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Original article

Role of Diaphragmatic Ultrasonography-Based Rapid Shallow Breathing Index in Predicting Weaning Outcome from Mechanical Ventilation Device

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Abstract:

Background: Rapid shallow breathing index (RSBI) is widely employed to predict weaning outcomes; however, multiple factors can influence its reliability. These include hemodynamic variables, respiratory muscle strength, and the ability to clear secretions through effective coughing. As such, relying solely on a single index may not provide an accurate prediction of weaning success. Several alternative indices have been suggested. Among them, the diaphragmatic rapid shallow breathing index (D-RSBI) has emerged as a potentially more accurate tool for evaluating weaning outcomes. Aim of the Study: To investigate the effectiveness of D-RSBI, measured via ultrasonography, in predicting successful weaning in cases deemed ready for extubation. **Subjects and Methods:** A prospective investigation involved 60 mechanically ventilated patients admitted to the ICU at Benha University Hospital. Each patient underwent a full clinical evaluation, including medical history, physical examination, laboratory tests, and imaging. Spontenous breathing trial (SBT) was performed after meeting weaning readiness criteria. Diaphragmatic excursion (DE) was assessed using ultrasonography 30 minutes after initiating SBT. RSBI and D-RSBI were measured, and weaning outcomes were documented. ROC analysis was conducted to determine diagnostic accuracy. **Results:** At a cut-off >2.26 breaths/min/mm, D-RSBI demonstrated superior predictive value, with sensitivity of 92.6%, specificity of 77.8%, and accuracy of 88.3%, compared to RSBI cut-off >42.05 breaths/min/L (sensitivity 88.9%, specificity 66.7%, accuracy 73.3%). A DE threshold >9.5 mm predicted successful extubation with 92.9% sensitivity, 77.8% specificity, and 88.3% accuracy—equivalent to D-RSBI. D-RSBI also exhibited the highest AUC (0.982). **Conclusion:** D-RSBI offers superior diagnostic accuracy for weaning outcomes compared to RSBI, supporting its use as a valuable index in clinical decision-making.

Keywords: Rapid shallow breathing index; Diaphragmatic rapid shallow breathing index; diaphragmatic excursion; Diaphragmatic ultrasound.

Introduction

Invasive mechanical ventilation (IMV) is widely acknowledged as one of the most vital and routinely applied interventions within intensive care units (ICUs), primarily serving to maintain respiratory function in individuals grappling with acute respiratory failure. After resolving of underlying cause of respiratory failure, it becomes imperative to promptly initiate the process of weaning from IMV, as unnecessary delays can give rise to additional complications. Notably, approximately 20% of intubated cases encounter difficulties in the extubation and weaning process, even when standard weaning criteria have been satisfied [1].

The timing of extubation is a pivotal determinant in the success of weaning from IMV [2]. Early and delayed weaning have been linked to increased mortality rates, extended ICU stays, and heightened healthcare expenditures [3-5]. Therefore, accurately identifying the ideal moment to begin the weaning process is crucial for improving clinical outcomes during a case's stay in the ICU.

Several clinical parameters and physiological indicators are employed to assess a case's readiness for spontaneous breathing and predict the likelihood of weaning success from IMV. One of these, the Rapid Shallow Breathing Index (RSBI), measured as the ratio of respiratory rate (RR) to tidal volume (VT), is one of the most commonly employed and clinically significant metrics to evaluate the potential for successful weaning [6]. Despite its widespread use, RSBI has notable drawbacks, such as its relatively low specificity and positive predictive value, which can result in inaccuracies in determining a case's readiness for weaning [7,8].

Weaning failure often arises from an imbalance between the mechanical load placed on the inspiratory muscles and the neuromuscular capacity of these muscles to meet the demands of breathing. This imbalance is most apparent in the diaphragm, the major muscle of inspiration, and its ability to meet the required workload. As such, assessing diaphragmatic function prior to initiating a weaning trial could act as an essential predictor of the probability of success or failure during the waning process [9].

To overcome the limitations of RSBI, Spadaro and co-authors. [10] Introduced the Diaphragmatic-RSBI (D-RSBI), which substitutes the VT component of the traditional RSBI with diaphragmatic excursion (DE). D-RSBI has shown superior predictive accuracy compared to the standard RSBI in forecasting weaning outcomes. DE is assessed through bedside ultrasonography, a non-invasive, straightforward, and effective approach for evaluating diaphragmatic function.

