DOI: 10.62838/jccm-2026-0052

Tracheostomy practices and timing after nontraumatic subarachnoid hemorrhage: a single-center retrospective cohort study

Jawdat Alali[1*], Mahmoud Tabouni[2], Khaled J Zaza[1], Mojahid Alhussein[1], Abdulmalik Jaber[1], Bakri Alali[1], Hana Elamin[1], Sohel Ahmed[1,3]

[1] Department of Anaesthesia, ICU & Perioperative Medicine, Hamad Medical Corporation (HMC), Doha, Qatar
[2] Internal Medicine Department, Hamad Medical Corporation (HMC), Doha, Qatar
[3] College of Medicine, Qatar University, Doha, Qatar

Abstract

Background: Tracheostomy is frequently required after nontraumatic subarachnoid hemorrhage (SAH) requiring prolonged mechanical ventilation, but the optimal timing remains uncertain and observational comparisons are susceptible to treatment-selection and time-dependent bias.

Methods: We conducted a single-center retrospective cohort study of mechanically ventilated adults with nontraumatic SAH admitted between January 2015 and December 2024. Early tracheostomy was defined as ≤10 days from intubation. Conventional clinical outcomes were compared descriptively. For ventilator liberation, follow-up began on the date of tracheostomy; death while still ventilated was treated as a competing event, and a cause-specific Cox model adjusted for age and admission Glasgow Coma Scale (GCS) was used. A ≤7-day definition was examined in sensitivity analysis.

Results: Among 127 included patients, 33 (26.0%) underwent tracheostomy. Tracheostomized patients had longer ventilation duration (22.0 vs 5.0 days), ICU stay (27.0 vs 14.5 days), hospital stay (52.0 vs 21.0 days), and more VAP (39.4% vs 5.3%; all p<0.001). Thirteen tracheostomies occurred ≤10 days and 20 occurred later. The early group had fewer total ventilator days (15.0 vs 25.5, p=0.001) and shorter hospital stay (28.0 vs 56.0 days, p=0.007), but post-tracheostomy ventilator duration among successfully liberated patients did not differ (11.5 vs 7.5 days, p=0.708). Thirty patients achieved ventilator liberation and three died while still ventilated. Early timing was not associated with a higher cause-specific rate of liberation (HR 0.93, 95% CI 0.42-2.06; p=0.854). The ≤7-day sensitivity analysis was consistent.

Conclusions: Patients undergoing tracheostomy represented a clinically selected subgroup with longer ventilation and hospital exposure. Although earlier tracheostomy was associated with fewer total ventilator days and shorter hospital stay in crude comparisons, analyses aligned to the date of tracheostomy did not demonstrate faster subsequent ventilator liberation. Residual confounding and treatment-selection bias preclude causal inference.

Keywords: Subarachnoid hemorrhage; Tracheostomy; Timing of tracheostomy; Mechanical ventilation; Neurocritical care; ICU outcomes; Retrospective cohort.

Received: 27 june 2026 / Accepted: 8 september 2026

Introduction

Subarachnoid hemorrhage (SAH) is a life-threatening neurologic condition associated with substantial morbidity and mortality, often necessitating prolonged intensive care and advanced airway management. Patients with SAH may develop impaired consciousness, diminished airway protective reflexes, and respiratory complications requiring endotracheal intubation and mechanical ventilation [1,2]. In this context, tracheostomy is frequently performed to facilitate prolonged ventilatory support, pulmonary hygiene, and reduction in sedation requirements [3].

Reported tracheostomy rates in patients with SAH are approximately 20-30%, particularly among patients with severe neurologic injury or anticipated prolonged ventilator dependence [4]. Tracheostomy may improve comfort, secretion clearance, and access to rehabilitation; however, receipt of tracheostomy also identifies patients who survive long enough and remain ventilator-dependent long enough to undergo the procedure [1,3]. Consequently, comparisons between patients with and without tracheostomy are inherently influenced by clinical trajectory and treatment selection.

Despite widespread use, the optimal timing of tracheostomy after SAH remains uncertain. Earlier tra-

* Correspondence to: Jawdat Alali, Department of Anaesthesia, ICU & Perioperative Medicine, Hamad Medical Corporation (HMC), Doha, Qatar, E-mail: Jawdat.4001@hotmail.com

cheostomy has been associated in observational studies with shorter mechanical ventilation, fewer respiratory complications, or shorter hospitalization [5-9]. Definitions of "early" vary, however, and large SAH cohorts have reported tracheostomy timing centered around the second week after intubation [6,7]. These differences complicate direct comparison across studies.

