Trends in Tracheostomy After Stroke: Analysis of the 1994 to 2013 National Inpatient Sample

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Abstract

Background: Real-world data on long-term trends in the use of tracheostomy after stroke are limited. **Methods:** Patients who underwent tracheostomy for acute ischemic stroke (AIS), intracerebral hemorrhage (ICH), or subarachnoid hemorrhage (SAH) were identified from the 1994 through 2013 releases of the National Inpatient Sample using previously validated *International Classification of Diseases, Ninth Revision, Clinical Modification* codes. Survey weights were used to report nationally representative estimates. Our primary outcome was the trend in tracheostomy use during the index stroke hospitalization over the last 20 years. Additionally, we evaluated trends in in-hospital mortality, timing of placement, and discharge disposition among patients who received a tracheostomy. **Results:** We identified 9.9 million patients with AIS, ICH, or SAH in the United States from 1994 to 2013, of which 170 255 (1.7%; 95% confidence interval [CI]: 1.6%-1.8%) underwent tracheostomy. Among all patients with stroke, tracheostomy use increased from 1.2% (95% CI: 1.1%-1.4%) in 1994 to 1.9% (95% CI: 1.8%-2.1%) in 2013, with similar trends across stroke types. From 1994 to 2013, the timing of tracheostomy decreased from 16.5 days (95% CI: 14.9-18.1 days) to 10.3 days (95% CI: 9.9-10.8 days) after mechanical ventilation. In-hospital mortality decreased from 32.6% (95% CI: 29.1%-36.1%) to 13.8% (95% CI: 12.3%-15.3%) among tracheostomy patients; however, discharge to a nonacute care facility increased from 42.9% (95% CI: 38.0%-47.8%) to 83.3% (95% CI: 81.6%-85.0%) and home discharge declined from 9.3% (95% CI: 7.3%-11.3%) to 2.9% (95% CI: 2.1%-3.7%). **Conclusion:** Over the past 2 decades, tracheostomy use has increased among patients with stroke. This increase was associated with earlier placement, reduced in-hospital mortality, and lower rates of home discharge.

Keywords

neurocritical care, stroke, intracerebral hemorrhages, subarachnoid hemorrhage, epidemiology

Despite significant progress in acute stroke treatment, as many as 12.5% of patients with stroke still develop acute respiratory failure necessitating mechanical ventilation.¹ For those patients who remain ventilator dependent, tracheostomy can facilitate the transition from acute care to a rehabilitation setting and allow supportive respiratory care until any potential recovery. A number of recent studies suggest that patients with stroke who receive a tracheostomy experience short-term improvements in functional status.²⁻⁴ On the other hand, performing a tracheostomy in patients with stroke may be viewed as futile by some clinicians, given the high morbidity of patients with stroke and acute respiratory failure.⁵⁻⁷

Existing studies have observed an increase in tracheostomy use across the general critical care population, suggesting the possibility that attitudes toward the procedure have become more favorable despite limited data with regard to optimal

timing.⁸⁻¹¹ However, mechanisms underlying respiratory failure in patients with stroke, a population of interest to neurohospitalists, vary from those of the general critical care population, and real-world data on patterns of tracheostomy use among patients with stroke are limited. Consequently, many aspects of tracheostomy use after stroke in clinical

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practice, such as inpatient mortality and the timing of placement, remain poorly characterized and unknown. We used a large, nationally representative sample of patients to evaluate trends in tracheostomy use among patients hospitalized with stroke over the past 2 decades. We evaluated factors associated with tracheostomy use among these patients, including demographics, mortality, timing, discharge disposition, and performance of other procedures to better understand specific trends observed.

Methods

Design

We used inpatient discharge data from the 1994 through 2013 releases of the Healthcare Cost and Utilization Project's National Inpatient Sample (NIS). The NIS is a nationally representative, de-identified database that is funded by the Agency for Healthcare Research and Quality.¹² The data that support the findings of this study are available upon reasonable request. This study was approved by the ethical committee and institutional review board at Weill Cornell Medical College, and the need for informed patient consent was waived due to the de-identified nature of the data.

