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Original Research Article

ASSESSMENT OF THE RATE OF CHANGE IN THE RAPID SHALLOW BREATHING INDEX AND ITS IMPACT ON EXTUBATION OUTCOMES IN MECHANICALLY VENTILATED PATIENTS

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Abstract: *Mechanical ventilation is a crucial intervention in critical care, but weaning and extubation can be complex. Extubation failure poses significant risks, including increased morbidity and mortality. The Rapid Shallow Breathing Index (RSBI) has been explored to predict extubation outcomes. Still, recent research suggests that assessing the rate of change of RSBI over time (ΔRSBI) could enhance prediction accuracy. In this prospective observational study, we analyzed data from patients with respiratory failure, including those with airway diseases and those without documented respiratory conditions. RSBI was measured at the 5th and 120th minutes of spontaneous breathing trials (SBT), and the ΔRSBI was calculated. Patients were categorized into extubation failure and success groups based on their post-extubation outcomes. Receiver-operating characteristic (ROC) curves were generated to determine optimal RSBI thresholds for predicting extubation failure. Out of 119 patients, 23 were excluded due to intolerance to the 120-minute SBT. The remaining 96 patients were divided into normal and airway groups. In the overall analysis, ΔRSBI had an AUC of 0.943, with a threshold of 26% ΔRSBI predicting extubation failure (sensitivity 96%, specificity 91%, overall accuracy 89%). RSBI 120 had an AUC of 0.837, with an optimal threshold of 71 (sensitivity 86%, specificity 78%, overall accuracy 82%). In the normal group, ΔRSBI (AUC 0.785) with a threshold of 24% (sensitivity 86%, specificity 92%, overall accuracy 88%) outperformed RSBI-120 (AUC 0.931) with a threshold of 70 (sensitivity 86%, specificity 91%, overall accuracy 86%). In the airway group, ΔRSBI (AUC 0.893) with a threshold of 26% ΔRSBI (sensitivity 88%, specificity 84%, overall accuracy 88%) and RSBI 120 (AUC 0.863) with a threshold of 76 (sensitivity 88%, specificity 84%, overall accuracy 84%) showed strong predictive capabilities. Assessing the rate of change of RSBI during a 120-minute SBT offers superior predictive value for extubation outcomes compared to a single RSBI measurement. This approach is particularly valuable in patients with airway diseases. Accurate extubation prediction can reduce reintubation rates and associated complications, ultimately improving patient care.*

Keywords: Rapid Shallow Breathing Index, RSBI, ΔRSBI, Extubation Failure, Spontaneous Breathing Trials, Critical Care, Respiratory Rate

Introduction

Patients in critical care situations often require mechanical ventilation to help them breathe (Lippi et al., 2022). However, extubating a patient after they have been weaned off of artificial ventilation is a challenging and crucial phase of care. The failure to successfully extubate a patient remains a major issue in intensive care, with rates between 10% and 20% recorded in various studies (Dres and Demoule, 2020; Kifle et al., 2022). When an extubation attempt fails and the patient needs to be re-intubated, it can lead to major complications for the patient, the healthcare system, and the budget. Therefore, it is crucial in clinical practise to be able to predict extubation success (Kaur et al., 2021)

In recent years, researchers have focused on determining which respiratory indicators can be used to predict whether or not a patient is ready to be extubated. The Rapid Shallow Breathing Index (RSBI) has been postulated as a potential predictor of extubation outcomes and is measured as the ratio of respiratory rate to tidal volume (RR/VT). Several researchers (Song et al., 2022) Patients with a lower RSBI value may be doing less work breathing and better tolerate extubation.

An increasing body of research suggests that the rate of change of RSBI (RSBI) over time may offer useful insights into the dynamic nature of a patient's respiratory status and preparation for extubation, in addition to the promise shown by RSBI as a predictor. This idea is based on the fact that patients' respiratory stability may fluctuate over their mechanical ventilation and that keeping track of these shifts may help us make better decisions about whether to extubate them.