A further methodological challenge is that tracheostomy timing is determined after intubation. Classifying patients as "early" or "late" at the start of follow-up can therefore introduce guarantee-time bias because patients assigned to a late group must remain alive and ventilated long enough to receive late tracheostomy [10]. In addition, death while ventilated precludes subsequent ventilator liberation and is a competing event rather than ordinary censoring [11].

Accordingly, this study evaluated tracheostomy practices and clinical outcomes in mechanically ventilated patients with nontraumatic SAH, with particular attention to timing. We examined conventional duration-based outcomes and, for the timing analysis, evaluated ventilator liberation from the date of tracheostomy while accounting for death on the ventilator as a competing event. We hypothesized that earlier tracheostomy would be associated with shorter subsequent ventilator dependence.

Methods

We conducted a retrospective cohort study of adult patients with radiologically confirmed nontraumatic SAH admitted to a single surgical intensive care unit at Hamad Medical Corporation between January 2015 and December 2024. A total of 301 records were screened; 127 mechanically ventilated patients met eligibility criteria. Exclusion criteria were traumatic SAH, prior tracheostomy, and incomplete or missing medical records. Category-specific exclusion counts were not retained in the final analytic dataset. A study flow diagram is provided in Figure 1.

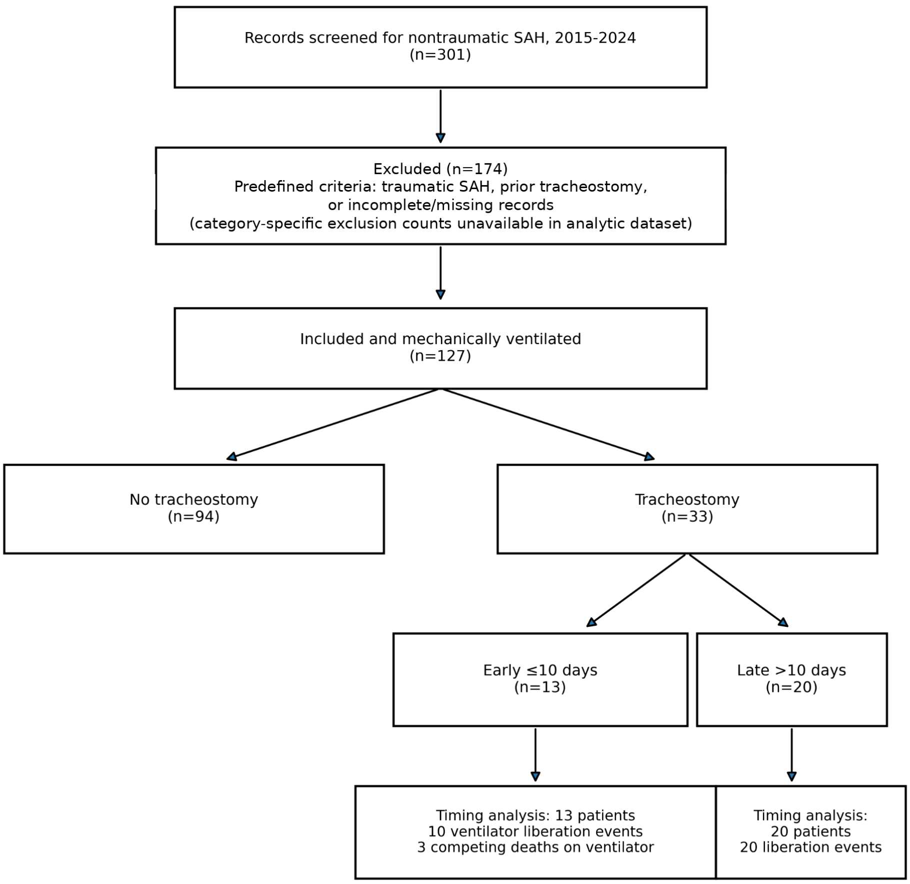


Figure 1. Study flow diagram. Of 301 records screened, 127 mechanically ventilated patients met eligibility criteria. Category-specific counts for the 174 excluded records were not retained in the analytic dataset. The 33 tracheostomized patients comprised 13 early and 20 late tracheostomies; 30 achieved ventilator liberation and 3 died while still ventilated.

The study was reviewed and approved by the Institutional Review Board (proposal ID: MRC-01-25-947; IRB review completed September 2, 2025). The requirement for informed consent was waived because of the retrospective design of the study. The study was conducted in accordance with the principles of the Declaration of Helsinki. The report was prepared in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations for observational cohort studies [12].

