

Prognostic Factors Associated with 90-Day Mortality Following Percutaneous Dilatational Tracheostomy: A Single-Center Retrospective Cohort Study

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Abstract

Background/Objective: Critically ill patients undergoing percutaneous dilatational tracheostomy (PDT) frequently require prolonged ventilatory support and have a high risk of adverse outcomes. This study investigated clinical and laboratory factors associated with 90-day mortality after PDT. **Materials and Methods:** We retrospectively evaluated adults who underwent PDT in a single intensive care unit between January 2021 and December 2025. Demographic characteristics, comorbidities, laboratory findings, Acute Physiology and Chronic Health Evaluation II and Sequential Organ Failure Assessment scores, and procedure-related variables were recorded. Independent associations with 90-day mortality were assessed using multivariable logistic regression. Model discrimination was evaluated by receiver operating characteristic analysis, and survival was examined using the Kaplan–Meier method. **Results:** Of 275 patients (median age, 74 years; 52.7% male), 204 (74.2%) died within 90 days after tracheostomy. Advanced age (OR 1.022, 95% CI 1.002–1.042; $p = 0.029$), higher Charlson Comorbidity Index (OR 1.495, 95% CI 1.144–1.952; $p = 0.003$), and lower serum albumin level (OR 0.815, 95% CI 0.743–0.893; $p < 0.001$) were independently associated with mortality. The model showed good discrimination (AUC 0.825, 95% CI 0.772–0.878). Patients with a Charlson Comorbidity Index ≥ 3 had significantly lower 90-day survival (log-rank $p = 0.015$). **Conclusion:** Advanced age, greater comorbidity burden, and lower serum albumin level were independently associated with 90-day mortality after PDT. These findings indicate that chronic health status and physiological reserve, in addition to acute disease severity, should be considered when evaluating prognosis. External validation in prospective multicenter cohorts is warranted.

Keywords: Albumins; Comorbidity; Intensive Care Units; Mortality; Prognosis; Tracheostomy

1. Introduction

Critically ill patients who remain dependent on ventilatory support for an extended period frequently undergo tracheostomy to provide durable airway access. Percutaneous dilatational tracheostomy (PDT) has become widely adopted in ICU practice because it is minimally invasive, can be undertaken at the bedside, generally takes less time than surgical tracheostomy, and is associated with comparable or lower complication rates.¹

Beyond securing the airway, PDT facilitates secretion clearance, may reduce sedation requirements, improves patient comfort, and supports liberation from mechanical ventilation. Nevertheless, uncertainty remains regarding the optimal timing of the procedure and the selection of appropriate patients. Studies conducted in Türkiye have also reported PDT to be a safe and feasible procedure in routine ICU practice.^{2,3}

Patients who undergo percutaneous tracheostomy constitute a high-risk clinical population characterized by prolonged dependence on mechanical ventilation and a substantial burden of comorbid disease. Estimating long-term outcomes in these patients is therefore relevant to clinical management, resource planning, and communication with their families. Mortality rates reported after tracheostomy vary considerably depending on patient characteristics, procedural indication, comorbidity burden, and length of follow-up.⁴ Previous studies have associated mortality with older age, greater comorbidity burden, more severe illness, vasopressor requirement, and complications arising during the ICU stay. In a retrospective cohort from Türkiye, Yakar et al. reported the Charlson Comorbidity Index (CCI), vasopressor requirement, and procedure-related complications as independent correlates of death within 90 days.⁵ This evidence emphasizes the importance of identifying dependable prognostic markers for patients undergoing percutaneous tracheostomy.

Two scoring systems frequently applied in critical care are the Acute Physiology and Chronic Health Evaluation II (APACHE II) and the Sequential Organ Failure Assessment (SOFA). These instruments support the evaluation of illness severity and the estimation of mortality risk.⁶ However, patients who undergo percutaneous tracheostomy frequently experience prolonged ICU stays and have a considerable burden of chronic disease.⁷ Consequently, evaluating their long-term prognosis may require consideration of chronic health status and physiological reserve in addition to acute physiological abnormalities. The CCI is an established tool for quantifying comorbidity burden and has demonstrated prognostic value for mortality in diverse patient populations.⁸ Serum albumin may also provide prognostic information because it reflects nutritional status, systemic inflammation, and physiological reserve and has been associated with mortality in critically ill patients.⁹ When considered together, CCI and serum albumin may therefore offer information that complements acute severity scores. Nevertheless, evidence evaluating their combined prognostic value for 90-day mortality after percutaneous tracheostomy remains limited.^{5,10}

We sought to identify clinical and laboratory correlates of 90-day mortality after percutaneous dilatational tracheostomy in a tertiary ICU, with particular emphasis on variables reflecting chronic comorbidity burden and physiological reserve.

