utilization. In secondary analyses, we examined the additional outcomes of hospital disposition, including mortality, discharge to skilled nursing and long-term acute care facilities, and discharge to home. As a composite measure of illness severity in NIS, we used the All-Patient Refined Diagnosis-Related Group (APR-DRG) classification, a proprietary measure developed by 3 M Health Information Systems [12] for the NIS. The APR-DRG incorporates principal diagnosis, age, multiple secondary diagnoses, and combinations of non-operating procedures.

Statistical Analysis

We used descriptive statistics to examine the demographic, clinical, and facility-level characteristics of the SABI cohort. We report categorical variables using counts and percentages and continuous variables using means and standard deviations. We calculated the cumulative incidence of tracheostomy utilization in the SABI cohort. Next, we derived national estimates using survey-weighted methods, using the individual weights provided for each patient in the NIS dataset. We then stratified the estimates to calculate the proportion of SABI patients that received a tracheostomy each year. We performed a Cochrane–Armitage test of trend to analyze changes in the utilization of tracheostomy over time [13]. We also stratified our analyses of trends in tracheostomy utilization by age categories (18–50, 51–65, 66–80, and > 80 years) and SABI categories (stroke, TBI, and cardiac arrest). We examined factors associated with tracheostomy utilization using multilevel mixed-effects logistic regression models, adjusting for patient demographic and clinical characteristics, SABI type, illness severity, and hospital characteristics. Due to the potential risk of death or recovery early in the hospitalization (and no longer being "at risk" for a tracheostomy), we conducted sensitivity analyses in a cohort of patients with hospital length of stay > 7 days and patients with hospital length of stay > 14 days. All statistical analyses were performed using STATA 15.0 (College Station, TX), with the *svy* package used for calculation of national population-based estimates.

Results

Between 2002 and 2011, there were 94,082 hospitalizations for SABI (corresponding to 324,132 hospitalizations when weighted nationally). Among these patients, 32% (30,455 patients in the sample and 103,916 patients when weighted nationally) received a tracheostomy. Demographic and clinical characteristics of the cohort are shown in Table 1. Among patients who received a tracheostomy, 61.6% were male and 37.4% had Medicare as the primary payer. Patients with stroke (46.5%) comprised the highest proportion of patients who received a tracheostomy, followed by TBI (38.1%) and cardiac arrest (15.4%). Significant cardiopulmonary comorbidities were common in the patients that received a tracheostomy, including hypertension (43.2%), diabetes (19.6%), congestive heart failure (16.4%) and chronic obstructive pulmonary disease (15.5%). Large (74.5%), teaching (64.6%), and urban (96%) hospitals cared for the highest proportion of SABI patients in the cohort.

Tracheostomy Utilization Trends

Figure 1 (Panel 1) shows the overall trends in tracheostomy utilization between 2002 and 2011, with stratification by age (Panel 2) and SABI type (Panel 3). In the nationally weighted sample, the overall proportion of patients with SABI who received a tracheostomy increased significantly over the study period, from 28.0% in 2002 to 32.1% in 2011 ($p < 0.001$). All age categories experienced an increased proportion of tracheostomy utilization over the study period ($p < 0.001$ for age 18–50, 51–65, and 66–80 years; $p = 0.02$ for age > 80 years). The largest increase in utilization was documented in younger patients (age 18–50 years), from 34.5% in 2002 to 42.1% in 2011. All categories of SABI experienced an increased proportion of tracheostomy utilization over the study period ($p < 0.001$ for TBI, stroke, and cardiac arrest).

