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Original Article

Etiology-Based Clinical Outcomes after Pediatric Tracheostomy in Intensive Care: A Retrospective Observational Study

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ABSTRACT

Aim: To evaluate etiology-based differences in clinical outcomes among pediatric patients undergoing tracheostomy in a tertiary pediatric intensive care unit.

Materials and Methods: In this retrospective observational study, the medical records of patients aged 1 month to 18 years who had undergone tracheostomy between October 2023 and December 2025 were reviewed. The patients were classified into three etiological groups: neuromuscular diseases, chronic respiratory failure, and upper airway obstruction/malformation. Their demographic characteristics, mechanical ventilation durations, intensive care and hospital length of stay, complications, and clinical outcomes were analyzed.

Results: A total of 59 patients were included. The most common tracheostomy indications were neuromuscular diseases (52.5%) and chronic respiratory failure (33.9%). Significant differences were observed among the groups regarding their age, anthropometric measurements, and mechanical ventilation durations ($p<0.05$). Those patients with chronic respiratory failure had longer pre- and post-tracheostomy mechanical ventilation durations and the lowest successful ventilator weaning rate. Early and late complication rates were 10.2% and 25.4%, respectively. The decannulation rate was 5.1%, and overall mortality was 22%.

Conclusion: Tracheostomy indication was significantly associated with clinical outcomes in pediatric intensive care patients. Those patients with chronic respiratory failure demonstrated prolonged mechanical ventilation and lower ventilator weaning success. Etiology-based individualized management strategies warrant further investigation in this population.

Keywords: Tracheostomy, intensive care units, pediatric, respiration, artificial, respiratory insufficiency, neuromuscular diseases

Introduction

Tracheostomy is a commonly utilized surgical intervention in pediatric intensive care units (PICUs) for those children who require prolonged respiratory or airway support. The procedure has several potential benefits, including improved comfort, decreased sedative and analgesic requirements, the facilitation of ventilator weaning, and a reduction in intensive care burden in selected patients (1). Previous studies have reported that nearly 1-3% of children admitted to PICUs undergo tracheostomy during their clinical course (2).

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Despite the increasing use of pediatric tracheostomy, standardized recommendations regarding optimal timing, indications, and long-term outcomes remain limited (3-5). The timing of tracheostomy in pediatric populations varies substantially according to the underlying disease, expected duration of ventilatory support, and institutional preferences, generally ranging between several weeks and months after the initiation of mechanical ventilation (2). In addition to prolonged mechanical ventilation, common indications include upper airway obstruction, impaired airway protection, swallowing dysfunction, ineffective cough reflex, and inadequate secretion clearance (6).

Several reports have suggested that tracheostomy may contribute to reduced ventilator-associated complications, shorter mechanical ventilation duration, and improved long-term respiratory management (7). Nevertheless, procedure-related complications such as bleeding, infection, accidental decannulation, and tracheal stenosis may still occur despite advances in intensive care practice (8).

Recent updates have further refined our understanding of contemporary indications, timing considerations, and long-term care pathways for pediatric tracheostomy, emphasizing prolonged mechanical ventilation as the predominant modern indication and highlighting the evolving practices in decannulation planning and multidisciplinary follow-up (9,10). Population-level data further indicate that pediatric tracheostomy rates and associated health care resource usage continue to evolve over time, underscoring the ongoing need for etiology-specific outcome data in order to guide clinical decision-making (11,12).

Although pediatric tracheostomy is widely performed, studies specifically evaluating the impact of different etiological indications on clinical outcomes remain relatively limited. Therefore, this study aimed to evaluate tracheostomy indications, complications, clinical course, and etiology-based outcome differences among pediatric patients managed in a tertiary PICU.

Materials and Methods

Study Design and Population

A retrospective single-center observational study was carried out in a tertiary PICU in accordance with the ethical principles of the Declaration of Helsinki. Ethical approval was obtained from the Institutional Review Board of University of Health Sciences Türkiye, İzmir City Hospital (approval no.: 2026/111; date: 18.02.2026). This study was conducted in a 54-bed tertiary PICU, which admits approximately 1,200 patients annually. This study was reported in accordance with the *Strengthening the Reporting of Observational Studies in Epidemiology*-STROBE statement for observational cohort studies.

The medical records of pediatric patients who had undergone tracheostomy between October, 2023 and December, 2025 were retrospectively reviewed following ethics approval. Follow-up data for decannulation and mortality outcomes were collected up until December 31st, 2025.

Inclusion and Exclusion Criteria

Children aged between 1 month and 18 years who had undergone tracheostomy and remained in the PICU for at least 24 hours were included in this analysis. Those patients with insufficient clinical data or PICU stays shorter than 24 hours were excluded.