Demographic, clinical, and radiologic data were extracted from electronic medical records, including age, sex, hypertension, smoking status, admission GCS, World Federation of Neurosurgical Societies (WFNS) grade, modified Fisher score, ventilation duration, ICU and hospital length of stay (LOS), neurosurgical intervention, respiratory and neurologic complications, thromboembolic events, discharge disposition, and mortality. All included patients had a recorded intubation date and ventilator duration. A uniform study-specific intubation protocol was not imposed; intubation was performed according to treating-team clinical judgment.

Tracheostomy-specific variables included indication, date, and technique. Usual indications included anticipated prolonged mechanical ventilation, airway protection, and facilitation of pulmonary toileting [3,10]. Timing was calculated directly from the recorded intubation and tracheostomy dates. Early tracheostomy was defined as ≤10 days from intubation and late tracheostomy as >10 days. The 10-day threshold was prespecified in the submitted analysis as a pragmatic cutoff within the range used in neurocritical care literature and near the median timing reported in a large aneurysmal SAH cohort [6,7]. A ≤7-day threshold was examined as a sensitivity analysis.

Clinical outcomes included total ventilator days, ICU LOS, hospital LOS, VAP, vasospasm/delayed cerebral ischemia (DCI), venous thromboembolism, and 30- and 90-day mortality. These were treated as general ICU or SAH-associated outcomes rather than tracheostomy-related procedural complications. VAP status was abstracted from the clinical record as documented during the admission; the source abstraction did not retain sufficient information to re-adjudicate diagnostic criteria or determine VAP timing relative to tracheostomy. Procedural/periprocedural complications were reported separately from the tracheostomy-specific complication field.

Ventilator liberation was defined using the source concept as successful discontinuation of invasive mechanical ventilation, either by extubation or by spontaneous breathing through a tracheostomy with a Swedish nose/heat-moisture exchanger. For the early-versus-late timing analysis, time zero was the date of tracheostomy. Patients recorded as death on ventilator (DOV) before successful liberation were classified as experiencing the competing event of death. Post-tracheostomy ventilator duration among successfully liberated patients was analyzed descriptively as a complementary outcome.

Statistical analyses were performed using IBM SPSS Statistics, Version 29.0. Descriptive and between-group analyses were conducted in SPSS, while competing-risk and cause-specific time-to-event analyses were performed in Python 3.13 using statsmodels 0.14.6, with the Efron method for tied events. Continuous variables were assessed for distribution and are presented as median and interquartile range (IQR). Between-group comparisons used the Mann-Whitney U test. Categorical variables are presented as counts and percentages and were compared using the chi-square test with continuity correction or Fisher exact test, as appropriate. Analyses used available observations without imputation; variable-specific denominators are reported where data were missing.

Cumulative incidence functions were used to describe successful ventilator liberation after tracheostomy with death on the ventilator treated as a competing event [11]. A cause-specific Cox proportional hazards model evaluated the association of early tracheostomy with ventilator liberation, adjusting parsimoniously for age and admission GCS. Covariate selection was limited a priori because only 33 patients underwent tracheostomy and 30 liberation events occurred, and to avoid overfitting with correlated neurologic-severity measures. The proportional hazards assumption was assessed using Schoenfeld residuals and showed no evidence of violation. An exploratory treatment-era comparison evaluated 2015-2019 versus 2020-2024. Two-sided $p<0.05$ was considered statistically significant.

Results

A total of 127 mechanically ventilated patients with nontraumatic SAH were included; 33 (26.0%) underwent tracheostomy and 94 (74.0%) did not. The cohort had a median age of 46 years (IQR 18), 73 patients (57.5%) were male, and hypertension was present in 66 (52.0%). Smoking status was available in 126 patients, of whom 15 (11.9%) were active smokers. Modified Fisher score was missing in 23 patients, hospital LOS in 1, vasospasm/DCI in 1, and 90-day mortality in 2.

Patients undergoing tracheostomy were older (median 57.0 vs 44.5 years, p<0.001) and more frequently male (78.8% vs 50.0%, p=0.008). Admission GCS, WFNS grade, modified Fisher score, and hypertension did not differ significantly between groups (Table 1). Neurosurgical intervention was recorded as coiling in 57 patients, clipping in 42, combined coiling and clipping in 2, flow diversion in 2, and no intervention in 23.