2. Methods

2.1. Study Design and Patient Population

The investigation followed a retrospective observational cohort design and involved four adult ICUs with a combined capacity of 43 beds at a single tertiary training and research hospital. The study covered the period from January 2021 through December 2025.

The study included patients aged ≥ 18 years who received PDT while admitted to the ICU within the specified period. For patients with more than one ICU admission, the analysis was restricted to the first admission in which PDT was performed. Ninety-day mortality status was available for every patient included in the analysis.

The study protocol was approved by the Scientific Research Ethics Committee for Health Sciences of Aksaray University (Decision No. 2026/145; dated April 30, 2026). The requirement for written informed consent was waived because of the retrospective design. The study was conducted in accordance with the principles of the Declaration of Helsinki.

2.2. Tracheostomy Procedure

PDT was performed at the ICU bedside under sterile conditions by intensive care physicians or anesthesiology and reanimation specialists. The Griggs guidewire dilating forceps method was used in every procedure. The treating ICU team determined the indication for tracheostomy by considering the patient's clinical status, anticipated need for prolonged mechanical ventilation, and requirement for airway protection.

2.3. Data Collection

Demographic characteristics (age and sex), admission diagnosis, tracheostomy indication, time from endotracheal intubation to tracheostomy, and readmission details were retrospectively retrieved from the electronic health records and patient charts.

APACHE II was computed from clinical and laboratory measurements recorded within the first 24 hours following ICU admission. SOFA was derived using the clinical and laboratory values obtained closest to the time of tracheostomy.

Each patient's CCI score was calculated from the comorbid conditions documented in the medical records.

For each patient, the serum albumin, urea, creatinine, and lactate measurements closest to the time of tracheostomy were selected for analysis.

The study's primary endpoint was death from any cause within 90 days after percutaneous dilatational tracheostomy.

2.4. Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 27.0 (IBM Corp., Armonk, NY, USA).

Normality of continuous variables was examined by inspecting histograms and probability plots and applying the Shapiro–Wilk test. Data with a normal distribution were reported as mean $\pm$ standard deviation (SD), whereas data without a normal distribution were reported as median and interquartile range (IQR).

For continuous data, differences between groups were evaluated using either the independent-samples *t* test or the Mann–Whitney *U* test, as appropriate. Categorical data were analyzed using the chi-square test or Fisher's exact test.

Independent associations between candidate factors and 90-day mortality were evaluated with a multivariable binary logistic regression model using the Enter method. Variables yielding $p < 0.05$ in the univariable analysis, together with those considered clinically relevant, were included in the multivariable model. Effect estimates were expressed as odds ratios (ORs) with 95% confidence intervals (CIs). Calibration of the model was examined using the Hosmer–Lemeshow goodness-of-fit test.

Tracheostomy indications were recategorized before multivariable analysis owing to limited patient numbers in several categories. Accordingly, airway-related and other indications were combined and used as a single reference category.

Discriminative performance was quantified using the area under the receiver operating characteristic (ROC) curve (AUC), derived from probabilities estimated by the multivariable model.

Survival was described using Kaplan–Meier estimates, and the group curves were compared by the log-rank test. A two-tailed *p* value below 0.05 was regarded as statistically significant.

3. Results

A total of 311 patients who underwent PDT during the study period were screened for eligibility. Twenty patients were excluded for missing data, 3 for being younger than 18 years, and 13 for incomplete post-tracheostomy follow-up. Consequently, the final analysis comprised 275 patients (Figure 1).

The analyzed cohort had a median age of 74 years (IQR, 62–84) and included 145 men (52.7%). At completion of the 90-day follow-up, 204 deaths (74.2%) had been recorded, while 71 patients (25.8%) were alive.