Patients and methods:

This prospective, non-randomized interventional investigation was conducted on 60 adult patients receiving MV. The investigation was held in the Critical Care Unit of Benha University Hospitals from March 2024 to March 2025.

Inclusion Criteria:

Participants were considered eligible for inclusion based on the fulfillment of the following specific conditions:

- Age greater than 18 years at the time of enrollment.
- Requirement for endotracheal intubation and MV for a duration exceeding 48 hours.
- Clinical readiness for weaning during the first spontaneous breathing trial (SBT), with the successful fulfilment of all the established weaning criteria **[2,11-14]**

These criteria include:

- Resolution or substantial improvement of the underlying condition that necessitated the use of MV.
- A fraction of inspired oxygen (FiO_2) ≤ 40%, with positive end-expiratory pressure (PEEP) set between 5 and 8 cmH_2O, RR ≤ 30–35 breaths per

minute, and a PaO_2/FiO_2 ratio more than 200 mmHg.

- Demonstrated hemodynamic stability, defined as a heart rate less than 100 beats per minute and mean arterial pressure (MAP) ≥ 65 mmHg, with no or minimal requirement for the administration of vasopressors or inotropic agents (e.g., noradrenaline dose less than 0.05 µg/kg/min).
- Normal values of essential clinical parameters such as serum electrolytes, blood glucose, and body temperature maintained at a level lower than 38°C.
- Minimal sedation with maintained cooperation and cognitive function, as evidenced by a Richmond Agitation-Sedation Scale (RASS) score of ±1, indicating that the case is neither overly sedated nor overly agitated.
- Presence of intact airway reflexes and an ability to effectively manage airway secretions, ensuring adequate airway protection during the weaning process.

Exclusion Criteria:

Patients were excluded from participation if they met any of the following exclusion criteria [14]:

- Age below 18 years at the time of enrollment.
- Pregnancy, due to potential risks associated with the study procedures.
- Presence of thoracostomy, pneumothorax, or pneumomediastinum, as these conditions may interfere with the weaning process or pose additional risks.
- Diagnosis of flail chest or rib fractures, which may compromise respiratory function and complicate the weaning process.
- A history or confirmed diagnosis of neuromuscular diseases, as these conditions may impair respiratory muscle function and affect the weaning outcome.
- Administration of neuromuscular blocking agents within 48 hours prior to the spontaneous breathing trial and diaphragmatic function assessment, as these agents may affect the evaluation of respiratory muscle strength.
- Failure to meet the specified criteria for weaning readiness, which would indicate that the case is not yet sufficiently stable or prepared to undergo the weaning process.

Methods:

All enrolled Patients underwent a comprehensive and thorough clinical assessment, which included the collection of demographic data such as age, sex, and body mass index (BMI). Additionally, the current illness and medical history were thoroughly reviewed, including significant factors such as smoking habits, cardiovascular disease, chronic pulmonary disorders, and chronic kidney disease. This process was followed by a detailed and systematic general and chest examination. RR was meticulously documented, and auscultation was performed to evaluate lung sounds. Laboratory investigations were conducted, including a complete blood count (CBC), renal function tests (urea and creatinine), and arterial blood gas (ABG) analysis, which provided valuable insights into the cases' overall health status. For a more comprehensive evaluation, radiological assessments were carried out using daily chest X-rays, and computed tomography (CT) scans were performed when clinically deemed appropriate, providing further diagnostic clarity.

MV was administered to all cases using the GE Carescape R860 ICU ventilator. Each case underwent a spontaneous breathing trial (SBT) once they successfully met the established readiness criteria for weaning from MV. The SBT was carefully monitored and immediately terminated in the event of any of the following indicators of failure, which are critical signs of the case’s inability to tolerate the weaning process **[15]** :

- RR exceeding 35 breaths per minute, indicating difficulty in maintaining proper ventilation.
- Oxygen saturation (SpO_2) dropping below 90%, despite the adequate administration of fraction of inspired oxygen (FiO_2), suggesting insufficient oxygenation.
- Clear signs of high work of breathing, such as the use of accessory muscles, nasal flaring, and paradoxical respiration, which point to respiratory distress.
- Heart rate exceeding 140 beats per minute or an increase greater than twenty percent from baseline, reflecting potential cardiovascular instability.
- Systolic blood pressure (SBP) rising more than 180 mmHg or falling below 90 mmHg, indicating severe hypertension or hypotension, respectively, both of which could compromise the case's hemodynamic stability.
- The onset of arrhythmias, which may compromise the cardiovascular function and complicate the weaning process.
- Profuse sweating (diaphoresis), which can indicate stress or instability during the weaning attempt.
- Case agitation or anxiety, suggesting that the case may not be able to tolerate the weaning process emotionally or physically.
- Any significant changes in mental status, which could reflect hypoxia, altered brain function, or other complications.
- Inability to keep a patent airway or effectively clear airway secretions, which is critical for safe and successful extubation.