The patients were grouped according to their underlying etiology into three groups: neuromuscular diseases (NMs), chronic respiratory failure (CRF) secondary to pulmonary disease, and upper airway obstruction/malformation (UAO/M). Tracheostomy was considered in those patients requiring prolonged invasive mechanical ventilation, persistent upper airway obstruction, impaired airway protection, or chronic respiratory insufficiency, following a multidisciplinary evaluation involving pediatric intensivists, pulmonologists, and otolaryngologists as appropriate. The patients were classified according to their primary/predominant clinical indication for tracheostomy, as determined by the treating multidisciplinary team; those patients with NM were classified in the NMs group when NM was considered the primary driver of respiratory failure, even if chronic respiratory insufficiency was also present as a consequence of the underlying neuromuscular disorder, whereas other patients were classified in the CRF group only when a chronic pulmonary process independent of NM was the primary/dominant indication. "Chronic lung disease" as a baseline comorbidity is conceptually distinct from the CRF etiological group and could be present in patients classified into any of the three groups.

Data Collection

The data retrieved from electronic hospital records included demographic information, tracheostomy indications, duration of mechanical ventilation, duration of hospitalization, complications, and outcome measures. Early complications were defined as those occurring within the first 7 days after tracheostomy, and late complications were defined as those occurring after day 7.

Statistical Analysis

All statistical analyses were performed using SPSS software version 23.0 (IBM Corp., Armonk, NY, USA). Continuous variables are presented as median and interquartile range, while categorical variables are expressed as numbers and percentages. Distribution normality was assessed using the Shapiro-Wilk test.

Comparisons between groups were conducted using the Mann-Whitney U or Kruskal-Wallis tests for continuous variables. Pairwise comparisons following a significant Kruskal-Wallis test were performed using Dunn's test with Bonferroni correction. Categorical variables were analyzed using chi-square or Fisher's exact tests where appropriate; given the small expected cell count in the UAO/M subgroup, the Fisher-Freeman-Halton exact test was additionally applied to the 3×2 comparison of ventilator weaning success by etiological group. Correlations between continuous variables were evaluated using Spearman correlation analysis. Statistical significance was accepted at $p<0.05$.

Results

A total of 59 pediatric patients were included in the study cohort. NMs and CRF represented the most frequent indications for tracheostomy. Demographic characteristics and accompanying comorbidities are summarized in Table I.

A comparison of the etiological groups demonstrated significant differences regarding age, body measurements, and mechanical ventilation duration parameters. The CRF group exhibited markedly prolonged pre- and post-tracheostomy ventilatory support durations compared with the remaining groups. Detailed comparisons of the ventilatory and clinical parameters are shown in Table II. Pairwise post hoc comparisons (Dunn's test with Bonferroni correction) are presented in Table II.

No statistically significant differences were identified between the groups in terms of PICU or overall hospital stay.

Early complications occurred in 10.2% of the patients (n=6), most commonly cannula-related problems/displacement (n=4) and air leakage (n=3); no bleeding was recorded. Late complications were observed in 25.4% of the patients (n=15), most commonly cannula-related problems/displacement (n=13) and granuloma (n=4); no tracheal stenosis, tracheomalacia or airway obstruction was recorded (some patients had more than one complication). Cannula displacement/malposition was the most frequently encountered complication during both the early and late periods. The overall clinical outcomes and ventilation-related findings are presented in Table III.

The overall decannulation rate was 5.1% (n=3), and the mortality rate was 22% (n=13). The mortality and decannulation rates according to their etiological group are summarized in Table IV; briefly, mortality was 29.0% in the NMs group, 20.0% in the CRF group, and 0% in the UAO/M

Table I. Demographic characteristics and comorbidities of patients

Variable	n (%) or median (IQR)
Total number of patients	59
Age (months)	11 (4-108)
Male sex	37 (62.7%)
Comorbidities	
Genetic syndrome	19 (32.2%)
Neurometabolic disease	17 (28.8%)
Chronic lung disease	10 (16.9%)
Others*	13 (22%)

*Permanent organ dysfunction secondary to various underlying conditions
IQR: Interquartile range

Table II. Clinical and ventilator parameters according to etiology groups

Variable	UAO/M	CRF	NM	p value	Post-hoc
Age (months)	5 (2.25-54.25)	4 (3-7.63)	62 (12-180)	<0.001	NM-UAO/M*, NM-CRF*
Weight (kg)	3.95 (3.43-10.88)	3.5 (3.23-3.98)	16 (7-44)	<0.001	NM-CRF*
Height (cm)	59 (51-95.75)	55 (50.25-57.5)	102 (65-148)	0.001	NM-CRF*
Pre-tracheostomy MV (days)	19 (1.75-34.5)	70.5 (42-96.75)	31 (24-36)	<0.001	CRF-UAO/M*, CRF-NM*
Post-tracheostomy MV (days)	9 (6-16)	130 (79-394)	16 (9-82)	0.002	CRF-UAO/M*, CRF-NM*
PICU length of stay (days)	71 (33.5-154.5)	133 (65.25-199)	67 (54-127)	0.199	-
Hospital length of stay (days)	140 (75.25-228)	202 (96.5-342)	105 (58-200)	0.059	-