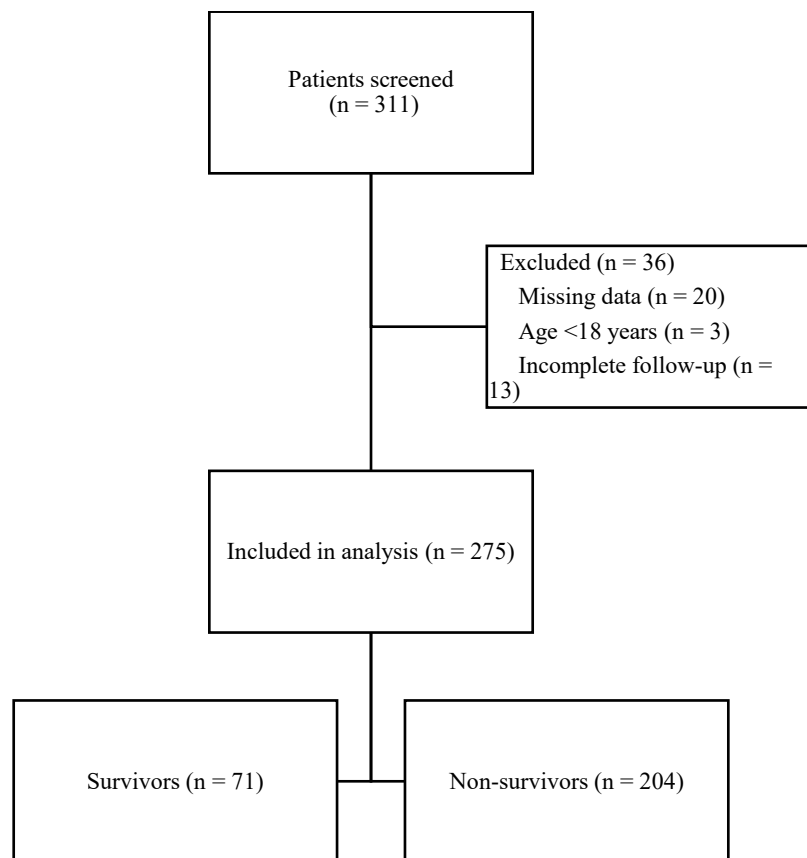


Figure 1. Flowchart of patient selection and study inclusion.

Demographic and clinical data stratified by 90-day outcome are provided in Table 1. Relative to survivors, 90-day non-survivors were older (77 [68.5–85] vs. 63 [52–74] years; $p < 0.001$) and had higher CCI scores (2 [1–3] vs. 1 [0–2]; $p < 0.001$). Lower serum albumin concentrations (21.4 [19.1–24.1] vs. 25.6 [22.8–27.8] g/L; $p < 0.001$) and higher urea concentrations (84 [49–139] vs. 62.5 [39–102] mg/dL; $p = 0.010$) were also observed in non-survivors.

No statistically significant between-group differences were observed in APACHE II score ($p = 0.125$), SOFA score ($p = 0.475$), the intubation-to-tracheostomy interval ($p = 0.484$), lactate level ($p = 0.065$), sex ($p = 0.070$), or admission diagnosis ($p = 0.251$). Conversely, the distribution of tracheostomy indications differed according to 90-day survival status ($p = 0.004$).

Table 1. Baseline demographic, clinical, and laboratory characteristics of patients according to 90-day mortality status.

Variable	Overall (n = 275)	Survivors (n = 71)	Non-survivors (n = 204)	<i>p</i> value
Age, years	74 (62–84)	63 (52–74)	77 (68.5–85)	<0.001
Female sex	130 (47.3)	27 (38.0)	103 (50.5)	0.070
Male sex	145 (52.7)	44 (62.0)	101 (49.5)	
APACHE II score	20 (16–24)	19 (15–23)	20 (16–25)	0.125
SOFA score	9 (7–10)	9 (8–10)	9 (7–11)	0.475

Variable	Overall (n = 275)	Survivors (n = 71)	Non-survivors (n = 204)	<i>p</i> value
Time from intubation to tracheostomy, days	19 (14–25)	21 (11.5–27)	18 (14–24)	0.484
Albumin, g/L	22.6 (20.0–25.6)	25.6 (22.8–27.8)	21.4 (19.1–24.1)	<0.001
Lactate, mmol/L	1.3 (1.0–1.9)	1.2 (1.0–1.5)	1.3 (1.0–2.0)	0.065
Urea, mg/dL	76 (47–128)	62.5 (39–102)	84 (49–139)	0.010
Creatinine, mg/dL	0.74 (0.46–1.40)	0.67 (0.45–1.24)	0.75 (0.48–1.44)	0.618
Admission diagnosis, n (%)				
Respiratory	95 (34.5)	28 (39.4)	67 (32.8)	0.251
Neurological	124 (45.1)	31 (43.7)	93 (45.6)	
Cardiovascular	24 (8.7)	7 (9.9)	17 (8.3)	
Sepsis	13 (4.7)	0 (0.0)	13 (6.4)	
Other	19 (6.9)	5 (7.0)	14 (6.9)	
Tracheostomy indication, n (%)				
Prolonged mechanical ventilation	132 (48.0)	29 (40.8)	103 (50.5)	0.004
Neurological impairment	124 (45.1)	31 (43.7)	93 (45.6)	
Airway-related/others	19 (6.9)	11 (15.5)	8 (3.9)	