Measurement of diaphragmatic excursion[16,17] :

Case Positioning: Cases were positioned in a semi-recumbent posture, with the head of the bed elevated between 30° and 45°, ensuring optimal positioning for ultrasound (US) imaging of the diaphragm.

US Equipment: DE was measured using a 2–5 MHz US transducer (Philips Affiniti 30 system), which is commonly employed in clinical settings for its ability to provide high-quality images.

US **Mode:** The right hemidiaphragm was thoroughly evaluated using both two-dimensional (2D) and motion mode (M-mode) imaging, which allowed for an accurate measurement of DE, reflecting the diaphragm's mobility during respiration.

Probe Placement: The US probe was strategically placed inferior to the right costal margin along the midclavicular line in a longitudinal axis. It was angled cephalad to ensure that the US beam was perpendicular to the posterior 1/3 of the right hemidiaphragm. The liver was utilized as an acoustic window to improve the quality of the imaging. The diaphragm was first visualized in 2D mode, providing a clear view of the diaphragm's movement.

Measurement Technique: In M-mode, DE was carefully quantified in centimeters by measuring the vertical displacement from the start to the end of inspiration (**Figure 1).** This technique provided precise measurements of diaphragmatic function and was an essential component of assessing the case's readiness for weaning from MV.

Calculation of RSBI [6]:

RSBI is measured after 30 minutes of SBT as the ratio of RR (f, breaths per minute) to VT (in liters).

Calculation of D-RSBI [10]:

D-RSBI is measured after 30 minutes of SBT through the ratio of RR to DE:

D-RSBI = RR (f) / DE (DE in mm)

Ethical consideration:

Written informed consents were obtained from the family members of the cases involved in the study. The investigation was conducted following approval from the Ethical Committee of the Faculty of Medicine, Benha University Hospitals.

The study was held between March 2024 and March 2025, with the approval code: Ms 18-3-2024. This approval ensured that all necessary ethical considerations were met throughout the research process.

Statistical analysis:

Statistical analysis was performed using IBM SPSS software, version 28 (IBM Corp., Armonk, NY, USA). Quantitative variables were expressed as mean values with corresponding standard deviations (SD), while qualitative variables were summarized as frequencies and percentages (%). The predictive accuracy of the D-RSBI, RSBI, and Diaphragmatic Excursion (DE) for successful weaning outcomes was evaluated using receiver operating characteristic (ROC) curve analysis. For each ROC curve, the following diagnostic parameters were measured: area under the curve (AUC), sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and the optimal cut-off point that demonstrated the highest combined sensitivity and specificity.

Results

The mean age of the cases included in the research was 55.62 ± 12.11 years, and the mean BMI was 25.6 ± 4.4 kg/m². Males comprised the majority of the cohort, representing 65% of the participants. Laboratory investigations revealed a moderate degree of anemia, with a mean Hb level of 10.9 g/dL. Urea levels were mildly elevated, while serum electrolytes (Na^+, K^+, Ca^{2+}, Mg^{2+}, PO_4^{3-}) and ABG parameters remained within normal reference ranges **(Table 1).** Among the comorbidities, the most prevalent were diabetes mellitus (DM) and hypertension (HTN), each present in 42% of the cases. Other chronic conditions observed included chronic obstructive pulmonary disease (COPD), chronic kidney disease (CKD), and ischemic heart disease (IHD) **(Figure 2).**

The cases were intubated and placed on MV due to a variety of causes, including hemodynamic instability, respiratory failure, heart failure, post-operative conditions, and neurological insult **(Figure 3).** The most common cause of MV was respiratory failure, accounting for 38.3% of the cases **(Table 2).** Among cases intubated due to neurological insult, the highest rate of successful extubation was observed, with 81.2% of these cases successfully extubated. In contrast, the lowest rate of successful extubation was exhibited among cases intubated due to heart failure, where only 33.3% of these cases were successfully extubated **(Table 3).**

After meeting the established weaning readiness criteria, cases were subjected to a SBT using pressure support ventilation mode (PSV). Of the 60 cases, 42 (70%) were successfully extubated, while 18 (30%) failed extubation.