Patient Population

We identified all patients hospitalized with stroke, defined as the composite of acute ischemic stroke (AIS), intracerebral hemorrhage (ICH), or subarachnoid hemorrhage (SAH). Cases of stroke were identified using a validated *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* code algorithm that was previously shown to have a sensitivity $\geq 82\%$ and a specificity $\geq 93\%$ for both ischemic and hemorrhagic strokes.¹³

Measurements

Our primary outcome was the trend in tracheostomy use during the index stroke hospitalization over the last 20 years. Tracheostomy use was identified using previously validated *ICD-9-CM* procedure codes 31.1, 31.2, 31.21, and 31.29.¹⁴ To better understand patterns of tracheostomy across subgroups of patients, we noted demographic factors (age, sex, race, and insurance status) and ascertained the comorbidity burden using an adaptation for the Charlson comorbidity index using *ICD-9-CM* codes.^{15,16} Subgroup analyses were performed to evaluate rates of tracheostomy use by stroke type (AIS, ICH, and SAH), age (dichotomized a priori as ≥ 60 vs <60 years of age), sex, race/ethnicity (white vs nonwhite), and socioeconomic status (median household income quartile of zip code).

We then evaluated trends in various hospitalization metrics for patients with stroke with and without tracheostomy placement. We focused on the timing of tracheostomy, mortality rates during the index hospitalization, and discharge disposition. We also evaluated factors that could be associated with

trends in these metrics, such as hemicraniectomy use (*ICD-9-CM* procedure codes 01.20, 01.24, and 01.25) and use of palliative care (*ICD-9-CM* diagnosis code V66.7). Finally, as most patients are mechanically ventilated prior to tracheostomy placement, to better understand tracheostomy use relative to the population of patients with stroke who were ventilated, we also performed a subgroup analysis of only patients with stroke who underwent mechanical ventilation. Mechanical ventilation was identified using previously validated *ICD-9-CM* procedure codes 96.71 and 96.72.¹⁷

Statistical Analysis

We used sampling weights provided by the NIS to obtain national estimates for all outcomes. To account for the NIS sample redesign, we used the updated trend weights for the period between 1994 and 2011 and the original discharge weights for the years 2012 to 2013. Variance-weighted linear least squares regression was used to test for temporal trends. All trend analyses were 2 tailed and statistical significance was defined as a *P* value $< .05$. Statistical analysis was performed using Stata (version 14.0, College Station, Texas).

Results

From 1994 through 2013, approximately 9.9 million patients were hospitalized with stroke in the United States. Among these patients, 170 255 (1.7%; 95% confidence interval [CI]: 1.6%-1.8%) received a tracheostomy. Overall rates of tracheostomy use were 1.1% (95% CI: 1.0%-1.2%) after AIS, 3.9% (95% CI: 3.7%-4.1%) after ICH, and 6.3% (95% CI: 5.9%-6.6%) after SAH. The mean age of patients undergoing tracheostomy was 63.5 years. Patients with stroke receiving tracheostomy were more likely to be men, younger than 60, nonwhite, and insured by commercial insurers or Medicaid (Table 1).

The rate of tracheostomy use after any stroke increased from 1.2% (95% CI: 1.1%-1.4%) in 1994 to 1.9% (95% CI: 1.8%-2.1%) in 2013 ($P < .001$). Rates of use increased from 0.8% (95% CI: 0.7%-1.0%) to 1.2% (95% CI: 1.1%-1.3%) after AIS, from 2.4% (95% CI: 1.9-2.9) to 4.4% (95% CI: 4.1%-4.8%) after ICH, and from 5.4% (95% CI: 4.4-6.4) to 6.7% (95% CI: 6.0%-7.5%) after SAH. Rates increased most notably among patients <60 years of age, women, nonwhites, and patients who appeared to come from lower socioeconomic status (Table 2).

Among patients undergoing tracheostomy, we found significant decreases over time in the average length of stay and rate of in-hospital mortality (Table 3). From 1994 to 2013, in-hospital mortality decreased from 32.6% (95% CI: 29.1%-36.1%) to 13.8% (95% CI: 12.3%-15.3%), while average length of stay decreased from 52.3 days (95% CI: 47.3-57.3 days) to 32.9 days (95% CI: 31.7-34.2 days), among patients with stroke who underwent tracheostomy. On the other hand,

Table 1. Baseline Characteristics of Patients Hospitalized With Stroke From 1994 to 2013, Stratified by Placement of a Tracheostomy.

