ARNMSMB Publisher
Research Journal of Medicine and Medical Sciences (RJMMS)
2019; 14(2): pages:10-20
ISSN: 1816-272X
Journal home page: http://arnmsmb.com/RJMMS/

Comparison between RSBI (Rapid Shallow Breathing Index) and NIF (Negative Inspiratory Force) as predictors of extubation failure in mechanically ventilated pediatric patients.

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ABSTRACT

Background: Weaning of mechanical ventilation implies a gradual separation of the patient from the ventilator. Extubation failure is defined as an inability to sustain spontaneous breathing after removal of the artificial airway and need for re-intubation within 24-48 hours. Weaning parameters as RSBI (rapid shallow breathing index) and NIF (negative inspiratory force) are the most clinically relevant predictors of extubation success.

Objectives: This study aimed to compare between NIF and RSBI as predictors of extubation failure in pediatric patients.

Patients and methods: This was a randomized clinical trial based on data collected by observation of 60 mechanically ventilated children with planned extubation in intensive care units at Cairo University Pediatric Hospitals from October 2017 to March 2018.

Results: 18 patients (30%) needed reintubation in the first 48 hours due to respiratory distress in 8 patients (44.4 %), apnea in 3 patients (16.7%), respiratory failure in 3 patients (16.7%) and disturbed conscious level in 3 patients (16.7%). Patients were randomly divided into two groups (One group was extubated on NIF value and the other according to RSBI value). (NIF) was a predictor for extubation success as it was statistically significant (P-value <0.001) with cutoff value -9.5 cm H2O, specificity 100% and sensitivity 90.9 %.

Conclusion: NIF is considered as a predictor for extubation success while RSBI is not.

Keywords: NIF, RSBI, extubation, ventilation, PICU.

Citation: Miriam Magdy Aziz, Mervat Ahmed Haroun, Bassant Meligy, Marwa N Saad, Comparison between RSBI (Rapid Shallow Breathing Index) and NIF (Negative Inspiratory Force) as predictors of extubation failure in mechanically ventilated pediatric patients. *Research Journal of Medicine and Medical Sciences*, 2019; 14(2): 10-20

Received 12 July 2019; accepted 28 November 2019; published 2 December 2019

INTRODUCTION

Weaning of mechanical ventilation implies a gradual separation of the patient from the ventilator. Weaning is a crucial milestone for ventilated patients. The timing of weaning is vital, the price to pay for premature extubation is re-intubation, with all the hazards of possibly unstable clinical situations –in addition to a significant risk of nosocomial pneumonia **[1].**

On the other hand, unnecessarily delayed weaning can expose the patient to the risks associated with protracted mechanical ventilation. Care must, therefore, be taken to plan for this critical event and prepare the patient beforehand [1].

Extubation failure is defined as the inability to sustain spontaneous breathing after removal of artificial airway e.g. endotracheal tube and need for re-intubation within 24-48 hours **[2].**

Incidence of extubation failure varies between 6 and 47 %. In 2005, Baisch reported that patients needing re-intubation had significantly increased the duration of mechanical ventilation as well as ICU and hospital stay and mortality **[3].**

Since the timing of weaning is so crucial, it is necessary to have reliable information that can help determine the success of the weaning trial. Weaning predictors in mechanically ventilated children have not been sufficiently investigated **[2].**

Weaning parameters can be divided into those that assess the following indices: the oxygenation capabilities of the patient's lung, the strength and

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stamina of the respiratory muscles, the respiratory drive, work of breathing and integrative indices **[4]**.

RSBI (Rapid Shallow Breathing Index) is a combination of the respiratory rate and tidal volume which considerably raise the individual predictive power of these two indices (respiratory rate/tidal volume (F/Vt). This index has strong positive and negative predictive values of 79 and 95, respectively, at a cut-off value of 105 **[5].**

Maximum inspiratory pressure or what is sometimes referred to as negative inspiratory force (NIF) is the most clinically relevant predictor of extubation success because the inspiratory muscles (the major one of which is the diaphragm) carry the largest burden of ventilatory work. It ranges from-50 to 0 cm H2O **[4].**

PATIENTS AND METHODS

Study Design

Randomized clinical trial based on data collected by observation of 60 mechanically ventilated children in intensive care units at Cairo University Pediatric Hospitals 24 hours before and for 48 hours after extubation. The study was conducted from October 2017 to March 2018 to include 60 mechanically ventilated pediatric patients with planned extubation. Informed consent was taken from patients' guardians before enrollment with the explanation of type of study. Approval of the ethical committee of faculty of medicine, Cairo University was obtained.

Inclusion criteria:

Mechanically ventilated patients admitted in ICU units and planned for extubation for the first time during their stay.

Exclusion criteria:

- Neuromuscular disorder.
- Accidental extubation.
- Patients with a tracheostomy tube.
- Cardiac patients.

Those patients were excluded to minimize the factors that affect extubation success and clearly assess NIF and RSBI as predictors of extubation failure and success.