Variation in Tracheostomy Utilization

Utilization of tracheostomy varied across individual hospitals (Fig. 2). Demographic and facility-level factors associated with utilization of tracheostomy among patients with SABI are shown in Table 2. Compared to males, female sex was associated with a reduced odds of tracheostomy utilization (OR 0.94, 95% CI 0.90–0.98, $p = 0.005$). Increased age was associated with a reduced odds of tracheostomy utilization (OR 0.76, 95% CI 0.70–0.863, $p < 0.001$ for age > 80 compared to 18–50 years). Racial minorities had higher odds of tracheostomy utilization, compared to white patients (OR 1.40, 95% CI 1.31–1.49, $p < 0.001$ for blacks compared to whites). Patients with Medicaid and private insurance had a higher odds of tracheostomy utilization compared to patients with Medicare (OR 1.29, 95% CI 1.19–1.39, $p < 0.001$). Facility-level characteristics associated with a higher odds of tracheostomy utilization included large hospitals (OR 1.34, 95% CI 1.18–1.53, $p < 0.001$, compared to small hospitals), teaching hospitals (OR 1.15, 95% CI 1.06–1.25, $p = 0.001$, compared to non-teaching hospitals), and urban hospitals (OR 1.60, 95% CI 1.33–1.92, $p < 0.001$, compared to rural hospitals).

Hospital Disposition

After tracheostomy, the proportion of SABI patients discharged to home was low and remained relatively stable over the study period, while in-hospital mortality decreased significantly from 19.3% in 2002 to 9.1% in 2011 (Fig. 3). At the same time, discharge to other facilities (long-term acute care facilities, skilled nursing facilities, etc.) increased from 70.2% in 2002 to 83.1% in 2011 ($p < 0.0001$).

Sensitivity Analyses

After restricting analyses to patients who survived > 7 days and > 14 days after SABI in an effort to restrict the cohort to patients "at risk" for receiving a tracheostomy, our findings of increasing trends in overall tracheostomy utilization over time and variation in tracheostomy utilization remained stable (Table e1 and Table e2).

Discussion

In this population-based study examining the use of tracheostomy following SABI in the USA, we found: (1) an increase in tracheostomy utilization among SABI patients over a decade; (2) substantial variability in tracheostomy utilization across the spectrum of patient and facility characteristics; and (3) among SABI patients who undergo tracheostomy, a decrease in hospital mortality potentially accounted for by a simultaneous increase in the proportion of patients discharged to skilled nursing and long-term acute care facilities.

The increasing trend in tracheostomy utilization after SABI that we observed, even when stratified by age and type of brain injury, is consistent with previous reports that indicate an increase in ICU beds in the USA [14, 15], an increase in the prevalence of chronically critically ill patients [16], and an increased use of tracheostomy for all mechanically ventilated patients [17]. Our findings suggest that an increasing proportion of patients with severe brain injuries (who are "at risk" for tracheostomy placement), with likely a great deal of prognostic uncertainty, are receiving tracheostomies. While these findings suggest that we have advanced in our abilities to offer the sickest patients a chance for survival, this may translate to more patients burdened by prolonged severe disability, long healthcare facility stays, and substantial healthcare

