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Tracheostomy following severe ischemic stroke: a population based study

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Abstract

Goal—Stroke can result in varying degrees of respiratory failure. Some patients require tracheostomy in order to facilitate weaning from mechanical ventilation, long-term airway protection, or a combination of the two. Little is known about the rate and predictors of this outcome in patients with severe stroke. We aim to determine the rate of tracheostomy after severe ischemic stroke.

Materials & Methods—Using the Nationwide Inpatient Sample database from 2007–2009, patients hospitalized with ischemic stroke were identified based on validated *International Classification of Diseases, 9th Revision, Clinical Modification* codes. Next, patients with stroke were stratified based on whether they were treated with or without decompressive craniectomy, and the rate of tracheostomy for each group was determined. A logistic regression analysis was used to identify predictors of tracheostomy after decompressive craniectomy. Survey weights were used to obtain nationally representative estimates.

Findings—In 1,550,000 patients discharged with ischemic stroke nationwide, the rate of tracheostomy was 1.3% (95% CI, 1.2–1.4%), with a 1.3% (95% CI, 1.1–1.4%) rate in patients without decompressive craniectomy and a 33% (95% CI, 26–39%) rate in the surgical-treatment

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group. Logistic regression analysis identified pneumonia as being significantly associated with tracheostomy after decompressive craniectomy (OR 3.95; 95% CI 1.95–6.91).

Conclusion—Tracheostomy is common following decompressive craniectomy and is strongly associated with the development of pneumonia. Given its impact on patient function and potentially modifiable associated factors, tracheostomy may warrant further study as an important patient-centered outcome among patients with stroke.

Keywords

Brain injuries; Brain edema; Intracranial pressure; Stroke; Tracheostomy; Decompressive craniectomy

Introduction

Stroke is a devastating event that results in high rates of disability and death. [1–3] During the acute hospitalization period, patients with severe stroke are routinely admitted to intensive care units given the potential for intracranial hypertension, secondary neurological deterioration, and multisystem organ failure, in addition to the need for supportive treatment. [4,5]

Despite best efforts, there remains a subpopulation of stroke patients that will go on to develop progressive, life-threatening "malignant" cerebral edema. [6–12] When this occurs, it is usually managed with an escalating level of care, ranging from optimization of ventilation to hyperosmolar therapy to decompressive craniectomy. [13] The care of any single patient is individualized and innovations including novel pharmacologic therapies [14,15] and neurosurgery [16–19] are expanding the armamentarium of available treatment options for this condition. While long-term neurological outcome and mortality are commonly-used outcome measures to measure the effect of these interventions, other patient-centered outcomes may also be important to use for comparison.

For stroke patients in particular, the severity of respiratory failure can be used as a quantifiable outcome metric. Intubation and mechanical ventilation are central tools that are frequently utilized in the acute care of severe ischemic stroke. [20–23] These procedures address the mechanical aspects of airway failure (obstruction and secretion clearance) associated with neurological injury. Additionally, mechanical ventilation can optimize gas exchange to prevent cerebral vasoconstriction and the progression of cerebral edema. Subsequently, some patients require tracheostomy in order to facilitate weaning from mechanical ventilation, long-term airway protection, or a combination of the two. [24] As of yet, no studies have specifically identified the rate of tracheostomy in a general sampling of patients with severe ischemic strokes. While the clinimetric properties of various outcomes scales are criticized, [25] the rate of tracheostomy is a well-documented patient-centered outcome. We therefore aimed to establish the rate and predictors of tracheostomy in patients suffering from severe ischemic stroke.

Materials and Methods

Hospital discharge data were obtained from the Nationwide Inpatient Sample (NIS), part of the Healthcare Cost and Utilization Project, a federal-state-industry partnership sponsored by the Agency for Healthcare Research and Quality. [26] The NIS is a 20% stratified sample of all US community hospitals as defined by the American Hospital Association: nonfederal, short-term, general, and specialty hospitals whose facilities are open to the public. Hospitals are selected for inclusion in the NIS based on five characteristics: rural/urban location, number of beds, region of the country, teaching status, and ownership. The NIS includes all discharges from the sampled hospitals and includes between 5–8 million discharges from an average of 1000 hospitals each year. Further information about the methodology used to create the dataset is available at http://www.hcup-us.ahrq.gov/nisoverview.jsp. The Partners Institutional Review Board approved the use of the NIS for this study. A waiver of informed consent was obtained for use of this publicly available, de-identified database.

