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Original article

Prevalence of extubation failure and associated factors among pediatric patients admitted to the Pediatric Intensive Care Unit at Tikur Anbessa Specialized Hospital, Ethiopia

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Abstract

Introduction: *A critical component of pediatric intensive care therapy is mechanical ventilation which used when the patient's spontaneous breathing is inadequate. In the pediatric intensive care unit, the need for mechanical ventilation ranges from 20% to over 60%, depending on the setting. Respiratory failure is the primary indication for the initiation of ventilator support in pediatric patients as a result of airway or lung disease, multiorgan failure or postoperative care.*

Objective: *Assessing the prevalence and factors associated with extubation failure among pediatric patients (0-14 years) admitted to the pediatric intensive care unit at Tikur Anbessa Specialized Hospital.*

Methods*: A facility-based cross-sectional study was conducted among 155 pediatric patients admitted to the pediatric intensive care unit during September 2019 to September 2023. Data were collected using a checklist, entered into Epi-info software, exported to SPSS version 25, and analyzed. Multivariate logistic regression identified factors associated with extubation failure. Variables with P values < 0.05 were considered statistically significant. Hosmer and Leme's goodness-of-fit test assessed model fitness. The adjusted odds ratio with the 95% confidence interval measured the association strength between outcome and independent variables.*

A total of 18.1% of intubated and extubated patients experienced extubation failure (95% CI: 12.9–24.5). Patients with hospital stays exceeding 30 days had significantly higher odds of extubation failure (AOR = 2.81, 95% CI: 5.23–15.60), as did those with hospital stays of 10–30 days (AOR = 2.31, 95% CI: 3.10–17.76). Additionally, the likelihood of extubation failure was 2.14 times higher

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for patients who were not nebulized immediately after extubation compared to those who were nebulized (AOR = 2.14, 95% CI: 5.87–9.46).

Conclusion: *This study revealed that the extubation failure rate was 18.1%. Prolonged hospital stays and failure to nebulize after extubation were found to be determinants of extubation failure.*

Keywords*: Extubation failure, Extubation success, Mechanical ventilation*

Introduction

A critical component of pediatric intensive care therapy is mechanical ventilation**.** It is used when the patient's spontaneous breathing is inadequate(1). In the pediatric ICU, the need for mechanical ventilation ranges from 20% to over 60%, depending on the setting. Respiratory failure is the primary indication for the initiation of ventilator support in pediatric patients as a result of airway or lung disease, multiorgan failure or postoperative care (2). An absolute indication for mechanical ventilation is cessation of breathing or respiratory arrest, which is an extreme form of respiratory failure. The presence of inadequate oxygenation or ventilation was defined as respiratory failure. Objectively inadequate oxygenation is defined as a partial pressure of arterial oxygen (Pao2) less than 60 Torr or an arterial hemoglobin oxygen saturation of less than 90% in room air. A PaO2/Fio2 ratio less than 300 can also indicate inadequate oxygenation (3). Discontinuing mechanical ventilation is a two-step process. The removal of mechanical ventilator support is defined as weaning, and extubation is defined as the removal of the artificial airway (4). The inability to maintain spontaneous breathing after extubation and the need for invasive mechanical ventilation within 48 hours after extubation is defined as extubation failure (5). Failed extubation is associated with longer hospital and PICU stays, longer mechanical ventilation, and a greater risk of tracheostomy tube placement than successful extubation (6). Additionally, a study showed that extubation failure is associated with an increased rate of mortality (7). Therefore, timely extubation is very important when the patient is ready for extubation.

Extubation failure is multifactorial, but in children, it is also associated with certain risk factors, such as age and duration of invasive mechanical ventilation (7,8). Predicting extubation redness and outcome is difficult. For adequate spontaneous breathing, several factors are important. These include a patent airway, effective airway reflex and clearance, adequate respiratory muscle strength, effective gas exchange, and effective respiratory drive (9). Therefore, supporting evidence of the use of methods to predict redness to extubation or extubation success in pediatric patients is lacking. The regular use of extubation readiness tests, apart from clinical judgment, is not supported (3,10). There was no significant difference in the use of weaning protocols.

