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Tracheostomy in Acute Ischemic Stroke: Declining National Utilization, Independent Predictors, and In-Hospital Outcomes Among 854,660 Hospitalizations

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Abstract

Background

Tracheostomy in acute ischemic stroke (AIS) is a high-stakes decision yet contemporary national data on utilization, predictors, and outcomes are limited. We analyzed 854,660 AIS hospitalizations (NIS, 2016–2023) to characterize tracheostomy use, identify predictors, examine timing effects, and explore mechanisms underlying a national decline.

Methods

Tracheostomy was identified by ICD-10-PCS codes and classified as early (≤ 7 days) or late (> 7 days). Multivariable logistic regression identified predictors among all AIS patients (Model A) and among mechanically ventilated (MV) patients (Model B). Outcomes included length of stay, in-hospital mortality, PEG placement, and discharge disposition. Temporal trends were assessed by Cochran-Armitage test and logistic regression; mechanistic analyses tested five pre-specified hypotheses including a year-thrombectomy interaction model.

Results

Tracheostomy occurred in 5,373 hospitalizations (0.63% of AIS; 12.1% of MV patients). Median procedure day was 11 (IQR 8–16); 22.0% were early and 78.0% late. In-hospital mortality was 9.84% (early) and 8.23% (late), versus 39.7% in ventilated patients without tracheostomy. Mean LOS was significantly shorter with early versus late tracheostomy (23.8 vs 34.4 days; adjusted LOS ratio 0.662; $p < 0.001$). Prolonged MV (OR 62.3), hemorrhagic transformation (OR 1.35), and decompressive craniectomy (OR 2.55) were the dominant independent predictors. Tracheostomy rates declined from 12.9% to 9.44% of MV patients ($Z = -6.54$; $p < 0.0001$), with the steepest drop in 2023. Mechanistic analyses showed thrombectomy utilization rose concurrently (15.3% to 22.2% among MV patients; $Z = +6.39$; $p < 0.0001$), prolonged MV declined ($Z = -6.77$; $p < 0.0001$), and a significant year-thrombectomy interaction ($p = 0.027$) suggested faster decline among thrombectomy-treated patients. PEG placement occurred in 78.3% of tracheostomy patients.

Conclusions

Declining tracheostomy rates in AIS likely reflect a convergence of factors: expanding thrombectomy utilization, shorter ventilator dependence, and evolving ICU practice — rather than a shift in the tracheostomy decision itself. Racial disparities persist after adjustment. These findings provide the largest contemporary national framework for tracheostomy decision-making and goals-of-care counseling in AIS.

Introduction

Mechanical ventilation (MV) complicates approximately 5% of acute ischemic stroke (AIS) hospitalizations and is strongly associated with increased morbidity, resource utilization, and mortality.[1,2] Among patients who require MV, a critical and consequential subset will ultimately require tracheostomy—either to facilitate ventilator weaning, provide long-term airway protection in the setting of impaired swallowing or consciousness, or manage complications such as aspiration pneumonia. Tracheostomy is among the most resource-intensive procedures performed in neurocritical care and is associated with prolonged hospitalizations, high costs, and uncertain long-term outcomes in the stroke population.[3,4]

The optimal timing of tracheostomy after stroke has been the subject of considerable debate and investigation. Observational studies using national inpatient databases established that early tracheostomy was associated with reduced ventilator-associated pneumonia, shorter length of stay, and lower hospital costs compared with late placement.[5,6] These findings generated clinical enthusiasm for earlier tracheostomy practices in severe stroke. However, the landmark SETPOINT2 randomized clinical trial, which enrolled 382 patients with severe ischemic or hemorrhagic stroke at 26 neurocritical care centers, found that early tracheostomy (≤ 5 days) did not improve functional outcome at 6 months compared with a standard approach (tracheostomy from day 10 if needed).[7] A subsequent meta-analysis of over 17,000 critically ill stroke patients confirmed that tracheostomy timing was not associated with mortality, neurological outcomes, or ICU or hospital length of stay.[8] These findings have reframed the clinical question: while early tracheostomy may not improve functional recovery, its effects on short-term in-hospital outcomes such as LOS, complications, and resource utilization remain clinically important and practice-relevant.

Contemporary nationally representative data characterizing tracheostomy in the AIS population are limited. Prior administrative database studies used data from 2007–2017 and focused either on stroke-specific tracheostomy populations,[4] on thrombectomy-specific cohorts,[6] or on all-stroke populations combining ischemic and hemorrhagic subtypes.[3] The period from 2016 onward represents a transformed era in AIS care, marked by widespread adoption of mechanical thrombectomy, expansion of thrombectomy-capable centers, and evolving neurocritical care practices. Studies examining tracheostomy specifically in AIS across this modern era, including the years during and after the COVID-19 pandemic, are lacking.

Furthermore, several important and under characterized aspects of tracheostomy in AIS warrant dedicated investigation. The role of hemorrhagic transformation (HT) as a driver of tracheostomy has not been systematically examined at national scale. The mechanistic pathway from prolonged MV to tracheostomy has not been quantified in large populations. Racial disparities in tracheostomy use after AIS have received little attention despite being well-documented in other neurocritical care populations. And the relationship between tracheostomy and co-procedures such as gastrostomy (PEG) placement — a marker of anticipated prolonged disability — has not been examined in this context. Notably, a 2021

national survey found no consensus on optimal tracheostomy timing in neurocritical patients, with clinicians reporting inconsistent practice driven by local culture rather than evidence.[9] A recent multicenter study in neurocritical patients confirmed that early tracheostomy is associated with shorter LOS and lower total hospital costs in stroke patients, yet also found a 40% lower likelihood of discharge to rehabilitation in the late-tracheostomy group — underscoring that the consequences of timing extend beyond mortality.[10] The 2026 Neurocritical Care Society neuro-prognostication guidelines for critically ill AIS patients now explicitly emphasize tracheostomy decannulation prediction and goals-of-care counseling for large hemispheric infarction as clinical priorities,[11] creating an urgent need for contemporary population-level data to anchor these recommendations.

Using a large, nationally representative cohort of 854,660 AIS hospitalizations from 2016–2023, we aimed to: (1) characterize the prevalence and temporal trends of tracheostomy in contemporary AIS care; (2) identify predictors of tracheostomy among all AIS patients and among those specifically requiring MV, including the novel contribution of decompressive craniectomy; (3) examine the association between tracheostomy timing (early vs. late) and in-hospital outcomes including LOS, mortality, PEG placement, and discharge destination; (4) compare outcomes across four clinically defined groups — no MV, MV without tracheostomy, early tracheostomy, and late tracheostomy; and (5) characterize racial and procedural subgroup differences in tracheostomy patterns. The cohort selection process is depicted in Fig. 1.

Methods

Data Source

This retrospective observational study used data from the National Inpatient Sample (NIS), Healthcare Cost and Utilization Project (HCUP), for years 2016 through 2023. The NIS is the largest publicly available all-payer inpatient database in the United States, representing approximately 20% of all U.S. hospitalizations through a stratified sampling design. Discharge weights enable generation of nationally representative estimates. All analyses followed HCUP methodological guidance. The NIS contains fully de-identified data; institutional review board approval and informed consent were not required.[12]

Study Population

Hospitalizations with a principal diagnosis of acute ischemic stroke (AIS) were identified using ICD-10-CM codes I63.x. Patients aged 18 to 90 years were included. Exclusions were applied for missing age, sex, discharge disposition, or invalid sampling weights. The final analytic cohort comprised 854,660 unweighted AIS hospitalizations, representing approximately 4.27 million weighted discharges. The stepwise cohort selection process, exclusion criteria, and analytic group derivation are illustrated in Fig. 1. Mechanical ventilation (MV) was identified using ICD-10-PCS procedure codes 5A1935Z (< 24 hours), 5A1945Z (24–96 hours), and 5A1955Z (> 96 hours).