Intervention

All patients were observed for:

A) 24 hours before extubation:

-History of all included patients was taken in the form of:

- ➢ Age.
- ➢ Sex.
- ➢ Original diseases (cause of ICU admission).
- ➢ System failure (type and number).
- ➢ (PRISM Score III) **[5].**

- Cause of ventilation was recorded.
- Duration of mechanical ventilation in days.

- Clinical examination was applied to the included patients to record:

- ➢ Vital signs in the form of heart rate, respiratory rate and blood pressure) **[6]**
- ➢ Chest examination in the form of air entry equality on both lungs and additional breath sounds – frequency of endotracheal suction and amount of respiratory secretions (minimal or excessive guided by frequency of suction. If the patient needed 3 times or less suction within the day it was considered minimal, if more than 3 times it was considered as excessive as copious airway secretions increase the likelihood of extubation failure. The need for frequent suctioning – e.g., more than once every couple of hours – indicates that extubation is better deferred **[7].**
- ➢ Saturation of patients.
- ➢ Pallor.
- ➢ Peripheral Perfusion (capillary refill time) 2- 3 seconds.
- ➢ Conscious level (modified pediatric Glascow Coma Scale) **[8]** Stoppage of sedation (off sedation at least 6 hours).
- ➢ Patients on Inotropic support were evaluated using inotropic score (IS) (Wernowsky IS = Dopamine dose (μg/kg/min) + Dobutamine dose (μg/kg/min) +100 × epinephrine dose (μg/kg/min) **[9].**

Laboratory:

- ➢ Serum level of hemoglobin **[10]**
- ➢ Serum level of Potassium **[10]**
- ➢ Serum level of calcium **[10]**
- ➢ Serum level of magnesium **[10]**
- ➢ Serum level of phosphorus **[10]**
- ➢ **Arterial blood gases (ABG).**

-**Imaging** chest –x-ray

-ventilator mode before extubation was either SIMV PC with PSV or CPAP PSV.

-All patients were put on New Port e360 T ventilator and the settings on a mechanical ventilator immediately before extubation were recorded.

-Predictors of extubation failure or success were recorded:-

- C dynamic.
- PaO2:FIO2 Ratio.

Then patients were randomly divided into two groups. One group was extubated on NIF value (from -50 to 0 cm H2O) calculated by the ventilator after breath-holding after expiration for 30 seconds **[4]** and the other was extubated according to RSBI value (‹200) **[5]** as recorded on the ventilator.

Patients were randomized by the computer software program by simple randomization.

B) After extubation:

Follow up of extubated patients for 48 hours regarding the following:

- ➢ **Clinically:**

Patients were observed for:

- The occurrence of respiratory effort and distress.
- Oxygen saturation.
- Amount of respiratory secretions (minimal or excessive)
- Conscious level.
- ABG
- **Imaging:** Chest –X-Ray

Extubation failure

Extubation failure was defined as an inability to sustain spontaneous breathing after removal of artificial airway e.g. endotracheal tube and need for re-intubation within 48 hours **[2].**

Causes of extubation failure were detected and recorded as:

- The occurrence of respiratory failure type I which was defined as an arterial PaO2 lower than 60 mmHg with normal or low PaCO2 **[11]**
- Occurrence of respiratory failure type II which was defined as an arterial PaCO2 higher than50 mmHg **[11]**
- Respiratory distress grade III or Iv and worsening of respiratory effort
- Apnea more than 20 seconds associated with bradycardia
- Increased respiratory secretions guided by frequent need for suction/day.
- Stridor grade III or IV.
- Deterioration of conscious level.
- Lung collapse not improving by chest physiotherapy.

Statistical analysis:

Data were coded and entered using the statistical package SPSS (Statistical Package for the Social Sciences) version 25. Data were summarized using mean, standard deviation, median, minimum and maximum in quantitative data and using frequency (count) and relative frequency (percentage) for categorical data. Comparisons between quantitative variables were done using the non-parametric Mann-Whitney test **[13]**. For comparing categorical data, Chi-square (x2) test was performed. Exact test was used instead when the expected frequency is less than 5 **[14]**. ROC curve was constructed with area under curve analysis performed to detect best cutoff value of RSBI/ NIF for detection of extubation success. P-values less than 0.05 were considered as statistically significant.

RESULTS

Demographic data:-

The study was conducted on 60 patients; 27 of them were females (45%) and 33 of them were males (55%), our patients' age ranged between 1.5 months old and 9 years(108 months)with mean 17.4 and ± 26 months.

Clinical presentation:-

Causes of PICU admission were variable among our patients as 71.7% (43 patients) of them were admitted by bronchopneumonia and respiratory failure, 5% (3 patients) were admitted by septic shock.

Table 1: Causes of ICU admission of studied patients.

		Count N=60	%
Causes of ICU admission	**Bronchopneumonia**	43	71.7%
	Septic shock	3	5.0%
	RDS	2	3.3%
	Bronchiolitis obliterans	2	3.3%
	Bronchiolitis	2	3.3%
	Others	8	13.4%

Other causes include (Asthma, intractable acidosis, Niemann pick, herpetic encephalitis, encephalomalacia, post corrosive, organ phosphorus poisoning and Kawasaki disease).

