Pediatric Anesthesia and Critical Care Journal 2022;10(1):1-9
doi:10.14587/paccj.2022.1

PACCJ

A prospective cohort study to assess the risk factors of failed extubation in mechanically ventilated pediatric patients admitted to the intensive care unit

M. A. Abdelnaser[1], H. M. Sakhr[2], A. Fetouh[3], A. A. Sabry[4], H.M. Qubaisy[2], A. M. Ismail[5], K. A. Abdelbaseer[2]

[1]Department of Anaesthesia and ICU, Faculty of Medicine, Assiut University, Egypt
[2]Department of Pediatrics, Qena Faculty of Medicine, South Valley University
[3]Department of Anaesthesia and ICU, Faculty of Medicine, Cairo University, Egypt
[4]Department of Anaesthesia and ICU, Faculty of Medicine, Ain Shams University, Egypt
[5]Department of Pediatrics, Faculty of Medicine, Aswan University, Egypt

Corresponding author: M. A. Abdelnaser, Department of Anaesthesia and ICU, Faculty of Medicine, Assiut University, Egypt. Email: monbasser@gmail.com

Keypoints

Failed extubation is more common in young children, in patients with respiratory illness, and those receiving prolonged mechanical ventilation.

Abstract

Introduction

Failed extubation is a challenge in the intensive care unit. It can cause increased morbidity, and mortality in addition to higher costs due to prolonged hospital stay. We aimed to determine the risk factors of failed extubation and predictors of weaning success among mechanically ventilated children.

Material and Methods

It was a prospective cohort study for children on mechanical ventilation for longer than 24 hrs where they were followed up for 48 hrs after extubation. Failed extubation is the need for tube reinsertion within 48 hrs post-extubation. Demographic characteristics and mechanical ventilation parameters were evaluated. Arterial blood gas values and rapid shallow breathing index (RSBI) were assessed on admission, before weaning from mechanical ventilation, and during weaning.

Results

Failed extubation was seen in 17.5% of patients;53.9% of them were ≤one year and 26.9% were between one and five years while 19.2% were ≥5 years. Of patients with a failed extubation, respiratory illnesses were the principal cause of ventilation (50%) followed by cardiac surgery ventilated cases (23% each), neurological (15.4%), envenomation (7.7%), and lastly drug intoxication cases (3.8%). Duration of ventilation, PaCO2, and RSBI were significantly higher in cases with failed extubation than others. Body Weight, Glasgow Coma Scale, tidal volume, PaO2, and PaO2/FiO2 were significantly higher with extubation success. PaCO2 < 45 showed the highest sensitivity followed by RSBI, breaths/min/ml/kg <7 for extubation success.

Conclusion

Based on the result of this study, failed extubation is more common in young children, in patients with respiratory illness, and those receiving prolonged mechanical ventilation. Close monitoring of oxygenation indices, and PaCO2 can avoid hazardous premature extubation. PaCO2 < 45 and rapid shallow breathing index with a threshold of <7 breath/min/ml/kg are good predictors for extubation

success and dependable parameters for extubation timing in children.

Keywords

Risk factors; Failed extubation; Mechanical ventilation

Introduction

Invasive mechanical ventilation (IMV) is a frequently used tool of management for more than 30% of critically ill patients admitted at pediatric intensive care units.[1] Despite the universally accepted benefits of mechanical ventilation for children suffering from respiratory distress, invasive support is directly associated with a series of complications. Reduction of IMV time is essential to minimize the risk of these hazards such as airway damage and ventilator-induced pneumonia. [2]

On the other hand, premature extubation may require emergency reintubation [3] and lead to respiratory failure and death. [4] After resolving of the condition requiring intubation, the decision to extubate, followed by planned weaning should be undertaken as soon as possible to avoid delayed extubation.

Even after an extensive evaluation of potential extubation, however, 10% to 19% of patients fail extubation and require reintubation shortly after extubation. [5,6] Risk factors of extubation failure include impaired muscle strength and gas exchange [7]in addition to prolonged duration of mechanical ventilation [8]. Furthermore, disturbed level of consciousness and the inability to manage secretions may be etiological factors.[9] Both failure to recognize the optimum time of extubation readiness and unsuccessful trials at extubation lead to prolonged length of stay, higher costs , and increased mortality. [7-9]

Identification of patients who may be successfully extubated can be done by extubation readiness tests where the child is placed on minimal ventilator settings and is observed for signs of distress or impaired gas exchange. [10]

It is important to assess the different factors that may predict the outcome of weaning.

