RESEARCH ARTICLE

A new index, Respiratory Insufficiency index and Modified Early Warning Scores predict extubation failure

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Background: Extubation failure occurs in 5%–20% of patients and is associated with poor clinical outcomes. The primary aim of this project was to determine the predictive ability of the Respiratory Insufficiency (RI) index, Respiratory Oxygenation (ROX) index and Modified Early Warning Score (MEWS) in identifying extubation failure.

Methods: This was a secondary analysis of a prior cross-sectional retrospective study conducted from February 2018 through December 2018 among adult subjects who received mechanical ventilation for more than 24 h. Extubation failure was defined as the need for reintubation or rescue non-invasive ventilation (NIV) within 48 h after planned extubation. Univariate analysis and logistic regression were used to identify the predictors and final model was validated using 10-fold cross validation. Nomogram was constructed based on the final model.

Results: Of 216 enrolled subjects, 46 (21.3%) experienced extubation failure. The median RI index 1-h post extubation was 20 [interquartile range [IQR] 16.33–24.24] for success group and 27.02 [IQR 22.42–33.83] for the failure group (P<0.001). The median ROX index 1-h post extubation was 16.66 [IQR 12.57–19.84] for success group and 11.11 [IQR 8.09–14.67] for failure group (P<0.001). The median MEWS 1-h post extubation was 2 [IQR 1–3] for the success group and 4 [IQR 3–5] for the failure group (P<0.001). In multivariable analysis, age >60 years [OR 3.89 (95% CI 1.56–9.73); P=0.004], MEWS >4 [OR 4.01 (95% CI (1.59–10.14); P=0.003] and, RI index >20 [OR 4.50 (95% CI 1.43–14.21); P=0.010] were independently associated with extubation failure.

Conclusion: In the present study, RI index and MEWS were independently associated with predicting extubation failure within 1 h of extubation. A prospective validation study is warranted to establish the role of these indices in predicting extubation outcome.

Key Words: *extubation failure; extubation outcome; mechanical ventilation; MEWS; Respiratory Insufficiency Index; ROX index*

INTRODUCTION

Mechanical ventilation is one of the most common life support interventions used to support patients who cannot maintain adequate gas exchange. After resolution of the underlying illness, 80–90% of the patients are successfully liberated from the ventilator with the first extubation attempt [1]. However, the timing of extubation is crucial as both premature and delayed extubation can cause long-term complications and increase mortality [1–4]. Approximately 5%–20% of patients who successfully complete a spontaneous breathing trial (SBT) and undergo planned extubation require reintubation [1, 3, 4]. Extubation failure is associated with mortality, morbidity, costs and increased hospital length of stay [1, 3, 4].

Timely recognition of extubation failure could allow earlier intervention with various clinical therapies to prevent reintubation [2]. Several studies investigating the role of weaning parameters to predict extubation outcome concluded that weaning parameters obtained before extubation are poor predictors of extubation outcome because most patients develop respiratory distress after extubation [2, 5–9].

Acute respiratory failure is the most common cause of extubation failure [1, 11]. Therefore, indices that predict respiratory failure can be effective in predicting extubation failure. Several studies have developed/validated indices to predict respiratory failure, such as Respiratory Oxygenation (ROX) index and Modified Early Warning Score (MEWS) [12, 13]. The ROX index, which is a ratio of oxygen saturation measured by pulse oximetry (SpO_2)/fraction of inspired oxygen (FiO_2) to breathing frequency (*f*), was developed to predict the outcome of high flow oxygen therapy [12]. The wide application of ROX index is limited because it has not been validated with low flow oxygen devices. MEWS is a multivariable, physiological scoring system based on five parameters: systolic blood pressure, heart rate (HR), *f*, temperature and level of consciousness. MEWS is widely used to improve the quality of care by allowing early recognition of clinical deterioration, and it has been used to predict intensive care unit (ICU) admission, cardiac arrest or death [13]. Despite the fact that both indices have been validated to predict respiratory failure, they were not examined for their ability to predict extubation outcome.