Table 1 Demographic and clinical characteristics of the study cohort

	Total	No tracheostomy	Tracheostomy
N	94,082 (100%)	63,627 (67.6%)	30,455 (32.3%)
Age (years) (*n* [%])			
18–50	26,536 (28.2%)	15,666 (24.6%)	10,870 (35.7%)
51–65	27,418 (29.1%)	18,382 (28.9%)	9036 (29.7%)
66–80	27,750 (29.5%)	19,929 (31.3%)	7821 (25.7%)
> 80	12,378 (13.2%)	9650 (15.2%)	2728 (9.0%)
Male (*n* [%])	55,306 (58.8%)	36,535 (57.4%)	18,771 (61.6%)
Race (*n* [%])			
White	47,055 (50.0%)	32,582 (51.5%)	14,473 (47.5%)
African-American	14,740 (15.7%)	9456 (14.9%)	5284 (17.4%)
Hispanic	8654 (9.2%)	5605 (8.8%)	3049 (10.0%)
Asian	2519 (2.7%)	1729 (2.7%)	790 (2.6%)
Others	3277 (3.5%)	2122 (3.3%)	1155 (3.8%)
Missing	17,837 (19.0%)	12,133 (19.1%)	5704 (18.7%)
Primary payer (*n* [%])			
Medicare	42,828 (45.7%)	31,474 (49.6%)	11,354 (37.4%)
Medicaid	13,859 (14.8%)	8292 (13.1%)	5567 (18.3%)
Private	25,939 (27.7%)	16,303 (25.7%)	9636 (31.8%)
Self-pay	6473 (6.9%)	4442 (7.0%)	2031 (6.7%)
Others	4724 (5.0%)	2958 (4.7%)	1766 (5.8%)
Median income quartile (*n* [%])[a]			
Level 1	26,571 (28.2%)	17,569 (27.6%)	9002 (29.6%)
Level 2	21,144 (22.5%)	14,071 (22.1%)	7073 (23.2%)
Level 3	18,867 (20.1%)	12,871 (20.2%)	5996 (19.7%)
Level 4	16,478 (17.5%)	11,392 (17.9%)	5086 (16.7%)
Missing	11,022 (11.7%)	7724 (12.1%)	3298 (10.8%)
Types of SABI (*n* [%])			
Traumatic brain injury	24,772 (26.3%)	13,185 (20.7%)	11,587 (38.1%)
Stroke	42,734 (45.4%)	28,567 (44.9%)	14,167 (46.5%)
Cardiac arrest	26,576 (28.3%)	21,875 (34.4%)	4701 (15.4%)
Comorbidities (*n* [%])			
Alcoholism	9340 (10.0%)	6165 (9.8%)	3175 (10.5%)
Anemia	16,328 (17.5%)	10,976 (17.4%)	5352 (17.7%)
Congestive heart failure	16,106 (17.3%)	11,167 (17.7%)	4939 (16.4%)
Chronic obstructive pulmonary disease	17,310 (18.6%)	12,647 (20.1%)	4663 (15.5%)
Coagulopathy	10.685 (11.5%)	7491 (11.9%)	3194 (10.6%)
Diabetes	17,061 (18.3%)	12,210 (19.4%)	4851 (16.1%)
Diabetes with complications	3870 (4.2%)	2819 (4.5%)	1041 (3.5%)
Hypertension	43,499 (46.7%)	30,460 (48.3%)	13,039 (43.2%)
Hypothyroidism	4735 (5.1%)	3558 (5.6%)	1177 (3.9%)
Chronic liver disease	2613 (2.8%)	1918 (3.0%)	695 (2.3%)
Obesity	5613 (6.0%)	3800 (6.0%)	1813 (6.0%)
Peripheral vascular disease	4931 (5.3%)	3615 (5.7%)	1316 (4.4%)
Pulmonary hypertension	2928 (3.1%)	1918 (3.0%)	1010 (3.4%)
Renal failure	11,972 (12.8%)	8893 (14.1%)	3079 (10.2%)
Solid tumor without metastasis	1532 (1.6%)	1190 (1.9%)	342 (1.1%)
Metastatic cancer	1231 (1.3%)	995 (1.6%)	236 (0.8%)
Hospital size (*n* [%])[b]			
Small	4958 (5.3%)	3810 (6.0%)	1148 (3.8%)

Table 1 (continued)

	Total	No tracheostomy	Tracheostomy
Medium	18,816 (20.2%)	12,963 (20.6%)	5853 (19.4%)
Large	69,508 (74.5%)	46,373 (73.4%)	23,135 (76.8%)
Hospital location (*n* [%])			
Rural	3773 (4.0%)	2991 (4.7%)	782 (2.6%)
Urban	89,509 (96.0%)	60,155 (95.3%)	29,354 (97.4%)
Hospital teaching status (*n* [%])			
Non-teaching	33,044 (35.4%)	24,667 (39.1%)	8377 (27.8%)
Teaching	60,282 (64.6%)	38,479 (60.9%)	21,759 (72.2%)
Hospital region (*n* [%])			
Northeast	18,645 (19.8%)	12,547 (19.6%)	6188 (20.3%)
Midwest	18,930 (20.1%)	12,704 (20.0%)	6226 (20.4%)
South	38,157 (40.6%)	25,627 (40.3%)	12,530 (41.1%)
West	18,350 (19.5%)	12,839 (20.2%)	5511 (18.1%)