There are no defined protocols for determining the rate of extubation failure in pediatric patients requiring invasive mechanical ventilation (IMV) support (9). Most studies have reported that the incidence of extubation failure ranges between 4% and 20% (4). In different countries and different studies, the prevalence of extubation failure differs. In one study conducted in the pediatric ICU of a public hospital located in the city of Bauru (São Paulo, Brazil), the results showed an extubation failure rate of 16% (6). In another large-scale study conducted among 548 patients, the failure rate of planned extubation was 4.9%. For those who had received IMV for >24 hours but who had been intubated for >48 hours, the failure rate was 7.9% (14). In another study from Spain on risk factors for extubation failure in the PICU, the rate of extubation failure was 5.32% (3). In a study performed in India, the prevalence of extubation failure among neonatal and pediatric patients admitted to the PICU was 28.3 % (95 % CI 0.21–0.38) (15). In Egypt, the prevalence of extubation failure was found to be 17.5% in a prospective cohort study (12). In South Africa, a prospective cohort study showed that the extubation failure rate was 11.4% at 48 hours of mechanical ventilation (13). The determining factor for failed extubation is also different based on the country and study area.

In India, failure to pass spontaneous breathing tests, altered respiratory effort following extubation, respiratory system involvement, poor cough reflex and thick secretions were the major causes of extubation failure (9). A study performed in Egypt revealed that younger age, longer ICU stay, low Glasgow coma scale score and low body weight were factors associated with extubation failure. Furthermore, they found that a prolonged time of mechanical ventilation (> 7 days) is associated with extubation failure. Respiratory causes were the main reason for extubation failure. (12) A study conducted in South Africa revealed that prematurity, an IMV > 48 hours, congenital anomalies, a low GCS score, a long duration of ventilation and a long PICU stay were factors associated with extubation failure (13). Investigating the factors associated with extubation failure is critical for preventing extubation failure.

Reintubation is an outcome to be avoided. It is associated with a prolonged hospital stay, increased cost, increased in-hospital mortality and increased need for tracheostomy, all of which are adverse patient outcomes (4).

In Ethiopia, there are no published data on the factors and prevalence of extubation failure in pediatric patients. In our PICU, formal spontaneous breathing trials and extubation readiness tests are not being performed. The decision to extubate was based on the assessment of the patient's clinical data by the attending physician. No adequate data were found on the outcomes and prevalence of extubation failure among Ethiopian pediatric patients admitted to the PICU. Therefore, the primary objective of this study was to determine the prevalence of extubation failure and secondary

factors associated with extubation failure among pediatric patients in Ethiopia, Addis Ababa.

Methods

Study design and setting

An institutional-based cross-sectional study was conducted among pediatric patients (0-14 years) who had been admitted to the TASH PICU from September 1, 2019 to September 9, 2023 G, C. Tikur Anbessa Specialized Hospital is located in Addis Ababa, the capital city of Ethiopia, and was estabished in 1998 G.C. as a school by the Federal Ministry of Health. Since then, TASH has served as the largest referral and teaching hospital in the country, with 700 beds, 200 doctors, 379 nurses, and 115 other health professionals, and it also has a separate pediatric intensive care unit with a total of 6 beds.