Characteristic ^a	Tracheostomy (n = 170 255)	No Tracheostomy (n = 9 765 923)
Age		
<60	62 889 (36.9)	2 008 970 (20.6)
≥ 60	107 365 (63.1)	7 756 954 (79.4)
Sex		
Male	89 182 (52.4)	4 451 286 (45.5)
Female	81 073 (47.6)	5 314 637 (54.4)
Race ^b		
White	97 834 (57.5)	7 148 128 (73.2)
Black	40 845 (23.9)	1 481 235 (15.2)
Hispanic	17 548 (10.3)	657 155 (6.7)
Asian	6939 (4.1)	241 735 (2.5)
Other	7090 (4.2)	237 670 (2.4)
Insurance ^b		
Medicare	87 533 (51.4)	6 672 498 (68.3)
Medicaid	26 236 (15.1)	609 880 (6.2)
Private	43 936 (25.8)	1 442 081 (14.8)
Other	12 178 (7.2)	601 584 (6.2)
Comorbidities, mean (SD), no.	2.34 (0.01)	2.22 (0.004)

^aData are presented as number (%) unless otherwise specified.

^bPercentages may not add to 100% due to missing values.

in-hospital mortality decreased from 13.8% (95% CI: 12.8%-14.8%) to 9.1% (95% CI: 8.9%-9.4%), while average length of stay decreased from 9.8 days (95% CI: 9.3-10.2 days) to 6.6 days (95% CI: 6.4-6.7 days), in the general stroke population during the same period.

The decline in mortality coincided with tracheostomy being performed after a shorter duration of mechanical ventilation; from 1994 to 2013, timing of tracheostomy placement decreased from 16.5 days (95% CI: 14.9-18.1 days) to 10.3 days (95% CI: 9.9-10.8 days) after mechanical ventilation. Moreover, while the percentage of patients going home after discharge did not change among the general stroke population, among tracheostomy patients, the rate of home discharge declined significantly from 9.3% (95% CI: 7.3%-11.3%) in 1994 to 2.9% (95% CI: 2.1%-3.7%) in 2013. The percentage of patients who received palliative care, underwent hemicraniectomy, and were discharged to nonacute care facilities all significantly increased among patients with stroke who received tracheostomy. The same metrics also increased among patients with stroke without tracheostomy placement, but to a lesser extent (Table 3).

Approximately 10% of patients hospitalized with stroke required mechanical ventilation (10.2%; 95% CI: 9.9%-10.5%). From 1994 to 2013, the rate of mechanical ventilation among patients with stroke increased from 8.0% to 11.8% ($P < .001$). When we restricted our analysis to only mechanically ventilated patients with stroke, rates of tracheostomy increased from 10.5% (95% CI: 9.6%-11.4%) in 1994 to 15.3% ($P < .001$; 95% CI: 14.5%-16.1%) in 2013.

Discussion

Within a large, nationally representative patient sample, we found that tracheostomy use in patients with stroke steadily increased over the past 2 decades. This increase was associated with significant decreases in the average length of stay and rate of in-hospital mortality. Importantly, the rise in tracheostomy also appeared to be associated with higher rates of discharge to nonacute care settings and a decrease in the rate of patients with stroke going home after discharge.

Our results build on recent data showing that the overall use of tracheostomy in critically ill patients has escalated.^{8,11} Most of our findings followed similar patterns as those identified by Mehta and colleagues in their analysis of tracheostomy among the general critical care population.¹¹ The growth in its utilization after stroke over the past 2 decades may stem from the increasing use of hemicraniectomy and improved survival after severe ischemic strokes, decreasing mortality in patients with ICH and SAH,¹⁸ and general improvements in survival after critical illness. Furthermore, the upward trend in tracheostomy procedures persisted when we restricted our cohort to patients with stroke undergoing mechanical ventilation.

Over the last 20 years, we found that tracheostomies were placed earlier in the course of hospitalization for acute stroke. We observed a steeper decline in the number of ventilator days prior to tracheostomy than that observed in the general critical care population.¹¹ Our results suggest that tracheostomies are now placed after a similar duration of mechanical ventilation compared to those with general critical care conditions. Presumably, perceived benefits in short-term outcomes extrapolated from prior literature^{2,3,19} may have motivated interventionists to perform tracheostomies at an earlier time point or the trend toward early tracheostomy may have been due to hospitals' initiatives to reduce lengths of stay. Over time, tracheostomy use was also associated with a declining rate of in-hospital mortality, a decrease in length of stay, an increase in discharge to nonacute care settings, and a decrease in the rate of home discharge. Despite the observed decreases in mortality and length of stay for patients who underwent tracheostomy, the concurrent rise in discharges to nonacute care settings and the decrease in home discharges suggest that burden of care for these patients may be shifting to long-term care facilities. The decrease in the rate of home discharge among patients with stroke undergoing tracheostomy is notable relative to the stable rate in the general stroke population as it may indicate that the increased use of tracheostomy has not necessarily improved functional outcomes or quality of life. Although we lacked data on long-term functional outcomes for patients with stroke discharged to nonacute care settings, prior data examining outcomes of mechanically ventilated patients transferred directly from critical care units to long-term care facilities demonstrated a low likelihood of survival and functional independence.²⁰

Table 2. Trends in Tracheostomy Utilization Rates (%) After Any Type of Stroke Stratified by Age, Sex, Race/Ethnicity, and Median Household Income Quartile of Each Patient's Zip Code From 1994 to 2013.