SABI severe acute brain injury

[a] Median household income for patient's ZIP code (1: 0–25th percentile; 2: 26th–50th percentile; 3: 51st–75th percentile; 4: 76th–100th percentile)

[b] Hospital size determined by number of hospital beds, based on hospital location and teaching status [small: rural (1–49 beds), urban non-teaching (1–99 beds), urban teaching (1–299 beds); medium: rural (50–99 beds), urban non-teaching (100–199 beds), urban teaching (300–499 beds); large: rural (≥ 100 beds), urban non-teaching (≥ 200 beds), urban teaching (≥ 500 beds)]

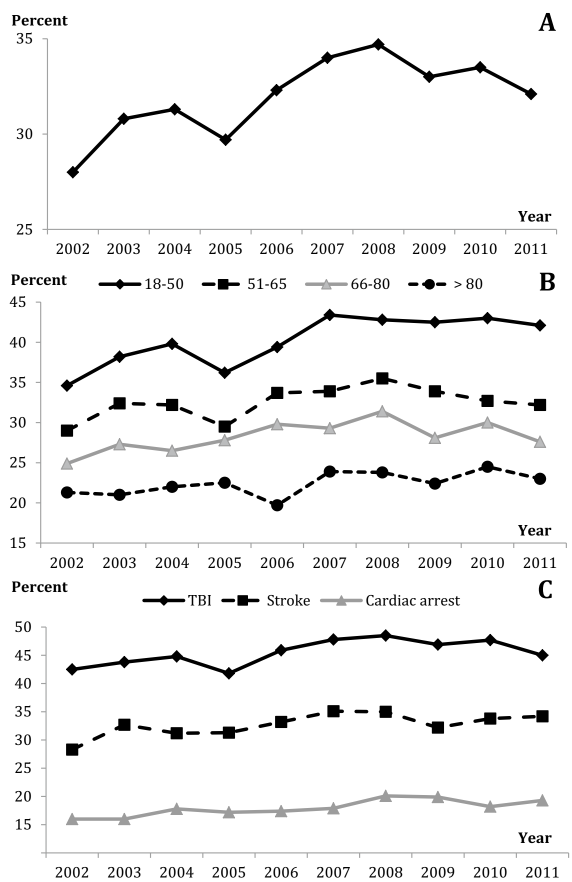

Fig. 1 Trend in tracheostomy utilization among patients with severe acute brain injury in the USA from 2002 to 2011: **a** overall trend, **b** by different age groups, and **c** by types of acute brain injury

expenses [18]. Only few studies follow patients after discharge to long-term acute care facilities, and more research is needed to better understand prognosis and trajectories after hospital discharge. Medical reasons for tracheostomy placement in our cohort may include: (1) easing weaning from the ventilator; (2) facilitation of earlier discharge from intensive care (particularly with regard to early tracheostomy); and (3) improved patient safety (transport, nursing care, etc.). In our study, patients with hypoxic ischemic encephalopathy after cardiac arrest had the lowest proportion of tracheostomy among SABI categories. This may be due to a different culture around the care of patients with hypoxic ischemic encephalopathy or possibly due to research regarding prognostication after cardiac arrest [19–21] resulting in a perception of better prognostic ability.