Sample size calculation and sampling procedure

All patients aged 0-14 years who had been admitted to the PICU and TASH were the source population. All patients aged 0-14 years admitted to the PICU and who were intubated were included in the study. The study included all patients aged 0-14 years. Those admitted to the PICU who continued on MV for a time equal to or greater than 24 hours underwent extubation and were followed up for up to 48 hours after extubation. Exclusion criteria included all cases of unplanned extubation. Patients who underwent tracheostomy after intubation, patients referred to another hospital while intubated and patients who passed away while on mechanical ventilation were excluded. We used two methods to calculate the sample size for the first and second objectives. for the first objective using the single population proportion formula with the following assumption: 11.4% proportion of extubation failure (13), 95% confidence interval, and 5% margin of error. In addition, it becomes 155. For the second objective, the sample size was calculated using Epi-enfo using the following variables: noninvasive ventilation postextubation, CI, 95%; power, 80%; outcome in the unexposed group, 76.2%; outcome in the exposed group, 50.3%; and AOR, 0.32. The sample size was 122. Therefore, we used the first sample size. This value is greater than the sample size for the second objective. We retrieved the charts of the patients retrospectively. Since some of the charts were not complete, we used all available charts to avoid incomplete charts.

Operational definition

Extubation failure was defined as the need for reintubation within 48 hours of planned extubation (16).

Extubation success was defined as the ability to maintain spontaneous ventilation without respiratory support after 48 hours following extubation (16).

Weaning is the gradual reduction of ventilator support (3)

Data collection tools and procedure

Semi structured data collection tools were developed based on different studies (2,4,6,11,12). The data collection tool contains

six parts. The first part collected data on socio-demographic, the second part collected data on primary diagnosis and comorbid conditions, The third portion collected data on per intubation factors like route of intubation, the scenario of intubation, the fourth part collected data on ventilator settings before extubation, the fifth part collected data on pre extubation parameters, and the last part collected information on other factors. The charts of patients who had been admitted and intubated to TASH, PICU, from September 2019–September 2019 were collected (2023 g/c). The secondary data were retrieved from patient charts. Two data collectors who are residents of TASH collected the data after they were trained by the principal investigator.

Data quality assurance

To ensure the data quality, properly designed data collection tools were used. The data collection tool was prepared in English. The principal investigator was the cordinator of the data collection. The collected data were reviewed and checked for completeness before data entry. In addition, the completeness of the data was checked by running frequency.

Data processing and analysis

The data were entered into Epi-info software version 7 and then exported to the SPSS version 25 statistical package for analysis. Summary and descriptive statistics were used to describe the study population and were presented using graphs and tables. The factors associated with extubation failure were traced by using a binary logistic regression model after checking the necessary assumptions of the model. Variables with a P value of <0.25 in the bivariate analysis were included in the multivariate regression analysis. In the multivariate regression, those variables with a P value <0.05 were considered statistically significant. The odds ratio with the corresponding 95% confidence interval (95% confidence interval) was used to measure the presence and strength of the associations between extubation failure and contributing factors multiple times were checked by variance inflation factors, and outliers were checked by box plots, stems and leaves. Hosmer and Lameshow goodness-of-fit tests were conducted to test the model fitness.

Ethical consideration

An ethical approval for this study was obtained from the Research and Publication Committee of Pediatrics and Child Health Department (DRCP) School of Medicine College of Health Science Addis Ababa University and the College Institutional Review Bord (IRB) of Addis Ababa University. Informed consent for the waiver of the participants was obtained from the College Institutional Review Bord (IRB) of Addis Ababa University. and authors had no access to information that could identify individual participants during or after data collection.

Results

Sociodemographic characteristics

A total of 165 charts were retrieved retrospectively from 2019 to 2023 GC patients.

Of these 159 records, 155 were complete. More than half 93 (60%) of the included patients were male, and the majority 56 (36.1%) were aged between 1 and 5 years (Figure 1).