There are very few studies that explored the role of post-extubation multi-parameters indices in predicting extubation outcome such as integrated pulmonary index (IPI), HR and respiratory rate (RR) variability and APACHE II score [3, 4, 14]. But, these available indices are either algorithm based requiring software, time consuming or not validated for extubation failure prediction [3, 4]. Additionally, most of the published data suggests using noninvasive ventilation (NIV) or high flow nasal

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cannula (HFNC) for at least 24 h after extubation among all the high risk patients [15, 16]. However, this is a resource intensive strategy that imposes a workload burden on clinicians. Thus, it is imperative to refine our clinical techniques to better identify high risk patients more dynamically in the immediate post extubation period.

Breathing frequency and SpO_2 are the two vital signs frequently measured to assess patient's respiratory status [16, 17]. Tachypnea and oxygen desaturation are the main clinical findings in patients experiencing post extubation respiratory failure; therefore, using the ratio of breathing frequency to oxygen saturation (f/SpO_2), we developed a Respiratory Insufficiency (RI) index to quantify respiratory status after planned extubation. The main objective of the present study was to test and validate the ability of RI index, ROX index, and MEWS to predict extubation failure.

METHODS

Study design and subjects

The present study is a secondary analysis of a previously published cross-sectional study conducted to evaluate potential predictors for extubation outcome with a new research question [4]. The original study was approved by Institutional Review Board (IRB 18112803) and included all adult subjects who were intubated for more than 24 h and received mechanical ventilation in the different ICUs (surgical, cardiac, medical and neurological) at an academic medical centre from February 2018 through December 2018.

Data collection

For the original study, demographic and anthropometric data, including age, sex, BMI, and race/ethnicity, indication for intubation, length of stay on mechanical ventilation, and SBT information, were obtained from the electronic medical record. Post extubation, each patient was placed on a Smart Capnoline Oxygen cannula (Medtronic, Minneapolis, MN) to provide oxygen and monitor end-tidal partial pressure of carbon dioxide ($PETCO_2$). Clinical data such as HR, *f*, $PETCO_2$, blood pressure, temperature, level of consciousness, SpO_2, F_iO_2 were collected. FiO_2 delivered via nasal cannula was estimated based on the rule of thumb that 1 L of oxygen increases FiO_2 by 4%. The RI index, ROX index and MEWS were calculated at 5 min, 30 min and 1 h post extubation. The extubation outcome within 48 h and use of NIV were also collected.

Definition of variables

Extubation outcome was defined as the ability to maintain spontaneous, unassisted breathing at 48 h post discontinuation of mechanical ventilation. The subject was considered failed extubation if they were re-intubated and returned to mechanical ventilation within 48 h after the initial discontinuation from the ventilator or if the subject required rescue NIV within 48 h post the initial discontinuation from the ventilation. Rescue NIV was defined as the use of NIV among patients who developed signs of post extubation respiratory distress. The RI index was calculated by dividing breathing frequency (*f*) with oxygen saturation measured by pulse oximeter (SpO_2) in decimals. For example, *f* of 22 breaths/min and SpO_2 of 88% would yield a RI index of 25 (22/0.88). Higher RI index value indicates respiratory compromise reflected by tachypnea, desaturation or both. ROX index values were calculated by dividing SpO_2/FiO_2 with *f*. A ROX$\geq$4.88 after 12 h use of HFNC is predictive of HFNC success [12]. MEWS was calculated using Dr. Subbe's online calculator (https://www.mdcalc.com/modified-early-warning-score-mews-clinical-deterioration. *Accessed October 1, 2021*). MEWS score range from 0 to 14 and higher number indicates clinical deterioration.

Statistical analysis

The categorical variables are reported as frequency distribution. The continuous variables are presented using measures of central tendency (means and standard deviations or as medians and interquartile [IQR] ranges). The differences between the study groups were evaluated using the 2-tailed t-test, or Mann-Whitney test, for quantitative variables, and with the chi-square test or Fisher exact test for categorical variables, as appropriate. Multivariable logistic regression model was used to explore the clinical variables associated with the extubation failure. Hosmer-Lemeshow test was used to assess the model fit and collinearity was assessed using variance inflation factor (VIF). Internal validation was performed using 10-fold cross validation technique with 100 repetitions to evaluate the predictive performance of the final model. ROC curve was used to evaluate the diagnostic performance and Youden's index was used to identify the optimal cutoff to differentiate between extubation success and failure. A nomogram was constructed based on the final multivariable model. Significance levels were set at P<0.05 and data analysis was performed using SPSS (26.0) and Caret package and MLeval package available in R (4.1.2).