Number and type of system failure.

Fifty-eight patients of our study (96.7%) presented with respiratory system failure only, while only 2 patients (3.3%) presented with combined respiratory, cardiac and renal systems failure.

PRISM score on admission ranged from (3-21) with mean 9.7 ±4.4 SD and duration of ventilation ranged from (2-100 days) with a mean 13.75 ±13.39 SD.

Clinical course pre-extubation:

During our study the patients were observed clinically for 24 hours before the first trial of extubation regarding vital signs and chest examination. Only 4 patients (6.7%) suffered from sinus tachycardia. Otherwise, all patients showed normal heart rate for age as well as normal blood pressure and respiratory rate for age. Chest examination was done and showed air entry equality on both lungs and no additional breath sounds in all patients, with excessive secretions during suction were noted in 46 patients (76.7%). Saturation of patients was normal in all patients pre extubation. No pallor was noted in all patients pre extubation. Peripheral Perfusion (capillary refill time) 2- 3 seconds was normal in all patients. Conscious level (modified pediatric Glascow Coma Scale was done in all patients pre extubation and showed that all patients were fully conscious. All patients were off sedation at least 6 hours before extubation trial. All patients were off inotropic support before extubation. Chest radiograph before extubation showed 29 patients with bronchopneumonia and only one patient suffered from pneumothorax otherwise was normal.

As regard, ventilation mode pre-extubation; 44 patients (73.7%) were on CPAP PS mode and the rest were weaned on SIMC (PC) with PSV.

Table 2: Ventilator settings and predictors of weaning of patients pre extubation.

	Mean	Standard Deviation	Median	Min	Max
PIP/ PS (ventilator)cm H2O	9.77	4.19	10.00	.00	20.00
Rate (ventilator) breath/ min	34.73	9.33	33.50	20.00	60.00
Vt (ventilator) ml/kg	8.61	3.24	8.10	4.00	24.00
FiO2 (ventilator) %	41.92	4.79	40.00	40.00	60.00
Cdyn (ventilator)ml/cmH2O	5.20	1.59	5.00	.30	10.00
RSBI (ventilator)F/Vt	174.47	92.18	142.00	65.00	520.00
NIF(ventilator)cm H2O	-14.17-	9.37	-13.00-	-37.00-	-2.00-
PaO2/FiO2	232.95	32.92	231.00	187.00	390.00

Table 3: PEEP before weaning

PEEP (ventilator)cm H2O	Count N=60	%
4	6	10.0%
5	51	85.0%
6	3	5.0%

Post extubation events:

Patients were monitored for 48 hours after extubation for failure and need for reintubation. General examination showed that 23 patients (38.3%) were tachypnic and 4 patients (6.7%) were bradypnic. Oxygen saturation after extubation ranged from40-100 % with mean of 95.9 ± 10.11 SD.

All patients were observed for conscious level and 3 of them (16.7%) were disturbed after extubation Chest examination showed that 46 patients (76.7%) had excessive secretions and needed frequent chest care and suctioning post-extubation. PaO2/FiO2 ratio post extubation ranged from 125-397 with mean 253 ±51 SD. Chest radiograph after extubation showed 20 patients (33.3%) had bronchopneumonia and 4 patients (6.7%) had post-extubation right lower lobe collapse.

Re intubated patients

In our study 18 patients (30%) needed re intubation in the first 48 hours.

Table 4: Causes of re intubation

		Count N=60	%
Causes of re-intubation	**Respiratory distress**	8	44.4%
	The occurrence of respiratory failure	3	16.7%
	Apnea	3	16.7%
	Disturbed conscious level	3	16.7%
	Stridor	1	5.6%
	Increased secretions	0	0%
	Lung collapse	0	.0%

Patients were randomly divided into two groups. One group was extubated on NIF value and the other was extubated according to RSBI value.

Comparison between two groups:

Duration of ventilation of weaned patients was statistically significant (P-value 0.045) as it was shorter in RSBI group than that of patients weaned on NIF

Serum calcium level was statistically significant between two groups (P-value 0.017) as it was lower in patients weaned on RSBI group than that of patients weaned on NIF group.

Table 5: comparison between RSBI and NIF group regarding age, PRISM and duration of ventilation

	RSBI group					NIF group					P-value
	Mean	**SD**	**Median**	**Min**	**Max**	**Mean**	**SD**	**Median**	**Min**	**Max**	
Age(months)	**13.13**	**19.50**	**8.00**	**1.50**	**102.00**	**21.67**	**31.01**	**6.50**	**1.50**	**108.00**	**.423**
PRISM score	**9.43**	**4.61**	**8.00**	**3.00**	**21.00**	**9.97**	**4.30**	**10.00**	**4.00**	**20.00**	**.704**
Duration(days)	**10.03**	**4.90**	**10.00**	**2.00**	**20.00**	**17.47**	**17.67**	**13.00**	**3.00**	**100.00**	**.045**

Table 6: comparison between RSBI and NIF group regarding laboratory results.