*Statistically significant pairwise comparison
CRF: Chronic respiratory failure, NM: Neuromuscular diseases, UAO/M: Upper airway obstruction/malformation, MV: Mechanical ventilation, PICU: Pediatric intensive care unit, IQR: Interquartile range

Table III. Clinical course, mechanical ventilation, and outcomes

Clinical parameter	Median (IQR) or n (%)
Pre-tracheostomy MV (days)	34 (24-65)
Post-tracheostomy MV (days)	25 (11-129)
PICU length of stay (days)	87 (54-177)
Hospital length of stay (days)	124 (65-252)
Complications	
Early complications	6 (10.2%)
Late complications	15 (25.4%)
Cannula-related problem/displacement (early)	4
Air leakage (early)	3
Infection (early)	1
Cannula-related problem/displacement (late)	13
Granuloma (late)	4
Outcomes	
Decannulation	3 (5.1%)
Mortality	13 (22%)

MV: Mechanical ventilation, PICU: Pediatric intensive care unit, IQR: Interquartile range

Table IV. Mortality and decannulation rates according to etiology groups

Etiology group	n	Mortality, n (%)	Decannulation, n (%)
NM	31	9 (29.0%)	2 (6.5%)
CRF	20	4 (20.0%)	0 (0%)
UAO/M	8	0 (0%)	1 (12.5%)

CRF: Chronic respiratory failure; NM: Neuromuscular diseases; UAO/M: Upper airway obstruction/malformation

group, while decannulation was 6.5% in the NMs group, 0% in the CRF group, and 12.5% in the UAO/M group. Of the three patients who achieved successful decannulation, one was a young infant with an underlying genetic syndrome and upper airway obstruction/malformation who required prolonged pre-tracheostomy ventilation; one was an infant with an underlying neurometabolic disorder, classified in the NM group; and one was an adolescent patient, also classified in the NM group.

Ventilator weaning success differed significantly according to the etiological category (χ^2=9.401, p=0.009). The highest successful weaning rate was observed in the UAO/M group, whereas patients with CRF demonstrated the poorest weaning outcomes. Weaning results according to the etiological groups are summarized in Table V. This finding was confirmed using the Fisher-Freeman-Halton exact test (p=0.011), given the small expected cell count in the UAO/M subgroup.

Table V. Mechanical ventilation weaning rates according to etiology groups

Etiology group	Weaned n (%)	Continued MV n (%)
UAO/M	6 (75%)	2 (25%)
CRF	3 (15%)	17 (85%)
NM	13 (41.9%)	18 (58.1%)

Statistical test: chi-square (χ^2=9.401, p=0.009)
CRF: Chronic respiratory failure; NM: Neuromuscular diseases; UAO/M: Upper airway obstruction/malformation; MV: Mechanical ventilation

Discussion

The present study demonstrated that underlying tracheostomy indication was significantly associated with clinical outcomes in pediatric intensive care patients. In particular, children with CRF experienced prolonged mechanical ventilation and lower successful ventilator weaning rates compared with the other etiological groups.

Our findings are consistent with previous studies emphasizing the importance of underlying disease characteristics in determining post-tracheostomy outcomes (13,14). Can et al. (13) conducted a retrospective study including 63 pediatric patients in a Turkish tertiary PICU and reported that upper airway obstruction was associated with a higher decannulation rate (12.6% overall) and more favorable weaning outcomes than prolonged mechanical ventilation for chronic systemic disease, with no deaths directly attributable to tracheostomy complications. Similarly, Tsuboi et al. evaluated long-term survival and decannulation outcomes in a pediatric tracheostomy cohort and reported that children with underlying neurological and neuromuscular disorders had lower decannulation rates and more prolonged ventilator dependence than those with airway-based indications (14).

In the present cohort, the CRF group consistently exhibited less favorable outcomes across multiple clinical parameters. Persistent pulmonary pathology, impaired respiratory mechanics, and accompanying comorbid conditions may explain the prolonged dependence on mechanical ventilation observed in these patients. In addition, chronic respiratory disorders frequently require long-term respiratory support, thereby complicating ventilator liberation. Recent evidence has shown that tracheostomized children with chronic respiratory disease are more likely to require home mechanical ventilation and rehospitalization following discharge (15).