Patient Population

Using the NIS, we designed a retrospective study covering 2007 through 2009. The study dates were selected to coincide with the time period following the publication of several randomized trials for decompressive craniectomy in ischemic stroke. [16–19] These studies helped to standardize routine stroke care protocols, allowing for analysis of a more homogenous population. Adult patients (ages 18 and older) who had an ischemic stroke were identified using *International Classification of Diseases, 9th Revision, Clinical Modification* (*ICD-9-CM*) codes and 433.x1, 434.x1, and 436. Patients with *ICD-9-CM* codes for hemorrhagic stroke (code 431), trauma (codes 800–804, 850–854), and subarachnoid hemorrhage (code 430) were excluded. Care performed in the rehabilitation setting following the initial hospitalization was also excluded using *ICD-9-CM* code V57. This algorithm has been shown to have 86% sensitivity and 95% specificity for acute ischemic stroke. [27]

Subgroup analysis

Patients were stratified into two groups: (1) those undergoing craniectomy for the development of malignant cerebral edema (*ICD-9-CM* codes 01.25 and 02.01), and (2) those receiving only medical management of stroke (the remainder of patients with stroke). The main outcome measure was performance of a tracheostomy (*ICD-9-CM* codes 31.1, 31.2, 31.21, and 31.29).

Statistical analysis

For the purposes of statistical analysis, we summed the data from 2007 through 2009. Chi-square testing was used to compare categorical variables and the Wald test was used to compare continuous variables between the two groups. To obtain national estimates, proper weights were applied as indicated in the HCUP–NIS *Calculating NIS Variances Guide*. For all statistical analyses, we used Stata software (Version 12, StataCorp, Texas). Statistical significance was predefined at $p < .05$, 2-tailed. Logistic regression analysis was performed to determine predictors of tracheostomy. Independent variables studied included potential confounders based on known risk factors for stroke complications, among others. This was represented in the composite Elixhauser comorbidity score, in addition to individual variables of age, gender, race, coronary heart disease, congestive heart failure, deep vein thrombosis, renal insufficiency, chronic obstructive pulmonary disease, atrial fibrillation, pneumonia, and sepsis. [28–40] We also evaluated for potential confounders that could independently affect the likelihood of an invasive procedure being offered: hospital size (small, medium, or large), hospital type (teaching or nonteaching), median household income in the patient's zip code, and primary insurance payer (Medicare, Medicaid, private insurance, or other).

Results

Between 2007 and 2009, there were an estimated 1,550,000 (95% confidence interval [CI], 1,500,000–1,600,000) patients discharged with ischemic stroke nationwide. Tracheostomy was performed in 20,300 (95% CI, 18,700–21,900) and decompressive craniectomy was performed in 1,300 (95% CI, 1,000–1,600) patients. Four hundred and thirty (95% CI, 300–550) patients underwent both decompressive craniectomy and tracheostomy. Overall, the rate of tracheostomy after stroke was 1.3% (95% CI, 1.2–1.4%), with a 1.3% (1.1–1.4%) rate in the medical-treatment group and 33% (95% CI, 26–39%) rate in the surgical-treatment group.

Among patients who received decompressive craniectomy for stroke, demographic and socioeconomic variables were similar between patients who did or did not receive tracheostomy, with the rate of pneumonia being the only comorbidity significantly different at 37% (95% CI, 27–46%) in the tracheostomy group versus 15% (95% CI, 10–19%) in those without tracheostomy. (Table 1) Logistic regression analysis identified pneumonia as being significantly associated with tracheostomy in patients who received craniectomy (OR 3.95; 95% CI 1.95–6.91). (Table 2)

Discussion

The severity of an ischemic infarct is classically defined by various criteria that relate to either factors that predict adverse outcomes [41–43] or the need for intensive therapy and surgical procedures. [7,44,45] It is possible that severe stroke may also be characterized by the need for life-sustaining procedures, such as tracheostomy. Previously, the rate of tracheostomy was unknown in the general ischemic stroke population. Our findings provide a nationwide estimate of the rate of this procedure after stroke (approximately 1.3%), and indicate that it is substantially higher in patients undergoing decompressive craniectomy (33%). We also discovered that pneumonia was significantly associated with tracheostomy in this latter subgroup.