Despite our observation of an increased utilization of tracheostomy in the management of SABI, we also observed significant variation in the selection of patients who underwent tracheostomy during the study period. This wide variation of tracheostomy use occurred across multiple factors including facility, individual, economic, and social. Variation across these diverse factors suggests that the decision to pursue tracheostomy may be due to a variation in clinician's perception and communication of prognosis, as well as individual or local norms for recommending the use of prolonged life-sustaining therapy. In other words, the outcome of two patients with the same type and severity of SABI may differ substantially depending on the facility they are admitted to. In addition, several patient-level factors, including age and race,

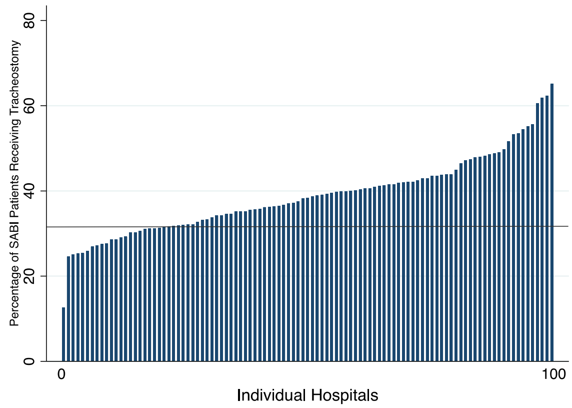

Fig. 2 Proportion of patients receiving tracheostomy among individual hospitals that admitted an average of 20 or more SABI patients/year from 2002 to 2011. Solid horizontal line represents the total proportion of patients receiving a tracheostomy in the study cohort. Each bar represents an individual hospital, and *x* axis represents proportion of all individual hospitals

were independently associated with tracheostomy utilization. While the decreased utilization of tracheostomy in very elderly patients is likely not surprising, race also remained associated with tracheostomy utilization across all analyses, suggesting possible healthcare disparities in the provision of tracheostomy in the SABI population. Further research should examine reasons for variation in healthcare utilization following SABI in more detail, in order to identify modifiable factors that may help to reduce variation and provide a standardized framework for healthcare providers and families of patients with SABI.

The proportion of patients discharged to home following SABI and tracheostomy was not significantly changed during the study period, and this stands in contrast to a significant decline in in-hospital mortality among SABI patients who underwent tracheostomy placement. Our mortality data are consistent with declining mortality among the general population of critically ill patients who underwent tracheostomy during a similar time period that was paralleled by an increase in discharge to skilled nursing and long-term acute care facilities [22, 23]. Because we have insufficient data regarding the long-term outcomes of these patients, the indication for tracheostomy may be manifold depending on a variety of clinical and non-clinical factors. Reasons for tracheostomy placement may include: (1) the provision of prolonged life-sustaining treatment, possibly in the setting of a time-limited trial; (2) the delivery of mechanical ventilation that is perceived as more comfortable; and (3) a means to expedite discharge from the acute care hospital [24]. It is unclear to what extent surrogates of

Table 2 Multilevel mixed-effect logistic regression analysis of factors associated with tracheostomy utilization

	OR	95% CI	*p*
Female	0.94	0.90–0.98	0.005
Age (years)			
18–50	1 (ref)		
51–65	0.96	0.91–1.02	0.207
66–80	0.98	0.91–1.05	0.517
> 80	0.76	0.70–0.83	< 0.001
Race			
White	1 (ref)		
African-American	1.40	1.31–1.49	< 0.001
Hispanic	1.19	1.10–1.28	< 0.001
Asian	1.22	1.09–1.37	0.001
Others	1.19	1.07–1.33	0.002
SABI type			
Traumatic brain injury	1 (ref)		
Stroke	0.96	0.90–1.01	0.13
Post-cardiac arrest	0.50	0.46–0.53	< 0.001
Primary payer			
Medicare	1 (ref)		
Medicaid	1.29	1.19–1.39	< 0.001
Private	1.04	0.98–1.12	0.20
Self-pay	0.63	0.56–0.70	< 0.001
Others	0.82	0.73–0.92	0.001
Median income quartile[a]			
Level 1	1 (ref)		
Level 2	1.02	0.96–1.09	0.531
Level 3	0.99	0.93–1.05	0.708
Level 4	0.97	0.91–1.04	0.464
Hospital size[b]			
Small	1 (ref)		
Medium	1.31	1.14–1.50	< 0.001
Large	1.34	1.18–1.53	< 0.001
Teaching hospital	1.15	1.06–1.25	0.001
Hospital region			
Northeast	1 (ref)		
Midwest	1.05	0.91–1.21	0.502
South	0.90	0.81–1.00	0.060
West	0.90	0.81–1.00	0.060
Urban location	1.60	1.33–1.92	< 0.001