This will be useful to shorten the duration of mechanical ventilation, reduce the risk of reintubation, improve the outcome, and provide clearer weaning guidelines. [9] Like other researchers, [11, 12] in addition to studying predictors of failed extubation, we tried to investigate the possible factors by which can predict extubation success as respiratory frequency-to-tidal volume (the rapid shallow breathing index), dynamic compliance, and arterial oxygenation parameters.

Material and Methods

A prospective cohort study was conducted from June 2019 to April 2021 at pediatric intensive care and postoperative critical care units of South Valley University Hospital in Qena Governorate.

The study included all patients aged between 1 month and 16 years who were admitted to the PICU, continued on MV for a time equal to or greater than 24 hours, be ready to undergo extubation, and followed up to 48 hrs after extubation. Exclusion criteria included all cases of unplanned extubation and patients with tracheostomy. Failed extubation was defined as the need for re-intubation within the first 48 hours after extubation and extubation success as the patient's ability to maintain spontaneous ventilation without respiratory support for 48 hours following extubation.

A total of 148 mechanically ventilated patients admitted to the pediatric ICU were eligible for the study. The factors affecting the timing of weaning and extubation include the patient's clinical condition, blood gas analysis, and parameters of ventilator support.

Demographic data collected at the time of extubation were the patient's age, weight, sex, admitting diagnosis, date of intubation, and extubation and coma scale. Modified Glasgow coma scale, which is Sharples' adaptation (personal communication) of the James' adaptation of the Glasgow coma scale (JGCS) was used to overcome the problem of intubation.

This score developed a grimace score to replace the verbal component in intubated children.(13) Additional collected data were pre-extubation arterial blood gases, peak inspiratory airway pressure (PIP; cmH2O), positive end-expiratory pressure (PEEP; cmH2O), corrected exhaled tidal volume from mechanical ventilator breaths (vVt;

ml/kg), and inspired oxygen fraction concentration (FiO2). Dynamic compliance (Cdyn, ml/kg/cm H2O) was calculated using the formula: vVt/ (PIP−PEEP). The rapid shallow breathing index (RSBI breaths/ml/ kg) was calculated as RR/sVt. Patients were assessed and examined daily, checking for the possibility of changing the initiated controlled ventilatory pressure mode to spontaneous breathing trial (SBT) using a T-tube (T-piece) or reducing the applied airway pressure to provide low levels of pressure support (PS) (5 to 10 cmH2O).

Pressure support was set according to endotracheal tube size (for tube size of 3.0–3.5 mm, pressure support of 10 cmH2O, for the size of 4.0–4.5 mm, pressure support of 8 cmH2O, and for the size of 5.0 mm, pressure support of 6 cmH2O).

The usual practice for SBT decision is the resolution of the condition that necessitated IMV, hemodynamic stability, and suitable ventilator parameters including Fio2 < 50%, PIP < 20 cmH2O, PEEP below 5 cmH2O and respiratory frequency of ventilator rate 6 to 8 breath/min before extubation.

The primary physician considers a failure of SBT if any sign of poor tolerance appeared as increased respiratory rate or heart rate than normal value for a given age, signs of increased respiratory distress, diaphoresis, deteriorated mental status, hypotension, and oxygen saturation lower than 90% measured by a pulse oximeter or partial pressure of arterial carbon dioxide higher than 50 mmHg.

Before re-institution of mechanical ventilation for those, rescue noninvasive ventilation (rNIV) was tried through a full-face mask or oronasal mask to prevent the reimplementation of IMV. NIV failure was defined as the need for endotracheal intubation within the first 48 hours manifested by hemodynamic alterations, progression of respiratory distress non-invasive hypoxemia.

Patients were considered as having passed the SBT if there were no changes in any of the parameters assessed.

The institutional ethics committee of our university approved the study and parents provided informed consent.

Statistical analysis

Statistical analyses of the data collected from the two outcome groups (extubation success and failed extubation) were compared using SPSS version 20 for Windows. Continuous variables were expressed as mean ± standard deviation, and categorical variables were expressed as frequency.

Pearson's chi-square was used for the comparison of categorical data between groups and t-test used for comparison of means.