RESULTS

Subject baseline characteristics

A total of 216 subjects' data was analyzed, 170 (78%) subjects were successfully extubated and 46 (21.3%) subjects failed extubation. Of these 46 subjects with failed extubation, 34 were reintubated and 12 received rescue NIV. Of these 12 subjects who received rescue NIV, seven were later reintubated. Overall, mean age of the participants with extubation success was 58.18 (SD±15.94) years and 93 (54.7%) subjects were men. The mean age of subjects with extubation failure was 63.07 (SD±11.37) years and 27 (58.7%) were men. The primary reason for intubation was airway protection in both the groups (Table 1). The median time to reintubation was 14 (IQR 3–32) h among those who received reintubation without use of rescue NIV and 96 (IQR 84–120) h among those who received rescue NIV before reintubation. The detailed subjects' baseline characteristics are reported in a previous original paper [4].

Extubation outcome assessment using RI index, ROX index and MEWS

The median RI index was significantly lower for the success group at 5 min (20.42 [IQR 17.02–24.24] vs 22.34 [IQR 18.9–26.91]; P=0.02), at 30 min

TABLE 1
Patient baseline characteristics

Variables	Extubation success (n=170)	Extubation failure (n=46)	P-value
Age, mean (SD)	58.18 (15.94)	63.07 (11.37)	0.053
Men, n (%)	93 (54.7)	27 (58.7)	0.73
BMI, median (IQR)	26.20 (22–32)	28.50 (24–36)	0.033
APACHE II, mean (SD)	11.86 (4.95)	15.73 (5.31)	<0.001
Ethnicity, n (%)			0.13
African American	68 (40)	11 (23.9)	
White	66 (38.8)	22 (47.8)	
Hispanic	18 (10.6)	6 (13)	
Asian	3 (1.8)	3 (6.5)	
Other	15 (8.8)	4 (8.7)	
Reason for mechanical ventilation, n (%)			0.66
Airway protection	69 (40.6)	19 (41.3)	
Elective	53 (31.2)	10 (21.7)	
Hypoxic respiratory failure	35 (20.6)	8 (17.4)	
Hypercapnic respiratory failure	7 (4.1)	8 (17.4)	
Cardiac arrest	6 (3.5)	1 (2.2)	
Duration of mechanical ventilation, h, median (IQR)	62.10 (42–110)	71.13 (40–123)	0.65
RSBI at the end of SBT, median (IQR)	43 (31–58)	53.5 (38–72)	0.02
Difficult weaning (3 or more failed SBT)	6 (3.5)	2 (4.3)	0.67

SD = standard deviation; BMI = body mass index; IQR = interquartile range; APACHE II = Acute Physiology and Chronic Health Evaluation II; RSBI = rapid shallow breathing index; SBT = spontaneous breathing trial (Used from Reference 4 with permission).

(19.29 [IQR 16.03–24.48] vs 25 [IQR 20.75–30.27]; P<0.001) and at 1 h (20 [IQR 16.33–24.24] vs 27.02 [IQR 22.42–33.83]; P<0.001) post extubation (Table 2). There was no significant difference in median ROX index at 5 min between the two groups. However, median ROX index was significantly higher in the success group at 30 min (15.2 [IQR 12.81–19.51] vs 11.78 [IQR 8.98–15.87]; P<0.001) and at 1 h (16.66 [IQR 12.57–19.84] vs 11.11 [IQR 8.09–14.67]; P<0.001) post extubation. The median MEWS was significantly lower in the success group at 5 min (2 [IQR 1–3] vs 3 [IQR 2–4]; P=0.007), at 30 min (2 [IQR 1–3] vs 3 [IQR 3–4]; P<0.001) and at 1 h post extubation (2 [IQR 1–3] vs 4 [IQR 3–5]; P<0.001).