The Rapid Shallow Breathing Index (RSBI) has been modified over time and studied in relation to spontaneous breathing trials (SBT). Manjush Karthika et al. split 160 patients into three groups in a prospective observational study. Rapid shallow breathing index (RSBI) rate of change from 5 minutes to 120 minutes was found to be a more accurate predictor of extubation success than the RSBI value at 120 minutes alone. Kartika et al. (2016). The term "RSBI rate," which quantifies the rate of RSBI change by serial measurements, was coined by Segal et al. According

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to research (Segal et al., 2010), success in extubating a patient is predicted more reliably by the percentage change in RSBI during SBT. This idea has yet to be tested in disease-specific populations, such as individuals suffering from airway or parenchymal problems. Versus testing this hypothesis, we will compare the predictive value of a single RSBI measurement made at the end of a 120-minute SBT to that of analyzing the rate of RSBI change throughout the entire SBT. Furthermore, we hope to compare the extubation success rates of ventilated patients with and without airway illness by analyzing the rate of change in RSBI during SBT.

Methodology

The Bahria Hospital Lahore Intensive Care Unit (ICU), the Services Hospital Lahore Intensive Care Unit (ICU), and the Rashid Hospital Dubai participated in this observational study between September 17, 2021, and December 15, 2022. Since this was an observational study, informed consent wasn't required, and the hospitals' institutional review boards gave their blessing.

Patients with respiratory failure from various causes were included in the study, such as those with airway disorders like asthma and chronic obstructive pulmonary disease and those with respiratory failure from other causes such as trauma or post-surgical sequelae. Patients had to be 18 or older, intubated with an endotracheal tube, on invasive ventilation for more than 24 hours, conscious and neurologically stable, attempting weaning for the first time (for two hours for spontaneous breathing trials), have recovered partially or completely from respiratory failure, have stable hemodynamics with minimal or no need for vasoactive drugs, and have no comorbidities unrelated to respiratory failure.

Patients with a ventilator duration of fewer than 24 hours, those undergoing a second weaning attempt, those who accidentally extubated during spontaneous breathing trials, those who had ET tube replacement due to obstruction during the trial, those who were discharged against medical advice during the study, those with fibrotic lung diseases and parenchymal lung diseases such as pneumonia or pulmonary edema, and those with neuropathic pain were excluded.

A normal group (N) and an airway group (A) were created from the patient cohort. Patients without a history of respiratory illness were placed in the "normal" group, while those with conditions affecting the airways were placed in the "airway" group.

Patients in the trial sat up in a semi-recumbent position with their heads propped up at an angle of 30 to 45 degrees to ease breathing and the process of changing positions. Endotracheal (ET) and oral suctioning were completed before a spontaneous breathing trial (SBT) began. The cuff pressure of the ET tube was set to 25 cm H2O, as recommended, to prevent leakage and aspiration.

Patients in the intensive care unit were given routine respiratory treatment and had their oxygenation, ventilation, airway, gag reflex, hemoglobin, and neuromuscular state continuously monitored. Blood acid and base (ABG) levels were measured case-by-case but were left out of the analysis.

Ventilators used in the SBT trial were checked and calibrated regularly to ensure accuracy, and they had proper apnea backup systems in place. Guidelines were followed while configuring alarms for critical respiratory parameters. During this time, the ventilation mode was changed to "spontaneous" with a pressure support level of 5-7 cm H2O, and the SBT initiation was recorded. The RSBI was first tracked at minute five of the SBT. Patients who did not complete the SBT within the first five minutes were switched back to the prior mode. Successful patients had their RSBIs measured. Modifications were made if patients had difficulty with the SBT, either subjectively or objectively.

Extubation was performed if the patient met the following criteria: consciousness, normal heart rate, and breathing, responsiveness to orders, intact cough and gag reflexes, and minimum secretions. All vital signs, including those related to breathing, the nervous system, oxygenation, ventilation, cardiac function, hemodynamics, and circulation, were tracked carefully after incubation.