A p value < 0.05 was considered statistically significant.

The sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were calculated for each variable.

Pearson's correlation was used to assess the correlation between different variables and a logistic regression model was used for clinically relevant significant variables to assess the relative effect of risk factors on the outcome.

Results

Our study included 148 mechanically ventilated patients who met the inclusion criteria.

The general characteristics of the patients were reported in Table 1. Failed extubation was seen in 26 patients, corresponding to 17.5% of the total; 53.9% of them were less than one year and 26.9% were between one and five years while 19.2% were more than 5 years in contrast to the patients with successful extubation.

Of the patients with a failed extubation, respiratory illnesses were the principal cause of ventilation (50%) followed by cardiac surgery ventilated cases (23% each), neurological (15.4%), envenomation (7.7%), and lastly drug intoxication cases (3.8%).

The use of sedatives > 5 days, duration of ventilation, length of hospital stay and mortality were significantly higher in cases with failed extubation than others with success.

Noninvasive ventilation was tried for cases of failed extubation who deteriorate and required reintubation and 11of them succeeded and escaped MV.

Table1. Demographic characteristics of ventilated patients.

Variable		Extubation success (n= 122)	Failed extubation (n= 26)	P value
Age (years) < 1 year >1y-<5y >5 years		8.07 ± 1.57 23(18.8%) 25(20.4%) 74(60.8%)	3.82 ± 1.90 14(53.8%) 7(26.9 %) 5(19.3%)	<0.001
Indications for ventilation	Respiratory diseases	85(69.7%)	13(50%)	<0.05
	Cardiac surgery	13(10.7%)	6 (23%)	
	Neurological	13(10.7%)	4 (15.4%)	
	Envenomation	8(6.5%)	2(7.8%)	
	Drug intoxication	3(2.5%)	1(3.8)	
Sex (male/female)		65/57	12/14	NS
Weight (kg)		23.35 ± 2.91	14.24 ± 4.42	<0.001
Use of sedatives > 5 days		42/122 (34.4)	14/26 (53.8%)	<0.01
Use of inotropes > 5 days		51/122 (41.8%)	12/26(46%)	NS
Duration of ventilation (days)		6.63 ± 2.08	12.84 ± 2.27	<0.001
Length of hospital stay (days)		10.43 ± 1.72	16.30 ± 3.87	<0.001
Mortality		10 (8%)	6 (23%)	<0.01

*Significant P value at P <0.*05, NS; Non-Significant

Table 2 shows the comparison of pre-extubation parameters between patients with successful and failed extubations. The group of failed extubation showed significantly lower values of GCS, tidal volume, PaO2, and CDYN, and higher PIP and PaCO2 compared with the successful group. Pre-extubation spontaneous breathing parameters show a significantly lower ventilator respiratory rate, and spontaneous respiratory rate, and higher RSBI.

Table 2: Pre-extubation ventilation parameters

Variable	Extubation success (n= 122)	Failed extubation (n= 26)	P value
Ventilator respiratory rate breaths/min	8.95 ± 2.44	8.03 ± 1.45	<0.05
Glasgow Coma Scale	10.76 ± 1.23	8.12 ± 1.62	<0.05
Tidal volume	10.77 ± 4.87	7.92 ± 2.15	<0.05
PEEP cm H2O	4.23 ± .86	4.38 ± .57	NS
PIP cm H2O	21.27± 1.81	23.73± 1.61	<0.001
PH	7.39 ± 0.07	7.41 ± 0.06	NS
PaO2 mmHg	110.24 ± 19.27	91.42 ± 10.13	<0.001
PaCO2 mmHg	40.31 ± 3.75	45.88 ± 6.29	<0.001
(PaO2/FiO2)	284.20 ± 87.16	185.23 ± 79.21	<0.001
CDYN mL/cmH2O	0.59± 0.24	0.38± 0.12	<0.001
Spontaneous respiratory rate breaths/min	35.53 ± 11.48	54.26 ± 16.96	<0.001
RSBI breaths/min /ml/kg	3.17± 0.41	9.90± 1.14	<0.001

PEEP*:* Positive end-expiratory pressure*; PIP : Peak inspiratory pressure ; PaO2: partial pressures of oxygen;* PaCO2*: partial pressures of carbon dioxide; PaO2/FiO2 ratio PaO2:FiO2 = oxygenation ratio; CDYN: Dynamic Compliance; RSBI: rapid Shallow Breathing Index; significant P value<0.05* NS; *Non Significant*

In **Table 3** sensitivity, specificity and predictive values of weaning indices for successful extubation were shown. While PaCO2 < 45 showed the highest sensitivity, RSBI < 7 breaths/min/ml/kg is a good predictor of weaning success.