Tracheostomy and Timing Classification

Tracheostomy was identified using ICD-10-PCS procedure codes for open (0B110F4, 0B110ZZ), percutaneous (0B113F4, 0B113ZZ), and percutaneous endoscopic (0B114F4, 0B114ZZ) approaches. Procedure day was extracted by matching tracheostomy procedure codes to corresponding PRDAY slots (PRDAY1 through PRDAY10). Tracheostomy timing was classified as early (≤ 7 days from admission) or late (> 7 days), consistent with recent administrative database studies in the stroke literature.[6,13] Patients with tracheostomy but missing procedure day data were classified separately. Gastrostomy tube placement (PEG) was identified using codes 0DH63UZ, 0DH64UZ, and 0DH60UZ.

Variables

Demographic variables included age, sex, and race/ethnicity. Comorbidities were derived using ICD-10-CM codes consistent with Elixhauser and Charlson classification systems: congestive heart failure (CHF), chronic obstructive pulmonary disease (COPD), atrial fibrillation (AFIB), chronic kidney disease (CKD), liver disease, coagulopathy, cancer, obesity, diabetes, and hypertension. Hemorrhagic transformation (HT) was identified by secondary ICD-10-CM codes I61.x or I62.x in the AIS cohort. Treatment exposures included mechanical thrombectomy (03CG3ZZ, 03CG4ZZ, 03CK3ZZ, 03CK4ZZ, 03CL3ZZ, 03CL4ZZ) and intravenous thrombolysis (3E033 series). In-hospital mortality was defined by discharge disposition code 20. Prolonged MV was defined as MV duration exceeding 24 hours (codes 5A1945Z or 5A1955Z).[14]

Statistical Analysis

Descriptive statistics compared tracheostomy and non-tracheostomy groups among all AIS patients (Table 1) and among mechanically ventilated patients (Table 2). Chi-square tests were used for categorical variables and t-tests for continuous variables. Two multivariable logistic regression models were developed: Model A identified predictors of tracheostomy among all AIS patients; Model B identified predictors among MV patients only, additionally including prolonged MV as a predictor. Results are reported as adjusted odds ratios (OR) with 95% confidence intervals.

Table 1

Baseline demographic, clinical, and treatment characteristics stratified by tracheostomy status among all AIS patients (n = 854,660). Values are number (%) or mean (SD).

Characteristic	No Trach (n = 849,287)	Trach (n = 5,373)	p
Age, mean (SD)	69.9 (14.0)	63.3 (13.6)	***
Sex — Female	461,644 (49.4%)	2,251 (41.9%)	***
Race — White	486,480 (57.3%)	2,174 (40.5%)	***
Race — Black	124,842 (14.7%)	1,481 (27.6%)	***
Race — Hispanic	60,986 (7.2%)	488 (9.1%)	***
Race — Asian/PI	22,347 (2.6%)	199 (3.7%)	***
Weekend Admission	237,754 (25.4%)	3,824 (26.3%)	*
Comorbidities			
Congestive Heart Failure	185,376 (19.8%)	4,336 (29.8%)	***
COPD	135,809 (16.0%)	974 (18.1%)	***
Atrial Fibrillation	213,347 (25.1%)	1,623 (30.2%)	NS
Chronic Kidney Disease	192,065 (20.5%)	3,127 (21.5%)	**
Liver Disease	16,932 (2.0%)	299 (5.6%)	***
Coagulopathy	50,201 (5.9%)	845 (15.7%)	***
Cancer	42,121 (5.0%)	197 (3.7%)	***
Obesity	139,638 (12.1%)	2,315 (15.9%)	**
Diabetes	369,228 (39.5%)	5,175 (35.5%)	***
Hypertension	723,897 (85.2%)	3,937 (73.3%)	***
Hemorrhagic Transformation	43,206 (5.1%)	1,447 (26.9%)	***
Treatments			
Mechanical Thrombectomy	32,004 (3.8%)	887 (16.5%)	***
IV tPA	81,327 (9.6%)	647 (12.0%)	***
MV (received)	37,339 (4.4%)	5,147 (95.8%)	***
Prolonged MV > 24h	27,251 (3.2%)	5,119 (95.3%)	***

**** p < 0.001; ** p < 0.01; * p < 0.05; NS = not significant. AIS = acute ischemic stroke; COPD = chronic obstructive pulmonary disease; CKD = chronic kidney disease; MV = mechanical ventilation; PEG = percutaneous endoscopic gastrostomy; LOS = length of stay.*

Characteristic	No Trach (n = 849,287)	Trach (n = 5,373)	p
PEG Tube	22,572 (2.7%)	4,103 (76.4%)	***
LOS, mean (SD)	5.09 (6.79)	32.29 (26.38)	***
In-hospital Mortality	33,971 (4.0%)	484 (9.0%)	***

*** p < 0.001; ** p < 0.01; * p < 0.05; NS = not significant. AIS = acute ischemic stroke; COPD = chronic obstructive pulmonary disease; CKD = chronic kidney disease; MV = mechanical ventilation; PEG = percutaneous endoscopic gastrostomy; LOS = length of stay.

Table 2

Characteristics stratified by tracheostomy status among mechanically ventilated AIS patients only (n = 42,486). Selected variables shown.

Characteristic	No Trach (n = 37,339)	Trach (n = 5,147)	p
Age, mean (SD)	68.5 (14.3)	63.3 (13.6)	***
Sex — Female	18,387 (49.2%)	2,151 (41.8%)	***
Race — White	19,683 (52.7%)	2,083 (40.5%)	***
Race — Black	5,896 (15.8%)	1,432 (27.8%)	***
Congestive Heart Failure	10,471 (28.0%)	1,418 (27.6%)	***
Atrial Fibrillation	13,889 (37.2%)	1,568 (30.5%)	***
Coagulopathy	4,881 (13.1%)	811 (15.8%)	***
Liver Disease	1,765 (4.7%)	285 (5.5%)	NS
Hemorrhagic Transformation	7,576 (20.3%)	1,400 (27.2%)	***
Mechanical Thrombectomy	7,052 (18.9%)	861 (16.7%)	***
Prolonged MV > 24h	27,251 (73.0%)	5,119 (99.5%)	***
PEG Tube	3,962 (10.6%)	4,029 (78.3%)	***
LOS, mean (SD)	10.8 (13.4)	32.1 (25.8)	***
In-hospital Mortality	14,822 (39.7%)	463 (9.0%)	***

*** p < 0.001; NS = not significant. Table restricted to selected clinically relevant variables. Full comparison available in supplementary material.

Outcomes were compared across four clinically defined groups: no MV, MV without tracheostomy, early tracheostomy (≤ 7 days), and late tracheostomy (> 7 days). Between-group outcome comparisons used chi-square tests for proportions and t-tests for continuous variables. Adjusted mortality models compared early versus late tracheostomy, controlling for age, sex, and key comorbidities. Decompressive craniectomy was identified using ICD-10-PCS codes for skull excision (0NB series) and

release of cerebral meninges (00N series), consistent with prior administrative database methodology. This variable was incorporated as an additional predictor in a pre-specified sensitivity model (Model B-extended) to quantify its independent contribution to tracheostomy risk among MV patients. Discharge disposition was categorized as: home or home health, skilled nursing facility (SNF) or long-term acute care hospital (LTACH), short-term hospital, or died. In-hospital complications including hospital-acquired pneumonia, sepsis, and acute kidney injury (AKI) were identified by secondary ICD-10-CM diagnosis codes. Temporal trends in tracheostomy rates were assessed using logistic regression with calendar year as a continuous predictor among MV patients; a Cochran-Armitage trend test was performed as a confirmatory analysis. To investigate potential mechanisms underlying the observed temporal decline in tracheostomy utilization, we performed a pre-specified mechanistic analysis testing five hypotheses: (1) rising mechanical thrombectomy utilization; (2) falling overall MV rates; (3) falling prolonged MV rates among MV patients; (4) case-mix severity shifts; and (5) COVID-19 confounding. Cochran-Armitage trend tests were applied to annual proportions for each hypothesis. A logistic interaction model (TRACH ~ YEAR × THROMBECTOMY + covariates) tested whether tracheostomy rates declined differentially by thrombectomy status. All analyses were performed in R version 4.5.2.