CI confidence interval, *OR* odds ratio, *SABI* severe acute brain injury

[a] Median household income for patient's ZIP Code (1: 0–25th percentile; 2: 26th–50th percentile; 3: 51st–75th percentile; 4: 76th–100th percentile)

[b] Hospital size determined by number of hospital beds, based on hospital location and teaching status [small: rural (1–49 beds), urban non-teaching (1–99 beds), urban teaching (1–299 beds); medium: rural (50–99 beds), urban non-teaching (100–199 beds), urban teaching (300–499 beds); large: rural (≥ 100 beds), urban non-teaching (≥ 200 beds), urban teaching (≥ 500 beds)]

patients discharged to long-term care facilities were prepared for the consequences of their decision. For example, one prospective cohort study following surrogates of

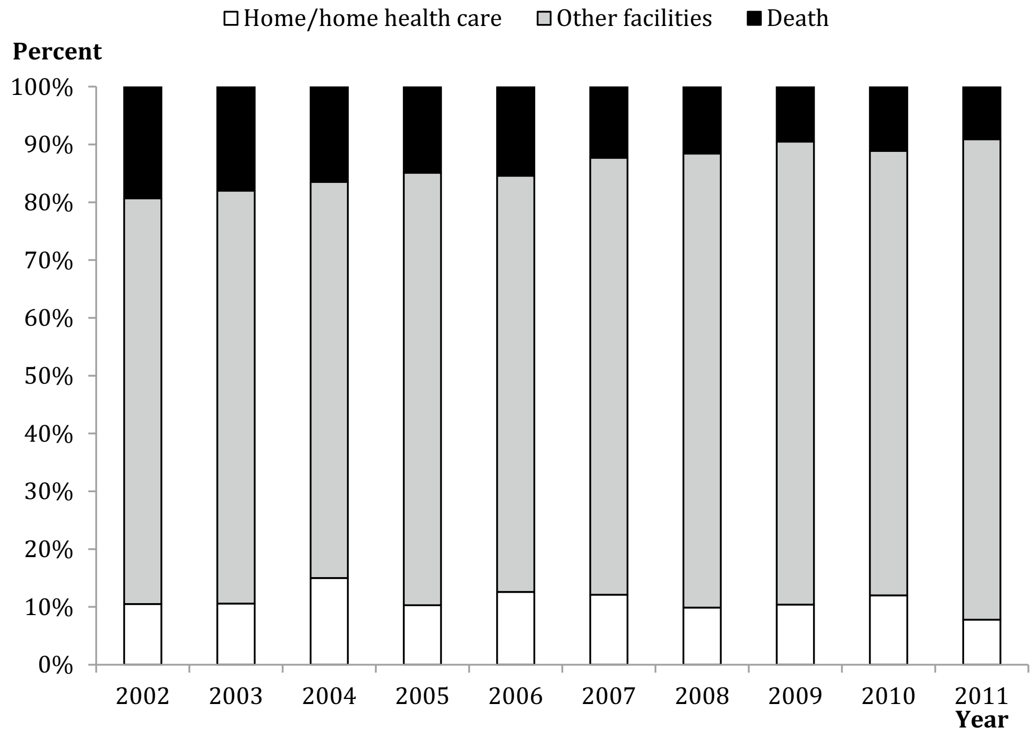

Fig. 3 Discharge/disposition outcomes among patients with severe acute brain injury who received tracheostomy from 2002 to 2011

ICU patients requiring prolonged mechanical ventilation over 1 year after tracheostomy placement showed high baseline expectations for one-year quality of life in 83% of surrogates, but only 9% of patients were alive and independent of major functional limitations at 1 year [25]. In a recent qualitative study, patients who had suffered a severe stroke and their caregivers noted a lack of preparation and discussion in the acute period around what a future with severe disability might look like compared with the possibility of death [26].