Extubation outcome assessment using vital signs

The median *f* was significantly lower in the success group at 5 min (20 [IQR 17–24] vs 22 [IQR 19–26]; P=0.011), at 30 min (19 [IQR 16–24] vs 24 [IQR 21–28] vs; P<0.001), and at 1 h (19 [IQR 16–24] vs 26 [IQR 22–31]; P<0.001) post extubation. (Table 2). The median SpO_2 was significantly higher for extubation success group at 5 min (98 [IQR 96–100] vs 97 [IQR 94–99]; P=0.009), at 30 min (98 [IQR 96–100] vs 96 [IQR 92–99]; P=0.025), and at 1 h (98 [96–100] vs 97 [93–99]; P=0.041) post extubation. There was no significant difference in the median HR between the two study groups. Similarly, there was no significant statistical difference in the $PETCO_2$ values between the study groups at 5 and 30 min after extubation. However, the median $PETCO_2$ recorded at 1-h post extubation was significantly higher for extubation success group (30 [IQR 27–35] vs 27 [IQR 19–34]; P=0.017). The extubation failure group received significantly higher FiO_2 at 5 and 30 min post extubation.

TABLE 2
Physiological variables and extubation outcome

Variables	Time (after extubation)	Extubation success (n=170)	Extubation failure (n=46)	P-value
RI index, median (IQR)				
	5 mins (T1)	20.42 (17.02–24.24)	22.34 (18.9–26.91)	0.02
	30 mins (T2)	19.29 (16.03–24.48)	25.00 (20.75–30.27)	<0.001
	1 h (T3)	20.00 (16.33–24.24)	27.02 (22.42–33.83)	<0.001
	Change 1 (T2-T1)	−0.73 (−3.2 to 2)	2.20 (−0.85 to 5.8)	0.001
	Change 2 (T3-T1)	−0.67 (−3.5 to 2.7)	3.99 (1.1–7.1)	<0.001
ROX index, median (IQR)				
	5 mins (T1)	14.97 (12.50–18.24)	13.34 (11.57–16.14)	0.050
	30 mins (T2)	15.82 (12.81–19.51)	11.78 (8.98–15.87)	<0.001
	1 h (T3)	16.66 (12.57–19.84)	11.11 (8.09–14.67)	<0.001
	Change 1 (T2–T1)	0.52 (−1.8 to 3.1)	−1.50 (−3.2 to 0.4)	<0.001
	Change 2 (T3–T1)	0.58 (−1.6 to 2.7)	−2.10 (−5 to −0.07)	<0.001
MEWS, median (IQR)				
	5 mins (T1)	2 (1–3)	3 (2–4)	0.007
	30 mins (T2)	2 (1–3)	3 (3–4)	<0.001
	1 h (T3)	2 (1–3)	4 (3–5)	<0.001
	Change 1 (T2–T1)	0 (−1 to 1)	0 (0–1)	0.015
	Change 2 (T3–T1)	0 (−1 to 1)	1 (0–1)	<0.001
RR, median (IQR)				
	5 mins (T1)	20 (17–24)	22 (19–26)	0.011
	30 mins (T2)	19 (16–24)	24 (21–28)	<0.001
	1 h (T3)	19 (16–24)	26 (22–31)	<0.001
	Change 1 (T2–T1)	0 (−3 to 2)	1 (−1 to 5)	0.004
	Change 2 (T3–T1)	0 (−3 to 3)	4 (1–6)	<0.001
SpO_2, median (IQR)				
	5 mins (T1)	98 (96–100)	97 (94–99)	0.009
	30 mins (T2)	98 (96–100)	96 (92–99)	0.025
	1 h (T3)	98 (96–100)	97 (93–99)	0.041
	Change 1 (T2–T1)	0 (−1 to 1)	−1 (−2 to 0.8)	0.033
	Change 2 (T3–T1)	0 (−1 to 1)	−0.5 (−2 to 1)	0.17
HR, median (IQR)				
	5 mins (T1)	93 (80–105)	94 (80–110)	0.58
	30 mins (T2)	89 (75–103)	94 (78–107)	0.31
	1 h (T3)	89 (75–103)	99 (75–104)	0.29
	Change 1 (T2–T1)	−3 (−8 to 1.2)	0 (−7 to 4)	0.07
	Change 2 (T3–T1)	−2 (−8 to 2)	−1 (−6 to 5.5)	0.22
$PETCO_2$, median (IQR)				
	5 mins (T1)	30 (27–35)	30 (25–34)	0.59
	30 mins (T2)	31 (27–35)	29 (24–35)	0.36
	1 h (T3)	30 (27–35)	27 (19–34)	0.017
	Change 1 (T2–T1)	0 (−2 to 2)	−1 (−2 to 1)	0.28
	Change 2 (T3–T1)	0 (−2 to 2)	−0.5 (−6 to 1)	0.10
FiO_2, median (IQR)				
	5 mins (T1)	0.28 (0.28–0.32)	0.32 (0.28–0.36)	0.023
	30 mins (T2)	0.28 (0.28–0.36)	0.36 (0.32–0.36)	0.009
	1 h (T3)	0.28 (0.28–0.36)	0.32 (0.29–0.36)	0.172
	Change 1 (T2–T1)	0 (0–0)	0 (0–0)	0.068
	Change 2 (T3–T1)	0 (0–0)	0 (0–0)	0.328