The prolonged pre- and post-tracheostomy ventilation durations identified in the CRF group are also consistent with previous reports demonstrating that prolonged ventilation and severe comorbidity burden are associated with poorer prognosis. A systematic review evaluating pediatric tracheostomy complications reported overall complication rates approaching 40%, particularly among younger patients and those with significant underlying disease (16).

The overall complication rate in our study was comparable with previously published pediatric tracheostomy series. Cannula displacement represented the most common complication and remains one of the major concerns in pediatric tracheostomy management.

The relatively low decannulation rate observed in this study may be explained by the large proportion of patients with chronic neuromuscular and respiratory disorders. Such patients frequently fail to achieve complete respiratory independence, thereby reducing the likelihood of successful decannulation. Previous reviews have identified effective cough reflex, preserved neurological function, and adequate secretion management as major predictors of successful decannulation, whereas chronic neurological disease is associated with lower decannulation success (17,18).

The overall mortality rate was 22%. Mortality in this population is likely more closely related to the severity of the underlying disease rather than the tracheostomy procedure itself. Previous studies similarly demonstrated that long-term survival in pediatric tracheostomy patients is strongly influenced by the primary diagnosis and associated comorbidities (14). Noy et al. (19) reported an overall mortality rate of 26% in a retrospective cohort of children undergoing tracheostomy, identifying prematurity, young age, congenital heart disease, and ventilatory dependency as factors associated with early mortality, while Kılıç and Başak Kılıç (20) reported a lower mortality rate (14.3%) in a smaller single-center Turkish PICU cohort in which most deaths were attributed to the underlying disease rather than tracheostomy-related complications, broadly consistent with our findings. Beyond mortality, recent population-level data have also indicated that health care resource usage and long-term care pathways after pediatric tracheostomy continue to evolve, further supporting the need for etiology-specific outcome data such as those presented here (11,12).

Taken together, these findings suggest that pediatric tracheostomy should not be approached as a uniform intervention, but rather as an etiology-specific management strategy. Careful patient selection and individualized follow-up planning which is tailored to the underlying etiology warrant further investigation in prospective studies as potential strategies to optimize both short- and long-term outcomes.

Study Limitations

This study had several limitations. First, the retrospective single-center design may limit generalizability. Second, the duration of mechanical ventilation prior to tracheostomy was available and analyzed; however, more granular information regarding the timing of the tracheostomy relative to the onset of the underlying illness or hospital admission, which would have allowed for the evaluation of "early" versus "late" tracheostomy strategies as discussed in the literature, was not systematically available, preventing additional timing-based analyses. The optimal timing of pediatric tracheostomy remains controversial and no universally accepted recommendations have yet been established for this patient population (21). Third, baseline differences in age and anthropometric characteristics among etiological groups may have partially confounded the observed associations between etiology and ventilatory outcomes. Due to the limited sample size in this study, multivariable adjustment was not performed, and these associations should therefore be interpreted with caution. Fourth, the UAO/M subgroup was small (n=8), which limits the statistical power of pairwise comparisons involving this group. Finally, patients enrolled toward the end of the study period had a shorter potential follow-up interval, which may have limited the ascertainment of later complications, decannulation, or mortality events in this subgroup.

Conclusion

The underlying tracheostomy indication appears to be significantly associated with clinical outcomes in pediatric intensive care patients. Children with CRF demonstrated prolonged ventilatory dependence and lower rates of successful ventilator weaning. Etiology-based differences should therefore be considered during both pre-tracheostomy evaluation and post-procedural management. Those patients with upper airway obstruction tended to exhibit more favorable respiratory outcomes, whereas chronic respiratory and neuromuscular disorders were associated with prolonged ventilatory support requirements. An individualized multidisciplinary management strategy tailored to the underlying disease process warrants further investigation as a means to help optimize outcomes in pediatric tracheostomy patients.

Ethics

Ethics Committee Approval: Ethical approval was obtained from the Institutional Review Board of University of Health Sciences Türkiye, İzmir City Hospital (approval no.: 2026/111; date: 18.02.2026).

Informed Consent: The requirement for informed consent was waived due to the retrospective nature of this study.

Footnotes

Authorship Contributions

Concept: F.D., E.P.K., G.Ö., D.K.T., Design: F.D., E.P.K., G.Ö., D.K.T., Data Collection or Processing: F.D., E.P.K., G.Ö., D.K.T., Analysis or Interpretation: F.D., E.P.K., G.Ö., D.K.T., Literature Search: F.D., E.P.K., G.Ö., D.K.T., Writing: F.D., E.P.K., G.Ö., D.K.T.

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