Our observations suggest several gaps in current research in patients with SABI. First, a better understanding of long-term outcomes of patients with SABI discharged from the hospital to a long-term care facility is necessary. These outcomes should include functional outcome, as well as measures of quality of life, psychological well-being, caregiver burden, financial burden, and retrospective evaluations of treatment choices. Second, a better understanding of the wide variation in tracheostomy utilization will need to include investigating current communication practices regarding tracheostomy placement after SABI, including family and clinician understanding of a "time-limited trial" of tracheostomy. Qualitative research with SABI patients and their families may provide insights into the best way to improve quality of care and communication and reduce unwanted care for this group of patients. Lastly, research on decision support for families of patients with SABI is required, to help lead the way for better decision-making in many other acute and critical illnesses.

There are limitations to our study. First, due to the administrative nature of the dataset, granular details about patient care including vital signs, ventilator variables, neurologic scoring systems, laboratory parameters, and pharmacotherapies were unavailable in the dataset. Thus, while our analyses provide population-based estimates, caution must be used when making individual-level conclusions. In addition, despite multivariable adjustment using covariates available in the dataset, our analysis may still be prone to residual confounding. For example, while our assumptions used disease severity adjustments for acutely hospitalized patients, these may not fully translate into neurologic populations. To minimize residual confounding, we restricted our population to patients with an ICD code for prolonged mechanical ventilation to define a population that was at the highest risk of receiving a tracheostomy; also, we conducted several sensitivity analyses with further restriction of the patient population. Second, because the case definition of SABI comprised diseases with diverse underlying pathophysiologic mechanisms and was suited for our population-based epidemiologic analysis, this may have also introduced relative heterogeneity into the case definition. Third, because we relied on ICD codes for ascertainment of exposures and outcomes in the data, there is a potential for misclassification. However, mechanical ventilation and tracheostomy are procedures that are associated with high reimbursement, and thus would be unlikely to be coded inaccurately [17]. Fourth, the examination of discharge disposition may not fully reflect disease severity, and may be influenced by additional factors, such as insurance availability. Lastly, our analysis was limited to in-hospital outcomes, and future studies should examine long-term outcomes in this patient population beyond mortality alone. While our study is, to our knowledge, the largest population-based study on trends in tracheostomy utilization in patients with SABI, our findings require confirmation in further large, heterogeneous, and prospective datasets.

Conclusion

In conclusion, tracheostomy utilization has increased in the USA among patients with SABI, with large variation by patient and facility-level factors. Future studies should aim to understand the reasons for variation in tracheostomy utilization and long-term outcomes in SABI patients who undergo tracheostomy, in order to improve decision support for healthcare providers and family members of patients with SABI.

Electronic supplementary material

The online version of this article (https://doi.org/10.1007/s12028-019-00697-5) contains supplementary material, which is available to authorized users.

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Author Contribution

All authors have given final approval of the published work. VK contributed to the conception and design of the work, analysis, interpretation, and drafting the manuscript. CLH, MSV, JK, AVL, KR, CJC contributed to the conception and design of the work, interpretation, and drafting the manuscript. NC contributed to the analysis, interpretation, and drafting the manuscript.

Source of support

NIH L30 NS084420 (Krishnamoorthy), K23 NS099421 (Creutzfeldt).

Conflicts of Interest

None

Publisher's Note

Published online: 27 March 2019

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