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Prevalence and Predictors of Extubation Failure in PICU of Tertiary Care Hospital Hospital of Karachi

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ABSTRACT

Objective: This study aimed to determine the prevalence and predictors of extubation failure among pediatric patients receiving invasive mechanical ventilation (IMV) in the Pediatric Intensive Care Unit (PICU) of a tertiary care hospital in Karachi, Pakistan. **Methodology:** A descriptive cross-sectional study was conducted at the National Institute of Child Health (NICH), Karachi, enrolling 98 children aged 1 month to 12 years who received IMV >24 hours. Data on demographic, clinical, and ventilatory parameters were collected. Extubation failure was defined as the need for re-intubation within 48 hours of planned extubation. Statistical analysis was performed using SPSS version 26, with a p-value <0.05 considered significant. **Results:** The overall prevalence of extubation failure was 18.4%. Younger age (<2 years), prolonged IMV duration, post-extubation stridor, and the need for non-invasive ventilation (NIV) after extubation were significant predictors of failure (p<0.05). The majority of extubation failures (72.2%) occurred within 24 hours of extubation. Respiratory illnesses were the most common primary diagnosis (57.1%), followed by sepsis (20.4%) and neurological disorders (12.2%). The overall mortality rate was 9.2%, with more than half of the deaths occurring in patients who experienced extubation failure. **Conclusion:** Extubation failure has been a major clinical issue within the pediatric critical care setting, especially in younger children and those with a history of long-term ventilation or airway complications. Enhancing the state of extubation readiness evaluation, the use of specific airways management, and the implementation of post-extubation monitoring are critical steps to achieving better results under the conditions of resource limitation.

INTRODUCTION

IMV is a life-saving intervention that delivers positive airway pressure to aid or substitute spontaneous breathing in patients with severe illnesses (Telias et al., 2022; Abdelrahim et al., 2021). It is mainly used to assist organ systems especially respiratory, cardiovascular, and neurological systems, in cases where the physiological mechanisms have been impaired. IMV is essential in the management of children with severe respiratory distress, sepsis, neurological deficiency, or postoperative issues in the pediatric critical care. The timely administration and discontinuation of IMV in the Pediatric Intensive Care Unit (PICU) is essential to maximize the outcomes and reduce complications (Egbuta and Easley, 2022; Lopez-Fernandez and Fernandez, 2024).

Despite the fact that IMV is frequently invaluable as a tool in the management of acute respiratory failure, years of reliance on ventilatory support are linked to multiple complications, such as ventilator-associated pneumonia, upper airway edema, respiratory muscle weakness, and cardiovascular dysfunction (Huang et al., 2022; Cutuli et al., 2023). Hence, an early and safe escape out of IMV is a primary objective of intensive care management (Zhang et al., 2024; Murali et al., 2024). The key requirements to a successful extubation are that the patient should have sufficient spontaneous ventilatory capacity, normal gas exchange, and stable neurological and hemodynamic activity (Sangsari et al., 2022). The question of the right time to remove the ventilators, nonetheless, is not an easy task and involves close consideration of clinical parameters, ventilatory indices, and patient-related factors to guarantee that they are ready (Shalish and Sant'Anna, 2023).

There is also a negative effect on premature and delayed extubation (Gal et al., 2022; Söderström et al., 2021). Early extubation prior to full recovery of breathing can lead to repeat extubation but unjustified persistence of IMV can lead to an escalation in the incidence of ventilator-associated complication, long PICU stay and health care expenditure. As such, there is a strong need to determine the optimal time within which an extubation should be performed to avoid such paradoxical risks (De Jong et al.,

2023). Several weaning and extubation preparation guidelines have been put forward over the years in order to standardize the intervention, such as the application of spontaneous breathing tests (SBTs), the measurement of cough intensity, and observation of airway clearance (Clerk et al., 2024). Nevertheless, the challenges associated with extubation failure are acute in the pediatric critical care, especially in case of a resource shortage (Jose and Parameswaran, 2023).