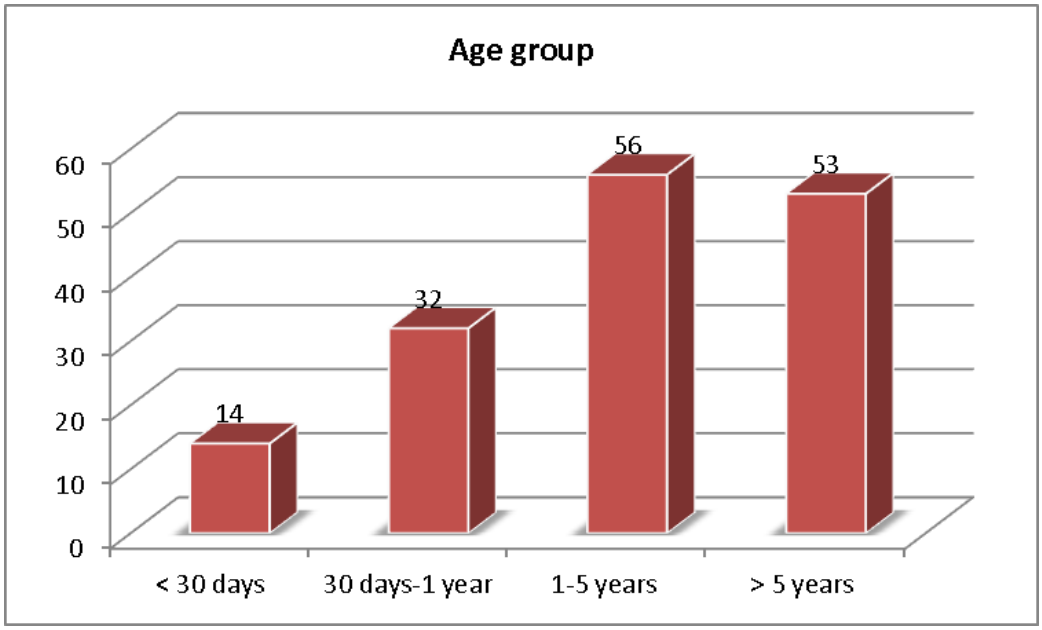

Figure 1: Age distribution of pediatric patients 0-14 years of age who were intubated or extubated at the pediatric ICU of TASH from 2019 to 2023

Comorbid conditions

Approximately 19 (12.3%) and 16 (10.3%) of patients had brain tumors and congenital heart disease, respectively (Figure 2).

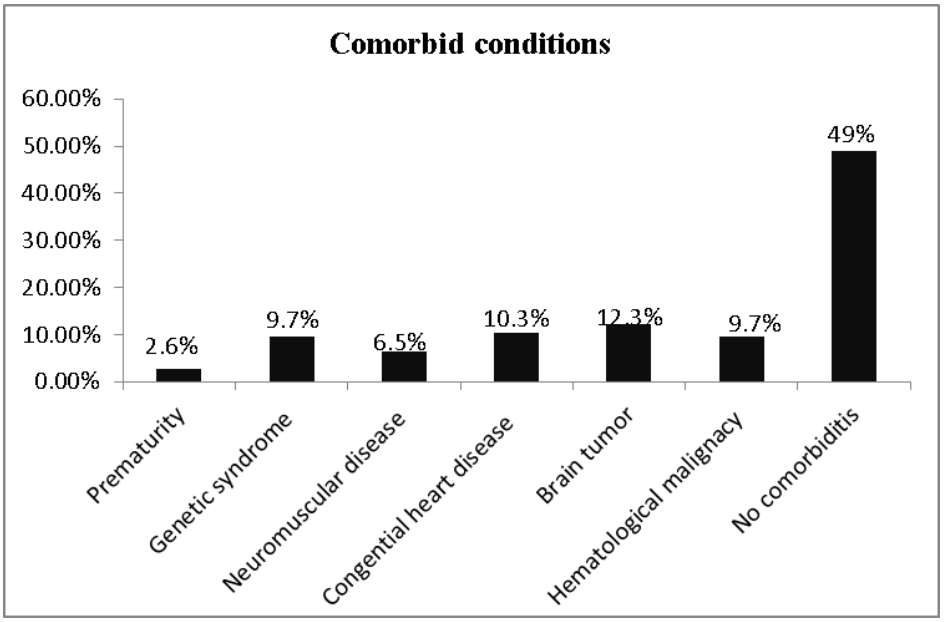

Figure 2: Comorbidity conditions for pediatric patients 0-14 years of age admitted to the pediatric ICU of TASH from 2019-2023 GC.