Conventional parameters were measured 30 minutes into the SBT, including RR, VT, fraction of inspired oxygen (FiO_2), and pressure support (PS). These values were presented as means with corresponding standard deviations (SD) **(Table 4).** After 30 minutes of SBT, RSBI was measured by dividing RR by VT, DE was measured using bedside ultrasonography, and D-RSBI was determined by dividing RR by DE. All values were displayed with means and standard deviations **(Table 5).**

ROC curve analysis was employed to evaluate the predictive accuracy of D-RSBI, RSBI, and DE in determining weaning outcomes. Sensitivity, specificity, PPV, NPV, and accuracy were measured for each parameter, with optimal cut-off values identified for predicting successful and unsuccessful weaning outcomes **(Table 6).**

RSBI demonstrated a sensitivity of 88.9% and specificity of 66.7%, with an optimal cut-off value of >42.05 breaths/min/L (AUC=0.848, 95% CI: 0.749 - 0.947) for predicting weaning failure **(Figure 4).** . D-RSBI exhibited a sensitivity of 92.6% and specificity of 77.8%, with an optimal cut-off value of >2.26 breaths/min/mm (AUC=0.982, 95% CI: 0.794 - 0.989) for predicting weaning failure **(Figure 5).**.DE showed a sensitivity of 92.9% and specificity of 77.8%, with an optimal cut-off value of >9.5 mm (AUC=0.855, 95% CI: 0.733 - 0.977) for predicting weaning success. **(Figure 6).**

Table 1: Demographic data, laboratory data and comorbidities.

		Mean	SD
Age (years)		55.62	12.114
BMI		25.609	4.408
Sex	**Male**	39(65%)	
	Female	21(35%)	
Hypertension		42(70%)	
Diabetes mellites		18(70%)	
Chronic obstructive pulmonary disease		10(16.7%)	
Chronic Kidney Disease		6(10%)	
Ischemic Heart Disease		6(10%)	
hemoglobin(g/dL)		10.945	1.855
Urea (mg/dl)		46.65	0.600
Creatinine (mg/dl)		1.083	.5829
Sodium (mmol/L)		137.23	4.549
Potassium (mmol/L)		4.133	.4542
Phosphate (mmol/L)		2.520	1.0792
Magnesium (mmol/L)		1.918	.2347
Calcium (mmol/L)		4.098	.2432
PH		7.35	0.046
PaO2 (mmHg)		75.0	16.04
oxygen saturation %		95.0	3.5
PCO2(mmHg)		41.5	0.89

Data are presented as mean ± SD or number (%), BMI: Body Mass Index, PaO2: partial pressure of oxygen, PCO2: partial pressure of carbon dioxide

Table 2: Causes of invasive mechanical ventilation.

Cause of mechanical ventilation	**Number of cases**
Respiratory failure	23 (38.3%)
Neurological insult	16 (26.7%)
Hemodynamic instability	15 (25%)
Post-operative condition	15 (25%)
Heart failure	3 (5%)

Table 3: Extubation outcomes regarding different causes of mechanical ventilation.

Causes of mechanical ventilation	**Successful extubation**	**Failed extubation**
Respiratory failure	16 (69.6%)	7 (30.4%)
Hemodynamic instability	7 (46.7%)	8 (53.3%)
Heart failure	1 (33.3%)	2 (66.7%)
Post-operative condition	12 (80%)	3 (20%)
Neurological insult	13 (81.2%)	3 (18.8%)

Table 4: Conventional Parameters during SBT.

Parameter	Minimum	Maximum	Mean	SD
VT (ml)	202	589	391.45	126.344
RR (breathes per minute)	12	35	21.15	6.356
PS (cmH2O)	8	10	8.57	0.909
Fio2	40%	40%	40.00	0.000

VT: Tidal volume, RR: Respiratory rate, PS: Pressure support, FiO2: Fraction of inspired oxygen.

Table 5: Predictive indices of weaning outcome.

Predictive index	Minimum	Maximum	Mean	SD
RSBI	21.10	157.70	65.5207	41.98326
DE	5.0	19.0	12.403	4.2956
D-RSBI	.760	7.000	2.19633	1.677686

RSBI: Rapid shallow breathing index, DE: diaphragmatic excursion, D-RSBI: Diaphragmatic rapid shallow breathing index.