Table 3: Predictive value of weaning indices for successful extubation

Variable	Threshold Value	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
RR, breaths/min	<45	91	73	94	63.3
PaCO2 mmHg	<45	98	69	93.7	90
PaO2/FiO2 ratio	>200	78.7	54.5	90.5	31.5
Tidal volume ml/kg	>5	82	23.8	82.6	18.5
RSBI, breaths/min/ml/kg	<7	96.7	80.7	95.9	84

RR: respiratory rate; PaCO2: partial pressures of carbon dioxide; PaO2/FiO2 ratio: oxygenation ratio; RSBI: Rapid Shallow Breathing Index; PPV: positive predictive value; NPV: negative predictive value

Table 4 showed logistic regression analysis for predictors of extubation. It revealed a significant association between failed extubation and RR, PaCO2, FiO2/PaO2, RSBI in addition to the duration of mechanical ventilation.

Table 4: Multivariate logistic regression analysis for predictors of failed extubation

Variable		Odds ratio	95% CI	P value
Higher RR, breaths/min	>50	1.79	0.81-3.66	<0.01
Higher PaCO2	>50	2.49	1.36-8.96	<0.001
Lower PaO2/FiO2 ratio	<200	1.98	0.91–4.84	<0.001
Higher RSBI,breaths/min/ml/kg	>7	3.14	1.46–10.0	<0.001
MV duration (days)	>10	4.72	1.95–16.4	<0.001

RR*: respiratory rate; PaCO2: partial pressures of carbon dioxide; PaO2/FiO2 ratio: oxygenation ratio; RSBI: Rapid Shallow Breathing Index; MV: mechanical ventilation*

Discussion

In the present prospective study, 17.5% of patients had failed extubation. This finding is consistent with previous studies in which the incidence of failed extubation ranged from 10 to 20%. [6, 14, 15] Patients who were reintubated within 48 to 72 hours had higher mortality outcomes and longer ICU stays. The increased mortality rate after failed extubation may reflect the critical illness of the studied cases. [14] Younger age and smaller body weight were associated with failed extubation and this agrees with those reporting that the smaller diameter of the upper airway at a younger age is responsible for the risk of failed extubation. [16] Furthermore, we found that a prolonged time of mechanical ventilation is associated with failed extubation. Silva et al. in 2018, [17] reported that MV time of greater than 7 days increased the risk of failed extubation by almost 4 times and this was consistent with Cruces et al., study which found that prolonged MV increased the

risk of failed extubation by almost 7 times compared to extubation success.[18]

Similar to previous studies, [19, 20] we detected that patients with failed extubation had longer ICU stays compared to the extubation success group. Increased length of stay may be related to several factors. Firstly, delayed extubation is associated with an increased risk for ventilator-associated pneumonia. Secondly, the re-intubation may reflect the severity of underlying illness or result in complications during re-intubation that prolong hospital stay. Thirdly, delayed re-implementation of ventilatory support may cause more deterioration and new organ failure. All of these factors lead to the prolongation of ICU stays with its impact on increased costs and increased mortality.

It was appreciated that respiratory causes were the main reason for failed extubation in our study and this was similar to Siva et al., [17] where respiratory illness constituted 56.67% of cases of failed extubation. This finding is a usual reflection of the frequency of respiratory diseases as an indication for PICU admission in comparison to other indications. Like other researches, [21, 22] patients with failed extubation were found to be of a lower coma scale than those who succeeded. They concluded that depressed mental status and brain dysfunction can contribute to failed extubation by impairing the capacity to protect the airway, as well as by causing hypoventilation.

We detected a highly statistically significant difference between the studied groups regarding PaO2, PaCO2, and PaO2/FiO2. This agreed with a study performed by Keyal et al. [23] that documented arterial blood gas analysis as a helpful tool in the identification of patients who can undergo failed extubation. In the study by Venkata Raman [24], an association was found between the oxygenation index and the risk of failed extubation. The failed extubation group showed a significant increase in respiratory rate with a concomitant significant reduction in tidal volume as compared with the success group. Nemer and Barbas, [25] found similar results during studying the predictive parameters for weaning from mechanical ventilation.