	1994-1998	1999-2003	2004-2008	2009-2013	P Value for Trend
Characteristic^a					
Discharges, no.	35 210	36 122	40 755	58 168	<.001
Age					
<60 years	2.6 (2.3-2.8)	2.7 (2.6-2.9)	3.1 (2.9-3.4)	3.4 (3.2-3.6)	<.001
≥60 years	1.1 (1.0-1.3)	1.3 (1.2-1.4)	1.5 (1.4-1.6)	1.5 (1.4-1.6)	<.001
Sex					
Male	1.6 (1.4-1.7)	1.8 (1.7-1.9)	2.2 (2.0-2.3)	2.2 (2.1-2.4)	<.001
Female	1.2 (1.0-1.3)	1.4 (1.3-1.5)	1.7 (1.5-1.8)	1.8 (1.7-1.9)	<.001
Race/ethnicity					
White	1.2 (1.0-1.3)	1.2 (1.1-1.3)	1.5 (1.4-1.6)	1.5 (1.4-1.6)	<.001
Black	2.1 (1.8-2.4)	2.4 (2.2-2.6)	2.8 (2.6-3.1)	3.2 (3.0-3.4)	<.001
Hispanic	2.0 (1.7-2.3)	2.4 (2.2-2.7)	2.9 (2.5-3.2)	2.9 (2.6-3.1)	<.001
Asian	2.2 (1.7-2.6)	2.8 (2.4-3.3)	2.8 (2.4-3.2)	3.1 (2.7-3.4)	<.001
Other	2.7 (1.7-3.6)	2.6 (2.1-3.1)	2.8 (2.3-3.3)	3.3 (2.9-3.7)	<.001
Median household income quartile of patient's zip code					
Quartile 1	1.4 (1.2-1.6)	2.0 (1.8-2.3)	2.1 (1.9-2.3)	2.4 (2.2-2.5)	<.001
Quartile 2	1.2 (1.1-1.4)	1.5 (1.3-1.6)	1.8 (1.6-1.9)	1.9 (1.8-2.0)	<.001
Quartile 3	1.3 (1.2-1.4)	1.4 (1.3-1.5)	1.7 (1.6-1.8)	1.8 (1.7-1.9)	<.001
Quartile 4	1.4 (1.2-1.5)	1.5 (1.4-1.6)	1.7 (1.5-1.8)	1.8 (1.7-1.9)	<.001

Abbreviation: CI, confidence interval.

^aData are presented as mean percentage (95% CI) unless otherwise specified.**Table 3.** Trends in Hospitalization Metrics Among Patients With Stroke With and Without Tracheostomy Placement.

	1994-1998	1999-2003	2004-2008	2009-2013	P Value for Trend
Characteristic^a					
Stroke without tracheostomy					
Length of stay, days	8.5 (8.0-9.0)	7.6 (7.5-7.8)	7.3 (7.2-7.5)	6.8 (6.7-6.9)	<.001
In-hospital mortality (%)	13.7 (13.3-14.0)	13.4 (13.1-13.6)	11.9 (11.7-12.2)	9.9 (9.7-10.0)	<.001
Discharge to home (%)	32.9 (31.9-33.9)	31.3 (30.7-31.9)	30.1 (29.4-30.8)	31.2 (30.8-31.6)	<.001
Transfer to nonacute care facility ^b (%)	48.6 (47.2-50.0)	50.4 (49.5-51.4)	53.2 (52.3-54.2)	54.4 (53.8-55.1)	<.001
Palliative care encounter (%)	0.2 (0.1-0.3)	0.7 (0.6-0.8)	1.9 (1.7-2.1)	6.5 (6.3-6.7)	<.001
Hemicraniectomy (%)	2.7 (2.3-3.2)	2.3 (2.1-2.6)	2.5 (2.2-2.9)	3.5 (3.2-3.8)	<.001
Stroke with tracheostomy					
Day of tracheostomy, days	15.5 (14.9-16.2)	15.1 (14.7-15.5)	14.6 (14.2-14.9)	13.9 (13.6-14.3)	<.001
Days after mechanical ventilation, days	13.7 (12.9-14.5)	12.0 (11.5-12.4)	11.2 (10.9-11.6)	10.6 (10.3-10.8)	<.001
Length of stay, days	43.8 (41.2-46.5)	39.3 (38.0-40.6)	37.3 (36.0-38.7)	34.1 (33.2-35.1)	<.001
In-hospital mortality (%)	27.4 (25.7-29.2)	24.7 (23.4-26.1)	19.8 (18.6-21.1)	14.4 (13.7-15.1)	<.001
Discharge to home (%)	7.9 (6.6-9.2)	5.4 (4.6-6.2)	4.9 (3.6-6.3)	3.2 (2.4-4.0)	<.001
Transfer to nonacute care facility ^b (%)	56.9 (54.1-59.7)	61.9 (59.8-63.9)	67.6 (65.1-70.2)	75.6 (73.8-77.4)	<.001
Palliative care encounter (%)	0.1 (0.0-0.2)	0.3 (0.2-0.4)	1.0 (0.7-1.4)	7.2 (6.5-7.9)	<.001
Hemicraniectomy (%)	3.2 (2.6-3.9)	3.4 (2.9-3.9)	3.9 (3.3-4.6)	6.6 (6.0-7.1)	<.001