Table 6: Performance of predictive indices of weaning outcome.

	AUC	Cut-Off	Sensitivity	Specificity	PPV	NPV	Accuracy	CI
RSBI	0.848	42.05	88.9%	66.7%	53.3%	93.3%	73.3%	0.749- 0.947
DE	0.855	9.5	92.9%	77.8%	90.7%	82.3%	88.3%	0.733 - 0.977
D-RSBI	0.982	2.26	92.6%	77.8%	90.6%	82.3%	88.3%	0.794 - 0.989

AUC: Area under the curve, PPV: positive predictive value, NPV: Negative predictive value, RSBI: Rapid shallow breathing index, D-RSBI: Diaphragmatic rapid shallow breathing index.

Fig. (1): Diaphragmatic excursion (cm) measured using M-mode.

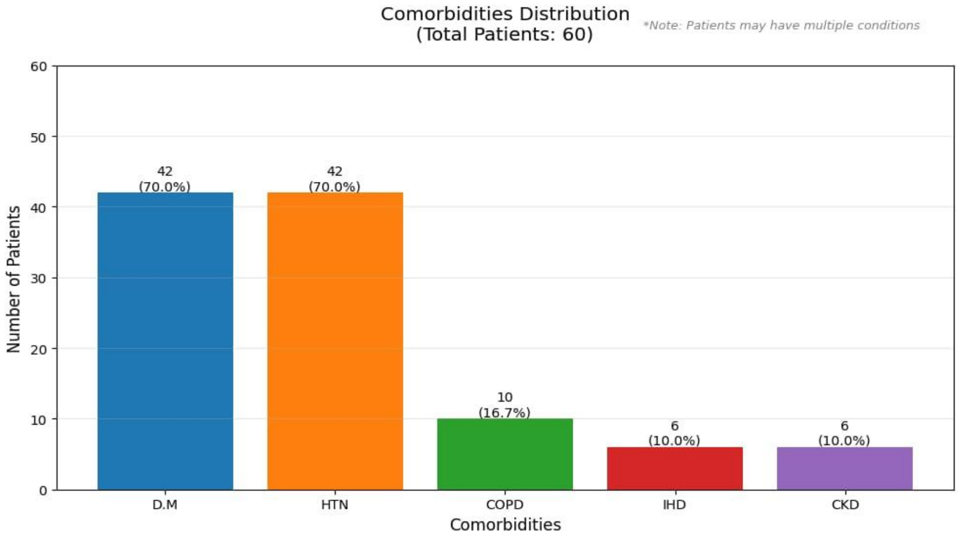

Fig. (2): Comorbidities distribution among studied cases.

HTN: Hypertension, DM: Diabetes mellites, COPD: Chronic obstructive pulmonary disease, IHD: ischemic heart disease, CKD: chroninc kidney disease.