	RSBI group	NIF group	P-value

	Mean	SD	Median	Min	Max	Mean	SD	Median	Min	Max	
Hb	11.27	1.23	11.00	9.30	15.00	10.85	1.07	10.80	8.90	14.60	.132
K	3.93	.56	3.90	2.20	4.90	3.94	.71	4.00	.70	4.90	.558
Mg	2.38	.63	2.20	1.30	4.80	2.43	.39	2.20	1.90	3.30	.302
Po4	3.77	1.18	3.50	1.30	6.60	3.77	.88	3.55	2.30	5.30	.784
Ca	8.95	.69	8.95	7.70	10.50	9.45	.83	9.45	7.70	11.40	.017

Relation to extubation success in RSBI group

Table (7a); Relation to extubation success in RSBI group (numerical)

Re-intubation											
	yes					no					p-value
	mean	SD	median	min	max	mean	SD	median	min	max	
Age(months)	13.10	14.22	10.00	2.00	48.00	13.15	22.02	8.00	1.50	102.00	0.58
PRISM score	9.40	4.60	9.50	3.00	17.00	9.45	4.73	8.00	5.00	21.00	0.982
Duration(days)	9.80	6.07	9.50	2.00	20.00	10.15	4.38	10.00	3.00	15.00	0.658
Hb	11.20	1.17	11.00	9.30	13.00	11.30	1.29	11.40	9.50	15.00	0.825
K	3.61	.59	3.75	2.20	4.20	4.10	.49	4.00	3.30	4.90	0.058
MG	2.38	.62	2.40	1.30	3.30	2.38	.65	2.20	1.90	4.80	0.45
Po4	3.54	1.05	3.50	1.30	5.00	3.88	1.25	3.55	2.30	6.60	0.758
CA	8.57	.55	8.75	7.70	9.50	9.14	.68	9.25	7.70	10.50	0.034
SPO2 (After extubation)	82.50	19.43	86.00	40.00	100.00	99.35	1.53	100.00	95.00	100.00	< 0.001
PIP/ PS (ventilator)	10.70	3.40	10.00	7.00	16.00	10.30	5.16	10.00	.00	20.00	0.757
RR (ventilator)	31.80	8.77	30.00	20.00	45.00	35.65	7.86	35.00	25.00	50.00	0.276
Vt (ventilator)	7.78	1.94	7.20	5.00	11.00	8.22	2.39	8.10	4.00	13.00	0.551
FiO2 (ventilator)	43.50	6.69	40.00	40.00	60.00	42.00	4.41	40.00	40.00	55.00	0.533
Cdyn (ventilator)	4.99	2.43	5.00	.30	10.00	4.94	1.74	5.00	2.00	10.00	0.561
RSBI (ventilator)	214.00	126.69	201.00	65.00	520.00	154.70	64.28	133.00	101.00	353.00	0.152
pH	7.43	.08	7.39	7.35	7.57	7.42	.06	7.40	7.35	7.55	0.843
PaCO2	37.30	11.10	35.00	20.00	56.00	36.60	8.04	35.00	27.80	58.00	0.758
PaO2	118.10	22.67	120.00	90.00	156.00	105.25	18.58	99.50	80.00	155.00	0.144
SaO2	96.00	4.71	98.50	88.00	100.00	96.09	3.59	98.00	89.00	100.00	0.656
HCO3	25.89	6.92	23.50	19.20	40.80	23.32	4.63	22.25	17.40	36.60	0.466
PaO2/FiO2	246.60	53.52	238.50	200.00	390.00	226.05	36.43	222.00	187.00	350.00	0.098
PH (After extubation)	7.35	.08	7.35	7.21	7.46	7.41	.05	7.40	7.35	7.59	0.013
PaCO2 (After extubation)	51.00	14.29	46.50	30.00	78.00	37.45	6.83	37.50	25.00	56.00	0.003
PaO2 (After extubation)	95.50	14.47	89.50	80.00	120.00	102.54	22.79	105.50	50.00	159.00	0.298
SaO2 (After extubation)	82.20	13.28	79.00	60.00	100.00	91.28	8.20	94.00	67.00	100.00	0.052
HCO3 (After extubation)	24.86	6.55	22.50	18.00	34.00	22.48	4.06	21.65	17.00	34.50	0.567
SPO2 (After extubation)	82.50	19.43	86.00	40.00	100.00	99.35	1.53	100.00	95.00	100.00	< 0.001
PH (After extubation)	7.35	.08	7.35	7.21	7.46	7.41	.05	7.40	7.35	7.59	0.013
PaCO2 (After extubation)	51.00	14.29	46.50	30.00	78.00	37.45	6.83	37.50	25.00	56.00	0.003
PaO2 (After extubation)	95.50	14.47	89.50	80.00	120.00	102.54	22.79	105.50	50.00	159.00	0.298
SaO2 (After extubation)	82.20	13.28	79.00	60.00	100.00	91.28	8.20	94.00	67.00	100.00	0.052
HCO3 (After extubation)	24.86	6.55	22.50	18.00	34.00	22.48	4.06	21.65	17.00	34.50	0.567

