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Prognostic Value of Rapid Shallow Breathing Index for Weaning Success in Intensive Care Unit Patients under Mechanical Ventilation

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Abstract

Background: The weaning success in intensive care unit patients under mechanical ventilation is very important. **Objective:** The purpose of this study was to investigate the efficacy and effects of rapid shallow breathing index (RSBI) in predicting weaning success in patients with prolonged mechanical ventilation more than 48 hours. **Methodology:** This prospective cohort study was conducted in the Department of Anesthesia, Pain Palliative & Intensive Care Unit of Dhaka Medical College Hospital, Dhaka, Bangladesh from January 2014 to December 2015 for a period of two (02) years. Patients on mechanical ventilation more than 48 hours with the age of 18 to 60 years were included in this study. During the weaning process, the arterial blood gases (ABG) values was checked and the patients was separated from mechanical ventilation. After measuring RSBI, patients was separated from mechanical ventilator and given T-piece trial (1 to 4 hours) and finally extubated as per advice of ICU consultant and observed for 48 hours. The patients were divided in two groups low RSBI ≤105 breath/min/L and high RSBI >105 breath/min/L. These patients were prospectively followed up to 48 hours in ICU and HDU. **Result:** A total of 117 patients were included in this study. The validity of RSBI evaluation for trail failure was correlated by calculating sensitivity, specificity, accuracy, positive and negative predictive values. The sensitivity of RSBI was 54.5% (95% CI 23.38% to 83.25%) and specificity was 82.1% (95% CI 73.43% to 88.85%). However, positive predictive value and negative predictive value were 24.0% (95% CI 13.84% to 38.30%) and 94.6% (95% CI 90.05% to 97.10%) respectively. The accuracy was found 79.5% (95% CI 71.03% to 86.39%). Receiver-operator characteristic (ROC) were constructed using RSBI of the weaning outcome, which gave a RSBI cut off value of ≥88 as the value with a best combination of sensitivity (72.7%) and specificity (61.3%), accuracy (60.7%), positive predictive value (15.7%), negative predictive value (95.5%) for trail failure. **Conclusion:** In conclusion the efficacy and effects of rapid shallow breathing index is found low sensitivity with high specificity in predicting weaning success in patients with prolonged mechanical ventilation more than 48 hours. *[Journal of National Institute of Neurosciences Bangladesh, 2020;6(1): 9-14]*

Keywords: : Prognostic value; rapid shallow breathing index; weaning success; intensive care unit; patients; mechanical ventilation

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Introduction

Endotracheal intubation and mechanical ventilation (MV) are two separate, distinct processes that occur together in critical care unit in order to be useful[1]. Endotracheal intubation is the insertion of a specialized tube into the trachea, for the purpose of maintaining a patent airway, managing overwhelming secretion and providing oxygenation or mechanical ventilation. Mechanical ventilation is the process of providing ventilation with a ventilator in order to maintain respiratory function[2]. Endotracheal intubation and mechanical ventilation are the most frequently performed and most costly interventions in intensive care units to support the respiratory function[3].

Mechanical ventilation is an invasive procedure and is associated with many serious complications, adverse physiological and psychological experiences[4]. The complications include injury to the vocal cords, trachea or larynx, tracheal stenosis, haemoptysis, ventilator-associated pneumonia (VAP), increased need for sedation, increased gastro-intestinal stress, skin breakdown and decubitus ulcers, muscle wasting, muscle weakness and pulmonary barotrauma[5]. Prolonged mechanical ventilation (longer than two days) can lead to diaphragmatic atrophy and contractile dysfunction[6]. Ventilator-associated pneumonia is by far the most serious complication of mechanical ventilation, and is often due to increased number of day of mechanical ventilation and the intubation procedure itself[7].

The direct complications may lead to indirect complications such as increased hospital length of stay (LOS), emotional distress, increased costs, decreased bed availability and increase in patient morbidity and mortality[8]. The daily cost in ICU is estimated to be six fold higher than that of normal wards[9]. Again, longer ICU stays is associated with increased cost significantly, mostly due to laboratory, pharmacy and imaging charges[10]. Thus, to avoid a lot of complication, cost and resource, patient should be weaned from mechanical ventilation at the earliest possible time. Considering the above mentioned facts that there was no exact data about this type of study in our country before. Therefore, this present study was undertaken to study efficacy of rapid shallow breathing index as a predictor of weaning of patients with prolonged mechanical ventilation by comparing between high and low rapid shallow breathing indexes.