It is generally considered that the mechanism of extubation failure is the requirement of re-intubation and invasive ventilation in 48 hours after scheduled extubation (Torrini et al., 2021; Onrubia and de Togares, 2023). The issue of extubation failure is multi-dimensional and can be explained by airways obstruction, muscle fatigue, residual sedation, cardiac malfunction, and a breakdown of the neurological drive (Cheung and Cheng, 2024). In a retrospective study, which was published in 2020, the rate of extubation failure was estimated at 16 percent in a children ICU, and in that study, laryngeal stridor was diagnosed in 57 percent of the patients (Yang et al., 2024). On the same note, a Saudi Arabian-based study in 2024 suggested a prevalence rate of 12% with younger age, low body weight, and long IMV duration as some of the most prevalent risk factors. A thorough examination of the Virtual Pediatric Systems registry showed that the 48 hours of extubation contain 4.6 per cent of extubation failures when younger age, high Pediatric Index of Mortality (PIM-III) scores and time of IMV turning into a determinant are considered.

The present study divided the range of disease in the ventilated children into five major groups, respiratory, sepsis, neurological, cardiovascular, and others, which is related to the various clinical manifestations of the chosen issue in the PICU. It is interesting to note that 90 percent of the cases implied opioid infusion, which is consistent with the existing recommendations on sedation and analgesia to maintain ventilator synchrony and minimize distress.

These results emphasize the multidimensionality of the concept of extubation failure and the variability of the risk factors in different populations and clinical conditions. Although monitoring and weaning interventions have helped to increase the overall overall success of the extubation process, the failure rate is still significant, especially in less-developed and middle-income nations where the resources available to support the implementation of standard weaning procedures might be insufficient (Kilba et al., 2022). Extubation failure is not only associated with the extension of mechanical ventilation and hospitalization but also leads to increased healthcare expenditures, family psychological distress, and mortality.

Considering the grave outcomes of the failure of extubation and the unavailability of the regional data on the same in Pakistan, there is an urgent need to determine its occurrence and the factors which follow in the local contexts. Knowledge of these predictors were used to detect high-risk subgroups, enhance the assessment of extubation readiness, and advance post-extubation monitoring plans. Thus, the study was established the prevalence of the extubation failure in the PICU of the National Institute of Child Health, Karachi, and determine the clinical and demographic predictors of the extubation failure. The results of this study can be used to design specific weaning guidelines and lead to better evidence-based outcomes in critical ill children in limited resource tertiary care settings.

METHODOLOGY

The current descriptive cross-sectional study taook place in Pediatric Intensive Care Unit (PICU) of the National Institute of Child Health (NICH), Karachi from 28 April 2025 to 15 August 2025. The main aim of the study is to establish the incidence of extubation failure and mark its predictors in relation to the pediatric patients undergoing invasive mechanical ventilation (IMV).

The study population comprised of all children aged between 1 month and 12 years involved in the PICU with a length of stay exceeding 24 hours using an endotracheal tube to administer IMV. Patients who are intubated less than 24 hours, accidental extubation, and deaths before extubation, tracheostomized patients, Do not Resuscitate (DNR)-coded patients, patients with anatomically abnormal airways, and patients with incomplete medical history was excluded.

The sample size was estimated in accordance with the reported frequency of 14.5 per cent of extubation failure among PICU patients in a previous study, with OpenEpi version 6, with a 7 per cent margin of error and 95 per cent confidence interval. The calculated minimum sample size was 98 patients. Patients who meet the inclusion criteria was enrolled consecutively with the consent of the Institutional Ethical Review Board (IERB) of NICH.

The primary investigator did data collection with the help of a qualified respiratory therapist, under the instructions of the PICU Head and Associate Professor of Critical Care, Dr. Murtaza Ali Gowa. Medical records and bedside observation charts were provided clinical and demographic data, a structured proforma was used to extract it. The variables that was recorded and included demographic and clinical variables of age, gender, weight, height, underlying diagnosis, indication of IMV, and disease spectrum as:

Characteristics of ventilatory and extubation parameters be recorded, such as the duration of IMV at extubation, fraction of inspired oxygen (FiO_2) at extubation (maintained at 0.3–0.4), and peak inspiratory pressure (PIP) at extubation. The criteria fulfillment of calm and sedative use was recorded, where opioid infusion were applied in 90 percent of the cases. Benzodiazepine or neuromuscular blocker infusion was also be noted. Other factors were included the presence of steroid use to treat upper airway edema, presence of stridor after the procedure, use of non-invasive ventilation (NIV) after the procedure, and re-intubation time (was categorized as less than 24 hours and 24 to 48 hours post-extubation).

Extubation failure, which was the necessity to re-intubate and IMV in the 48 hours after the scheduled extubation, overall PICU length of stay, and mortality was the outcome variables. Additional clinical characteristics including genetic syndromes, heart involvement, need of inotropes, and use of sedatives or muscle relaxants were evaluated. Patients were stratified into three age categories to

examine age variation in the incidence of extubation failure; age groups: <2 years, 2–5 years, and >5 years.