Table (7b) Relation to extubation success in RSBI group (categorial)

Re-intubation						
		yes		no		p-value
		count	%	count	%	
Gender	Female	5	50.0%	10	50.0%	1
	Male	5	50.0%	10	50.0%	
System failure number	One system	10	100.0%	18	90.0%	0.540
	Three systems	0	.0%	2	10.0%	
System failure	RESPIRATORY FAILURE	10	100.0%	18	90.0%	0.540

type	RESPIRATORY FAILURE +CARDIAC+RENAL	0	.0%	2	10.0%	
HR Before extubation	Normal	9	90.0%	19	95.0%	1
	Tachcardic	1	10.0%	1	5.0%	
RR Before extubation	Normal	10	100.0%	20	100.0%	---
BP Before extubation	Normal	10	100.0%	20	100.0%	----
Secretions	EXCESSIVE	8	80.0%	18	90.0%	0.584
	MINIMAL	2	20.0%	2	10.0%	
CXR	Bronchopneumonia	4	40.0%	13	65.0%	0.255
	Normal	6	60.0%	7	35.0%	
Mode (ventilator)	SIMV PC with PSV	3	30.0%	8	40.0%	0.702
	CPAP PSV	7	70.0%	12	60.0%	
PEEP (ventilator)	4	0	.0%	2	10.0%	0.335
	5	8	80.0%	17	85.0%	
	6	2	20.0%	1	5.0%	
RR (After extubation)	Normal	1	10.0%	13	65.0%	0.006
	Bradypnic	2	20.0%	0	.0%	
	Tachypnic	7	70.0%	7	35.0%	
secretions (After extubation)	EXCESSIVE	10	100.0%	15	75.0%	0.140
	MINIMAL	0	.0%	5	25.0%	
CXR (After extubation)	Bronchopneumonia	5	50.0%	5	25.0%	0.242
	Collapse	1	10.0%	1	5.0%	
	Normal	4	40.0%	14	70.0%	

Relation to extubation success in NIF group

Table 8a: Relation to extubation success in NIF group (categorial)

Re-intubation						
		yes		no		p-value
		Count	%	count	%	
Gender	female	2	25.0%	10	45.5%	0.419
	Male	6	75.0%	12	54.5%	
System failure number	One system	8	100.0%	22	100.0%	---
System failure type	RESPIRATORY FAILURE	8	100.0%	22	100.0%	---
	RESPIRATORY FAILURE +CARDIAC+RENAL	0	.0%	0	.0%	
HR Before extubation	Normal	8	100.0%	20	90.9%	1
	Tachycardic	0	.0%	2	9.1%	
RR Before extubation	Normal	8	100.0%	22	100.0%	---
BP Before extubation	Normal	8	100.0%	22	100.0%	---
Secretions	EXCESSIVE	6	75.0%	14	63.6%	0.682
	MINIMAL	2	25.0%	8	36.4%	
CXR	Bronchopneumonia	4	50.0%	8	36.4%	0.767
	Normal	4	50.0%	13	59.1%	
Mode (ventilator)	SIMV PC with PSV	2	25.0%	3	13.6%	0.589
	CPAP PSV	6	75.0%	19	86.4%	
PEEP (ventilator)	4	0	.0%	4	18.2%	0.550
	5	8	100.0%	18	81.8%	
CXR (After extubation)	Bronchopneumonia	3	37.5%	7	31.8%	0.080
	Collapse	2	25.0%	0	.0%	
	Normal	3	37.5%	15	68.2%	
RR (After extubation)	Normal	0	.0%	19	86.4%	< 0.001
	Bradypnic	2	25.0%	0	.0%	
	Tachypnic	6	75.0%	3	13.6%	
secretions (After extubation)	EXCESSIVE	8	100.0%	13	59.1%	0.067
	MINIMAL	0	.0%	9	40.9%	

Table (8b): Relation to extubation success in NIF group (numerical)

Re-intubation										
	yes					no				
	mean	SD	median	min	max	mean	SD	median	min	max	Pvalue
Age(months)	6.38	5.72	4.50	1.50	18.00	27.23	34.58	8.50	2.00	108.00	0.067
PRISM score	11.38	5.32	10.50	5.00	20.00	9.45	3.88	10.00	4.00	20.00	0.338
Duration(days)	15.13	9.34	14.00	3.00	30.00	18.32	19.98	13.00	3.00	100.00	1
PIP/ PS (ventilator)	10.75	2.76	10.00	8.00	15.00	8.50	3.88	9.00	.00	16.00	0.135