Methodology

This prospective cohort study was conducted in the Department of Anesthesia, Pain Palliative & Intensive Care Unit of Dhaka Medical College Hospital, Dhaka, Bangladesh from January 2014 to December 2015 for a period of two (02) years. Patients on mechanical ventilation more than 48 hours with the age of 18 to 60 years were included in this study. Patients with tracheotomy, patients with spinal cord injury, self-extubation or unplanned extubation, patients who expired before spontaneous breathing trial, patients shifted to another hospital before weaning and within 48 hours of weaning were excluded from this study. Ethical clearance certificate from Ethical Review Committee of Dhaka Medical College was obtained. Standard weaning criteria was considered as resolution of the primary cause of respiratory failure, state of alertness, cooperation, response to commands and Glasgow coma scale (GCS) scores ≥9. One type of ventilator (eVent Medical) was used in all patients. Primary and daily setting of ventilators and the decision to weaning of the patient was made by the ICU consultants. The arterial blood gases (ABG) values was checked during the weaning process and the patients was separated from mechanical ventilation by gradually decreasing the respiratory rate and pressure support (PS) in SIMV (synchronized intermittent mandatory ventilation) and PSV (pressure support ventilation) modes. Then spontaneous breathing trial was induced while the patient was attached to the ventilator with a low level of PS (7 cm of H_2O) and low PEEP (5 cm of H_2O or less). After one hour of spontaneous breathing trial (SBT) respiratory frequency (f) and exhaled tidal volume (EVT) in one minute was recorded from the ventilator scales. These data was served to calculate the minute volume and average tidal volume by dividing the minute volume by the respiratory frequency. RSBI was then measured through respiratory frequency divided by average exhaled tidal volume in liters (f/EVT). Throughout the weaning trial, the FiO_2 setting was variable while vital signs, pulse oximetry, oxygen saturation (SPO_2) and hemodynamic status monitoring. After measuring RSBI, patients was separated from mechanical ventilator and given T-piece trial (1 to 4 hours) and finally extubated as per advice of ICU consultant and observed for 48 hours. If any patient was failed to T-piece trial then reconnected with mechanical ventilator and prepared the patient for further weaning. The patients were divided in two groups low RSBI ≤ 105 breath/min/L and high RSBI >105 breath/min/L. These patients were prospectively followed up to 48 hours in ICU and HDU. Those groups of patients who were not reintubated within 48 hours are considered as success and those who needed reintubation or expired within 48 hours was considered as failure. Reintubation criteria within 48 hours of extubation was oxygen saturation below 90% in spite of high flow O_2, respiratory rate <8 breath/min or >35 breath/min more than 5 minutes, pulse>140 beats/min, systolic BP >180 mm of Hg or 40 mm Hg above baseline or <90 mm of Hg, use of the accessory muscles of respiration, paradoxical breathing, reduced level of consciousness (GCS 8 or less), absence gag or cough reflex, bronchospasm, aspiration of lung secretions, excessive lung secretions, and further advice of consultants. Statistical analyses were carried out by using the Statistical Package for Social Sciences version 20.0 for Windows (SPSS Inc., Chicago, Illinois, USA). The mean values were calculated for continuous variables. The qualitative observations were expressed by frequencies and percentages.

Results

A total of 117 patients were included in this study. Majority 43(36.8%) patients belonged to age 21 to 30 years and only 13(11.1%) patients belonged to age 50 to 60 years. The mean age was found 35.42±13.66 years with range from 18 to 60 years (Table 1).