Patients who underwent tracheostomy had longer total mechanical ventilation (median 22.0 vs 5.0 days), ICU LOS (27.0 vs 14.5 days), and hospital LOS (52.0 vs 21.0 days), with p<0.001 for each comparison (Table 2). VAP was documented in 13/33 (39.4%) tracheostomized patients and 5/94 (5.3%) non-tracheostomized patients (p<0.001). Vasospasm/DCI occurred in 9/33 (27.3%) versus 26/93 (28.0%; p=1.000), and DVT/PE in 0/33 versus 2/94 (2.1%; p=1.000).

Crude 30-day mortality was 3/33 (9.1%) after tracheostomy and 25/94 (26.6%) without tracheostomy (p=0.050). Ninety-day mortality was 4/33 (12.1%) versus 27/92 (29.3%; p=0.061). Six explicitly documented brain-death cases occurred in the non-tracheostomy group. Withdrawal-of-life-sustaining-treatment and goals-of-care decisions were not systematically captured in the analytic dataset. Discharge disposition among tracheostomized patients was rehabilitation in 27, home in 3, and death in hospital in 3.

Among the 33 tracheostomized patients, 20 underwent percutaneous tracheostomy, 12 surgical tracheostomy, and 1 percutaneous procedure was converted to surgical. The tracheostomy-specific complication field documented minimal oozing in 2 patients, stoma-site infection in 1, and cardiac arrest in 1. Entries for tracheobronchitis and VAP were reclassified as respiratory/ICU events rather than procedural complications. No posterior tracheal wall injury, false passage, pneumothorax, or accidental decannulation was documented in this field.

The median time from intubation to tracheostomy was 11 days (IQR 7-21). Thirteen patients underwent early tracheostomy (≤10 days; median timing 6 days, IQR 5-7) and 20 underwent late tracheostomy (>10 days; median timing 20 days, IQR 14.75-24). Early tracheostomy patients had fewer total ventilator days (15.0 vs 25.5; p=0.001) and shorter hospital LOS (28.0 vs 56.0 days; p=0.007), whereas ICU LOS did not differ significantly (22.0 vs 32.5 days; p=0.080) (Table 3). Among patients who achieved successful ventilator liberation, post-tracheostomy ventilator duration did not differ significantly between early and late groups (11.5 vs 7.5 days; p=0.708; Figure 2).

Thirty tracheostomized patients achieved successful ventilator liberation and 3 died while still ventilated; all three competing deaths occurred in the early group. Cumulative incidence functions from the date of tracheostomy are shown in Figure 3. In the cause-specific Cox model, early tracheostomy was not associated with a higher rate of ventilator liberation (HR 0.93, 95% CI 0.42-2.06; p=0.854). Age (HR 1.01, 95% CI 0.98-1.05; p=0.383) and admission GCS (HR 0.95, 95% CI 0.86-1.05; p=0.329) were also not significant (Table 4).

Using ≤7 days as a sensitivity definition produced materially similar results: early timing was not associated with a higher cause-specific rate of ventilator liberation (adjusted HR 0.89, 95% CI 0.36-2.17; p=0.793). In an exploratory era analysis, tracheostomy occurred in 16/58 (27.6%) patients during 2015-2019 and 17/69 (24.6%) during 2020-2024 (p=0.862); median timing was 15 versus 9 days, respectively (p=0.083).

Discussion

In this retrospective single-center cohort of mechanically ventilated patients with nontraumatic SAH, approximately one-quarter underwent tracheostomy, consistent with previously reported rates in SAH populations requiring prolonged ventilatory support [4]. Patients receiving tracheostomy were older and more frequently male in unadjusted comparisons, while admission GCS, WFNS grade, and modified Fisher score were similar between groups.

Patients who underwent tracheostomy had substantially longer mechanical ventilation, ICU stay, and hospital stay than patients managed without tracheostomy. These differences should not be interpreted as consequences of tracheostomy. Receipt of tracheostomy requires survival and continued ventilator dependence long enough for the procedure to occur; conversely, the non-tracheostomy group includes patients who are rapidly liberated as well as patients who deteriorate or die before tracheostomy becomes appropriate. The six documented brain-death cases, all in the non-tra-