Results

Cohort and Tracheostomy Prevalence

The final analytic cohort included 854,660 AIS hospitalizations, of which 42,486 (5.0%) required MV. Tracheostomy was performed in 5,373 hospitalizations (0.63% of all AIS; 12.1% of MV patients). Among non-MV patients, tracheostomy was exceedingly rare (n = 226, 0.03%), confirming that tracheostomy in AIS is almost exclusively a phenomenon of the ventilated population. Among the 5,373 tracheostomy cases, 5,147 (95.8%) had concurrent MV documentation.

Patient Characteristics

Tracheostomy patients were substantially younger than non-tracheostomy AIS patients (mean 63.3 ± 13.6 vs 69.9 ± 14.0 years; $p < 0.001$; SMD 0.482) and more frequently male (58.1% vs 50.6%; $p < 0.001$) (Table 1). Pronounced racial differences were observed: Black patients comprised 27.6% of tracheostomy cases compared with 14.7% of non-tracheostomy cases ($p < 0.001$), and White patients were underrepresented in the tracheostomy group (40.5% vs 57.3%; $p < 0.001$; SMD 0.358). Among MV patients, coagulopathy was present in 15.8% of tracheostomy versus 13.1% of non-tracheostomy patients, liver disease in 5.5% versus 4.7%, and CHF in 27.6% versus 28.0% (Table 2). Hemorrhagic transformation was identified in 27.2% of tracheostomy patients compared with 20.3% of non-tracheostomy MV patients (SMD 0.163; $p < 0.001$). Among ventilated patients, 99.5% of tracheostomy recipients had prolonged MV (> 24h) compared with 73.0% of ventilated patients without tracheostomy ($p < 0.001$; Table 2).

Tracheostomy Timing

Among 5,217 tracheostomy patients with documented procedure day data, the median procedure day was 11 (IQR 8–16). Early tracheostomy (≤ 7 days) was performed in 1,146 patients (22.0%) and late tracheostomy (> 7 days) in 4,071 patients (78.0%). Procedure day data were missing in 156 patients (2.9%). The predominance of late tracheostomy is consistent with prevailing practice patterns in which tracheostomy is considered after failed weaning attempts typically beginning around day 7–10 after intubation.

Tracheostomy Rate by MV Duration

Tracheostomy rates increased markedly with MV duration. Among patients with short-duration MV (< 24h), tracheostomy was performed in 0.33%; in the 24–96h group, 1.36%; and in patients with prolonged MV (> 96h), 29.1%. This gradient confirms that tracheostomy in AIS is largely a function of ventilatory dependence rather than decision-making at the time of initial intubation.

Predictors of Tracheostomy

In Model A (all AIS patients; Table 3), hemorrhagic transformation demonstrated the strongest independent association with tracheostomy (adjusted OR 5.19; 95% CI 4.86–5.54; $p < 0.001$), followed by mechanical thrombectomy (OR 3.04; 95% CI 2.81–3.28), coagulopathy (OR 2.18; 95% CI 2.02–2.36), liver disease (OR 2.05; 95% CI 1.81–2.32), and CHF (OR 1.58; 95% CI 1.48–1.68). Age was strongly and inversely associated (OR 0.972 per year; 95% CI 0.970–0.974; $p < 0.001$). Cancer (OR 0.665; 95% CI 0.573–0.768) and White race (OR 0.557; 95% CI 0.482–0.648 vs Asian/PI reference) were independently associated with lower odds of tracheostomy. IV tPA was not independently associated with tracheostomy in Model A (OR 1.01; 95% CI 0.93–1.09; NS), and obesity was likewise not significant (OR 1.03; 95% CI 0.96–1.10; NS).

Table 3

Multivariable logistic regression predictors of tracheostomy: Model A (all AIS patients) and Model B (mechanically ventilated patients only). Selected significant predictors shown.

Variable	Model A OR	95% CI	p	Model B OR †	95% CI	p
Age (per year)	0.972	0.970–0.974	< .001	0.981	0.979–0.983	< .001
Female (vs Male)	0.873	0.844–0.903	< .001	0.939	0.904–0.976	.001
Race — Black (vs Asian/PI)	1.28	1.10–1.49	< .001	1.13	0.96–1.35	NS
Race — White (vs Asian/PI)	0.557	0.482–0.648	< .001	0.571	0.484–0.677	< .001
Comorbidities						
Hemorrhagic transformation	5.19	4.86–5.54	< .001	1.35	1.26–1.44	< .001
Coagulopathy	2.18	2.02–2.36	< .001	1.10	1.01–1.19	.028
Liver disease	2.05	1.81–2.32	< .001	1.00	0.88–1.15	NS
CHF	1.58	1.48–1.68	< .001	0.95	0.88–1.02	NS
COPD	1.22	1.14–1.31	< .001	1.05	0.97–1.14	NS
Atrial Fibrillation	1.38	1.29–1.47	< .001	0.932	0.869–1.00	NS
CKD	0.907	0.843–0.976	.010	0.864	0.796–0.936	< .001
Obesity	1.03	0.96–1.10	NS	1.16	1.07–1.25	< .001
Diabetes	1.08	1.02–1.14	.009	1.11	1.04–1.18	< .001
Treatments						
Mechanical thrombectomy	3.04	2.81–3.28	< .001	0.955	0.88–1.04	NS
IV tPA	1.01	0.93–1.09	NS	0.863	0.786–0.945	< .001
Prolonged MV > 24h	—	—	—	62.3	43.9–92.6	< .001

Model A = all AIS patients (n = 854,660). Model B = mechanically ventilated AIS patients only (n = 42,486); additionally includes prolonged MV as predictor. Reference category for race = Asian/Pacific Islander. NS = not significant. OR = adjusted odds ratio; CI = confidence interval. Note the directional reversal of comorbidity ORs between Models A and B — see Discussion.

In Model B (MV patients only; Table 3), the predictor structure changed substantially. Prolonged MV (> 24h) was overwhelmingly the dominant predictor (OR 62.3; 95% CI 43.9–92.6; p < 0.001), reflecting the near-deterministic relationship between extended ventilatory dependence and the tracheostomy decision. Among clinical variables, hemorrhagic transformation remained independently associated (OR 1.35; 95% CI 1.26–1.44; p < 0.001). Notably, traditional comorbidities including CHF (OR 0.95; NS), liver disease (OR 1.00; NS), and CKD (OR 0.864) no longer showed independent positive associations in the MV-only model—reflecting that among ventilated patients, those with severe systemic comorbidity die before reaching the tracheostomy decision threshold rather than surviving to require it. Age remained independently inversely associated (OR 0.981 per year; p < 0.001). In the pre-specified sensitivity analysis incorporating decompressive craniectomy (Model B-extended), this procedure was independently and strongly associated with tracheostomy (OR 2.55; 95% CI 2.31–2.80; p < 0.001), confirming at national scale that the decompressive craniectomy pathway in AIS is tightly coupled with subsequent tracheostomy placement — an observation previously documented only in single-center large vessel occlusion cohorts.[15]

Outcomes by Tracheostomy Timing Group

Outcomes differed substantially across the four clinical groups (Table 4; Figs. 3 and 4). In-hospital mortality was lowest in the no-MV group (2.32%) and highest in the MV-no-tracheostomy group (39.7%), reflecting the severity of acute illness in those who die before the tracheostomy threshold is reached. Mortality was 9.84% in the early tracheostomy group and 8.23% in the late tracheostomy group (unadjusted p = 0.007). After adjustment for age, sex, and comorbidities, early tracheostomy was associated with significantly higher mortality compared with late tracheostomy (adjusted OR 1.36; 95% CI 1.08–1.70; p = 0.007) — consistent with confounding by indication, in which patients selected for early procedure are systematically sicker.