RI = respiratory insufficiency; IQR = Interquartile range; ROX = ROX index; MEWS = modified early warning score; RR = respiratory rate; SpO_2 = oxygen saturation measured by pulse oximetry; HR = heart rate; $PETCO_2$ = end tidal CO_2.

Multivariable analysis

Based on the Youden Index, age >60, MEWS >4 and RI >20 at 1 h post extubation were identified as optimal cutoffs to predict extubation failure. The area under receiver operating characteristic curve (AUROC) for the RI >20 at 1 h was 0.69 and improved by adding other variables. Therefore, in the multivariable regression model, age >60 years, sex, RI index >20, and MEWS >4 at 1 h post extubation were included. The results of predictive multivariable logistic regression model showed age >60 (OR 3.89 [95% CI 1.56–9.73]; P=0.004), MEWS >4 (OR 4.01 [95% CI 1.59–10.14]; P=0.003), and RI index >20 (OR 4.50 [95% CI 1.43–14.21]; P=0.010) were independently associated with extubation failure (Table 3). The AUROC curve for predictive model was 0.79 (95% CI 0.66–0.89) with 0.96 (95% CI 0.92–0.99) sensitivity and 0.34 (95% CI 0.19–0.53) specificity. Furthermore, the predictive model maintained the performance when assessed using *k* fold cross validation method demonstrating the AUROC of 0.78 (0.49–0.98) with 0.97 (95% CI 0.88–1.0) sensitivity and 0.21 (95% CI 0.0–0.67) specificity (Table 4). Based on the final regression model, a nomogram was constructed to predict extubation failure by assigning a score to the risk factors. A total score was calculated using sex, age >60 years, MEWS >4 and RI >20. Each value was given a score on the point scale axis, and a total score was calculated by adding each risk factor to predict the probability of extubation failure (Figure 1).

TABLE 3
Logistic model for predicting extubation failure

	Univariable analysis		Multivariable analysis	
Variables	OR (95% CI)	P-value	OR (95% CI)	P-value
Sex	0.85 (0.44–1.64)	0.63	0.64 (0.27–1.52)	0.31
Age >60 years	2.99 (1.47–6.08)	0.002	3.89 (1.56–9.73)	0.004
MEWS >4	4.99 (2.25–11.06)	<0.001	4.01 (1.59–10.14)	0.003
RI Index >20	7.57 (2.56–22.38)	<0.001	4.50 (1.43–14.21)	0.010

OR = odds ratio; RI = respiratory insufficiency; MEWS = modified early warning score.

TABLE 4
Model accuracy

	Logistic regression model	Cross validation model
AUROC curve (95% CI)	0.79 (0.66–0.89)	0.78 (0.49–0.98)
Sensitivity (95% CI)	0.96 (0.92–0.99)	0.97 (0.88–1)
Specificity (95% CI)	0.34 (0.19–0.53)	0.21 (0–0.67)

AUROC = area under receiver operating characteristic curve.