Abbreviations: APACHE II, Acute Physiology and Chronic Health Evaluation II; SOFA, Sequential Organ Failure Assessment. Data are presented as median (IQR) for continuous variables and number (%) for categorical variables. p values were calculated using the Mann–Whitney U test, Student's t-test, chi-square test, or Fisher's exact test, as appropriate.

Table 2 provides the estimates obtained from multivariable logistic regression. Age, CCI, and serum albumin were independently associated with 90-day mortality. A one-year increment in age was associated with 2.2% higher odds of death (OR, 1.022; 95% CI, 1.002–1.042; $p = 0.029$). Similarly, a one-point increment in CCI was associated with 49.5% higher odds (OR, 1.495; 95% CI, 1.144–1.952; $p = 0.003$). In contrast, the odds of 90-day mortality were 18.5% lower for every 1 g/L increment in serum albumin (OR, 0.815; 95% CI, 0.743–0.893; $p < 0.001$). No independent associations after adjustment were observed for urea, sex, or tracheostomy indication.

Table 2. Multivariable logistic regression analysis of factors associated with 90-day mortality in patients undergoing percutaneous dilatational tracheostomy.

Variable	Adjusted OR	95% CI	p value
Age (per year)	1.022	1.002–1.042	0.029
Charlson Comorbidity Index	1.495	1.144–1.952	0.003
Albumin (g/L)	0.815	0.743–0.893	<0.001
Urea (mg/dL)	0.998	0.993–1.002	0.353
Male sex	0.704	0.359–1.381	0.307
Tracheostomy indication			0.741
Airway-related/Other	Reference	—	—
Prolonged mechanical ventilation	1.697	0.415–6.946	0.462
Neurological impairment	1.716	0.428–6.883	0.446

Abbreviations: OR, odds ratio; CI, confidence interval. Adjusted ORs were obtained from a multivariable logistic regression model using the Enter method. Variables included in the model were age, Charlson Comorbidity Index, albumin, urea, sex, and tracheostomy indication. Model calibration was acceptable according to the Hosmer–Lemeshow goodness-of-fit test ($\chi^2 = 6.382$, $df = 8$, $p = 0.605$).

The ROC curve based on model-derived probabilities is displayed in Figure 2. Good discrimination for 90-day mortality was observed, with an AUC of 0.825 (95% CI, 0.772–0.878; $p < 0.001$).

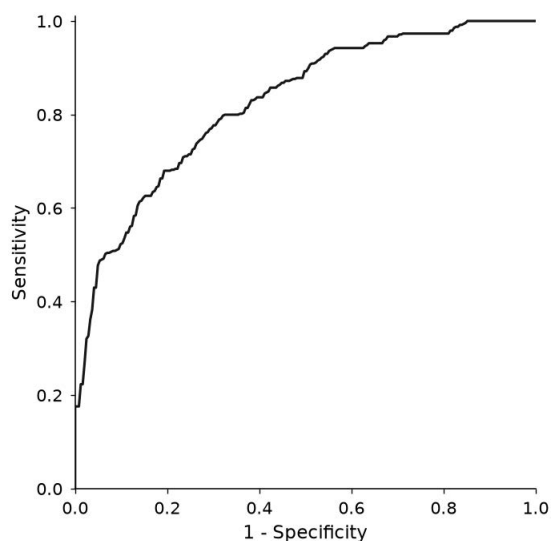


Figure 2. Receiver operating characteristic curve of the multivariable logistic regression model for predicting 90-day mortality (AUC = 0.825; 95% CI 0.772–0.878). AUC, area under the curve; CI, confidence interval.

Lower 90-day survival was observed in patients with CCI ≥ 3 compared with those with CCI ≤ 2 in the Kaplan–Meier analysis (log-rank $p = 0.015$; Figure 3).