Table 1: Distribution of the Patients by Age (n=117)

Age Group	Frequency	Percent
<30 Years	58	49.6
31 to 50 Years	46	29.9
41 to 50 Years	22	18.8
>50 Years	13	11.1
Mean±SD	35.42±13.66	
Range (min-max)	18 to 60	

High RSBI was found in 25 cases of which reintubation was performed in 6(24.0%) cases and the rest 19(76.0%) cases were without reintubation required. Low RSBI was found in 92 cases of which reintubation was performed in 5(5.4%) cases and the rest 87(94.6%) cases were without reintubation required. Thus, in RSBI evaluation of trail failure, true positive 6 cases, false positive 19 cases, false negative 5 cases and true negative 87 cases (Table 2).

Table 2: RSBI Findings in the Evaluation for Trail Failure (n=117)

RSBI	Re-intubation required (failure)		Percent
	Positive	Negative	
High RSBI (>105)	6(24.0%)	19(76.0%)	25(100.0%)
Low RSBI (≤105)	5(5.4%)	87(94.6%)	92(100.0%)
Total	**11**	**106**	**117**

The validity of RSBI evaluation for trail failure was correlated by calculating sensitivity, specificity, accuracy, positive and negative predictive values. The sensitivity of RSBI was low which was 54.5% (95% CI 23.38% to 83.25%). The specificity was high which was 82.1% (95% CI 73.43% to 88.85%). However, the Positive predictive value and Negative predictive value were 24.0% (95% CI 13.84% to 38.30%) and 94.6% (95% CI 90.05% to 97.10%) respectively. The accuracy was found 79.5% (95% CI 71.03% to 86.39%) (Table 3).

Table 3: Values of RSBI Evaluation for Prediction of Trail Failure

Validity test	Value	95% CI
Sensitivity	54.5%	23.38% to 83.25%
Specificity	82.1%	73.43% to 88.85%
Positive predictive value	24.0%	13.84% to 38.30%
Negative predictive value	94.6%	90.05% to 97.10%
Accuracy	79.5%	71.03% to 86.39%

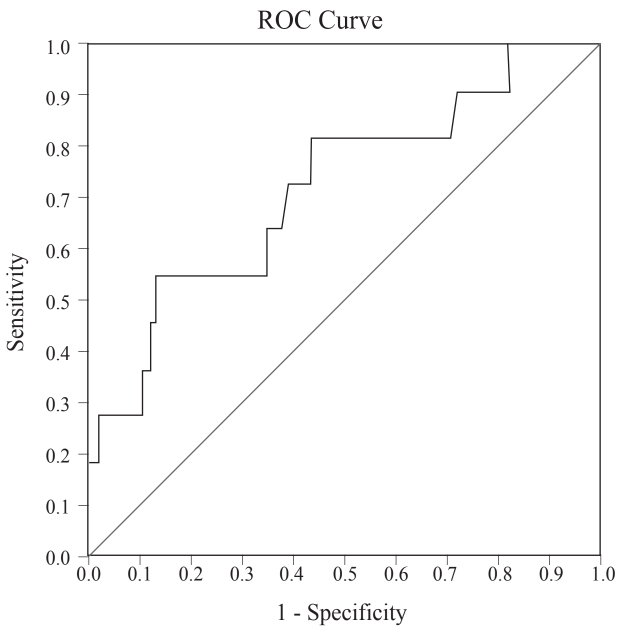

Figure I: Receiver-operator characteristic curves of the rapid shallow breathing index.

Receiver-operator characteristic (ROC) curve of RSBI for prediction of trial failure: The area under the receiver-operator characteristic (ROC) curves for the predictor of trail failure is depicted in the following table. Based on the receiver-operator characteristic (ROC) curves RSBI had the best area under curve (Figure I).

Receiver-operator characteristic (ROC) were constructed using RSBI of the weaning outcome, which

Table 4: Receiver-operator characteristic (ROC) curve of RSBI for prediction of trail failure