Regarding RSBI, our results of significantly higher values ($p<0.001$) in the failed group were matched with results published by Osman et al., [26] Furthermore, hypercapnia was shown as the most sensitive predictor of failed extubation where $PaCO2 < 45$ showed the highest sensitivity followed by RSBI, breaths/min/ml/kg<7 which also was a good predictor of weaning success. This was in agreement with previous studies [27, 28] that reported frank hypercapnia as a sign of weaning failure and milder hypercapnia a marker of increased risk for re-intubation. Patients extubated despite hypercapnia ($PaCO2 \geq 45$ mm Hg) had a higher rate of death due to respiratory failure, compared to patients who do not develop hypercapnia during spontaneous breathing test. [27]

Higher RR, prolonged MV days, lower PaO2/FiO2 ratio, and higher RSBI, breaths/min/ml/kg were significantly correlated with extubation failure. These findings were comparable to several previous supporting studies. [29-31] Cases of failed extubation in our study were subjected to a trial of noninvasive ventilation hoping avoidance of IMV and 11 cases succeeded to avoid. Trevisan reported the NIV effectiveness following unsuccessful weaning trials especially if applied shortly after extubation [32] and Nava described that NIV decreased the need for tube reinsertion in cases developing respiratory failure following extubation [33]. This finding encourages further future studies using NIV electively during weaning of mechanical ventilated children or directly after extubation.

The strength of the present study is demonstrated in that it was a prospective study and proposes cut-off points for some parameters that are being regularly used in PICU and help for extubation decisions as

PaCO2 and RSBI. Also, the current prospective study was based on daily clinical practice allowing findings to be beneficial for clinical application for studied cases. Furthermore, despite the observational design, inclusion and MV re-implementation criteria were well defined following our ICU protocol. Several limitations of this study can be appreciated. First, the study was conducted in a single-center, a factor that limits the generalization of our results. Second is the small size of the study, hence a larger sampled study with a greater number of extubation failures potentially could have the power to identify other important risk factors. Lastly, the absence of studying the effect of anesthetic drugs used for cardiac surgery cases could be an important effector on GCS.

Conclusion

Prediction of extubation outcome is of potential importance because both extubation delay and unsuccessful extubation are associated with a poor outcome. Failed extubation is more common in young children, patients with respiratory illness, and those receiving prolonged mechanical ventilation. Duration of ventilation, length of hospital stay, PaCO2 and RSBI were significantly higher in cases with failed extubation than others. Body Weight, Glasgow Coma Scale, tidal volume, PaO2, and PaO2/Fio2 were significantly higher with extubation success. Close monitoring of oxygenation indices, and PaCO2 can avoid hazardous premature extubation. PaCO2 < 45 and rapid shallow breathing index with a threshold of 7 breath/min/ml/kg are dependable parameters for predicting the extubation timing in children. The use of rescue NIV had decreased the need for re intubation in some cases of failed extubation.

List of abbreviations

cdyn: Dynamic compliance
ERTs: Extubation readiness tests
FiO2: fraction of inspired oxygen
GCS: Glasgow coma scale
IMV: Invasive mechanical ventilation
JGCS: James' adaptation of the Glasgow coma scale
MV: mechanical ventilation
NIV: noninvasive ventilation
NPV: negative predictive value
PaCO2*: partial pressures of carbon dioxide*
PaO2: partial pressures of oxygen;
PaO2/FiO2 ratio: oxygenation ratio
PEEP: positive end-expiratory pressure
PICU: pediatric intensive care unit
PIP: peak inspiratory airway pressure
PPV: positive predictive value;
rNIV: rescue noninvasive ventilation
RR: respiratory rate
RSBI: rapid shallow breathing index
SBT: spontaneous breathing trial
vVt;: tidal volume

Declarations:

- ***Ethics approval and consent to participate***: this study was approved by the ethical committee of south valley university and consent was taken from parents for participation in the study and publication.
- ***Availability of data and materials***: the datasets used and analyzed during the current study are available from the corresponding author on reasonable request.
- ***Competing interests***: The authors declare that they have no competing interests. No support from any organization for the submitted work and no financial relations with any organizations.
- ***Funding:*** This study received no funds from any institution.
- ***Authors contributions:***

Mohamed Abdallah Abdelnaser performed the study, analyzed data, and co-wrote the paper. Khaled Abd Allah Abdel Baseer shared in study design, data

collection, co-wrote the paper. All authors read and approved the final version of the manuscript.