The Statistical Package for the social Sciences (SPSS) version 26.0 was used to enter and analyze data. The presentation of the descriptive statistics were in the form of frequencies and percentages of categorical variables and the mean and standard deviation (SD) or median and interquartile range (IQR) of continuous variables based on data distribution. To test the normality of quantitative data, the Shapiro–Wilk test is going to be applied. The Chi-square test or Fisher exact test was used to compare associations between categorical variables and either extubation outcomes where there is a difference between the two and independent t-test or Mann Whitney U test was used to compare continuous variables, depending on the data distribution. The statistical significance level was 0.05 and all the results was presented with 95 percent confidence interval.

In order to maintain data quality, there wasdouble data entry, and further to make certain that data is accurate, 10 percent of the data was cross-read by a third party who was independent. Research ethics was followed by the standards of an institution and the ethical principles of Helsinki Declaration concerning research with human subjects.

RESULTS

The study enrolled 98 pediatric patients who received invasive mechanical ventilation (IMV) with over 24 hours. The average age of respondents was 4.1 (±3.2) years in the range of 1 month to 12 years with a male to female ratio of 1.3:1. The general extubation failure rate stood at 18.4 (n = 18).

Demographic and Clinical Characteristics

The distribution of age among the study population showed that 41.8% of the patients were less than 2 years old, 29.6% between 2-5 years and 28.6% above 5 years. Most children (57.1%), sepsis (20.4%), neurological causes (12.2%), cardiovascular conditions (6.1%), and other causes (4.1) were hospitalized with respiratory illnesses.

The average IMV time prior to extubation was 4.6+ 2.3 days and the average PICU length of stay was 8.2 + 3.9 days.

The demographic and baseline clinical characteristics of the study group are summarized in Table 1.

Table 1

Demographic and Baseline Characteristics of Study Participants (n = 98)

Variable		Frequency (n)	Percentage (%)
Age Group	<2 years	41	41.8
	2–5 years	29	29.6
	>5 years	28	28.6
Gender	Male	56	57.1
	Female	42	42.9
Primary Diagnosis	Respiratory illness	56	57.1
	Sepsis	20	20.4
	Neurological disorder	12	12.2
	Cardiovascular disorder	6	6.1
	Others	4	4.1
Mean IMV duration (days)			4.6 ± 2.3
Mean PICU stay (days)			8.2 ± 3.9

Extubation and Ventilatory Parameters

The FiO_2 at extubation was kept at 0.3-0.4 in all instances, whereas the average end-expiratory pressure (PIP) at extubation was 12 +/-3 cmH_2O.. The calm criteria were achieved in 88.8% of patients before extubation. In 90 percent of patients, opioid infusion was employed, 39.8 percent benzodiazepine infusion, and 22.4 percent neuromuscular blocker infusion was employed. The use of steroids in the treatment of upper airway edema was noted at 31.6 and post-extubation stridor was reported at 17.3%. Post-extubation non-invasive ventilation (NIV) was administered to 24.5 percent of the patients.

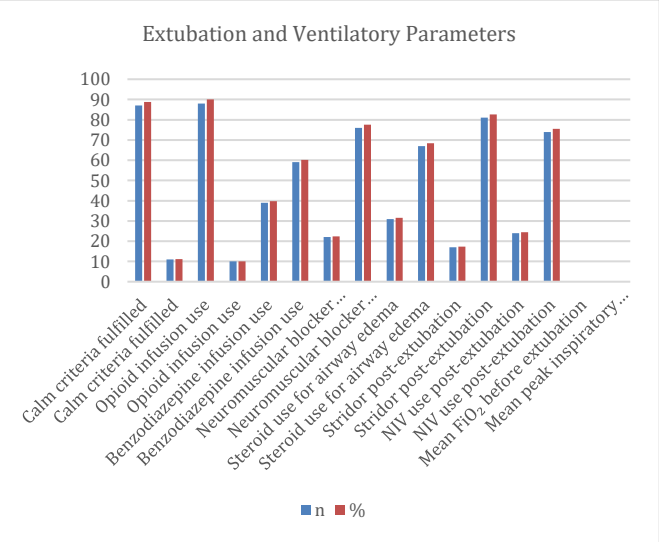
Extubation failure was not statistically related to increased inspiratory pressures (≥15 cmH_2O)