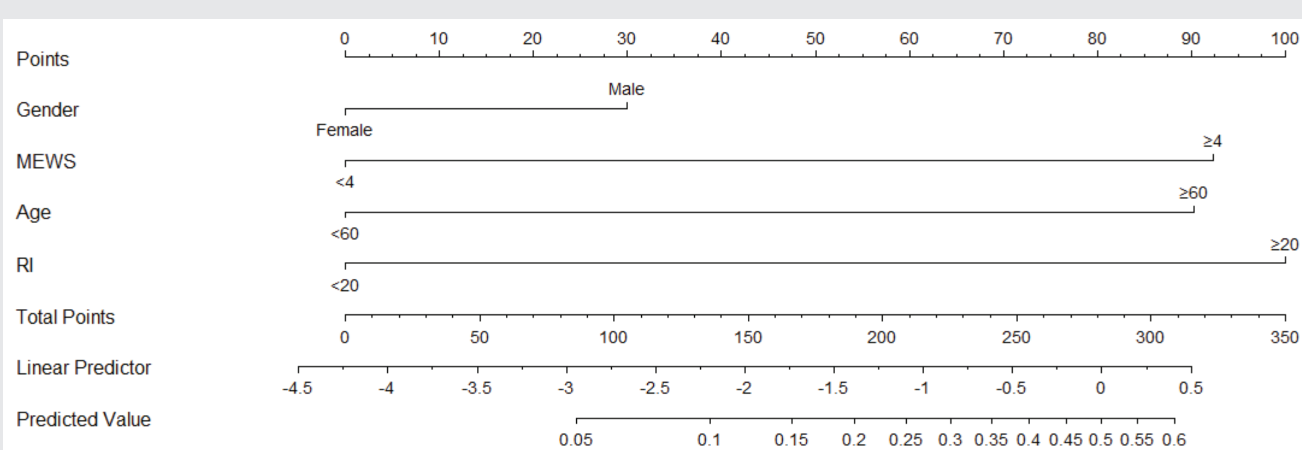
DISCUSSION

In the present study, we developed a simple tool, RI index, that is significantly associated with predicting extubation failure within 1 h of extubation. The nomogram based on the age, RI index and MEWS values had AUROC of 0.79 in predicting extubation failure. The model's higher sensitivity is important because the tool can be used to identify patients at risk of failure and tailor respiratory care to improve the score and prevent failure. Additionally, the study results demonstrated a significant association between commonly measured vital signs such as *f* and SpO_2 and extubation outcome. However, $PETCO_2$ and HR did not appear to have any association with extubation outcome.

The usefulness of pulse oximetry and breathing frequency as early warning signs for detecting respiratory failure is well recognized [18, 19]. Thus, we evaluated the role of RI index to quantify patient's respiratory status in the post extubation period. Breathing frequency and SpO_2 are parts of the algorithm based IPI. In a previous study, we reported that mean IPI 1 h post extubation in the extubation failure group was lower by 1.19 (P=0.044) than the success group, and the IPI decline increased the odds of developing extubation failure (OR 1.57, 95% CI 1.001–2.454) [3]. However, IPI monitoring requires proprietary software, which might not be readily available at all facilities. Thus, we examined an index using *f* and SpO_2 that are readily available for bedside clinicians. We identified that subjects who developed extubation failure had higher RI index values that increased over time after extubation, and a higher RI index was independently predictive of extubation failure. Additionally, we looked at the change in RI index from baseline to 30 min and baseline to 1 h; it did not have better AUROC than the individual RI values (data not shown). This finding is thought to reflect respiratory compromise leading to either tachypnea or oxygen desaturation or both. Of caution, breathing frequency used to calculate RI index in the present study, was obtained via $PETCO_2$ monitor. Inaccuracy of recording breathing frequency from cardiopulmonary monitors using electrical impedance is well known [20] and may result in different findings when used to calculate RI index.