Patients' conditions within the first 24 hours after extubation were used to divide them into two groups: extubation failure and extubation success. Extubation failure was defined as the need for invasive airway reintubation within 24 hours of extubation, while extubation success was defined as no need for ET reintubation within 24 hours of extubation. Because all patients stayed in the intensive care unit for at least 24 hours after extubation, and because about 20% of all patients would require reintubation at some point during their hospital stay (50% within the first 24 hours and the median time is 22 hours), we decided to focus on that period of time.

The RSBI was measured twice during the SBT, once at the 5-minute mark and again at the 120-minute mark. Extracting the RSBI numbers from the ventilator screen was done manually. The following formula was used to determine the RSBI rate: Multiplying (RSBI in the 120th minute minus RSBI in the 5th minute) by 100 and dividing by RSBI in the 5th minute. This rate represents the RSBI's rate of change between these two time periods.

IBM® SPSS Statistics 21 (version 25) of the Statistical Package for the Social Sciences was used to analyze the data. Unless otherwise noted, continuous data will be given as a mean SD. Using descriptive statistics. We synthesized the various demographic factors. Independent T-tests and Mann-Whitney U-tests were used to compare the two data sets.

The optimum cutoffs for the RSBI and RSBI 120 in predicting group extubation failure were determined using receiver-operating characteristic (ROC) curves. We calculated their sensitivity, specificity, and total accuracy for each set of thresholds.

Results

Out of the initial pool of 119 patients, 23 were excluded from the analysis due to their inability to tolerate the 120-minute spontaneous breathing trial (SBT). This intolerance occurred early during the trial, preventing the measurement of RSBI at the 120th minute. Of the remaining 96 patients, comprising 50 with normal lung function, 46 in the airway

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disease group completed the full two-hour SBT and were included in the final analysis (Figure 1).
Demographically, the average age of patients in both the Extubation Success and Extubation Failure groups is quite similar, with a slight numerical difference noted (62 ± 12 vs. 63 ± 15). The calculated p-value of 0.09 indicates that this age difference does not reach statistical significance. Likewise, the distribution of gender among patients in these groups shows no statistically significant difference, with approximately 59% males in the Extubation Success group and 68% in the Extubation Failure group (p-value = 0.715).
Turning to lung status, the data reveals that a higher proportion of patients with normal lung function and airway status experienced extubation success, with 76% and 65.2%, respectively, in the Extubation Success group compared to 24% and 34.8% in the Extubation Failure group. Although the p-values of 0.09 and 0.08 suggest a potential association between lung and airway status and extubation outcomes, they do not reach statistical significance.
The table also highlights the crucial variables of RSBI 120 (Rapid Shallow Breathing Index at 120 minutes) and RSBI 5-120 (Rate of Change of RSBI between 5 and 120 minutes) in the patient groups. Notably, RSBI 120 values are significantly lower in the Extubation Success group (65 ± 4.96) compared to the Extubation Failure group (76 ± 4.12), with a highly significant p-value of ≤0.001. This pattern also holds true when examining patients with normal lung and airway status.
Similarly, RSBI 5-120 values exhibit a substantial difference between the Extubation Success and Extubation Failure groups. Patients in the Extubation Success group have markedly lower RSBI 5-120 values (18 ± 1.8) than those in the Extubation Failure group (28.5 ± 7.1), with a highly significant p-value of ≤0.001. Once again, this trend is consistent when looking at patients with normal lung and airway status.

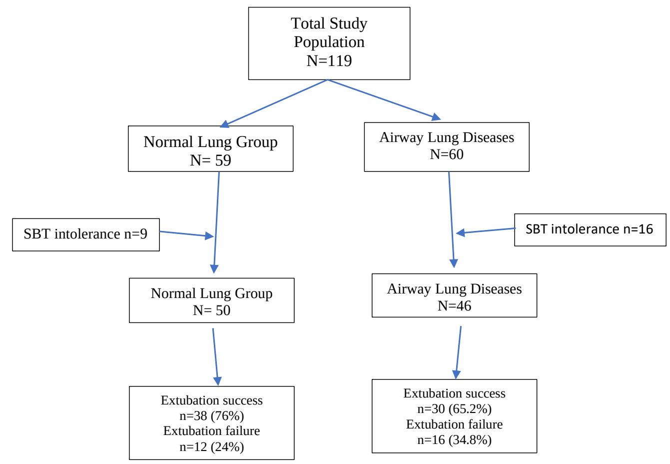

Figure 1: Flow chart showing the selection of patients in two groups.