Table 4

In-hospital outcomes by ventilation and tracheostomy status group.

Outcome	No MV (n = 812,174)	MV, No Trach (n = 37,339)	Early Trach ≤7d (n = 1,146)	Late Trach >7d (n = 4,071)
LOS, mean (SD), days	4.8 (6.2)	10.8 (13.4)	23.8 (22.9)	34.4 (26.2)
In-hospital mortality	2.32%	39.7%	9.84%	8.23%
PEG placement	2.3%	10.6%	77.2%	78.5%
Discharge home	54.4%	13.4%	4.5%	3.9%
Discharge to SNF/LTACH	39.4%	41.7%	80.7%	84.2%

All between-group differences p < 0.001 except early vs. late tracheostomy mortality (unadjusted p = 0.007; adjusted OR 1.36, 95% CI 1.08–1.70, p = 0.007 — indicating higher adjusted mortality with early tracheostomy, consistent with confounding by indication) and PEG co-placement between early and late tracheostomy (p = 0.38). LOS difference between early and late tracheostomy: mean 10.6 days (95% CI 9.3–12.4; p < 0.001); adjusted LOS ratio 0.662 (95% CI 0.638–0.687; p < 0.001). Early = ≤ 7 days from admission; Late = > 7 days. SNF = skilled nursing facility; LTACH = long-term acute care hospital. MV = mechanical ventilation; PEG = percutaneous endoscopic gastrostomy. Discharge home includes home health care. Decompressive craniectomy was performed in 16.3% of tracheostomy and 4.4% of non-tracheostomy MV patients (p < 0.001).

Length of stay differed significantly across groups. Early tracheostomy patients had a mean LOS of 23.8 ± 22.9 days, compared with 34.4 ± 26.2 days for late tracheostomy (mean difference 10.6 days; 95% CI 9.3–12.4 days; p < 0.001). PEG tube co-placement was present in 77.2% of early and 78.5% of late tracheostomy patients, compared with 10.6% in ventilated patients without tracheostomy and 2.3% in the no-MV group, indicating that the majority of tracheostomy patients are expected to require long-term enteral nutrition. Discharge destination paralleled these findings: 85.5% of early tracheostomy and 87.7% of late tracheostomy patients were discharged to institutional settings (skilled nursing facility, long-term acute care hospital, or inpatient rehabilitation), compared with 46.5% of mechanically ventilated patients without tracheostomy. Only 4.5% and 3.9% of early and late tracheostomy patients, respectively, were discharged home or to home health care, reinforcing the interpretation that tracheostomy in AIS signals anticipated long-term disability.

Temporal Trends

Tracheostomy rates among MV patients declined significantly over the study period, from 12.9% in 2016 to 9.44% in 2023 (Cochran-Armitage Z = − 6.54, p < 0.0001; logistic trend OR per year 0.958; 95% CI 0.946–0.970; Fig. 2). The steepest single-year decline occurred from 2022 to 2023 (− 2.78 percentage points). Median procedure day was stable at Day 11 in 2016–2020 and shifted to Day 12 in 2021–2023. Mechanistic analyses identified convergent structural explanations for the declining tracheostomy rate. The overall MV rate rose significantly over the study period (4.44% in 2016 to 5.04% in 2023; Cochran-Armitage Z = + 11.4, p < 0.0001), excluding fewer severely ill patients reaching the ICU as an explanation. However, among already-ventilated patients, the proportion requiring prolonged MV (> 24 hours) declined

significantly from 78.5% in 2016 to 73.9% in 2023 (Z = − 6.77, p < 0.0001), and the proportion requiring > 96 hours of ventilation reached a dataset low of 34.6% in 2023 — indicating that a growing proportion of AIS patients are being extubated before reaching the tracheostomy decision threshold. Mechanical thrombectomy utilization rose substantially over the study period. Among MV patients, the thrombectomy rate increased from 15.3% in 2016 to 22.2% in 2023 (Cochran-Armitage Z = + 6.39, p < 0.0001); across all AIS patients, thrombectomy utilization expanded from 2.86% to 4.77% (Z = + 20.9, p < 0.0001). A significant year-thrombectomy interaction (OR 0.960 per year, 95% CI 0.926–0.995; p = 0.027) confirmed that tracheostomy rates declined faster in thrombectomy-treated patients than in non-thrombectomy patients (7.28% vs 10.1% in 2023), consistent with thrombectomy-mediated recanalization enabling earlier neurological recovery and earlier extubation success. COVID-19 contributed a transient reduction in tracheostomy rates during 2020–2021, with partial rebound in 2022; the 2023 decline therefore represents a new post-COVID structural change. In-hospital mortality among MV patients who did not receive tracheostomy fell from 43.4% in 2016 to 36.6% in 2023, further supporting a shift toward a population with higher rates of successful ventilator liberation.

Thrombectomy Subgroup

Among MV patients, tracheostomy rates differed by thrombectomy status (10.9% in thrombectomy vs 12.4% in non-thrombectomy patients; p < 0.001). Thrombectomy patients who did receive tracheostomy had shorter LOS (30.7 vs 32.4 days) and markedly lower mortality (7.44% vs 8.87%), likely reflecting better baseline neurologic reserve and purposeful patient selection for tracheostomy among those with perceived recovery potential.

Discussion

In this nationally representative analysis of 854,660 AIS hospitalizations from 2016 to 2023, we demonstrate that tracheostomy occurs in 0.63% of all AIS patients and 12.1% of those requiring mechanical ventilation. These figures are consistent with prior national estimates spanning earlier eras[3,4] and provide the first national mechanistic analysis of declining tracheostomy rates in contemporary AIS care. Our findings extend prior work in several important dimensions: we demonstrate that the declining tracheostomy trend is driven primarily by upstream changes in ventilatory trajectory — specifically, rising thrombectomy utilization enabling earlier extubation and a structural decline in prolonged MV duration — rather than a shift in the tracheostomy decision itself; we characterize a mechanistic hierarchy of tracheostomy predictors; we document marked racial disparities in tracheostomy use; and we confirm that early tracheostomy is associated with shorter LOS but not survival benefit after adjustment, consistent with the SETPOINT2 trial.[7,8]

The Dominant Role of Prolonged MV and Hemorrhagic Transformation

The most striking finding of our regression analysis is the near-complete dominance of prolonged MV (OR 62.3) as a predictor of tracheostomy in the ventilated population. This finding, while mathematically expected given the high collinearity between prolonged ventilatory dependence and the clinical decision to place a tracheostomy, provides important quantitative context: once a patient with AIS has required more than 24 hours of MV, the probability of ultimately requiring tracheostomy is more than 62-fold higher than among those with short-duration MV. This suggests that the tracheostomy decision in AIS is less about comorbidity profiling and more about the trajectory of ventilatory dependence, consistent with prior single-center observations in large vessel occlusion patients.[15]

Hemorrhagic transformation emerged as the second strongest predictor in the MV-only model (OR 1.35) and the strongest overall predictor across all AIS patients (OR 5.19). This finding has not been previously highlighted in the tracheostomy literature at national scale. HT likely contributes to tracheostomy need through multiple mechanisms: secondary neurologic deterioration impairing consciousness and airway protective reflexes, hemorrhagic expansion requiring surgical intervention, and increased complications including seizures and elevated intracranial pressure. The observation that HT is present in 27.2% of tracheostomy patients — more than a fivefold higher rate than non-tracheostomy AIS patients (5.1%) — suggests that HT should be incorporated into future tracheostomy prediction models and discussed in goals-of-care contexts when HT is identified.