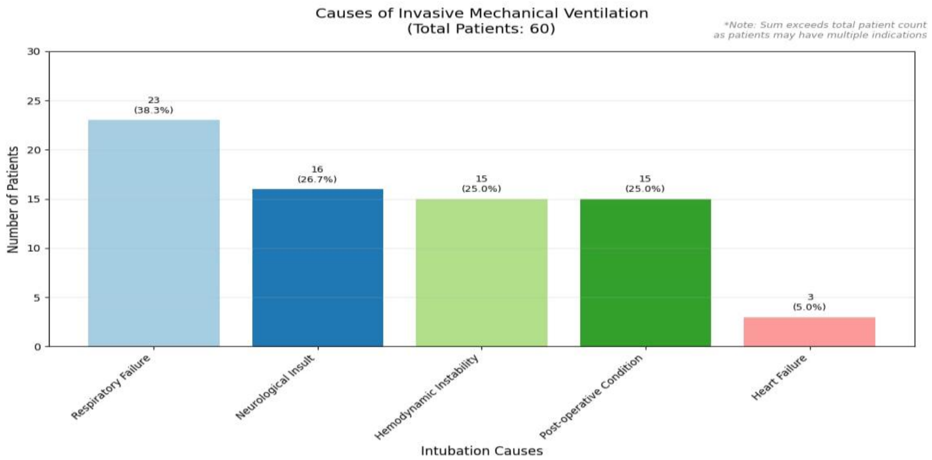

Fig. (3): Causes of invasive mechanical ventilation

RSBI and extubation success

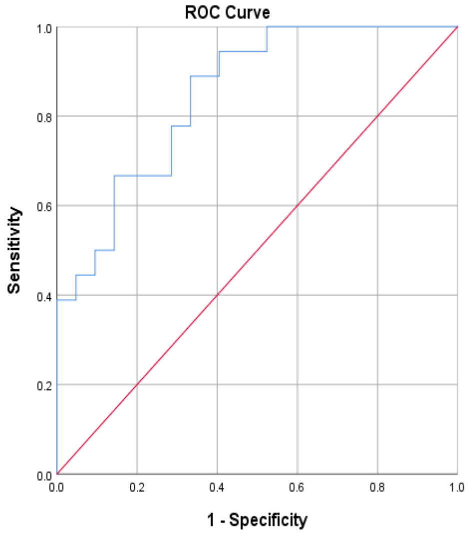

Fig. (4): ROC curve for RSBI.

RSBI: rapid shallow breathing index, ROC: receiver operator characteristic

DRSBI and extubation success

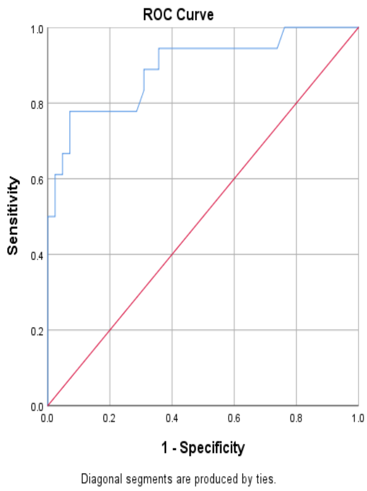

Fig. (5): ROC curve for D-RSBI.

D-RSBI: Diaphragmatic rapid shallow breathing index, ROC: Receiver operator characteristic.

DE and extubation success

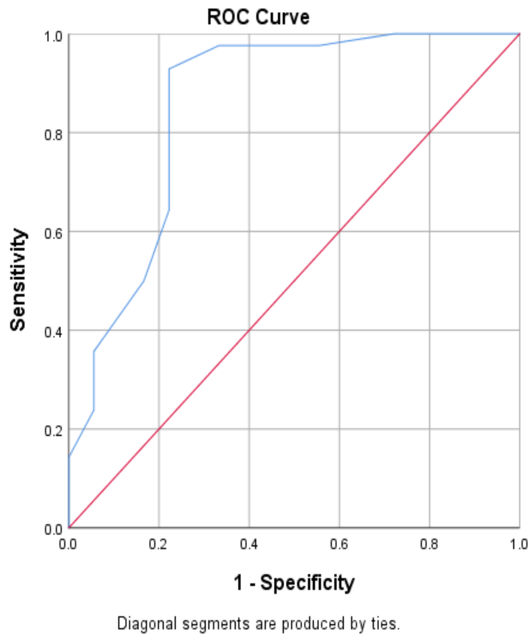

Fig. (6): ROC curve for DE.

DE: Diaphragmatic excursion, ROC: Receiver operator characteristic.

Discussion:

RSBI, initially introduced by Yang and Tobin in 1991[6], has been widely employed to predict weaning outcomes in MV cases. In their preliminary study, RSBI was measured by dividing RR by VT during SBT. A threshold of 105 breaths/min/L was proposed, demonstrating an impressive sensitivity of 97% and specificity of 64% in predicting weaning failure. This early research established the fundamental framework for the application of RSBI, which continues to be widely employed in numerous medical settings.

In the current study, however, RSBI values exhibited significant and notable differences from the preliminary reference. The mean RSBI in cases successfully extubated was 50.77 ± 31.20 breaths/min/L, while those who failed extubation showed a markedly elevated mean RSBI of 95.44 ± 39.5 breaths/min/L. The optimal cut-off value identified in this research was 42.05 breaths/min/L, yielding a sensitivity of 88.9% and specificity of 66.7%, with an AUC of 0.848 (95% CI: 0.749–0.947). These differences can likely be attributed to various factors, such as variations in case populations, ventilator settings, underlying pathologies, body position, and variations in the size of the ETT, all of which could potentially influence the RSBI and its predictive capacity. This complexity further underscores the challenge of relying solely on this metric to predict weaning outcomes [18,19,20,21].