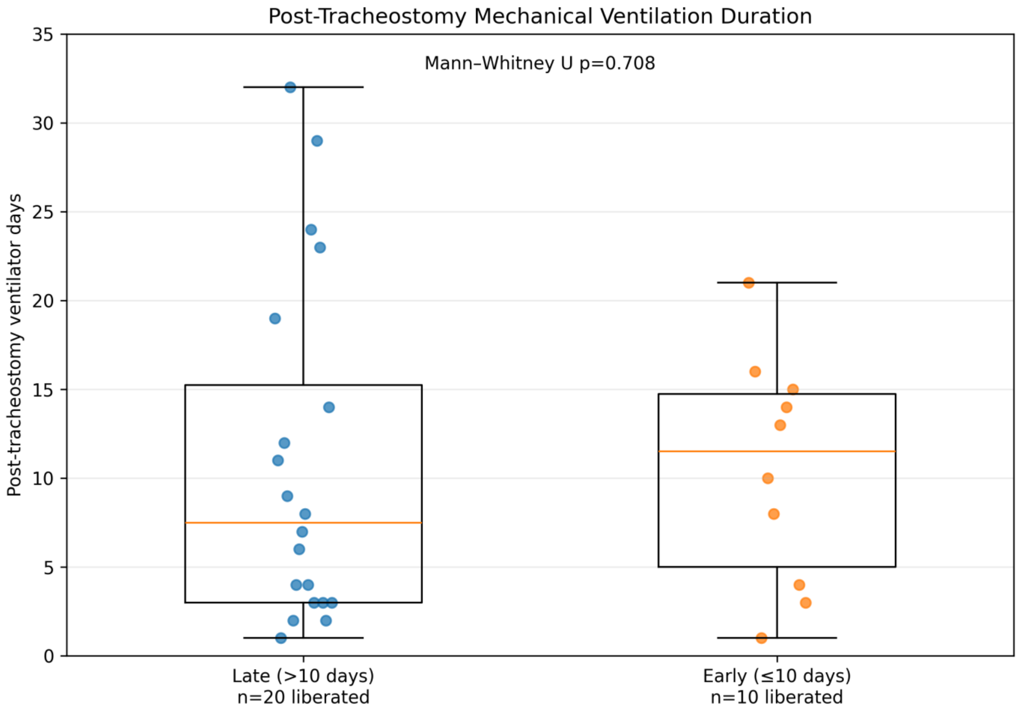
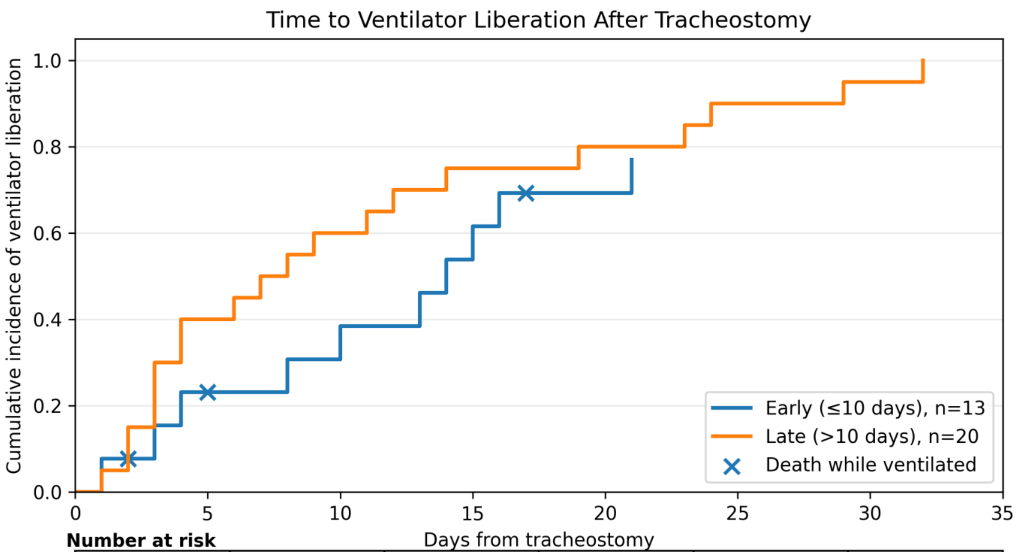


Figure 2. Post-tracheostomy mechanical ventilation duration according to tracheostomy timing.
Distribution of post-tracheostomy ventilator days among patients who achieved successful ventilator liberation after early (≤10 days) or late (>10 days) tracheostomy. Boxes represent the interquartile range, horizontal lines indicate medians, whiskers extend to 1.5 times the interquartile range, and individual observations are displayed. Three patients in the early group died while still ventilated and are therefore not included in this descriptive boxplot; these deaths are handled as competing events in Figure 1 and the time-to-event analysis. Mann–Whitney U p=0.708.



Number at risk

	0	7	14	21	28	35
Early	13	8	5	1	0	0
Late	20	11	6	4	2	0

Figure 3. Time to ventilator liberation after tracheostomy according to tracheostomy timing.
Cumulative incidence of successful ventilator liberation from the date of tracheostomy in patients undergoing early (≤10 days) versus late (>10 days) tracheostomy. Death while still mechanically ventilated was treated as a competing event; three competing deaths occurred in the early group and none in the late group. Numbers at risk are shown below the plot. No additional right-censoring occurred in the tracheostomy cohort.