Primary indications for intubation

The majority 77 (50.3%) of patients were intubated primarily for respiratory failure and airway protection 63 (40.6%) (Figure 3).

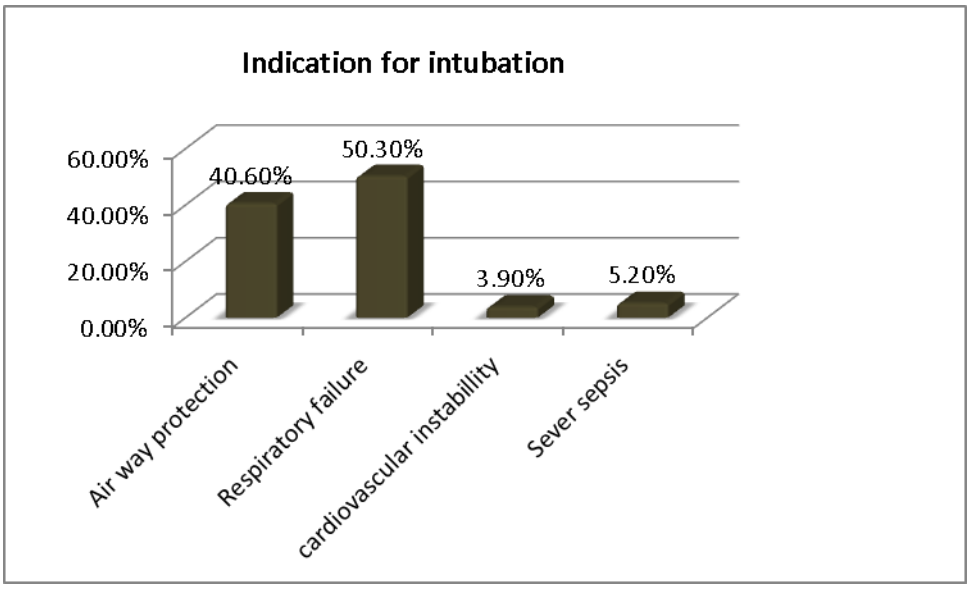

Figure 3: Primary indications for intubation of pediatric patients 0-14 years of age admitted at the pediatric ICU of TASH from 2019-2023 GC.

Pre-intubation factors

Most of the patients 124 (80%) received noninvasive ventilation before intubation. More than half 85 (55.5%) of the patients were intubated on an emergency basis. There were no more than two attempts at intubation or nasal intubation (Table 1).

Table 1: Pre-intubation factors for intubated pediatric patients 0-14 years of age admitted at the pediatric ICU of TASH from 2019-2023 GC.

Pre-intubation factors	Category	Frequency	Percent (%)
Use of noninvasive ventilation (NIV) before intubation	Yes	124	80
	No	31	20
Emergency intubation	Yes	86	55.5
	No	69	44.5

Ventilator settings prior to extubation

The fraction of inspired oxygen before extubation was <40% for the majority 99 (63.9%) of the patients, and the peak inspiratory pressure was in the range of 5-10 cm H2O for more than half of the patients 96 (61.9%). Furthermore, almost half 81(52.3%) of the patients had positive end expiratory pressure in the range of 5-10 cm (Table 2).

Table 2: Ventilator settings prior to extubation for pediatric patients 0-14 years of age intubated at the pediatric ICU of TASH from 2019-2023 GC.