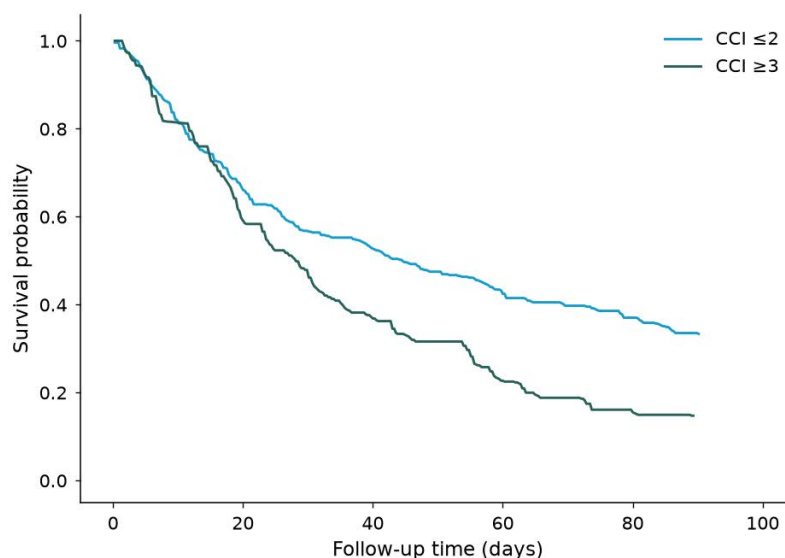


Figure 3. Kaplan–Meier survival curves according to Charlson Comorbidity Index category (CCI ≤ 2 vs. CCI ≥ 3). Differences between groups were compared using the log-rank test. CCI, Charlson Comorbidity Index.

4. Discussion

This retrospective cohort study evaluated factors associated with 90-day mortality after PDT in a tertiary ICU population. Independent relationships with mortality were

retained for older age, higher CCI, and lower serum albumin after multivariable adjustment. In contrast, no significant differences in APACHE II or SOFA scores were identified between survivors and non-survivors in the unadjusted comparisons. The multivariable model showed good discrimination, while Kaplan–Meier analysis demonstrated lower 90-day survival among patients with $\text{CCI} \geq 3$. Collectively, these findings suggest that comorbidity burden and physiological reserve may provide prognostic information that complements measures of acute disease severity in critically ill patients undergoing PDT.

Older age was independently associated with 90-day mortality after PDT in our cohort. Aging is accompanied by reduced physiological reserve, impaired immune function, sarcopenia, and progressive dysfunction across multiple organ systems.¹¹ These age-related changes may increase susceptibility to infection, complicate liberation from mechanical ventilation, and limit recovery after critical illness. Thus, the observed association with age may reflect underlying biological vulnerability in addition to chronological age. This finding is consistent with previous studies linking older age to mortality among patients undergoing percutaneous tracheostomy.⁵

CCI was independently associated with 90-day mortality in the present cohort. Unlike a simple count of coexisting diseases, the CCI incorporates both the presence of individual comorbidities and their assigned prognostic weights and has been used for mortality assessment in diverse patient populations.⁸ Patients who undergo PDT in the ICU are commonly older, require prolonged mechanical ventilation, and have multiple chronic conditions.^{4,11} In this context, the association between CCI and mortality indicates that underlying comorbidity burden may contribute to prognosis after tracheostomy.

Our finding regarding CCI accords with earlier evidence from tracheostomy cohorts. Yakar et al. reported that CCI independently predicted death within 90 days in a retrospective cohort of critically ill patients,⁵ whereas Parsikia et al. linked greater comorbidity burden to early mortality after tracheostomy.¹⁰ In our cohort, Kaplan–Meier analysis additionally showed lower 90-day survival among patients with $\text{CCI} \geq 3$. Although this finding supports the prognostic relevance of comorbidity burden, the clinical usefulness of this CCI threshold for risk stratification requires validation in independent populations.