Table 1. Baseline characteristics of patients with and without tracheostomy.

Variable	No tracheostomy (n=94)	Tracheostomy (n=33)	p-value
Age (years), median (IQR)	44.5 (13.75)	57.0 (18.0)	<0.001
Initial GCS, median (IQR)	12.5 (7.0)	12.0 (7.0)	0.574
WFNS grade, median (IQR)	3.5 (3.0)	4.0 (2.0)	0.257
Modified Fisher score, median (IQR)	4.0 (1.0) [n=78]	4.0 (1.0) [n=26]	0.891
Male sex, n (%)	47 (50.0)	26 (78.8)	0.008
Hypertension, n (%)	46 (48.9)	20 (60.6)	0.341

Data are median (IQR) or n (%). GCS = Glasgow Coma Scale; WFNS = World Federation of Neurosurgical Societies. Mann-Whitney U test was used for continuous variables, chi-square with continuity correction or Fisher exact test for categorical variables. Modified Fisher score was available in 104/127 patients.

Table 2. Clinical outcomes according to tracheostomy status.

Variable	No tracheostomy (n=94)	Tracheostomy (n=33)	p-value
Ventilator days	5.0 (5.0)	22.0 (16.0)	<0.001
ICU LOS	14.5 (6.75)	27.0 (21.0)	<0.001
Hospital LOS	21.0 (15.0) [n=93]	52.0 (32.0)	<0.001
VAP, n (%)	5 (5.3)	13 (39.4)	<0.001
Vasospasm/DCI, n (%)	26 (28.0) [n=93]	9 (27.3)	1.000
DVT/PE, n (%)	2 (2.1)	0 (0)	1.000
30-day mortality, n (%)	25 (26.6)	3 (9.1)	0.050
90-day mortality, n (%)	27 (29.3) [n=92]	4 (12.1)	0.061

Data are median (IQR) or n (%). ICU = intensive care unit; LOS = length of stay; VAP = ventilator-associated pneumonia; DCI = delayed cerebral ischemia; DVT/PE = deep vein thrombosis/pulmonary embolism. Variable-specific denominators are shown where observations were missing. Comparisons are descriptive and should not be interpreted causally.

Table 3. Clinical outcomes according to timing of tracheostomy.

Variable	Late (>10 days) (n=20)	Early (≤10 days) (n=13)	p-value
Total ventilator days	25.5 (11.75)	15.0 (11.0)	0.001
Post-tracheostomy ventilator days to successful liberation*	7.5 (12.25) [n=20]	11.5 (9.75) [n=10]	0.708
ICU LOS	32.5 (26.0)	22.0 (18.0)	0.080
Hospital LOS	56.0 (19.75)	28.0 (16.0)	0.007
VAP, n (%)	9 (45.0)	4 (30.8)	0.485
90-day mortality, n (%)	1 (5.0)	3 (23.1)	0.276

Early tracheostomy was defined as ≤10 days from intubation and late tracheostomy as >10 days. Data are median (IQR) or n (%). *Post-tracheostomy ventilator days to successful liberation excludes three early-group patients who died while still ventilated; these deaths are handled as competing events in the time-to-event analysis. Mann-Whitney U or Fisher exact tests were used as appropriate.

Table 4. Cause-specific Cox proportional hazards analysis for ventilator liberation after tracheostomy.

Variable	HR	95% CI	p-value
Early tracheostomy (≤10 days)	0.93	0.42-2.06	0.854
Age (per year)	1.01	0.98-1.05	0.383
Initial GCS (per point)	0.95	0.86-1.05	0.329

Time origin was the date of tracheostomy. Successful ventilator liberation was the event; death while still ventilated was treated as a competing event and censored in the cause-specific hazard model. Thirty liberation events and three competing deaths occurred among 33 patients. HR >1 indicates a higher cause-specific rate of liberation. Tied event times were handled using the Efron approximation. The proportional hazards assumption was assessed using Schoenfeld residuals and showed no evidence of violation.

cheostomy group, illustrate this selection mechanism. The higher crude VAP prevalence in tracheostomized patients likewise cannot be attributed to the procedure because VAP timing relative to tracheostomy was not available and cumulative ventilator exposure differed markedly between groups.