The Mortality Paradox: Selection Bias in the MV-No-Tracheostomy Group

The stark mortality difference between MV-no-tracheostomy patients (39.7%) and those who received tracheostomy (9.84% early, 8.23% late) is counterintuitive but well-recognized as a survivorship phenomenon. Patients who require MV but die before the tracheostomy decision threshold — typically days 7–10 of hospitalization — populate the MV-no-tracheostomy group, while tracheostomy patients represent survivors to that decision point. This is not a causal protective effect of tracheostomy but rather a reflection of the natural history of acute respiratory failure in severe stroke, where early in-hospital mortality concentrates in those too critically ill for elective airway procedures. Similar observations have been made in prior stroke-specific analyses[5,16] and in the general critical care literature on tracheostomy. Stroke-associated pneumonia complicates a substantial proportion of ventilated AIS patients and independently worsens mortality and length of stay,[17] likely contributing to the higher early hazard observed in this group.

Tracheostomy Timing and the SETPOINT2 Context

Our finding that early tracheostomy (≤ 7 days) was associated with higher adjusted in-hospital mortality but with significantly shorter LOS (23.8 vs 34.4 days, $p < 0.001$) is broadly consistent with the SETPOINT2 trial's conclusion that early tracheostomy does not improve functional outcome at 6 months.[7] The Premraj et al. meta-analysis of over 17,000 stroke patients similarly found no association between tracheostomy timing and mortality, ICU LOS, or neurological outcome.[8] A more recent meta-analysis of 19 RCTs and 3,586 critically ill patients similarly reported only a modest mortality benefit with

early tracheostomy alongside a clear reduction in ICU length of stay,[18] paralleling the LOS pattern observed here. However, the substantial LOS difference in our data — approximately 10 days shorter for early tracheostomy — represents a clinically meaningful finding for resource utilization and hospital capacity planning, consistent with prior NIS-based observations by Villwock et al.[5] and Albert et al.[3]

The decline in tracheostomy rates is most parsimoniously explained by a convergence of structural forces rather than any single cause. The dominant mechanism appears to be the dramatic expansion of mechanical thrombectomy — which rose from 15.3% to 22.2% of MV patients over the study period — enabling recanalization of large vessel occlusions, faster neurological recovery, and earlier extubation success. This is directly supported by the significant year-thrombectomy interaction (p = 0.027) and by the parallel decline in prolonged MV duration, both of which predate SETPOINT2 publication and indicate a structural shift in the ventilatory trajectory of AIS patients. COVID-19–era aerosol precaution protocols contributed a transient suppression of tracheostomy rates in 2020–2021, with partial rebound in 2022. The additional sharp 2023 decline — the first full calendar year after SETPOINT2 publication — is temporally consistent with a practice-level shift in tracheostomy thresholds informed by that trial's negative findings, though causality cannot be established from administrative data. The most defensible interpretation is that the 2023 decline reflects a convergence: thrombectomy-driven earlier liberation from MV, improving ICU care practices, post-COVID normalization, and possibly growing clinician comfort with deferring or declining tracheostomy in borderline cases following SETPOINT2.

Racial Disparities in Tracheostomy Use

Black patients were disproportionately represented among tracheostomy recipients (27.8% of tracheostomy vs 15.8% of non-tracheostomy MV patients), a disparity that was attenuated after adjustment for demographics and comorbidities (adjusted OR 1.13 vs Asian/PI reference in Model B; p = 0.15) but remained significant in the overall AIS model (OR 1.28; 95% CI 1.10–1.49; p = 0.001). Hispanic patients were under-represented after adjustment (adjusted OR 0.739 vs Asian/PI; p = 0.002), while White patients were significantly under-represented (40.5% vs 57.3%; adjusted OR 0.557 in Model A; OR 0.571 in Model B). This multi-racial pattern of disparity likely reflects a convergence of mechanisms operating at biological, structural, and interpersonal levels. Biologically, Black patients with AIS carry a disproportionate burden of comorbidities independently associated with tracheostomy — including coagulopathy, hemorrhagic transformation, and liver disease — and present at younger ages with more severe neurological impairment. Structurally, Black and Hispanic patients have historically had lower rates of thrombectomy access, higher residual deficits after stroke, and greater post-acute care needs, all of which increase the probability of prolonged MV and subsequent tracheostomy. At the interpersonal level, documented differences in goals-of-care communication quality, surrogate decision-making dynamics, and implicit bias in prognostication may alter the threshold at which tracheostomy is offered or pursued across racial groups. Prior work has demonstrated that minority race is independently associated with non-beneficial gastrostomy tube placement following stroke,[19] and that Black patients with intracerebral hemorrhage are significantly less likely to undergo withdrawal of life-sustaining therapy than White patients despite comparable in-hospital outcomes.[20] These findings are consistent

with broader patterns of racial inequity in neurocritical care — including documented differences in supplemental oxygen delivery attributable to pulse oximetry bias in non-White patients[21] — and represent an important and incompletely understood driver of healthcare resource utilization after severe stroke. Prospective studies incorporating neurological severity, surrogate preferences, and communication quality are needed to disentangle these mechanisms.

PEG Co-Placement as a Marker of Anticipated Disability

PEG tube co-placement in 77.2–78.5% of tracheostomy patients — compared with 10.6% in ventilated patients without tracheostomy — highlights that tracheostomy in AIS almost universally signals anticipated long-term disability with impaired oral intake. The DECAST study demonstrated that decannulation was achieved in only 59% of stroke patients surviving 12 months after tracheostomy, and was associated with better functional outcomes compared with permanent cannulation.[16] Our discharge destination data extend this observation further: 80.7–84.2% of tracheostomy patients were discharged to SNF or LTACH, and fewer than 5% reached home, compared with 13.4% home discharge among ventilated patients without tracheostomy. A recent multicenter neurocritical care study found that early tracheostomy was associated with a 40% lower likelihood of discharge to rehabilitation versus late tracheostomy, suggesting timing itself may shape post-acute trajectories beyond its effect on LOS.[10] Taken together, the tracheostomy–PEG–LTACH triad represents a distinct, high-intensity care trajectory carrying profound implications for patients, families, and health systems. Goals-of-care discussions should ideally occur prospectively — at the point when prolonged MV becomes apparent — rather than reactively after procedures are already placed, because both the tracheostomy and PEG decisions signal a clinical trajectory that is rarely reversed.

Thrombectomy Subgroup Implications

The lower tracheostomy rate among thrombectomy MV patients (10.9% vs 12.4%) and their markedly better outcomes when tracheostomy is performed (mortality 7.44% vs 8.87%) likely reflect purposeful patient selection: thrombectomy patients undergo a reversibility-guided triage in which tracheostomy is reserved for those with anticipated neurological recovery. This is clinically important context for interpreting the association between thrombectomy and MV observed in our companion paper on mechanical ventilation predictors — thrombectomy-related intubation encompasses both procedural airway management and genuine respiratory failure, and the two groups have substantially different prognostic trajectories.