Tracheostomy has traditionally been utilized as a determinant of outcome (particularly with respect to timing), rather than an outcome itself. [24,46,47] The epicenter of study has been on the timing of the intervention. For example, evidence from the recent SETPOINT trial found that early tracheostomy in ventilated intensive care stroke patients is feasible and safe, in addition to decreasing sedation requirements and lowering ICU mortality rates. [48] In another series of stroke patients who required ventilator assistance and tracheostomy, early tracheostomy resulted in shorter ICU and hospital stays, corresponding to lower costs. [49] Our study provides a broader context to interpret this ongoing area of research beyond the timing of the intervention. By demonstrating the rate of tracheostomy, we hope to establish a metric that can be used to help define the overall burden of disease and care interventions in patients with severe ischemic stroke.

In our analysis, pneumonia was found to be a predictor of tracheostomy. Ventilator associated pneumonia is a common complication of mechanical ventilation, developing in 10–20% of patients. [50] In general, patients who develop pneumonia are twice as likely to die, in addition to having longer ICU stays and incurring higher hospitalization costs. [50] While there is conflicting evidence for the ability of the timing of tracheostomy to influence the development of pneumonia in critically ill patients [51,52], there is a paucity of information regarding the impact of pneumonia on rate of tracheostomy. It can be postulated that in patients with an already tenuous respiratory status, the development of pneumonia impairs pulmonary function necessary to consider extubation. Alternatively, in patients with robust pulmonary function who are likely to successfully tolerate extubation otherwise, the development of pneumonia may impair pulmonary function to the point where a tracheostomy is required. Our data cannot distinguish between the timing of pneumonia relative to the timing of tracheostomy. It is not known whether pneumonia plays a causative role in the need for tracheostomy, but it is a potentially modifiable risk factor. These results support the importance of preventative measures for ventilator associated pneumonia, including topical antibiotics, probiotics, and patient positioning, among others. [53–56] In addition, several small randomized trials have suggested that prophylactic antibiotics may prevent infections in stroke patients, who are at high risk of infection due to many factors including post-stroke immunodepression. [57] Given the high rate of pneumonia in patients with stroke and decompressive craniectomy, and the association between pneumonia and the need for tracheostomy, the subpopulation of patients with severe stroke necessitating craniectomy may be a suitable group for further trials of prophylactic antibiotics.

Additionally, our study contributes to a limited body of evidence that suggests that the rate of tracheostomy is high in the decompressive craniectomy subgroup. [58] [59] Decompressive craniectomy is performed for the treatment of malignant cerebral edema, a condition that is well known to be associated with high rates of morbidity and mortality. [8] By defining the rate of tracheostomy following this procedure, a baseline is established by which to compare outcomes from treatments being evaluated to prevent and/or treat cerebral edema. [14,15] Furthermore, knowing the rate of tracheostomy is important for accurate prognostication in the pre-operative evaluation, as the likelihood of a tracheostomy (albeit many times a temporary measure) can weigh heavily in the perceived quality of life following an operation.

Our study has certain limitations inherent in its methodology. The identification of diagnoses and procedures was largely dependent on *ICD-9-CM* codes collected for billing purposes and thus may be susceptible to underascertainment or misclassification bias. Importantly, the NIS also lacks clinical information regarding stroke severity, time from symptom onset to treatment, radiographic characteristics, or outcomes following discharge. Clinical variables such as neurological disability, as measured by the National Institutes of

Health Stroke Scale score, are significant predictors of many outcomes from stroke and their association with tracheostomy deserves further study. It should also be noted that when assessing rates of tracheostomy with this database, it is not possible to account for patients who received comfort care measures and may have died shortly after their hospitalization or procedure. Therefore, the rate of tracheostomy may be even greater if all patients were treated aggressively. Even with these potential pitfalls, the NIS is a widely regarded resource for population-based data that encompass hundreds of thousands of patients.

Tracheostomy is common following decompressive craniectomy for ischemic stroke, and is associated with the development of pneumonia. Given its impact on patient function and potentially modifiable associated factors, tracheostomy may warrant further study as an important patient-centered outcome among patients with stroke.

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Table 1

Baseline Characteristics of Patients with Stroke and Decompressive Craniectomy, Stratified by Whether Tracheostomy Was Performed[a].