Table 1: Demographic and clinical characteristics of patients against the outcome

Characteristic	Extubation Success	Extubation Failure	P-value
Demographics			
Age (years)	62 ± 12	63 ± 15	0.09
Gender (Male)	47 (59%)	23 (68%)	0.715
Lung Status			
Normal Lung	38 (76%)	12 (24%)	0.09
Airway	30 (65.2%)	16 (34.8%)	0.08
RSBI 120			
All Patients	65 ± 4.96	76 ± 4.12	≤0.001
Normal Lung	65 ± 4.8	76 ± 4.1	≤0.001
Airway	66 ± 5.8	75 ± 4.2	≤0.001
RSBI 5-120			
All Patients	18 ± 1.8	28.5 ± 7.1	≤0.001
Normal Lung	20 ± 1.9	30 ± 5.9	≤0.001
Airway	21 ± 4.8	31± 7.8	≤0.001

Figure 2 depicts the results of generating ROC curves to evaluate the predictive performance of RSBI and RSBI 120 in identifying extubation failure. A remarkable Area Under the Curve (AUC) of 0.943 was reported for RSBI in the patient cohort using ROC analysis. According to this investigation, extubation failure can be predicted with RSBI 5-120 with a rate of change of 26%. The overall accuracy of this cutoff was 89%, with a sensitivity of 96% and a specificity of 91%.
The area under the ROC curve (AUC) for the total patient cohort when evaluating RSBI 120 was 0.837. For RSBI 120, a cutoff of 71 was best for predicting extubation failure across the board. The overall accuracy was 82%, the sensitivity was 86%, and the specificity was 78% with this cutoff.

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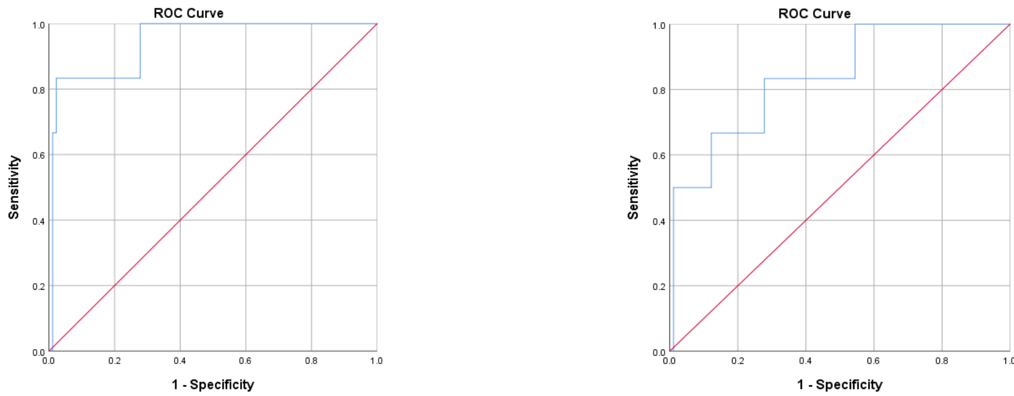

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Figure 2 shows the receiver-operating characteristic curve comparing the predictive thresholds in the whole patient group for RSBI of 5-120 (AUC = 0.943) and RSBI of 120 (AUC = 0.837).

The area under the ROC curve (AUC) for RSBI in the Normal Group was 0.785. A cutoff of 24% for the rate of change of RSBI was found to be highly predictive of extubation failure, with a sensitivity of 86%, specificity of 92%, and accuracy of 88%. The AUC of the ROC curve for RSBI 120 in this cohort was 0.931, and a cutoff of 70 was the most accurate in predicting extubation failure. At this cutoff, we saw a sensitivity of 86%, a specificity of 91%, and an accuracy of 86%. (Figure 3).