Ventilator settings	Category	Frequency	Percent (%)
Peak inspiratory pressure (PIP)	5-10 cm H2O	96	61.9
	11-15 cm H2O	56	36.2
	16-20 cm H2O	3	1.9
Positive end-expiratory pressure (PEEP)	3-5 cm H2O	74	47.7
	6-10 cm H2O	81	52.3
Fraction of Inspired Oxygen (FIO2)	<40%	99	63.9
	40-60%	32	20.6
	61-80%	21	13.5
	81-100%	3	1.9

Pre-extubation parameters

Approximately 43.9% of patients stayed in the hospital for 11-30 days. Similarly, 65 (43.2%) of the participants were intubated for 3-7 days, and 16 (10.3%) of the patients used sedation for more than 5 days. In contrast, only 9 of the participants used inotropes for more than 5 days. Most 127(81.9%) of the patients used dexamethasone 24 hours prior to extubation. Furthermore, almost all 145(93.5%) patients received immediate nebulization after extubation; 151(97.4%) of the participants were provided with noninvasive ventilation after extubation, and 28 (18.1%) of patients had ventilator-associated pneumonia (Table 3).

Table 3: Pre extubation parameters of pediatric patients age 0-14 years admitted to the pediatric ICU of TASH from 2019-2023

Pre-extubation parameters	Category	Frequency	Percent (%)
Length of hospital stays	2-10 days	49	31.6
	11-30 days	68	43.9
	>30 days	38	24.5
Duration of intubation	48 hrs	56	36.2
	3-7days	67	43.2
	>7days	32	20.6
Use of sedation for more than 5 days	Yes	16	10.3
	No	139	89.7
Use of inotropes for more than 5 days	Yes	1	0.6
	No	154	99.4
Use of dexamethasone 24 hrs before extubation	Yes	127	81.9
	No	28	18.1
Immediate nebulization after extubation	Yes	145	93.5
	No	10	6.5
Use of NIV after extubation	Yes	151	97.4
	No	4	2.6
Does the patient have VAP	Yes	28	18.1
	No	127	81.9

The prevalence of extubation failure

This study revealed that 18.1% of pediatric patients who were intubated or extubated at the pediatric ICU of TASH between 2019 and 2023 experienced extubation failure (CI: 12.9 –24.5). (Fig 4)

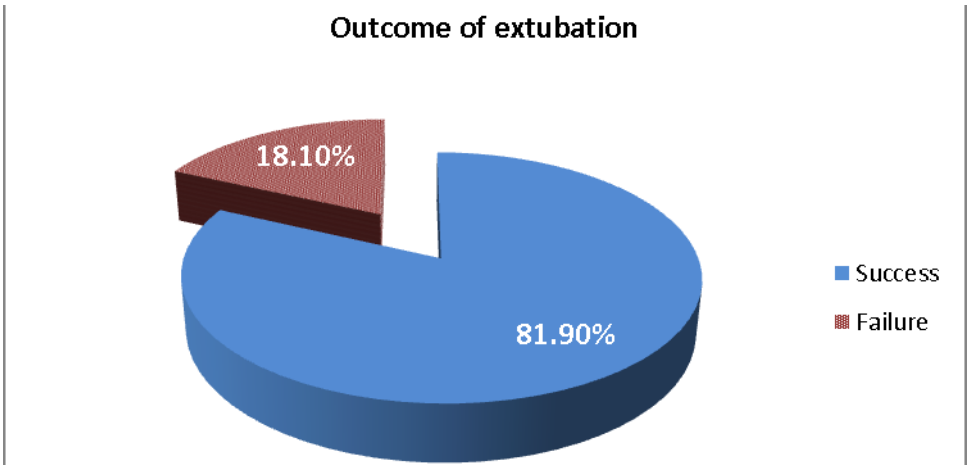

Figure 4: Incidence of extubation failure for pediatric patients aged 0-14 years admitted to the pediatric ICU of TASH from 2019 to 2023

Factors associated with extubation failure

The associations between extubation failure and the predictors were analyzed using a binary logistic regression model. All factors that fulfilled the chi-square assumptions and had a P value <0.2 in the bivariable analysis were considered multivariable logistic regression. Hence, the use of dexamethasone 24 hours before extubation, immediate nebulization after extubation, length of hospital stay, duration of intubation, PEEP, PIP, FIO2, the presence of ventilator-associated pneumonia, the use of a sedative for more than five days, the use of noninvasive ventilation before intubation and the primary indication for intubation were included in the multivariable analysis, and immediate nebulization after extubation and length of hospital stay were found to be statistically significant with a P value <0.5 and were considered to be determinants of extubation failure.