RR (ventilator)	39.62	10.29	35.50	30.00	60.00	33.45	10.22	32.00	20.00	55.00	0.165
Vt (ventilator)	9.21	3.37	10.00	5.00	14.00	9.12	4.24	8.50	5.00	24.00	0.687
FiO2 (ventilator)	41.25	3.54	40.00	40.00	50.00	41.36	4.68	40.00	40.00	60.00	0.822
Cdyn (ventilator)	5.40	1.56	5.00	4.20	9.00	5.46	.92	5.10	4.00	8.00	0.311
NIF(ventilator)	-3.62-	2.33	-3.00-	-9.00-	-2.00-	-18.00-	7.86	-16.00-	-37.00-	-8.00-	< 0.001
Hb	10.80	.87	10.70	9.60	12.50	10.87	1.16	10.80	8.90	14.60	0.869
K	3.87	.41	3.80	3.40	4.70	3.96	.80	4.05	.70	4.90	0.126
MG	2.53	.43	2.45	1.90	3.00	2.40	.38	2.20	1.90	3.30	0.34
Po4	3.96	.95	3.85	2.70	5.20	3.70	.87	3.50	2.30	5.30	0.452
CA	9.01	.76	9.20	7.70	10.00	9.61	.81	9.60	8.20	11.40	0.11
PH	7.42	.06	7.42	7.34	7.50	7.41	.06	7.40	7.30	7.57	0.888
PaCO2	38.34	8.29	39.50	22.00	49.00	35.82	7.17	35.50	21.20	51.00	0.385
PaO2	113.75	20.69	113.00	88.00	155.00	106.68	12.59	106.00	88.00	132.00	0.423
SaO2	93.88	4.16	94.00	88.00	100.00	93.75	3.97	93.50	88.00	100.00	0.981
HCO3	24.95	5.29	22.60	20.00	34.90	23.10	4.79	22.45	17.00	35.00	0.385
PaO2/FiO2	235.25	30.01	237.50	187.00	290.00	232.18	13.44	233.50	197.00	250.00	0.869
SPO2 (After extubation)	94.38	5.45	94.00	85.00	100.00	99.41	1.59	100.00	94.00	100.00	0.003
pH (After extubation)	7.29	.12	7.32	7.01	7.39	7.41	.07	7.39	7.29	7.58	0.004
PaCO2 (After extubation)	52.88	10.93	50.50	42.00	70.00	41.03	7.58	41.50	23.00	57.00	0.01
PaO2 (After extubation)	99.75	32.82	87.50	63.00	149.00	103.09	17.09	105.50	70.00	131.00	0.526
SaO2 (After extubation)	85.00	12.11	86.50	68.00	99.00	91.11	7.94	92.60	65.00	100.00	0.258
HCO3 (After extubation)	20.94	3.08	20.50	16.00	25.00	25.05	5.19	22.55	20.10	38.00	0.025
PaO2/FiO2 (After extubation)	253.88	78.02	218.50	157.00	372.00	257.82	40.82	252.00	197.00	327.00	0.673

NIF value was statistically significant (P value <0.001) as it was lower and more negative in patients with successful extubation.

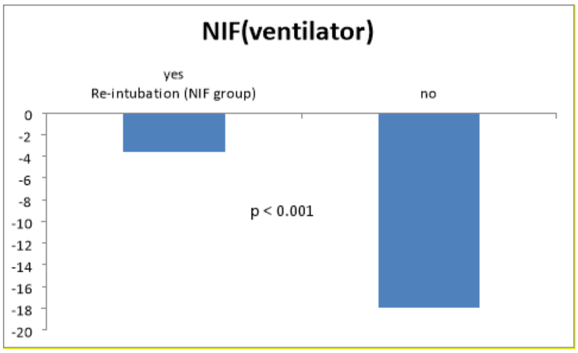

Figure 1: NIF value on ventilator and re intubation

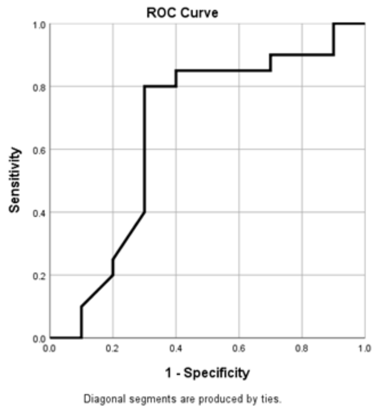

Figure 2: ROC curve using RSBI as predictor of extubation success

Table9: RSBI as predictor of extubation success.

Area Under the Curve	P value	95% Confidence Interval	
		Lower Bound	Upper Bound
.662	.153	.427	.898

No statistical value of RSBI as a predictor of weaning from ventilator

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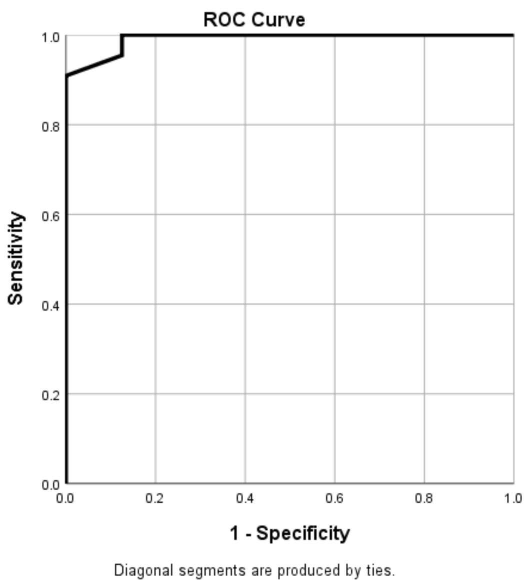

Figure (3): ROC curve using NIF as a predictor of extubation success

Table 10: cutoff value, sensitivity and specificity of NIF value as a predictor of extubation success.