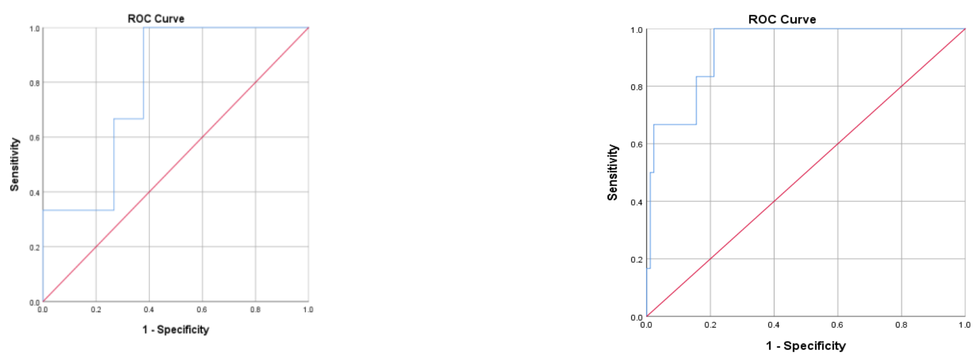

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Figure 3: Receiver-operating characteristic curve (ROC) comparing predictive thresholds for RSBI in normal lung group: (a) RSBI 5-120 (AUC = 0.785) and (b) RSBI 120 (AUC = 0.931).

With an AUC of 0.893, the ROC curve for RSBI in the Airway Group determined that a rate of change of 26% was the most accurate threshold for predicting extubation failure. Using this cutoff, we found a sensitivity of 88%, a specificity of 84%, and an overall accuracy of 88%.

More so, RSBI 120 in the Airway Group had an AUC of 0.863 based on its ROC curve. It was determined that a cutoff of 76 on the RSBI 120 was optimum for predicting extubation failure in patients with airway disorders, with a sensitivity of 88%, specificity of 84%, and overall accuracy of 84%. (Figure 4).

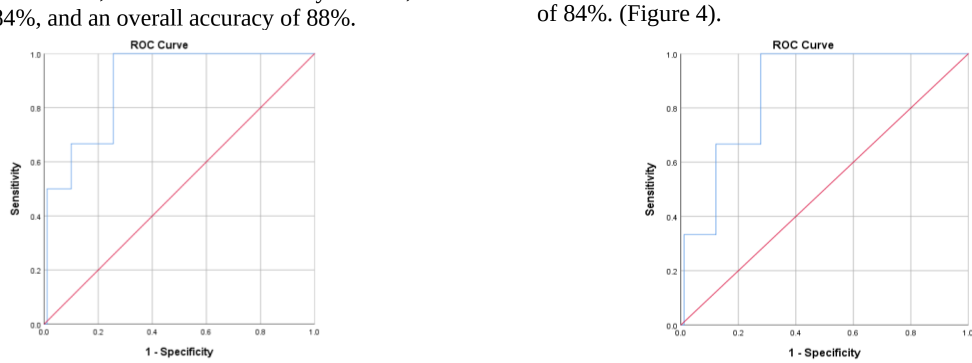

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Figure 4: Receiver-operating characteristic curve comparing predictive thresholds in the airway disease group: (a) RSBI 5-120 (AUC = 0.893) and (b) RSBI 120 (AUC = 0.863).

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Discussion

Our research aims to evaluate the predictive value of a single RSBI (Rapid Shallow Breathing Index) measurement taken at the end of a spontaneous breathing trial (SBT) to the rate of change of RSBI between the 5th and 120th minutes of an SBT. Compared to a single RSBI reading taken after the SBT, we found that the rate of change in RSBI was a more accurate predictor of extubation success. We can learn a lot about a patient's readiness for extubation by tracking the rate of change in RSBI during the initial stages of weaning.

In the setting of increased respiratory demands, existing literature emphasizes the significance of respiratory muscle weakening and exhaustion. This can cause the person to breathe quickly and shallowly. Since RSBI can predict weaning results during spontaneous breathing trials, it is important to employ it, especially when considering subsets of patients with different conditions.