The odds of extubation failure among those patients who stayed in the hospital longer than 30 days and 10-30 days were 2.81 and 2.32 times greater, respectively. Those who stayed in the hospital for 2-10 days were included. (AOR=2.81, 95% CI 5.23-15.60; AOR=2.31, 95% CI 3.10-17.76). The incidence of extubation failure was 2.14 times greater for patients who were not nebulized immediately after extubation than for those who were nebulized. (AOR=2.14, 95% CI 5.87-9.46). (Table 4)

Table 4: Bivariable and multivariable logistic regression models predicting the likelihood of extubation failure among pediatric patients 0-14 years of age admitted to TASH from 2019-2023

Variables	**Category**	**Extubation**		**COR (95%CI)**	**AOR (95%CI)**
		Successful	Failed		
Use of dexamethasone	Yes	124	3	1	1
	No	3	25	0.03(0.01-0.05)	0.71(0.67-2.56)
Immediate nebulization	Yes	126	19	1	1
	No	1	9	0.17(0.02-0.14)	2.14(5.87-9.46)*
Length of hospital stay	2-10 days	47	2	1	1
	10-30 days	63	5	3.51 (2.21-7.10)	2.31(3.10-17.76)*
	>30 days	17	21	3.83 (3.13-9.22)	2.8 2(5.23-15.60)*
Duration of intubation	48 hrs	56	1	1	1
	3-7 days	62	4	0.29(0.09-0.92)	0.99(0.11-12.6)
	>7 days	9	23	0.45(0.05-0.96)	1.01(0.66-5.72)
PIP	5-10 cm H2O	87	9	1	1
	11-15 cm H2O	39	16	0.19(0.08-0.44)	1.23(0.16-5.77)
	16-20 cm H2O	1	3	1.31(0.04-0.67)	0.22(0.87-7.11)
PEEP	3-5 cm H2O	70	4	1	1
	6-10 cm H2O	57	24	0.13(0.05-0.41)	0.44(0.57-8.97)
FI02	<40%	92	7	1	1
	40-60%	27	5	4.88(2.81-8.69)	0.66(0.97-8.71)
	61-100%	8	16	3.12(2.21-6.79)	0.31(0.01-9.22)
Ventilator associated pneumonia	Yes	14	14	3.80(3.20-10.01)	0.72(1.00-5.77)
	No	113	14	1	1
Use of noninvasive ventilation	Yes	97	26	2.34(1.08-9.13)	0.97(0.32-10.1)
	No	30	2	1	1
Indication for intubation	Air way protection	60	3	1	1
	Respiratory failure	56	22	0.74(0.54-2.31)	1.33(0.47=13.4)
	Severe sepsis	11	3	1.87(0.17-5.21)	0.79(0.12-20.1)

Discussion

This study revealed that the extubation failure rate among pediatric patients admitted and intubated for at least 48 hours at TASH was 18.1% (95% CI: 12.9–24.5). Compared to that in a study performed in South Africa (11.4% extubation failure), the failure rate was greater in our study. The possible explanations for this could be that the majority of the patients in the South African study were intubated for airway protection (postoperative). In contrast, most of our patients were intubated for respiratory failure, and the presence of comorbidities such as hematologic malignancy increased extubation failure in our study (6). However, a study conducted in Egypt showed that the extubation failure rate was 17.5%, which is almost comparable to our study (12). A study performed in India showed that the extubation failure rate was 28.4% greater than that in our study. A possible explanation for this finding is that most of the patients included in the study population in the Indian study were neonates and infants who were primarily intubated for respiratory failure. Additionally, the patients included in the study population had multisystem (more than one system) involvement and CNS involvement, and the majority were intubated for respiratory failure, not for airway protection (25%)(9). In addition, a study conducted in Brazil had comparable results to our study, with an extubation failure rate of 16% (6). Another study conducted in Spain reported a lower extubation failure rate (5.32%) than our study. A possible explanation for this difference is that well-developed countries such as Spain have better PICUs and more well-trained human resources than our country (3).