Limitations

This study has limitations inherent to administrative data. The NIS does not capture neurologic severity scores such as the NIH Stroke Scale, infarct location or volume, or the clinical indications and context surrounding individual tracheostomy decisions. Without stroke severity data, residual confounding in both predictor and outcome models cannot be excluded; in particular, the adjusted LOS comparison between early and late tracheostomy groups should be interpreted with appropriate caution, as patients

selected for early tracheostomy may differ systematically from those receiving late tracheostomy in ways not captured by available covariates. Procedure day data were missing in 2.9% of tracheostomy patients, limiting precision in timing analyses. Causal inference is precluded in this observational design, and the survivorship bias inherent in comparing tracheostomy versus non-tracheostomy ventilated patients is explicitly addressed in the Discussion. The NIS does not capture long-term functional outcomes, tracheostomy decannulation rates, or post-discharge survival — outcomes that the 2026 Neurocritical Care neuro-prognostication guidelines identify as priority endpoints for this population.[11] Hospital region was not available in the analytic dataset and was therefore excluded from multivariable models; residual geographic confounding cannot be excluded. ICD-10-CM coding for hospital-acquired complications such as pneumonia and sepsis may reflect documentation variation across institutions rather than true incidence differences. Importantly, the NIS does not include the SETscore or equivalent variables — consciousness level, swallowing function, and predicted MV duration at admission — that would enable direct comparison with SETPOINT2 eligibility criteria. The racial disparity findings, while robust after adjustment, do not permit causal attribution to specific mechanisms such as implicit bias, goals-of-care communication differences, or structural access inequities; disentangling these requires prospective study designs with qualitative components. Despite these limitations, the NIS provides a uniquely powered platform for characterizing the national tracheostomy landscape in AIS during and immediately surrounding the SETPOINT2 era, with sample sizes and temporal range unavailable in any prior AIS-specific study.

Conclusions

Tracheostomy occurs in approximately 12.1% of mechanically ventilated AIS patients and is characterized by prolonged hospitalization, near-universal gastrostomy co-placement, predominantly institutional discharge, and significantly declining national rates — from 12.9% to 9.44% of MV patients over 2016–2023 (Cochran-Armitage $Z = -6.54$; $p < 0.0001$). Prolonged ventilation and hemorrhagic transformation are the dominant independent predictors among ventilated patients; decompressive craniectomy carries an adjusted OR of 2.55 for tracheostomy and should be incorporated into future prediction models. Early tracheostomy is associated with significantly shorter hospitalization but not survival benefit after adjustment, consistent with the SETPOINT2 trial and subsequent meta-analyses. The median procedure day drifted toward later placement during 2020–2022, most likely driven by COVID-19–era caution rather than SETPOINT2 dissemination, as that trial was published in May 2022 — our study extends through 2023, capturing the first full year post-publication. Racial disparities persist after risk adjustment: Black patients had 28% higher adjusted odds of tracheostomy than Asian/PI patients in the overall AIS model (Model A, $p = 0.001$), though this difference was attenuated and not statistically significant when restricted to MV patients (Model B OR 1.13; $p = 0.15$); addressing these disparities requires prospective investigation of goals-of-care communication quality, surrogate decision-making dynamics, and structural access inequities. The tracheostomy–PEG–LTACH care pathway represents a high-intensity clinical trajectory with profound implications for patients and families that warrants prospective goals-of-care integration. These findings provide the largest and most

contemporary national framework for tracheostomy in AIS, directly informing neurocritical care decision-making, resource planning, and the design of future prospective studies on timing optimization and equity.

Declarations

Disclosures: The authors report no conflicts of interest.

Data Source: National Inpatient Sample, HCUP, AHRQ (2016–2023). De-identified data; IRB waiver applied.

1. Compliance with Instructions for Authors

The authors confirm that this manuscript complies with all instructions outlined in the Neurocritical Care Instructions for Authors, including formatting, word count, reference style, table and figure preparation, and submission requirements for an Original Work (Clinical Investigation).

2. Author Contributions

Mian Urfy, MD, MSc: Conceptualization; study design; data acquisition; statistical analysis; interpretation of results; drafting of the manuscript; critical revision for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work.

Mariam Tariq Mir, MD: Literature review; interpretation of results; critical revision of the manuscript for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work.

Both authors meet all four ICMJE authorship criteria.

3. Authorship Requirements and Final Approval

All listed authors meet the authorship criteria established by the International Committee of Medical Journal Editors (ICMJE): (1) substantial contributions to the conception or design of the work, or the acquisition, analysis, or interpretation of data; (2) drafting the work or revising it critically for important intellectual content; (3) final approval of the version to be published; and (4) agreement to be accountable for all aspects of the work. The final manuscript has been read and approved by all authors.

4. Originality and Exclusive Submission

This manuscript has not been published, in whole or in part, in any other journal, and is not currently under consideration for publication elsewhere. No portion of the work has appeared in any prior publication, including preprint servers, abstracts, or conference proceedings, beyond what is permitted by the journal's policies.

5. Ethical Approval and Informed Consent

This is a retrospective observational analysis of de-identified administrative data from the Healthcare Cost and Utilization Project (HCUP) National Inpatient Sample (NIS), 2016–2023. Per the HCUP Data Use Agreement and 45 CFR 46.102(e), this work does not constitute human subjects research because it involves only secondary analysis of fully de-identified, publicly available data. Accordingly, Institutional Review Board (IRB) review and informed consent were not required. The authors followed all HCUP methodological and reporting requirements, including cell-size suppression rules where applicable.

6. Conflicts of Interest

The authors declare that they have no conflicts of interest, financial or otherwise, relevant to the subject of this manuscript. Neither author has any financial relationships, consulting arrangements, equity interests, patents, or other competing interests that could be perceived to influence the conduct or reporting of this work. ICMJE Disclosure forms have been completed by each author and are available upon request.

7. Reporting Checklist

This study is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for cohort studies. A completed STROBE checklist is included as a supplemental file with this submission.

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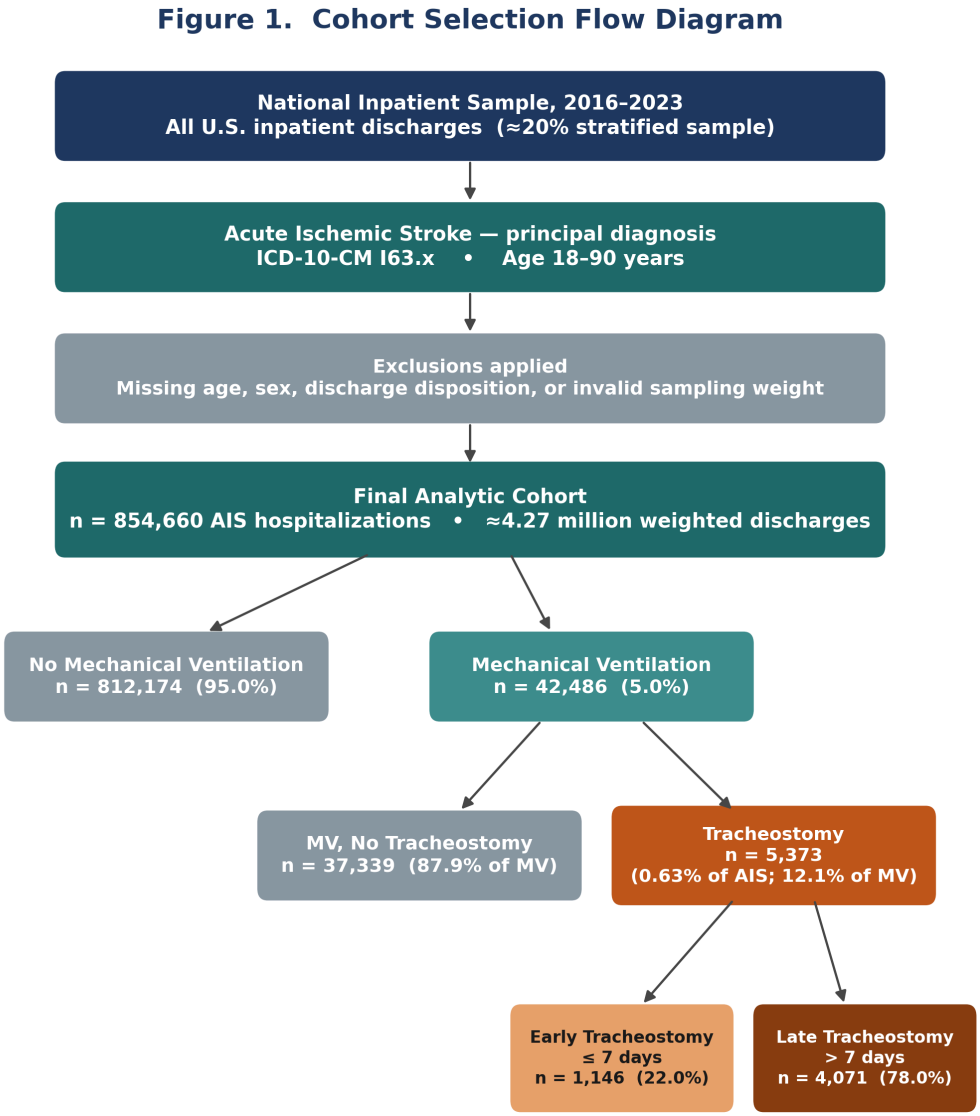
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Figures