	Cut of value	Sensitivity	Specificity	Accuracy	PPV	NPV	P value	Area under the ROC curve	95% Confidence interval (CI)	
									Lower	Upper
RSBI (breath/min/L)	≥88	72.7	61.3	60.7	15.7	95.5	0.042^{s}	0.720	0.552	0.888
RSBI (breath/min/L)	≥100	54.5	77.4	72.6	18.2	94.0	0.041^{s}	0.720	0.552	0.888
RSBI (breath/min/L)	≥105	54.5	82.1	79.5	24.0	94.6	0.011^{s}	0.720	0.552	0.888
RSBI (breath/min/L)	≥109	27.3	89.6	83.6	21.4	92.2	0.126^{ns}	0.720	0.552	0.888

gave a RSBI cut off value of ≥88 as the value with a best combination of sensitivity (72.7%) and specificity (61.3%), accuracy (60.7%), positive predictive value (15.7%), negative predictive value (95.5%) for trail failure. Using a threshold value of ≥100, the sensitivity, specificity, accuracy, PPV, NPV for weaning outcome were 54.5%, 77.4%, 72.6%, 18.2% and 94.0% respectively. Using a threshold value of ≥ 105, the sensitivity (54.5%), specificity (82.1%), accuracy (79.5%), PPV (24.0%), and NPV (94.6%) for weaning outcome. Using a threshold value ≥109, the sensitivity, specificity, accuracy, PPV and NPV were 27.3%, 89.6%, 83.6%, 21.4% and 92.2% for weaning outcome respectively (Table 4).

Discussion

Many ICUs use RSBI for weaning[11], however, some studies have considered RSBI as a useless method[12]. Patel and his colleagues[13] tried different methods for RSBI measurement. This prospective cohort study was carried out with an aim to investigate the efficacy of low rapid shallow breathing index on successful extubation and to assess the efficacy of high rapid shallow breathing index on successful extubation. A total of 117 patients of ICU who fulfilled the criteria of extubation after 48 hours in mechanical ventilation under Anesthesia, Pain, Palliative and Intensive Care unit of Dhaka Medical College Hospital, Dhaka were included in this study.

In this present study it was observed that 36.8% patients were in 3rd decade and only 11.1% patient were in 6th decade. The mean age was found 35.42±13.66 years with range from 18 to 60 years. Goncalves et al[14] and Berg et al[15] showed the mean ages were 61.47±14.54 years and 70±16 years respectively. In another study Fadaii et al16 found that the mean age was 69.4 ± 13.1 years varying from 40 to 91 years, which all are higher with the current study. Similarly, higher mean age was also observed by Bien et al[17], Patel et al[13] and Chao and Scheinhorn[18]. The higher mean ages and age ranges obtained by the above authors due to geographical variations, racial, ethnic differences, genetic causes, different lifestyles, and increased life expectancy may have significant influence of their study patients.

In this study high RSBI group (>105 breath/min/L) failure is 6(24.0%) cases and success is 19(76.0%) cases. Low RSBI group (≤105 breath/min/L) failure is found 5(5.4%) and success is 87(94.6%). Failure is significantly ($p<0.05$) higher in patients with high RSBI group. Fadaii et al[16] have showed 90.0% patients had RSBI ≤105 (breath/min/L), among them 77.0.% patients had successful weaning and did not need reintubation while the remaining had unsuccessful weaning ($P<0.05$). The mean weaning index for patients with successful extubation is 66 ± 57.2 and 76.9 ± 28.1 for patients with unsuccessful extubaion, which is higher in unsuccessful extubaion but the difference is not significant between the means ($P>0.05$). Mahoori et al[19] have showed the mean RSBI values which are significantly different between the failure and success groups. There was no significant difference regarding the values of other prediction criteria between the two groups. Kuo et al[20] reported that RSBI was significantly higher in patients with extubation failure (95.9 ± 20.6) and trial failure (98.0 ± 50.0) than in patients with weaning success (64.6 ± 26.3) ($p < 0.05$). The above findings are consistent with the current study.

Bien et al[17] used a threshold value of the RSBI of ≤ 105 breaths/min/l to analyze the accuracies of predicting weaning success. The RSBI measured under each strategy had high sensitivity and positive predictive values and low specificity and negative predictive values as reported previously[21]. In Bien et al[17] analysis of the area under the ROC curve showed that the predictive accuracies of the RSBI measured under these 5 strategies were lower than those reported previously[22]. Similarly, using a cutoff RSBI value of 105 breaths/min/l, the diagnostic accuracies of predicting weaning success measured under these 5 strategies were also lower than those reported previously[17,21]. A heterogeneous population with a high percentage of acutely exacerbated COPD patients in Bien et al[16] study patients may have contributed to these results[22].