Consistent with our findings, a number of other studies conducted in different clinical contexts have exhibited lower RSBI predictive values compared to those preliminarly suggested by Yang and Tobin, which supports the relevance of our observations. In the research conducted by Zaytoun and co-authors [22], the mean RSBI for cases who were successfully extubated was 55.5 ± 11.15 breaths/min/L, while those who failed extubation showed a significantly elevated mean RSBI of 86.3

± 19.18 breaths/min/L. They proposed a cut-off value of RSBI < 65 breaths/min/L for predicting successful weaning, with an AUC of 0.883 (95% CI: 0.788–0.978).for predicting successful weaning, with an AUC of 0.883 (95% CI: 0.788–0.978).

Shamil and co-authors [23] identified an RSBI cut-off value of 45.72 breaths/min/L in their work. Additionally, Fan and co-authors [24] exhibited that RSBI values for cases successfully extubated (44.91 ± 14.51 breaths/min/L) were significantly lower than those for cases who failed extubation (61.70 ± 25.00 breaths/min/L).

Furthermore, Fan and co-authors [24] highlighted the importance of a critical threshold of RSBI at 57 breaths/min/L, noting that when RSBI exceeded this value, the risk of reintubation rose from 11% to 18%. This finding further underscores the clinical utility of RSBI in predicting reintubation risk and making informed decisions during the weaning process.

Frutos-Vivar and co-authors [25] identified an RSBI threshold of 57 breaths/min/mL, noting that the risk of reintubation significantly increased from 11% to 18% when RSBI exceeded this threshold, further underlining the potential of RSBI as a critical indicator in weaning assessment. Similarly, Lai and co-authors [26] exhibited that an RSBI value of 68 breaths/min/mL emerged as the most accurate predictor of extubation failure based on their comprehensive ROC analysis.

Despite its widespread use and broad application in clinical settings, RSBI has several important limitations that need to be carefully considered. It has been exhibited in various studies that RSBI may not be a reliable predictor in cases whose primary weaning challenges are not related to respiratory rate or tidal volume but are instead linked to ineffective cough, excessive secretions, or impaired airway protection [8,27].

Moreover, RSBI does not directly assess the respiratory muscles capacity, particularly the diaphragm, which plays a critical and essential role in the weaning process. Diaphragmatic dysfunction is a significant contributor to failure of weaning, and the early identification of such dysfunction is vital to prevent potential extubation failure. This gap in predictive capability highlights the need for more nuanced assessments that consider muscle strength and function during the weaning process.

To address these limitations, Spadaro and co-authors. [10] Introduced the D-RSBI, a modified index in which the VT in the preliminary RSBI formula is replaced by DE, also referred to as diaphragmatic displacement (DD). This new parameter, the D-RSBI, was proposed with the intent to improve predictive accuracy over the conventional RSBI, particularly in cases who may present with issues not accounted for by the preliminary formula. Their investigation demonstrated that D-RSBI had a remarkably high sensitivity of 94.1% and a specificity of 64.7% for predicting weaning failure, with an optimal cut-off value greater than 1.3 breaths/min/mm. Additionally, the AUC for D-RSBI (0.89) was significantly elevated than that for RSBI (0.72), with a p-value of 0.006, indicating the superior predictive value of D-RSBI in evaluating weaning outcomes. This finding suggests that D-RSBI may offer a more reliable and accurate assessment tool, particularly for cases at elevated risk of extubation failure due to diaphragmatic dysfunction.

D-RSBI was exhibited to have a sensitivity of 94.1% and a specificity of 64.7% for predicting weaning failure, with an optimal cut-off value of > 1.3 breaths/min/mm. The area AUC for D-RSBI (0.89) was significantly greater than that of RSBI (0.72), with a p-value of 0.006, indicating the superior predictive accuracy and value of D-RSBI in accurately predicting weaning outcomes, as demonstrated by Spadaro and co-authors [10].

In concordance with these previous findings, our results demonstrated that D-RSBI indeed outperformed RSBI in predicting weaning failure, further substantiating its clinical relevance and potential as a valuable diagnostic tool. Specifically, at a cut-off value of > 2.26 breaths/min/mm, D-RSBI exhibited an exceptional AUC of 0.982 (95% CI: 0.794–0.989), with a sensitivity of 92.6%, specificity of 77.8%, and overall accuracy of 88.3%. This indicates a highly accurate predictive model for determining weaning outcomes, with robust performance in identifying those at risk for failure. In comparison, RSBI at a cut-off value > 42.05 breaths/min/L yielded a sensitivity of 88.9%, specificity of 66.7%, and overall accuracy of 73.3%, which, while informative, were notably lower than the D-RSBI values. Moreover, the AUC of D-RSBI was significantly elevated than that of RSBI (0.982 vs. 0.848).