† Procedure day was missing for 156 tracheostomy patients (2.9%); these patients were classified separately and excluded from timing analyses.

Tracheostomy ICD-10-PCS codes: 0B110F4, 0B110ZZ, 0B113F4, 0B113ZZ, 0B114F4, 0B114ZZ. Mechanical ventilation ICD-10-PCS codes: 5A1935Z (<24 h), 5A1945Z (24–96 h), 5A1955Z (>96 h).

Abbreviations: AIS, acute ischemic stroke; HCUP, Healthcare Cost and Utilization Project; ICD-10-CM, International Classification of Diseases, 10th Revision, Clinical Modification; ICD-10-PCS, International Classification of Diseases, 10th Revision, Procedure Coding System; MV, mechanical ventilation; NIS, National Inpatient Sample.

Figure 1

See image above for figure legend

Figure 2. Declining Tracheostomy Rates in AIS: A Mechanistic Analysis

National Inpatient Sample, 2016–2023



National Inpatient Sample (HCUP/AHRQ), 2016–2023; mechanically ventilated AIS patients, n = 42,486.

Dotted vertical line marks SETPOINT2 publication (May 2022). Dotted trend lines show linear fits.

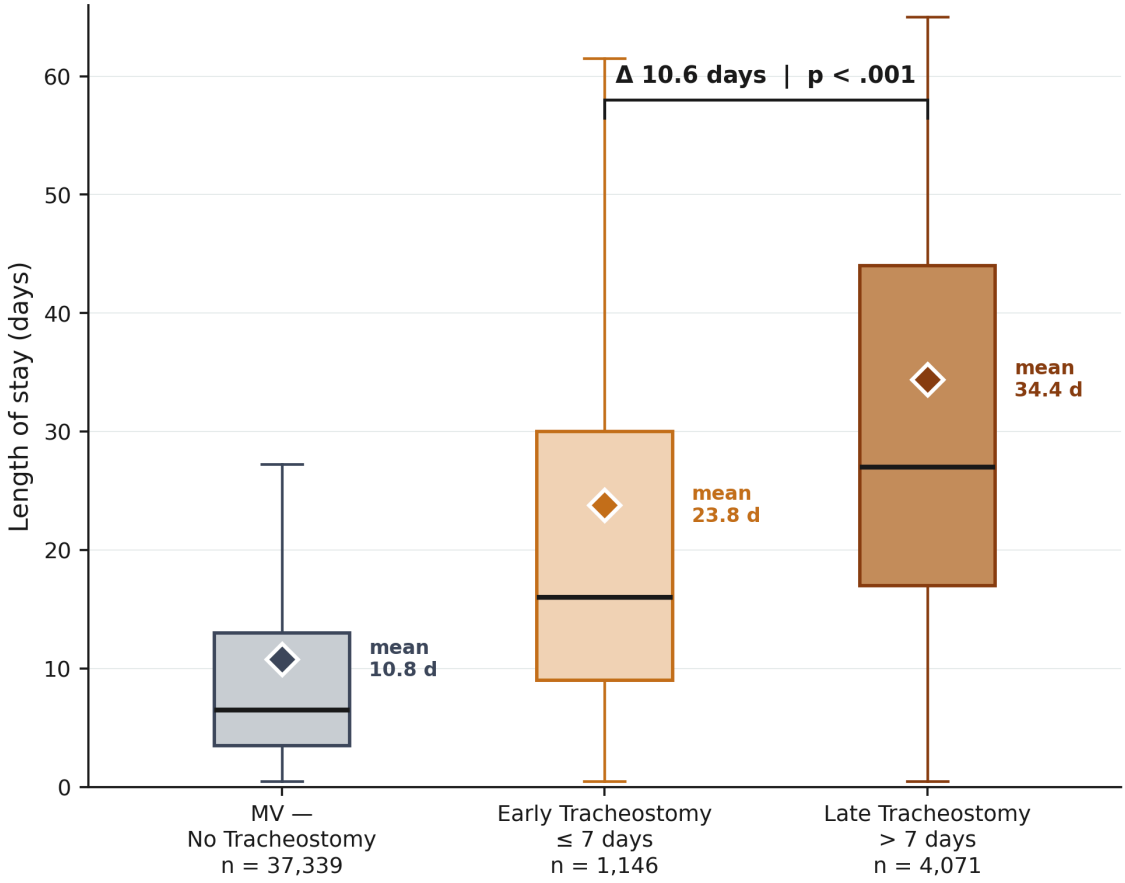
AIS, acute ischemic stroke; MV, mechanical ventilation; pp, percentage points.