Our major goal was to evaluate the predictive value of RSBI 120 (a single RSBI measurement performed at 120 minutes) versus RSBI (the rate of change of RSBI between the 5th and 120th minutes). To meet the varying respiratory features of our patient population while keeping anxiety to a minimum, we employed pressure support ventilation (PSV) as the weaning approach.

To establish the superiority of RSBI on PSV in predicting extubation outcomes, Shingala et al. conducted research that compared RSBI values acquired during PSV with those obtained during spontaneous breathing with a T-piece. They also found that patients had an easier time getting RSBI on PSV. Several tweaks, such as serial measurements and the rate of change of RSBI, have been proposed to increase RSBI's predictive usefulness.

Some individuals have stable breathing patterns at the beginning of a spontaneous breathing trial but may experience worsening later on, which is why serial RSBI measures were developed. This may result from underlying issues with respiratory mechanics or muscle endurance that aren't immediately noticeable. As a result, scientists started looking into RSBI evaluation intervals. RSBI evaluated 30 minutes into a spontaneous breathing experiment, as opposed to RSBI recorded at the start of weaning, was found by Chatila et al. to be a more reliable predictor of weaning outcomes (Chatila et al., 1996).

Based on findings from earlier studies, we identified the need to monitor patients undergoing weaning trials, from controlled ventilation to spontaneous breathing. To detect clinical intolerance as soon as possible, we opted to take RSBI (Rapid Shallow Breathing Index) readings within the first five minutes of the study. Twenty-three of the 116 patients surveyed displayed intolerance during this time for various reasons, including but not limited to hypoxia, respiratory distress, decreased respiratory effort, restlessness, and hemodynamic instability.

After the first five minutes of the spontaneous breathing trial (SBT), 9 patients indicated intolerance and 14 could not complete the study for the ensuing 120 minutes. In light of this, it's clear that there should be shorter assessment periods in place of the full 120 minutes of the SBT. RSBI measured after the start of the SBT was more accurate than RSBI measured at the beginning of the research, according to another study focusing on serial RSBI measures.

Some evidence suggests that RSBI thresholds well below the traditionally used 105 breaths/min/L may be more indicative of successful weaning or extubation. The best cutoff value was determined to be 65 breaths/min/L based on a meta-analysis of 65 observational studies. Our research has demonstrated that the RSBI threshold should be lowered for certain patient subsets with specific diseases. Successful weaning was more reliably predicted by an RSBI score of 75 breaths/min/L in PSV.

Segal et al. first proposed tracking RSBI growth over time via repeated measurements. Given the dynamic nature of respiratory failure, they postulated that the rate of change in RSBI could be a useful predictor of weaning success. After two hours of SBT, they found that a rate of 20% predicted weaning success. The authors observed that compared to a single RSBI assessment, the percent change in RSBI during an SBT was a more accurate predictor of successful extubation.

Our research explored this idea amongst subsets of patients with various diseases. With a sensitivity of 96%, specificity of 91%, and overall accuracy of 86%, we determined that a rate of change greater than 26% was the best threshold for predicting extubation failure. We discovered that a trough of more than 71 breaths/min/L at the end of the SBT predicted extubation failure for a single RSBI determination.

Notably, the total accuracy of RSBI was slightly better than the relevant RSBI 120 thresholds when applied to each outcome group separately.

This study has limitations due to a small sample size, observational nature, and restricted generalizability of findings. The study primarily focuses on ICU patients with respiratory failure, which limits its applicability to broader clinical settings. To enhance the relevance of predictive tools, future research should address these limitations through larger, more diverse samples and exploration of relevant clinical outcomes.

Conclusion

Assessing the rate of change of the Rapid Shallow Breathing Index (RSBI) during a 2-hour Spontaneous Breathing Trial (SBT) provides better predictive value for extubation outcomes compared to a single RSBI measurement. This approach is particularly beneficial for patients with airway diseases. Accurately predicting extubation can help reduce reintubation rates and associated complications, improving overall patient care.

Declarations

Data Availability statement

All data generated or analyzed during the study are included in the manuscript.

Ethics approval and consent to participate.

Approved by the department concerned.

Consent for publication

Approved

Funding

Not applicable

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Conflict of interest

The authors declared the absence of a conflict of interest.

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