Area Under the Curve	P-value	95% Confidence Interval		Cutoff value	Sensitivity	Specificity
		Lower Bound	Upper Bound			
.991	< 0.001	.968	1.000	-9.5	90.9 %	100 %

Negative inspiratory force (NIF) was statistically significant as a predictor of extubation success with 90.9% sensitivity, 100% specificity and cutoff value -9.5 cm H2O.

DISCUSSION

Weaning is a crucial milestone for ventilated patients. The timing of weaning is vital, the price to pay for premature extubation is re- intubation, with all the hazards of possibly unstable clinical situations –in addition to a significant risk of nosocomial pneumonia. On the other hand, unnecessarily delayed weaning can expose the patient to the risks associated with protracted mechanical ventilation. Care must, therefore, be taken to plan for this important event and prepare the patient beforehand **[1].**

This was a randomized clinical trial based on data collected by observation of 60 mechanically ventilated children in the Intensive care units at Cairo University Pediatric Hospitals 24 hours before and for 48 hours after extubation. The study was conducted from October 2017 to March 2018 to include 60 mechanically ventilated pediatric patients with planned extubation.

This study was done to compare between Negative Inspiratory Force (NIF) and Rapid Shallow Breathing Index (RSBI) as predictors of extubation failure in mechanically ventilated pediatric patients, detect frequency of extubation failure in mechanically ventilated patients in PICUs of Cairo University, evaluate RSBI and NIF cut-off value as predictors of extubation success in mechanically ventilated patients.

RSBI is a combination of the respiratory rate and tidal volume which considerably raise the individual predictive power of these two indices (respiratory rate/tidal volume (F/Vt)).

NIF maximum inspiratory pressure is sometimes referred to as NIF. Measurement of maximum inspiratory pressure is the most clinically relevant because the inspiratory muscles (the major one of which is the diaphragm) carry the largest burden of ventilatory work.

The study was conducted on 60 patients; 27 of them were females (45%) and 33 of them were males (55%), our patients' age ranged between 1.5 months old and 9 years (108 months).

Fifty eight patients of the present study (96.7%) presented with respiratory system failure only, while only 2 patients (3.3%) presented with a combined respiratory, cardiac and renal systems failure.

Respiratory failure was the main indication of mechanical ventilation of our patients (100%) which was expected as in similar study; out of 2,156 patients admitted to pediatric intensive care units, main indications for mechanical ventilation were acute respiratory failure in 78% of the patients, altered mental status in 15%, and acute on chronic pulmonary disease in 6% **[15].**

A study in 2009 showed the extubation failure rates ranged from 2–20% and beard little relationship to the duration of mechanical ventilation. Upper airway obstruction is the single most common cause of extubation failure **[4].** Thirty-four patients (8.3%) were re intubated within 48 hours of extubation. Re intubation risk factors included lower maximum airway pressure during airway occlusion (aPiMax) pre extubation, longer length of ventilation, post extubation upper airway obstruction, and high respiratory effort post-extubation **[16].**

These results are in accordance with the results in the present study that revealed 18 patients (30%) needed re intubation in the first 48 hours and causes of extubation failure ranged from respiratory distress in 8 patients (44.4 %), apnea in 3 patients (16.7%), respiratory failure in 3 patients (16.7%), disturbed conscious level in 3 patients (16.7%) and one patient for stridor. High percentage of extubation failure in our study could be contributed to younger age of patients, lack of air way protection, weak cough reflex and frequent suctioning post extubation. Also this may be due to positive fluid balance 24 hours preceding extubation.

A study in 2017 found that the most commonly preferred mode by the author for initiation of mechanical ventilation (MV) was synchronized intermittent mechanical ventilation (SIMV) with pressure support (PS) and the most commonly preferred method of weaning was PS with continuous positive airway pressure (CPAP)in 115/154 (74.7%) cases **[17].** This is in keeping with the results in the present study as 44 patients (73.7%) were weaned on CPAP PSV mode.

It is noteworthy to mention that there is a great controversy between extubation failure and duration of ventilation. **Gaies et al** showed increasing extubation failure rates for patients ventilated greater than 24 hours **[18].** The findings of Kurachek et al in 2003 showed that the rate of extubation failure went up markedly after 48 hours (8.2%) and 10 days (17.5%) of ventilation in a general PICU cohort **[19].** On the other hand, the results in the present work revealed the reverse. Extubation failure was more likely with patients ventilated for a shorter time. This may be due to premature extubation of patients without complete resolving of lung pathology. Also, duration of ventilation of patients weaned on RSBI was statistically significant (P- value 0.045) shorter than that of patients weaned on NIF.