Table 2

Extubation and Ventilatory Parameters

Parameter	Yes n (%)	No n (%)
Calm criteria fulfilled	87 (88.8)	11 (11.2)
Opioid infusion use	88 (90.0)	10 (10.0)
Benzodiazepine infusion use	39 (39.8)	59 (60.2)
Neuromuscular blocker infusion use	22 (22.4)	76 (77.6)
Steroid use for airway edema	31 (31.6)	67 (68.4)
Stridor post-extubation	17 (17.3)	81 (82.7)
NIV use post-extubation	24 (24.5)	74 (75.5)
Mean FiO_2 before extubation: 0.35 ± 0.04		
Mean peak inspiratory pressure (cmH_2O): 12 ± 3		

Figure 1



Predictors of Extubation Failure

In 18 (18.4) patients, extubation failure was witnessed. Out of this, 61.1% happened in children below the age of 2 years, which showed that younger patients are at a higher risk of failure (p = 0.03). Most (72.2) of the failures were witnessed in the first 24 hours of extubation. The presence of stridor after extubation (p = 0.01), NIV after extubation (p = 0.02), and increased IMV duration before extubation (p = 0.04) were significantly related to extubation failure. There was no statistically significant relationship between use of sedative or neuromuscular blocker infusions. The total death rate in the research was 9.2 (n=9), with five (55.6) patients being killed due to lack of extubation.

Table 3
Comparison Between Extubation Success and Failure Groups

Variable	Extubation Success (n=80)	Extubation Failure (n=18)	p-value
Age <2 years	29 (36.2%)	11 (61.1%)	0.03*
Male gender	44 (55.0%)	12 (66.7%)	0.42
IMV duration (days, mean ± SD)	4.2 ± 2.1	6.1 ± 2.8	0.04*
Calm criteria fulfilled	72 (90.0%)	15 (83.3%)	0.39
Stridor post-extubation	9 (11.2%)	8 (44.4%)	0.01*
NIV use post-extubation	14 (17.5%)	10 (55.6%)	0.02*
Steroid use for airway edema	23 (28.7%)	8 (44.4%)	0.19
Mortality	4 (5.0%)	5 (27.8%)	0.006*

Statistically significant ($p < 0.05$)

It was found that the total prevalence of extubation failure in the study population was 18.4. Interestingly, the most frequent incidence of extubation failure, which was 61.1, was recorded among children under two years old which is a risk factor of age. Some of the critical predictors of extubation failure included the presence of stridor following extubation, non-invasive ventilation (NIV) following extubation and an extended duration of invasive mechanical ventilation (IMV). Furthermore, their mortality rate was 9.2 and their amount was much more in patients where there was failure of extubation, which again shows the clinical importance of early detection and intervention of high-risk patients.

DISCUSSION

The present paper evaluated the occurrence and anticipators of extubation failure among children receiving invasive mechanical ventilation (IMV) in a tertiary care PICU. Findings indicated that the Rates of extubation failure were 18.4% globally and were equal to the estimates of 10-20 percent in the literature of severely ill children (Torrini et al., 2021; Onrubia and de Togores, 2023).This comparatively high rate highlights the continuous problem of successful extubation in pediatric critical care, particularly in resource-constrained units where unified weaning guidelines, post-extubation follow-ups, and advanced respiratory care machines might be inaccessible (Kilba et al., 2022).

The present work has shown that younger age especially less than two years old was a strong predictor of extubation failure. This observation is in line with previous researches that have indicated greater susceptibility in infants and younger children as a result of smaller airway caliber, immature respiratory muscles, and higher susceptibility to upper airway obstruction and fatigue (Yang et al., 2024; Cheung and Cheng, 2024). Stridor in the post-extubation period was also strongly linked to extubation failure and a significant outcome of airway edema and laryngeal dysfunction as key factors in re-intubation. Yang et al. (2024) report a similar observation and found post-extubation laryngeal stridor as a cause of early extubation failure in over 50% of the cases. The evidence that corticosteroids are used to reduce airway edema in almost a third of patients in the current study indicates an aggressive response to the reduction of this risk, yet, even with their use, airway complications were still a significant cause of failure.