The analysis of tracheostomy timing requires consideration of the chosen time origin. When early and late groups were classified from intubation, early tracheostomy remained associated with fewer total ventilator days and shorter hospital stay. However, total ventilator duration is structurally related to the exposure definition because patients classified as late must already have remained ventilated for more than 10 days before tracheostomy. When follow-up instead began at the date of tracheostomy, post-tracheostomy ventilator duration among successfully liberated patients did not differ significantly between groups, and the cause-specific Cox model did not demonstrate a higher rate of ventilator liberation with early tracheostomy.

These findings should be interpreted alongside prior observational studies reporting shorter ventilation or hospitalization with earlier tracheostomy in SAH and other acute brain injury populations [5-8,11]. Gessler et al. defined early tracheostomy within 7 days and reported fewer respiratory adverse events and shorter ventilation, whereas Dasenbrock et al. reported a median tracheostomy timing of 11 days and associations between later timing and selected medical complications [6,7]. Differences in exposure definitions, time origin, patient selection, and clinical practice may contribute to heterogeneous findings. In the present study, a ≤7-day sensitivity analysis yielded the same overall conclusion as the 10-day analysis: earlier timing was not associated with faster subsequent ventilator liberation once follow-up was aligned to tracheostomy.

Neurologic and thromboembolic complications did not differ between tracheostomy groups in the available data. VAP was more frequent in tracheostomized patients overall but did not differ significantly between early and late tracheostomy groups. Because diagnostic re-adjudication and VAP timing were unavailable, these findings should be regarded as descriptive rather than as procedural safety outcomes. Procedural events recorded in the tracheostomy-specific field were uncommon, although retrospective documentation may underestimate minor events.

Crude mortality was numerically lower among patients who underwent tracheostomy; however, this comparison is particularly susceptible to survivor and treatment-selection bias. Observational SAH cohorts similarly include non-tracheostomized patients with early neurologic deterioration, brain death, or limitation of life-sustaining treatment [13,14]. Therefore, we did not interpret the observed crude mortality difference as evidence of a protective effect of tracheostomy and did not retain the previous fixed-exposure mortality regression. In our multivariable analysis, tracheostomy was not independently associated with mortality, consistent with large database studies reporting no clear causal relationship between tracheostomy timing or performance and survival outcomes [15]. Long-term mortality and neurologic recovery after SAH are primarily determined by the initial severity of hemorrhage and subsequent neurologic complications rather than by tracheostomy itself [4,6,16].

This study has several limitations. The retrospective single-center design restricts generalizability, and only 33 patients underwent tracheostomy, limiting the stability of multivariable adjustment and subgroup analyses. Tracheostomy timing was determined by clinical trajectory, anticipated prognosis, airway-protection requirements, physician judgment, and procedural availability, leaving substantial potential for residual confounding. Aneurysmal versus nonaneurysmal SAH, rebleeding, hydrocephalus/EVD status, sedative exposure, vasopressor requirements, VAP timing, and withdrawal-of-care decisions were not captured in a sufficiently structured manner for reliable adjustment. Modified Fisher score was missing in 23 patients. Category-specific exclusion counts from the screening cohort were not retained in the analytic dataset. Although an exploratory era analysis did not show statistically significant differences in tracheostomy rate or timing, the study may be underpowered to detect changes in practice over the 10-year period. Standardized long-term functional outcomes such as modified Rankin Scale or Glasgow Outcome Scale and reliable decannulation data were unavailable [9,14]. These limitations prevent causal inference regarding optimal tracheostomy timing.

Conclusion

In mechanically ventilated patients with nontraumatic SAH, tracheostomy was used in approximately one-quarter of cases and identified a subgroup with longer ventilation, ICU stay, hospital stay, and more documented VAP. Earlier tracheostomy (≤10 days) was associated with fewer total ventilator days and shorter hospital stay in crude comparisons, but these outcomes are strongly influenced by treatment selection and the timing definition itself. When analysis began at the date of tracheostomy and death while ventilated was treated as a competing event, earlier tracheostomy was not associated with faster subsequent ventilator liberation. These findings support cautious, associative interpretation and underscore the need for prospective multicenter studies with standardized timing strategies and neurologic outcomes.

Authors' contributions

JA: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Visualization, Writing – original draft preparation, Writing – review & editing.

MT: Methodology, Formal analysis, Validation, Writing – review & editing.

KZ: Investigation, Data curation, Validation, Writing – review & editing.

MA: Investigation, Data curation, Writing – review & editing.

AJ: Investigation, Resources, Data curation, Writing – review & editing.

BA: Investigation, Resources, Writing – review & editing.

HE: Investigation, Data curation, Writing – review & editing.