References

1. Goldwasser R, Farias A, Freitas EE, Saddy F, Amado V, Okamoto V. Mechanical ventilation of weaning interruption. J Bras Pneumol. 2007; 33 Suppl 2S:S128-36
2. Rowin ME, Patel VV, Christenson JC. Pediatric intensive care unit nosocomial infection: epidemiology, sources and solutions. Crit Care Clin. 2003; 19(3):473–487. PMID: 12848316
3. Gil B, Frutos-Vivar F, Esteban A. Deleterious effects of reintubation of mechanical ventilated patients. Clin Pulm Med. 2003; 10(4):226-30. Deleterious effects of reintubation of mechanical ventilated patients. Clin Pulm Med. 2003.
4. Bousso A, Ejzenberg B, Ventura AM, Fernandes JC, Fernandes IC, Góes PF, et al. Evaluation of the dead space to tidal volume ratio as a predictor of failed extubation. J Pediatr (Rio J) 2008; 82(5):347–353. doi: 10.2223/JPED.1520.
5. Penuelas O, Frutos-Vivar F, Fernandez C, et al Characteristics and outcomes of ventilated patients according to time to liberation from mechanical ventilation. Am J Respir Crit Care Med 2011; 184:430–437?
6. Thille AW, Harrois A, Schortgen F, et al Outcomes of failed extubation in medical intensive care unit patients. Crit Care Med 2011; 39:2612–2618.
7. Khemani RG1, Sekayan T, Hotz J, Flink RC, Rafferty GF, Iyer N, Newth CJL. Risk Factors for Pediatric Failed extubation: The Importance of Respiratory Muscle Strength. Crit Care Med. 2017 Aug; 45(8):e798-e805.
8. Miltiades AN1, Gershengorn HB, Hua M, Kramer AA, Li G, Wunsch H. Cumulative probability and time to reintubaton in U.S. ICU's. Crit Care Med. 2017 May; 45(5):835-842
9. Faustino EV1, Gedeit R, Schwarz AJ, Asaro LA, Wypij D, Curley MA; Accuracy of an extubation readiness test in predicting successful extubation in children with acute respiratory failure from lower respiratory tract disease. Crit Care Med. 2017 Jan; 45(1):94-102.
10. Newth CJ1, Venkataraman S, Willson DF, Meert KL, Harrison R, Dean JM, Pollack M, Zimmerman J, Anand KJ, Carcillo JA, Nicholson CE. Weaning and extubation readiness in pediatric patients. Pediatr Crit Care Med. 2009 Jan; 10(1):1-11
11. Liu Y, Wei LQ, Li GQ, et al. A decision-tree model for predicting extubation outcome in elderly patients after a successful spontaneous breathing trial. Anesth Analg 2010; 111:1211–1218. doi: 10.1213/ANE.0b013e3181f4e82e. Epub 2010 Sep 14.
12. Su WL, Chen YH, Chen CW, et al. Involuntary cough strength and extubation outcomes for patients in an ICU. Chest 2010; 137:777–782. doi: 10.1378/chest.07-2808. Epub 2010 Jan 22.
13. James HE, Anas NG, Perkin RMJames HE, Trauner DA (1985) The Glasgow coma scale in Brain insults in infants and children. eds James HE, Anas NG, Perkin RM (Grune and Stratton, Orlando), pp 179–182.
14. Epstein SK, Ciubotaru RL, Wong JB. Effect of failed extubation on the outcome of mechanical ventilation. Chest. 1997; 112(1): 186–192.
15. Frutos-Vivar F, Esteban A, Apezteguia C, González M, Arabi Y, Restrepo MI, Gordo F, Santos C, Alhashemi JA, Pérez F, et al. Outcome of reintubated patients after scheduled extubation. J Crit Care 2011; 26:502–509. doi: 10.1016/*j*.jcrc.2010.12.015.
16. Fontela PS., et al. "Risk factors for failed extubation in mechanically ventilated pediatric patients". Pediatric Critical Care Medicine 6.2 (2005): 166-170.