Concerning the relation between serum calcium level and extubation failure, it is evident from the results of the present study that hypocalcaemia was considered a risk factor for extubation failure. It was significantly lower in patients weaned on RSBI group than that of patients weaned on NIF group (P-value 0.017).

A systematic review found a correlation between vitamin D deficiency and muscle strength. There have been several studies over the years that showed an association between reduced muscle strength or physical performance and low vitamin D status. Most studies involved elderly subjects, and it is not clear whether physical performance declines because of age or due to a deficiency of vitamin D **[20].**

In spite of the fact that many integrated weaning indices look promising, yet no longer index has proven to be ideal. Until the description of rapid shallow breathing index (RSBI) by **Yang and Tobin in 1991**, clinicians depended mainly on weaning predictors such as vital capacity, maximum inspiratory pressure, and minute ventilation. Yang and Tobin described RSBI as the ratio of respiratory rate (RR) to tidal volume (VT), with a threshold value of >105 breaths/min/L being highly predictive of weaning failure, while RSBI <105 breaths/min/L is associated with weaning success [5].

Another study found that an RSBI >105 breaths/min/L was associated with weaning failure, while an RSBI <105 breaths/min/L predicted weaning success with a sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of 97%, 64%, 78%, and 95%, respectively **[21].**

In 2006, **Frutos-Vivar et al**. had identified that the RSBI as one of the best predictor associated with extubation failure, with a positive fluid balance and pneumonia as the other factors **[22].**

Contrary to expectations, the results in the present study displayed the insignificant statistical value of RSBI as predictor of extubation success. This could be explained by the younger age of patients in RSBI group, premature extubation of patients in RSBI group and presence of hypocalcaemia.

Besides, the time on CPAP PSV mode being prolonged more than two hours made the respiratory effort needed to overcome the endotracheal tube resistance much higher, with subsequent higher RSBI value.

As expected, the present study revealed that the NIF was of statistical significant value with cutoff value (-9.5 cmH2O) and was 100% specific and 90% sensitive predictor of extubation success.

This is similar to other studies evaluating the respiratory muscles using common procedures. Measurement of NIF is the most clinically relevant because the inspiratory muscles (the major one of which is the diaphragm) carry the largest burden of ventilatory work.

In the PICU, true maximal NIF can be produced only when the subject inspires from residual volume – a condition rarely met in intubated patients. NIF of at least −30 cmH2O has been found predictive of extubation success in adults and also in children as part of the CROP index or as a stand-alone test under rigorous conditions with CO2 stimulation. However, **Venkataraman et al in 2002** did not find this test useful for prediction as part of the CROP index or as a single test. In the PICU, the test is usually performed quickly at the bedside with an uncalibrated manometer and with both inspiration and exhalation obstructed, i.e. an invalidated technique **[8].**

Although the measurement of a true NIF in critically ill patients should be a useful indicator of global respiratory muscle function, it is highly dependent on numerous variables and there is no accepted, standardized approach. Consistently low values (i.e. above −15 cmH2O), irrespective of technique, are unlikely to be associated with successful weaning **[4].**

We considered that respiratory rate and oxygen saturation post-extubation are signs of extubation failure as in the study which was done at 2013 and aimed primarily to evaluate the efficacy of noninvasive ventilation (NIV) and to identify possible predictors for success of NIV therapy in preventing extubation failure in critically ill children with heart disease. Significant variables identifying a responder included a lower risk-adjusted classification for congenital heart surgery, a good left ventricular ejection fraction, a normal respiratory rate (RR), normal or appropriate oxygen saturation **[23].**

Normal blood gases post extubation can help in extubation success as in 2011 study which showed that seventy-four patients were treated with NIV. One patient did not tolerate mask ventilation and needed immediate invasive ventilation. In patients with NIV success blood gases improved significantly 1- 2 hour after starting NIV **[24].**

In conclusion, present study proved the significance of NIF value as predictor of extubation success which prevented premature extubation and its complications as the weaning process is an art. It needs to be clinically gauged and gradual.

In both groups weaned on either RSBI or NIF, post extubation decreased oxygen saturation was statistically significant in re intubated patients (p-value <0.001 in RSBI group, 0.003 in NIF group). Also, post extubation blood gases in patients weaned on RSBI showed that pH was statistically significantly lower in cases needing re intubation (p-value 0.013), while PaCO2 was statistically significantly higher (p-value 0.003). Similarly, regarding the NIF group, pH was statistically significantly lower in cases needing re intubation (p-value 0.004) while PaCO2 was statistically significantly higher (p-value 0.01).

Regarding respiratory rate post extubation in patients needing re intubation, it is evident that it is statistically significantly higher in both groups (p-value 0.006 in RSBI group and <0.001 in the NIF group). It is also evident from the results in the present study that hypocalcaemia in RSBI group was among the factors responsible for re intubation (p value 0.034).

So respiratory rate, desaturation, blood gases and hypocalcaemia have an important role and correlation with extubation failure or success.

In conclusion, the present study proved the significance of NIF value as predictor of extubation success which prevented premature extubation and its complications as the weaning process is an art. It needs to be clinically gauged and gradual.

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