SA: Conceptualization, Methodology, Supervision, Validation, Writing – review & editing.

Acknowledgments

OpenAI ChatGPT (GPT-5.6 Sol) was used during manuscript revision to assist with language editing and statistical support. All analyses and manuscript content were independently reviewed and verified by the authors, who take full responsibility for the final work.

Conflict of interest

None declared.

Funding

No external funding was received.

References

1. Wahlster S, Sharma M, Chu F, et al. Outcomes after tracheostomy in patients with severe acute brain injury: a systematic review and meta-analysis. Neurocrit Care. 2021;34(3):956-967. doi:10.1007/s12028-020-01109-9.
2. Rass V, Ianosi BA, Lindlbauer M, et al. Factors associated with prolonged mechanical ventilation in patients with subarachnoid hemorrhage - the RAISE score. Crit Care Med. 2022;50(1):103-113. doi:10.1097/CCM.0000000000005189.
3. Mehta C, Mehta Y. Percutaneous tracheostomy. Ann Card Anaesth. 2017;20(Suppl 1):S19-S25. doi:10.4103/0971-9784.197793.
4. Chang YM, Lee TH, Liao CC, Huang YH. Characterization of tracheotomized patients after spontaneous subarachnoid hemorrhage. Medicine (Baltimore). 2020;99(28):e21057. doi:10.1097/MD.0000000000021057.
5. Bini G, Russo E, Antonini MV, et al. Impact of early percutaneous dilatative tracheostomy in patients with subarachnoid hemorrhage on main cerebral, hemodynamic, and respiratory variables: a prospective observational study. Front Neurol. 2023;14:1105568. doi:10.3389/fneur.2023.1105568.
6. Gessler F, Mutlak H, Lamb S, et al. The impact of tracheostomy timing on clinical outcome and adverse events in poor-grade subarachnoid hemorrhage. Crit Care Med. 2015;43(11):2429-2438. doi:10.1097/CCM.0000000000001195.
7. Dasenbrock HH, Rudy RF, Gormley WB, Frerichs KU, Aziz-Sultan MA, Du R. The timing of tracheostomy and outcomes after aneurysmal subarachnoid hemorrhage: a Nationwide Inpatient Sample analysis. Neurocrit Care. 2018;29(3):326-335. doi:10.1007/s12028-018-0619-4.
8. McCann MR, Hatton KW, Vsevolozhskaya OA, Fraser JF. Earlier tracheostomy and percutaneous endoscopic gastrostomy in patients with hemorrhagic stroke: associated factors and effects on hospitalization. J Neurosurg. 2020;132(1):87-93. doi:10.3171/2018.7.JNS181345.
9. Schneider H, Hertel F, Kuhn M, et al. Decannulation and functional outcome after tracheostomy in patients with severe stroke (DECAST): a prospective observational study. Neurocrit Care. 2017;27(1):26-34. doi:10.1007/s12028-017-0390-y.
10. Suissa S. Immortal time bias in pharmaco-epidemiology. Am J Epidemiol. 2008;167(4):492-499. doi:10.1093/aje/kwm324.
11. Austin PC, Lee DS, Fine JP. Introduction to the analysis of survival data in the presence of competing risks. Circulation. 2016;133(6):601-609. doi:10.1161/CIRCULATIONAHA.115.017719.
12. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Ann Intern Med. 2007;147(8):573-577. doi:10.7326/0003-4819-147-8-200710160-00010.
13. Chalard K, Szabo V, Pavillard F, et al. Long-term outcome in patients with aneurysmal subarachnoid hemorrhage requiring mechanical ventilation. PLoS One. 2021;16(3):e0247942. doi:10.1371/journal.pone.0247942.
14. Rosseland LA, Narum J, Stubhaug A, Kongsgaard U, Sorteberg W, Sorteberg A. The effect of tracheotomy on drug consumption in patients with acute aneurysmal subarachnoid hemorrhage: an observational study. BMC Anesthesiol. 2015;15:47. doi:10.1186/s12871-015-0029-5.
15. Küchler J, Wojak JF, Smith E, et al. Management of tracheostomized patients after poor grade subarachnoid hemorrhage: disease related and pulmonary risk factors for failed and delayed decannulation. Clin Neurol Neurosurg. 2019;184:105419. doi:10.1016/j.clineuro.2019.105419.
16. Trouillet JL, Collange O, Belafia F, et al. Tracheotomy in the intensive care unit: guidelines from a French expert panel. Ann Intensive Care. 2018;8(1):37. doi:10.1186/s13613-018-0381-y.