17. Silva-Cruz AL, Velarde-Jacay K, Carreazo NY, Escalante-Kanashiro R. Risk factors for failed extubation in the intensive care unit. Rev Bras Ter Intensiva. 2018; 30(3): 294–300. doi: 10.5935/0103-507X.20180046.
18. Cruces P, Donoso A, Montero M, López A, Fernández B, Díaz F, et al. Predicción de fracaso de extubación en pacientes pediátricos: experiencia de dos años en una UCI polivalente. Rev Chil Med Intensiva. 2008; 23(1):12–17.
19. Gaies M, Tabbutt S, Schwartz SM, Bird GL, Alten JA, Shekerdemian LS, et al. Clinical Epidemiology of Failed extubation in the Pediatric Cardiac ICU: A Report from the Pediatric Cardiac Critical Care Consortium. Pediatr Crit Care Med. 2015; 16(9):837–845.
20. Gupta P, Chow V, Gossett JM, Yeh JC, Roth SJ. Incidence, predictors, and outcomes of failed extubation in children after orthotopic heart transplantation: a single-center experience. Pediatr Cardiol. 2015; 36(2):300–307.
21. Namen AM, Ely EW, Tatter SB, et al.: Predictors of successful extubation in neurosurgical patients. Am J Respir Crit Care Med 2001, 163:658–664.
22. Khamiees M, Raju P, DeGirolamo A, et al.: Predictors of extubation outcome in patients who have successfully completed a spontaneous breathing trial. Chest 2001, 120:1262–1270.
23. Keyal N, Shrestha G, Amatya R, ShresthaP, Acharya S, Marhatta M, et al.: 1117: Influence Of ABG To Guide Extubation In Icu Patients After Spontaneous Breathing Trial. Critical Care Medicine. 2018 Jan 1; 46(1):542.
24. Venkataraman ST,Khan N,Brown A. "Validation of predictors of extubation success and failure in mechanically ventilated infants and children". Critical Care Medicine 28.8 (2000): 2991-2996.
25. Nemer SN and Barbas CS.: Predictive parameters for weaning from mechanical ventilation. Jornal Brasileiro de Pneumologia. 2011; 37(5):669-79.
26. Osman AM and Hashim RM.:Diaphragmatic and lung ultrasound application as new predictive indices for the weaning process in ICU patients. The Egyptian Journal of Radiology and Nuclear Medicine. 2017; 48(1):61-6. ,
27. Ferrer M, Valencia M, Nicolas JM, Bernadich O, Badia JR, Torres A. Early noninvasive ventilation averts failed extubation in patients at risk: a randomized trial. Am J Respir Crit Care Med 2006; 173(2): 164–170.
28. Mokhlesi B, Tulaimat A, Gluckman TJ, Wang Y, Evans AT, Corbridge TC. Predicting failed extubation after successful completion of a spontaneous breathing trial. Respir Care. 2007 Dec; 52(12):1710-7. PMID:18028561
29. Preisman S, Lembersky H, Yusim Y, Raviv-Zilka L, Perel A, Keidan I, et al. A randomized trial of outcomes of anesthetic management directed to very early extubation after cardiac surgery in children. J Cardiothorac Vasc Anesth. 2009; 23:348–57.
30. Harris KC, Holowachuk S, Pitfield S, Sanatani S, Froese N, Potts JE, et al. Should early extubation be the goal for children after congenital cardiac surgery? J Thorac Cardiovasc Surg. 2014; 148:2642–7.
31. Shahzad Alam, Akunuri Shalini, Rajesh G Hegde, Rufaida Mazahir, Akanksha Jain. Predictors and Outcome of Early Extubation in Infants Postcardiac Surgery: A Single-center Observational Study. Ann Card Anaesth. 2018 Oct-Dec; 21(4): 402–406.
32. Trevisan CE, Vieira SR. Noninvasive mechanical ventilation may be useful in treating patients who fail weaning from invasive mechanical

ventilation: a randomized clinical trial. Crit Care. 2008; 12:R51.

33. Nava S, Gregoretti C, Fanfulla F, Squadrone E, Grassi M, Carlucci A, Beltrame F, Navalesi P. Noninvasive ventilation to prevent respiratory failure after extubation in high-risk patients. Crit Care Med. 2005; 33:2465–2470