Characteristics	Overall	Tracheostomy	No Tracheostomy	*P* value
Age, mean (95% CI), y	53 (52–55)	53 (50–56)	54 (52–55)	0.87
Female	40 (34–45)	40 (30–51)	39 (32–46)	0.85
Race/ethnicity				0.84
White	38 (31–46)	37 (26–47)	39 (30–48)	
Black	18 (13–24)	21 (12–30)	17 (11–23)	
Hispanic	11 (6–15)	12 (5–19)	10 (4–16)	
Asian	5 (2–7)	5 (1–10)	4 (1–8)	
Other	28 (20–37)	25 (15–35)	30 (20–40)	
Payment method				0.38
Medicare	23 (18–29)	25 (16–34)	22 (16–29)	
Medicaid	21 (16–27)	27 (17–37)	19 (13–24)	
Private insurance	45 (38–51)	39 (29–50)	47 (39–55)	
Other	11 (6–15)	9 (1–16)	12 (7–17)	
Elixhauser comorbidity score, mean (95% CI)	3.3 (3.0–3.5)	3.5 (3.1–3.9)	3.2 (2.9–3.4)	0.13
Comorbidities				
CHD	18 (14–22)	15 (8–22)	19 (14–25)	0.40
CHF	11 (7–15)	12 (5–20)	10 (5–15)	0.55
DVT	17 (12–22)	21 (12–31)	15 (8–21)	0.24
Renal insufficiency	4 (2–7)	5 (0–10)	4 (1–7)	0.72
COPD	5 (2–7)	6 (1–11)	5 (1–8)	0.72
Atrial fibrillation	21 (16–26)	21 (13–29)	21 (15–27)	0.96
Pneumonia	**22 (17–26)**	**37 (27–46)**	**15 (10–19)**	**<0.001**
Sepsis	6 (3–9)	9 (1–16)	5 (2–8)	0.34
Median household income by zip code				0.66
Quartile 1 (lowest)	30 (23–36)	32 (20–43)	28 (21–36)	
Quartile 2	22 (16–27)	22 (13–31)	21 (15–28)	
Quartile 3	27 (21–34)	23 (12–33)	30 (23–37)	
Quartile 4	21 (16–27)	24 (15–33)	20 (14–27)	
Hospital bed size				0.41
Tertile 1 (smallest)	2 (0–4)	1 (0–4)	2 (0–5)	
Tertile 2	15 (8–22)	12 (4–20)	16 (8–25)	
Tertile 3	83 (76–90)	87 (79–95)	82 (73–90)	
Teaching hospital	77 (71–84)	73 (61–84)	79 (72–87)	0.29

[a]Data are presented as No. (%) unless otherwise specified.

Table 2

Independent Predictors of Tracheostomy in Patients with Stroke and Decompressive Craniectomy.

Characteristics	**OR**	***P* value**	**95% Confidence interval**
Age			
Quartile 1	1 (ref)		
Quartile 2	0.5	0.10	(0.2–1.2)
Quartile 3	0.8	0.63	(0.3–2.0)
Quartile 4	1.2	0.82	(0.4–3.7)
Female sex	1.2	0.63	(0.6–2.3)
Payment source			
_Medicare	1 (ref)		
Medicaid	1.4	0.51	(0.5–4.1)
Private insurance	0.9	0.90	(0.3–2.6)
Other	0.8	0.77	(0.2–3.5)
Race			
_White	1 (ref)		
Black	1.4	0.42	(0.6–3.1)
Hispanic	1.4	0.54	(0.5–4.6)
Asian	1.5	0.51	(0.5–5.2)
Other	1.0	0.98	(0.5–2.1)
Elixhauser comorbidities	1.1 (per condition)	0.46	(0.9–1.3)
Comorbidities			
CHD	0.6	0.25	(0.3–1.4)
CHF	0.9	0.81	(0.3–2.3)
DVT	1.8	0.17	(0.8–4.2)
Renal insufficiency	0.8	0.79	(0.2–3.6)
COPD	0.9	0.84	(0.2–3.4)
Atrial fibrillation	0.9	0.76	(0.4–2.0)
Pneumonia	**3.7**	**<0.001**	**(1.9–6.9)**
Sepsis	1.7	0.42	(0.5–6.4)
Median household income by zip code	0.9	0.55	(0.7–1.2)
Hospital bed size	1.3	0.56	(0.6–2.7)
Teaching hospital	0.6	0.23	(0.3–1.4)