In our study, extubation failure was greater in patients who stayed in the hospital or PICU longer. The odds of extubation failure for those patients who stayed longer than 30 days in the hospital was 2.81. However, for patients who stayed for 11-30 days, the odds ratio was 2.31. Those who stayed in the hospital for 2-10 days were included. This means that patients who stay alone for more than 30 days in the hospital are 2.81 times more likely to experience extubation failure than patients who stay for 2-10 days. Similarly, patients who stayed in the hospital for 10-30 days were 2.31 times more likely to experience extubation failure. This is supported by other studies conducted in Spain and Brazil showing that patients who stay longer in the PICU or hospital are more likely to develop extubation failure (3,6)

Another associated factor was found to be immediate nebulization with adrenaline. Patients who were not nebulized after extubation were 2.14 times more likely to experience extubation failure than those who were nebulized. This finding was supported by other randomized controlled studies (17).

A study conducted in Egypt revealed that there was a statistically significant association between extubation failure and prolonged mechanical ventilation and respiratory failure as the primary indications for intubation (12).

Another study conducted in South Africa showed that emergency cardiac admissions, dysmorphology/genetic syndrome, prematurity, a low GCS score and >48 hours of IMV (13). Similarly, a study conducted in India showed that low birth weight, younger age, prolonged duration of ventilation, prematurity, use of inotropes and sedation were associated with extubation failure (9). However, we could not find any associations between these factors.

Limitations

Since the study was retrospective and based on chart review, some of the charts were not completely missing some data, such as sociodemographic data. The study was conducted at a single-center referral hospital in Ethiopia, which is not conclusive.

Conclusion

The findings of the study showed that the rate of extubation failure was 18.1%. Since there is no acceptable rate for extubation failure, most studies have reported that the rate of extubation failure is in the range of 4-20%. Our study is in line with most studies from different countries. A prolonged hospital stay and failure to nebulize immediately after extubation were factors that significantly affected the rate of extubation.

List of abbreviations

AAU=Addis Ababa University, AOR=Adjusted odds ratio, CI=Confidence interval, CHS=Collage of Health Science, CNS=Central nervous system. COR=Crude Odd Ratio, EF=Extubation Failure EC=Ethiopian Calendar, FIO2=Fraction of Inspired Oxygen, GCS=Glasgow Coma Score, ICU=Intensive Care Unit, IMV=Invasive Mechanical Ventilation, NIV=Noninvasive Ventilation, MV=Mechanical Ventilation, PAO2= Partial Pressure of Oxygen, PIP=Peak Inspiratory Pressure, PEEP=Positive End Expiratory Pressure, PCH=Pediatrics and Child Health, PICUs=Pediatric Intensive Care Units, TASH=Tikur Anbessa Specialized Hospital, VAP=Ventilator Associated Pneumonia, SBT=Spontaneous Breathe Test

Declarations

Ethical approval and consent to participate

An ethical approval for this study was obtained from the Research and Publication Committee of Pediatrics and Child Health Department (DRCP) School of Medicine College of Health Science, Addis Ababa University and the College Institutional Review Board (IRB) of Addis Ababa University. Informed consent for the waiver of the participants was obtained from the College Institutional Review Bord (IRB) of Addis Ababa University.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interest

The authors declare that they have no conflicts of interest.

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No funding was obtained for this study.

Authors' contributions

Y.B, A.D and G A wrote the first draft of the manuscript and Y.B, A.D and S.A. wrote the main manuscript text. All authors reviewed the manuscript.

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