In RSBI evaluation of trail failure, true positive 6 cases, false positive 19 cases, false negative 5 cases and true negative 87 cases. The validity of RSBI evaluation for trail failure was correlated by calculating sensitivity 54.8%, specificity 82.1%, accuracy 79.5%, positive predictive values 24.0% and negative predictive values 94.6%. The sensitivity, specificity, PPV, and NPV of RSBI compared favorably to those of Sassoon and Mahutte[23] and Tu[24] studies that used more complicated parameters to predict weaning success. As noted in previous studies, the prevalence of weaning failure can influence the performance of a weaning index. The prevalence of weaning failure in turn can be influenced by various factors that differ among institutions, including clinical judgment, criteria for selecting patients for weaning trials and also for defining respiratory failure.

Receiver-operator characteristic (ROC) were constructed using RSBI of the weaning outcome it was observed in this study that, RSBI cut off value ≥88 had best combination of sensitivity 72.7% and specificity 61.3%, accuracy 60.7%, positive predictive value 15.7%, negative predictive value 95.5% for trail failure. Using a threshold value of ≥100, the sensitivity 54.5%, specificity 77.4%, accuracy 72.6%, PPV 18.2% and NPV 94.0% for weaning outcome of trail failure. Using a threshold value of ≥105, the sensitivity 54.5%, specificity 82.1%, accuracy 79.5%, PPV 24.0% and NPV 94.6% for weaning outcome of trail failure. Using a threshold value ≥109, the sensitivity 27.3%, specificity 89.6%, accuracy 83.6%, PPV 21.4% and NPV 92.2% for weaning outcome of trail failure. Kuo et al20 observed by using a threshold value of 105, the sensitivity 91.0%, specificity 25.0% and accuracy 85.0% for weaning outcome. The best accuracy of RSBI 75.0% was achieved when a threshold value of 88 was used, with a sensitivity 83.0%, specificity 64.0%, positive predictive value 78.0% and negative predictive value 70.0%, which is closely resembled with the present study. Sensitivity, specificity, and predictive values are of limited value for predicting outcomes in weaning studies because they generally apply to single cut-off points obtained by another researcher[17]. A threshold value of 100 was used, the accuracy of RSBI in Kuo et al[20] study 84.0% was similar to that of RSBI reported by Chatila et al[25] measured at 30 minutes after an SBT 85.0%. Chao et al[26] found that the predictive accuracy of Yang and Tobin's ICU RSBI threshold of 105 was only 59.0%. In Chao and Scheinhorn[18] RT-implemented weaning protocol the authors chose a low RSBI threshold of 80 for advancing the patient to 1-hour SBT. This conservative threshold, chosen to minimize false positives (patients below threshold RSBI but who fail to tolerate 1-hour SBT), was from a published evidence-based recalculation of Yang and Tobin's data for the ICU population[28]. Chao and Scheinhorn[18] found that this threshold value allowed 28.0% of patients to start SBTs earlier, and 89.0% of these patients tolerated the SBT[27]. RSBI correlated well in Chao and Scheinhorn[27] study with the patients' ability to tolerate 1-hour SBT (area under the receiver operating characteristic curve 0.844). They calculated that an RSBI threshold of 80 had a sensitivity of 62.4% and specificity of 88.5%. The authors found that by re-plotting the sensitivity and specificity separately against the log of RSBI they were able to calibrate a threshold RSBI to the desired combination of sensitivity and specificity. Increasing the RSBI threshold to 97 increased the sensitivity by 15.0% while sacrificing specificity by 4.0%.

Conclusion

In conclusion the rapid shallow breathing index (RSBI) is a useful index for prediction of weaning failure and success of patients with prolonged mechanical ventilation and it should be worthy to note here that RSBI help the physician in the rational approach of patient management. Furthermore, RSBI has definite value in the diagnosis of weaning outcome and can be regarded as a sensitive and specific index for prediction of weaning success and failure of patients with prolonged mechanical ventilation. Further studies may be undertaken on RSBI regarding successful weaning from mechanical ventilation including large number of patients.

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