These findings are consistent with those of Mowafy and co-authors [28], who observed that after 30 minutes of SBT, the AUC for D-RSBI was significantly greater than that for RSBI (0.979 vs. 0.891), highlighting the superior predictive power of D-RSBI. In addition to the elevated AUC, D-RSBI demonstrated considerably better sensitivity and specificity, with values of 97.3% and 93.9%, respectively, compared to the more modest 83.6% and 69.7% for RSBI. These results further underscore the advantages of D-RSBI over RSBI in accurately predicting weaning outcomes, particularly in identifying cases at risk for extubation failure.

Similarly, Shamil and co-authors [23] exhibited an elevated AUC for D-RSBI compared to RSBI (0.97 vs. 0.70), reinforcing the growing body of evidence supporting the superior performance of D-RSBI as a predictive tool in clinical settings. This further verifies D-RSBI's potential for providing more reliable and accurate assessments, offering clinicians a more effective means of evaluating cases during the weaning process and improving overall case care outcomes.

In contrast to the preliminary findings exhibited by Spadaro and co-authors [10], our investigation demonstrated a elevated D-RSBI cut-off value of > 2.26 breaths/min/mm. This discrepancy may be attributed to several important factors, including differences in the study populations, variations in case characteristics, and the methodology employed for conducting the SBT. Specifically, in our study, SBT was performed using a pressure support ventilation (PSV) trial, which may have influenced the results. In contrast, Spadaro and co-authors [10] employed spontaneous ventilation through a T-tube circuit, a method that could yield different predictive outcomes.

Supporting our findings, several other studies have also exhibited elevated D-RSBI cut-off values than those observed in the preliminary research [10], as in the investigation done by Shamil and co-authors [23], they identified a D-RSBI cut-off value of 1.767 breaths/min/mm, which was elevated than the preliminary value proposed by Spadaro et al. Similarly, in the research by Abbas and co-authors [29], they exhibited that a D-RSBI cut-off value of > 1.9 breaths/min/mm was indicative of an increased risk for weaning failure, further corroborating the notion that cut-off values for D-RSBI may vary depending on the clinical context and methodology employed. These findings emphasize the need for continued research to refine and adapt D-RSBI thresholds based on specific case populations and ventilation strategies.

In addition to evaluating D-RSBI, our investigation also assessed the predictive value of DE as an independent index for weaning outcome. We observed that DE had a sensitivity of 92.9% and specificity of 77.8%, with an optimal cut-off value of > 9.5 mm for predicting successful weaning (AUC = 0.855; 95% CI: 0.733–0.977). These findings suggest that DE offers superior predictive performance compared to RSBI alone.

In agreement to our results, Fan and co-authors [24] exhibited that the AUC for DE of 0.830, D-RSBI of 0.851, and RSBI of 0.711, with both DE and D-RSBI demonstrating superior predictive performance when compared to RSBI. The cut-off value for DE in their research was identified as 11.15 mm, further supporting the utility of DE as a reliable indicator for predicting weaning outcomes

Similarly, in the research by Abbas and co-authors [29] it was exhibited that DE with a cut-off value of < 12 mm for predicting weaning failure exhibited significantly elevated sensitivity, specificity, and AUC compared to RSBI (92.3%, 91.9%, and 0.975 vs. 69.2%, 61.2%, and 0.669, respectively). These results emphasize the superiority of DE as a predictive tool, especially in comparison to RSBI, and suggest that DE may offer more accurate assessments in predicting weaning failure.

Also, Flevari and co-authors [30] exhibited that a cut-off value of DE for the right hemi-diaphragm of 10 millimeters was most effective for predicting successful weaning, which aligns with the growing body of evidence suggesting that DE is a key parameter in assessing respiratory muscle function during weaning.

Limitations:

Ultrasonographic measurement of DE is highly operator-dependent, with the variability in probe placement, case anatomy, and sonographer experience can lead to inconsistent results, also no established threshold or standardized protocol for D-RSBI has yet been validated in the different populations exhibited within the ICU. Different studies have proposed different cut-off values for D-RSBI. In adittion to the previous limitations, there is shortage of trained personnel.

Conclusion:

The application of D-RSBI for guiding the decision on a case's weaning from MV demonstrates superior predictive performance and accuracy compared to the traditional RSBI in forecasting weaning outcomes. A cut-off value of 2.26 mm is linked to the highest diagnostic accuracy.

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