Abbreviation: CI, confidence interval.

^aAll estimates are reported as mean (95% CI) unless otherwise specified.^bIncluded discharge to skilled nursing facilities, subacute care centers, and chronic rehabilitation centers.

There are several factors that may have contributed to the significant decline in in-hospital mortality among tracheostomy patients compared to the decline among the general stroke population. One explanation is the general trend toward more aggressive treatment of patients with severe stroke, which is supported by the increasing use of hemicraniectomy. In addition, earlier placement of tracheostomy over time may

have led to improved in-hospital survival as patients may be less likely to develop a complication of mechanical ventilation such as pneumonia.²¹

We also found that tracheostomy use has increased to a greater degree among nonwhite patients with stroke as compared to white patients with stroke. Our results corroborate data from prior studies indicating that nonwhite patients are

more likely to receive aggressive life-sustaining procedures (eg, tracheostomy, mechanical ventilation, percutaneous endoscopic gastrostomy) after stroke than white patients,^{22,23} a finding which contrasts with the significantly higher rates of stroke-specific therapies such as intravenous thrombolysis and carotid revascularization that white patients are more likely to receive.²² This contrast may partly be related to socioeconomic status; minority race and ethnicity are known to be associated with lower socioeconomic status,^{24,25} and we found that tracheostomy utilization rates tended to be higher and increased to a greater extent among patients who resided in zip codes from lower median household income quartiles. However, we acknowledge that our data are not sufficient to allow for a complete explanation of this disparity. Nonwhite and ethnic minority patients have also been reported to have different perspectives on comfort measures and quality of life compared to white patients,^{26,27} and we did not have access to such information.

The results of this study should be considered in light of its limitations. Because we used administrative claims data, clinical details regarding stroke characteristics such as stroke severity, size, and location were unavailable. Many of these stroke characteristics are established predictors of mechanical ventilation and subsequent tracheostomy,²⁸⁻³⁰ and their absence limits further insight into reasons for differences in tracheostomy use among our heterogeneous patient population. Changing trends in stroke severity could conceivably lead to an increase in tracheostomies, but studies have shown little change in stroke severity over time.^{31,32} In addition, we lack data regarding whether tracheostomy led to functional independence or other qualitative or quantitative measures of improved quality of life. Another limitation of this study was the lack of information regarding whether tracheostomies were performed in an open or percutaneous fashion, and it may be that increasing availability of a percutaneous option may have influenced the likelihood of performing tracheostomy. Lastly, we did not have information regarding patients' advance directives or their surrogates' wishes regarding potentially life-sustaining therapy such as tracheostomy.

Tracheostomy use in patients with stroke has steadily increased over the past 2 decades. The rise in tracheostomy use was associated with earlier placement, reduced in-hospital mortality, and shorter average length of stay over time. However, rates of discharge to nonacute care settings increased, while rates of home discharge decreased among patients with stroke who underwent tracheostomy. Further prospective studies are necessary to better characterize how tracheostomy is influencing long-term outcomes of patients with stroke.

Declaration of Conflicting Interests

The authors declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Dr H.K. reports having served on a speakers bureau for Genentech on the topic of alteplase for acute ischemic stroke, serving as an unpaid

consultant for Medtronic and iRhythm, and serving as an associate editor for *JAMA Neurology*.

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