Figure 2

See image above for figure legend

Figure 3. Length of Stay by Ventilation and Tracheostomy Status

Mechanically ventilated AIS patients, National Inpatient Sample 2016–2023



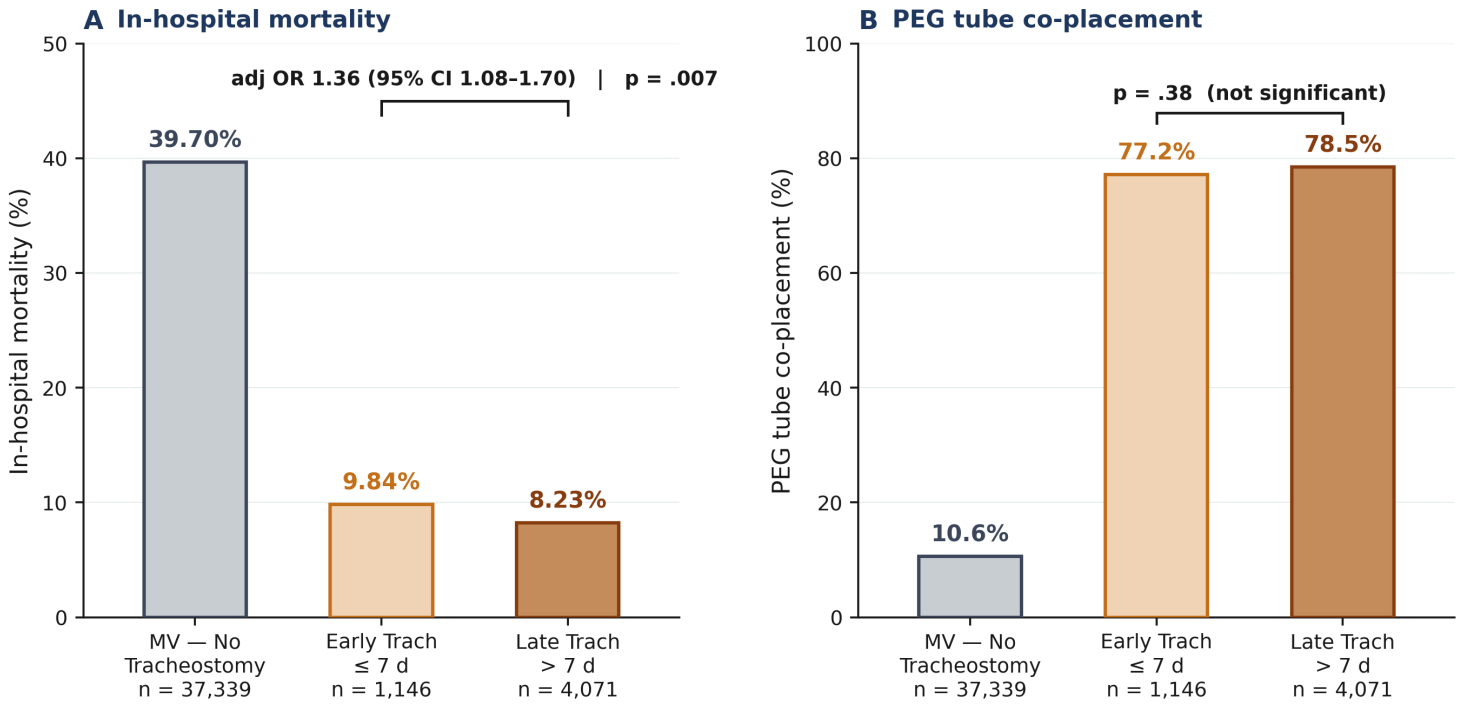
Boxes show Q1–Q3 with median line; diamonds indicate means; whiskers extend to 1.5 × IQR. Adjusted LOS ratio (early vs late) 0.662 (95% CI 0.638–0.687). GLM (gamma, log link) adjusting for age, sex, race, prolonged MV, hemorrhagic transformation, decompressive craniectomy, and thrombectomy. AIS, acute ischemic stroke; GLM, generalized linear model; IQR, interquartile range; LOS, length of stay; MV, mechanical ventilation.

Figure 3

See image above for figure legend

Figure 4. In-Hospital Mortality and PEG Tube Co-placement

Mechanically ventilated AIS patients, National Inpatient Sample 2016–2023



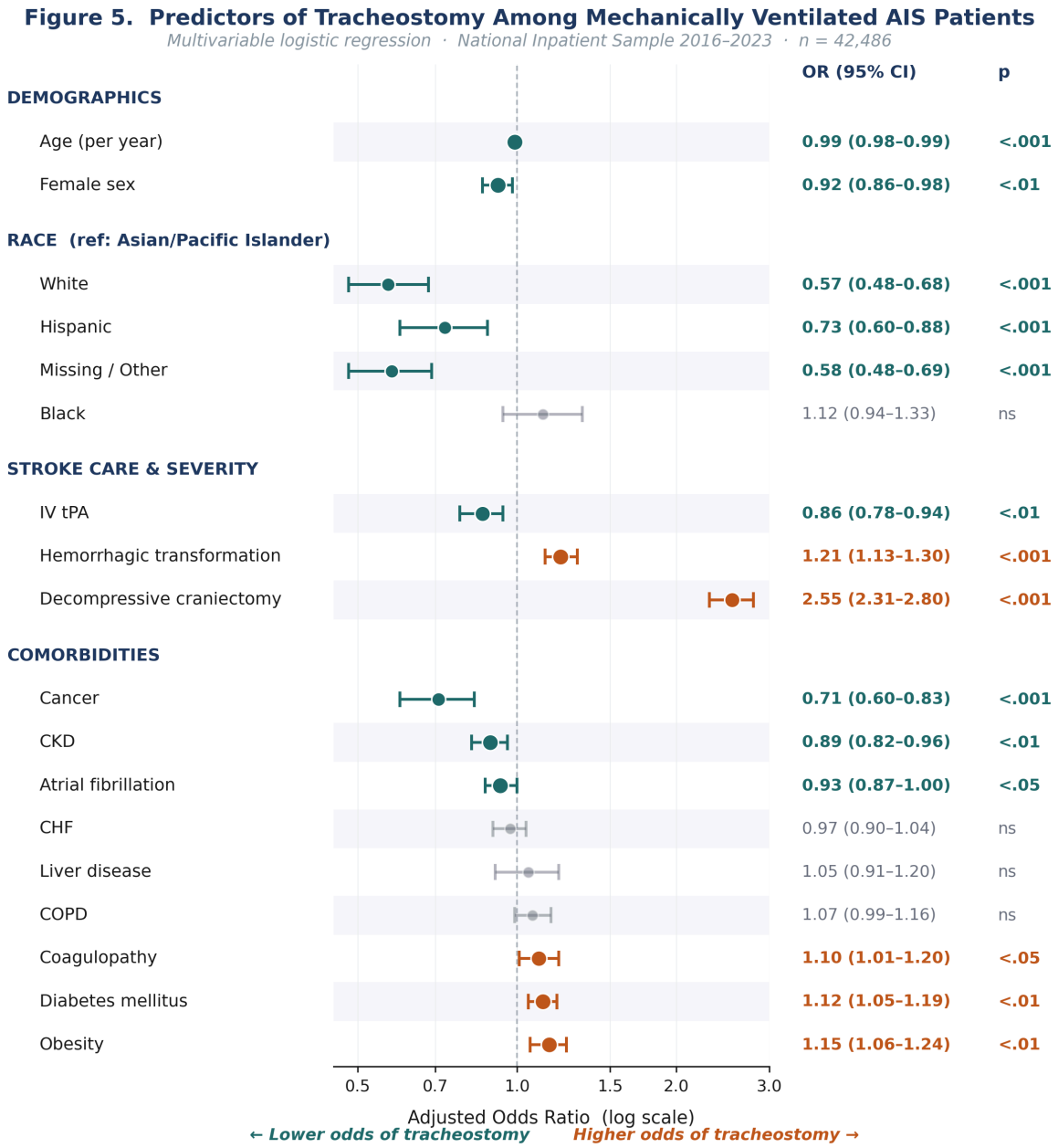
Mortality comparisons of MV—No Tracheostomy vs tracheostomy groups are descriptive only; the MV—No Tracheostomy group is enriched for patients who died before the tracheostomy decision window (days 7–10), producing apparent survivorship selection.

The higher adjusted mortality with early tracheostomy likely reflects confounding by indication (sicker patients undergoing earlier tracheostomy); see Discussion. The primary, within-exposure comparison is Early vs Late tracheostomy. Adjusted OR from multivariable logistic regression.

AIS, acute ischemic stroke; CI, confidence interval; MV, mechanical ventilation; OR, odds ratio; PEG, percutaneous endoscopic gastrostomy.

Figure 4

See image above for figure legend



Prolonged mechanical ventilation (>24 h) was omitted from this model due to near-collinearity with tracheostomy exposure (OR 58.1, 95% CI 40.9–86.5, p < .001 when included). Marker size is proportional to precision (inverse CI width).

AIS, acute ischemic stroke; CHF, congestive heart failure; CI, confidence interval; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; OR, odds ratio; tPA, tissue plasminogen activator.

Figure 5

See image above for figure legend