Lower serum albumin was independently associated with 90-day mortality in our cohort. Albumin concentration is affected by nutritional status as well as systemic inflammation, illness severity, hepatic protein synthesis, and physiological reserve.⁹ During critical illness, inflammation may contribute to hypoalbuminemia by suppressing albumin synthesis and increasing capillary permeability, thereby promoting its redistribution into the extravascular compartment.⁹ Hypoalbuminemia may therefore integrate several adverse biological processes rather than represent nutritional status alone. The inverse albumin–mortality relationship observed in our cohort accords with earlier reports in critically ill populations.¹²

The independent associations of both CCI and serum albumin with 90-day mortality are noteworthy. CCI primarily reflects established comorbidity burden, whereas serum albumin is influenced by nutritional status, systemic inflammation, illness severity, and physiological reserve. Their simultaneous presence in the multivariable model suggests that prognosis after tracheostomy may be related to both premorbid disease burden and the patient's current biological condition rather than to acute physiological severity alone.

No significant differences in APACHE II and SOFA scores were observed between survivors and non-survivors in the unadjusted analyses. These scores primarily characterize acute physiological disturbance and organ dysfunction, whereas longer-term outcomes after tracheostomy may also be influenced by chronic health status and physiological reserve.⁶ PDT is generally performed later in the ICU course among patients who survive the early phase of critical illness but continue to require mechanical ventilation.^{1,4} In this setting, measures of comorbidity burden and nutritional or biological status may

provide prognostic information that complements acute severity scores. Nevertheless, because APACHE II and SOFA were not included in the multivariable model, their independent prognostic contributions cannot be determined from the present analysis.

The multivariable model yielded an AUC of 0.825, indicating good discrimination for 90-day mortality within the development cohort. Because the model was based on routinely available clinical and laboratory variables, it may offer a practical approach to prognostic assessment after tracheostomy. However, its performance was estimated using the same single-center cohort in which it was developed and may therefore be optimistic. The model must be tested in independent external cohorts before its clinical implementation can be considered.

Overall, the pattern of our findings suggests that factors associated with outcome may vary across the course of critical illness. Acute physiological abnormalities and organ dysfunction are important determinants of early ICU outcomes, whereas chronic health status and physiological reserve may assume greater relevance among patients who survive the initial phase and subsequently undergo tracheostomy. This distinction may partly explain why APACHE II and SOFA scores did not vary significantly according to 90-day survival status, although their independent prognostic contributions were not evaluated. Care and rehabilitation after ICU discharge may also influence 90-day outcomes,¹³ but they were not evaluated in this analysis and require prospective investigation. Age, CCI, and serum albumin are readily available variables that may complement prognostic assessment after tracheostomy, although their clinical utility requires external validation. The combined evaluation of CCI and serum albumin within the same cohort and the use of 90-day mortality as the primary outcome allowed us to consider both the continuing ICU course and the early period after discharge. Tracheostomy indication did not retain an independent association with 90-day mortality after multivariable adjustment. Comparable observations were reported by Yakar et al. and Parsikia et al.; in their studies, mortality was more closely related to patient-level characteristics, including comorbidity burden, serum albumin, and vasopressor requirement, than to the indication for tracheostomy.^{5,10}

4.1. Limitations

Several limitations need to be acknowledged in the interpretation of these results. First, selection bias, information bias, and residual confounding may have arisen from the retrospective, single-center design. Second, specific causes of death, post-discharge care, rehabilitation, and functional status were unavailable and could not be incorporated into the analysis. Third, model performance was estimated in the same cohort used for model development. As external validation has not yet been performed, the model's transportability and clinical utility remain undetermined. Finally, the evaluated variables were obtained at clinically relevant but different time points, introducing temporal heterogeneity into the predictor set. A comparatively large cohort of patients undergoing PDT, complete ascertainment of 90-day mortality status, and the complementary use of logistic regression and survival analyses represent the main strengths of this study.

5. Conclusion

Older age, higher CCI, and lower serum albumin were independently associated with 90-day mortality among critically ill patients undergoing PDT. These findings indicate that chronic disease burden and physiological reserve may provide relevant prognostic information when assessing longer-term outcomes after tracheostomy. However, the prognostic performance and clinical utility of these variables require confirmation through external validation in prospective multicenter cohorts.

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Ethical Approval: The study protocol was approved by the Scientific Research Ethics Committee for Health Sciences of Aksaray University (Decision No. 2026/145; dated April 30, 2026) and was conducted in accordance with the principles of the Declaration of Helsinki.

Informed Consent: Waiver of informed consent was granted due to the retrospective observational design.

Data Availability Statement: The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Generative AI Statement: No artificial intelligence-based tools or generative AI technologies were used in this study. The entire content of the manuscript was originally prepared, reviewed, and approved by all authors.

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