Another important factor that is related to failure was the prolonged period of IMV before extubation, which could be explained by the diaphragm dysfunction caused by the ventilator, respiratory muscle atrophy, and airway secretions caused by the prolonged mechanical support (Murali et al., 2024; Zhang et al., 2024). Patients that needed to receive IMV over an extended period had an increased chances of developing challenges in sustaining sufficient spontaneous ventilation even after removal of the endotracheal tube, thus requiring re-intubation. In addition to this, the researchers noted that post-extubation non-invasive ventilation (NIV) was significantly related to extubation failure and therefore, it is possible that NIV was used as a rescue and not a preventive intervention in patients with near-normal respiratory conditions. These findings align with the study by De Jong et al. (2023), who proposed that, although early NIV implementation can potentially decrease re-intubation in a specific adult and pediatric population, its implementation depends on promptness and patient selection.

Notably, the administration of sedatives, in particular, opioids, benzodiazepines, and neuromuscular blockers did not show any significant relationship with extubation outcome. This finding may reflect adherence to the sedation rules, 90 percent of the patients involved in this study were receiving opioid infusions in a controlled condition that would not cause a high degree of respiratory depression but would ensure ventilator synchrony. This type of balanced sedation and approaches is important to achieve calm requirements prior to the extubation procedure, where it was met in nearly 89 per cent, proving that the correct evaluation of weaning preparedness was met (Clerk et al., 2024; Shalish and Sant'Anna, 2023).

The top of the list of diseases, leading to PICU admission in this cohort, was occupied by respiratory illnesses (57.1%), sepsis, and neurological causes, which is in line with the trends in other countries in terms of IMV prevalence in PICUs (Egbuta and Easley, 2022; Lopez-Fernandez and Fernandez, 2024). It may be found that the relatively higher rates of extubation failure in the instances of respiratory diseases could be attributed to the presence of inflammation in the airways following the persistent inflammation, dysfunctional exchange of gases, and the postinfectious constriction leading to the airduct blocking and complicating the successful recovery of spontaneous breathing following the extubation. Less prevalent and equally difficult, are cardiovascular and neurological causes, which are marked by hemodynamic instability and impaired central respiratory drive respectively.

This study has reported a mortality rate of 9.2% which is comparable to other reports of pediatric critical care settings (Jose & Parameswaran, 2023). Nevertheless, patients with extubation failure were overrepresented in death rates, and more than half of all deaths were observed in the specified subgroup. This result highlights the prognostic importance of the extubation outcomes as a surrogate of the clinical stability and recovery course in general. Not only does failed extubation extend the PICU stay and consumption, but it also leads to secondary infections, cardiovascular stress, and distress in

caregivers, causing a significant burden to both healthcare and families (Söderström et al., 2021; Gal et al., 2022).

Combined, the findings of this study support the role of an integrated, multidisciplinary program of the extubation preparedness and post-extubation vigilance. The recognition of high-risk subgroups should be used to tailor the weaning plan and early intervention and supportive factors, including prophylactic corticosteroids, high-flow nasal cannula, or the early application of NIV, especially in younger patients and those with prolonged ventilation or airway edema. Furthermore, it is necessary to create locally adapted extubation preparation algorithms that would respond to the specific limitations of resources-constrained PICUs, including those of Pakistan, to enhance the patient outcomes.

To sum up, the current research adds useful regional information about the incidence and the factors that determine the failure of the extubation procedure in a tertiary care pediatric unit. Earlier age, long IMV, stridor after extubation and necessity of NIV became important predictors of failure. These results emphasize the necessity of consensus extubation practices, close post-extubation monitoring, and specific measures to decrease the rates of re-intubation and the morbidity of the latter. The multicenter trials with objective weaning indices, respiratory muscle strength measurements, and long-term follow-up should be conducted in the future to fine-tune predictive models and maximize the success of extubation in the critical care of children.

CONCLUSION

This study established an 18.4% incidence of extubation failure among children in a developed care PICU in Karachi. The critical predictors of failure included younger age (less than 2 years), a prolonged duration of mechanical ventilation, a post extubation stridor, and non-invasive ventilation. These findings demonstrate the complexity of the phenomenon of extubation failure in its relation to the challenges in the correction of the airways, preoperative assessment, and the elaboration of weaning strategies in the critically ill children. The prognostic importance of successful ventilator liberation is supported by the fact that more patients are classed as dead following unsuccessful extubation. Introduction of standard weaning and extubation protocols, incorporation of early assessment of airway, and maximization of post-extubation respiratory care would potentially have enormous effects in reducing the failure rates and raising the survival rates. Future research in multicenter should be directed at the development of predictive instruments that would be specific to the needs of low-resource pediatric populations.

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