ROX index has been validated to predict the HFNC outcome and identify patients at high risk of intubation. In a study by Roca et al, the prediction accuracy of ROX index was reported to increase over time with ROX index ≥4.88 after 12 h of HFNC was shown to be associated with a lower intubation rate (successful HFNC) [12]. Another study evaluated the role of ROX index in identifying patients at high risk of HFNC failure and included 46

FIGURE 1
Nomogram to predict the probability of extubation failure.



patients that received HFNC after extubation [21]. Among these extubated patients, the mean ROX index at 1 h after extubation was 8.23 (6.58–11.44) among HFNC success group and 6.55 (5.61–8.91) among those who failed HFNC therapy and required reintubation (P=0.04) with AUROC 0.68 (0.52–0.85) [21]. Our findings were similar in that the extubation failure group had lower median ROX index values as compared with the extubation success group but, contrary to Goh's study, the median ROX index in our study was 16.66 (12.57–19.84) for the extubation success group and 11.11 (8.09–14.67) for the failure group. The higher ROX index values among our extubation failure group compared with Goh's study (11.11 vs 6.55) could be attributed to the different oxygen delivery devices. Goh's study used HFNC, a fixed performance oxygen delivery device, offering the ability to record exact FiO_2 delivered to the patients. On the other hand, low flow oxygen devices such as nasal cannula, are variable performance devices in which FiO_2 delivered depends on the patient's breathing pattern, thus making it challenging to calculate the exact delivered FiO_2. In our study, most patients received oxygen therapy via nasal cannula. In addition, failure to wean FiO_2 when SpO_2 is greater than 96% could have provided erroneous SpO_2/ FiO_2 ratios used in calculating the ROX index.

A previous study examined the potential for MEWS to predict acute respiratory failure and to identify subjects who require intubation and reported that MEWS >4 had a PPV of 7% and sensitivity of 67% [12]. Our study revealed that MEWS values remained stable approximately 2 in the extubation success group, while the extubation failure group had median MEWS of 4 at 1 h post extubation. Previous studies have shown MEWS≥4 to be associated with poor patient outcomes such as mortality, ICU admission, and severe injury among trauma patients [22–24].

Breathing frequency is an essential vital sign to examine a patient's overall respiratory status and can be the first alarm for clinical deterioration [17]. Tachypnea (f>36 breaths/min) is associated with increased hospital mortality [25]. However, our study revealed that subjects who failed extubation had *f* increased from baseline 22 breaths/min to 26 breaths/min within an hour post extubation. This is an important finding because this small change in *f* is usually not alarming for clinicians to intervene. Therefore, a composite index that includes other variables such as SpO_2 could be beneficial when implementing post extubation routine monitoring strategy. Interestingly, the present study revealed no significant association between post extubation HR, $PETCO_2$ values and extubation outcome.

The present study has several limitations. First, the present study is a secondary analysis of a retrospective study which is susceptible to bias due to the lack of randomization, inflated statistical significance, etc. However, these study types provide exploratory information that could be used to generate hypotheses for future studies. Furthermore, the retrospective study design limited the data available for analysis to only 1-h post-extubation interval. While monitoring during the first hour after extubation is critical to prevent delayed re-intubation, the more extended duration measurements may have provided different results. The retrospective nature of the study may have also affected the accuracy of respiratory compromise RI index and MEWS. Most enrolled subjects received oxygen via nasal cannula in which the FiO_2 is variable. We used the estimated FiO_2 based on the set flow to calculate ROX index and FiO_2 was not titrated to achieve a targeted SpO_2. Due to collinearity between ROX and RI index, ROX was not included in the final model. Additionally, breathing frequency was recorded from the $PETCO_2$, which is more accurate than impedance electrocardiography. Using a less precise measure of breathing frequency may alter these findings. The study population was heterogeneous with 60–70% of subjects intubated either for airway protection or electively, which may alter the study's generalizability. Lastly, RI index value could be impacted by the non-respiratory factors leading to tachypnea, such as fever, pain or agitation.

CONCLUSION

The present study suggests that RI index measured by frequency/pulse oximeter saturation (f/SpO_2) and MEWS score are useful in predicting extubation failure within 1 h of extubation. MEWS A prospective validation study is warranted to validate these indices in determining the extubation outcome.

DISCLOSURES

Ethics approval

The original study was approved by Institutional Review Board (IRB 18112803).

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None

Declaration of interests

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Authors' contributions

RK, DLV and AAA conceived the study design; RK and DLV participated in study coordination. AAA and RK collected data. RK, ER, BM and DLV participated in data analysis. AAA, RK, ER, BM and DLV participated in data interpretation and prepared the manuscript. AAA, RK, ER, BM and DLV reviewed and edited the manuscript. All authors read and approved the final manuscript for submission.

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