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Diaphragm Thickening Fraction vs Rapid Shallow Breathing Index in Predicting Weaning Success: A Prospective Diagnostic Study

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Abstract

Introduction: Weaning from mechanical ventilation is a critical step in intensive care, and inaccurate assessment may increase the risk of complications. The rapid shallow breathing index (RSBI) is widely used to evaluate weaning readiness but does not directly assess diaphragmatic function. Diaphragm thickening fraction (DTF), measured by bedside ultrasound, has been proposed as an additional predictor of weaning success. This study aimed to compare the diagnostic performance of DTF and RSBI in mechanically ventilated ICU patients.

Patients and Methods: This prospective diagnostic accuracy study was conducted in a tertiary hospital in Denpasar, Indonesia, from September to December 2022, in accordance with STARD 2015 guidelines. Adult patients aged 18–65 years who received invasive mechanical ventilation for >24 hours and were considered ready for weaning were included. RSBI and right-sided DTF were measured at the fifth minute of a spontaneous breathing trial. Weaning success was defined as extubation without reintubation, noninvasive ventilation, or death within 48 hours.

Results: Fifty-six patients were included, of whom 73.2% achieved successful weaning. DTF demonstrated high sensitivity (95.4%) and moderate specificity (75.0%), with a positive predictive value of 93.3% and a negative predictive value of 81.8%. RSBI showed sensitivity of 97.5% and specificity of 80.0%, with higher discriminative performance (AUC 0.88 vs 0.79). Confidence intervals and statistical comparisons between AUCs were not performed.

Conclusion: Both RSBI and DTF were associated with weaning success. RSBI demonstrated superior overall diagnostic performance and remains the primary assessment tool. DTF may provide additional physiological information on diaphragmatic function and serve as a complementary parameter during weaning assessment.

Keywords: Diaphragm; Intensive Care Units; Mechanical Ventilation; Ultrasonography; Ventilator Weaning

Introduction

Weaning from mechanical ventilation is a critical component of the care of critically ill patients and is often challenging in the intensive care unit. A substantial proportion of the total duration of mechanical ventilation is spent during the weaning phase, and inappropriate timing may adversely affect patient outcomes. Premature extubation can lead to respiratory muscle fatigue and the need for reintubation. Conversely, delayed weaning increases the risk of ventilator-associated pneumonia, prolonged ICU stay, and higher mortality.[1,2] Therefore, identifying patients who are likely to achieve successful weaning is essential.

The Rapid Shallow Breathing Index (RSBI) is widely used to assess readiness for weaning. An RSBI value of <105 breaths/min/L is generally considered predictive of successful weaning.[3]

However, RSBI has several limitations. It does not directly assess diaphragm function, which plays a crucial role in spontaneous breathing. In addition, RSBI may be influenced by factors such as fever, sepsis, anxiety, patient positioning, and airway resistance, potentially reducing its accuracy in certain clinical conditions. [4,5]

Diaphragm dysfunction is common in patients receiving mechanical ventilation and represents a major cause of weaning failure. Recently, diaphragm ultrasound has emerged as a bedside, noninvasive method for evaluating diaphragm function. One parameter, diaphragm thickening fraction (DTF), reflects diaphragmatic contraction during inspiration and has shown potential in predicting weaning outcomes.[6] However, reported cutoff values for DTF vary considerably, and its diagnostic accuracy remains inconsistent. Previous studies have reported heterogeneous cutoff values, ranging from approximately 20% to 40%, likely due to differences in patient populations, ventilator settings, and ultrasound techniques. Furthermore, data from Indonesian or regional ICU populations remain limited, where patient characteristics and clinical practices may differ.

Therefore, this study aimed to compare diaphragm thickening fraction and rapid shallow breathing index in predicting weaning success in mechanically ventilated adult ICU patients. In addition, this study sought to identify an optimal cutoff value for diaphragm thickening fraction and to evaluate whether DTF could serve as an adjunct to RSBI during weaning assessment. We hypothesized that RSBI would demonstrate superior overall diagnostic performance, while DTF would provide additional physiological information as a complementary parameter in predicting weaning success.

Patients and Methods

This was a prospective diagnostic accuracy study conducted in a tertiary hospital in Denpasar, Indonesia, between September and December 2022. The study was reported in accordance with the STARD 2015 guidelines for diagnostic accuracy studies. Ethical approval was obtained from the Institutional Ethics Committee of the Faculty of Medicine, Universitas Udayana and RSUP Prof. Dr. I.G.N.G. Ngoerah (No. 2887/UN14.2.2.VII.14/LT/2022, issued in 2022). Written informed consent was obtained from all patients or their legal representatives prior to enrollment. A formal sample size calculation was not performed. The sample size was

determined based on consecutive eligible patients during the study period.

Furthermore, a journal article is not similar to textbook writing or thesis report. That implies that authors should follow the design-specific guidelines that are presented on our website (i.e., clinical trials should follow CONSORT checklist, observational studies should follow STROBE checklist, etc.).

Adult patients receiving invasive mechanical ventilation and undergoing the weaning process in the ICU were screened for eligibility. Inclusion criteria were age 18–65 years, duration of mechanical ventilation >24 hours, and readiness for weaning based on routine clinical assessment by the attending intensivist. Attending clinicians were not blinded to patient condition as part of standard care. Patients were excluded if they had known diaphragmatic disease, neuromuscular disorders, prior diaphragmatic weakness, phrenic nerve palsy, open wounds or recent surgery at the ultrasound probe placement site, or other conditions that could interfere with diaphragm ultrasound assessment. Ultrasound examinations were performed by a trained operator experienced in bedside diaphragm ultrasonography who was not involved in clinical decision-making; however, full blinding to RSBI values and clinical outcomes was not implemented, and intra- and interobserver variability were not formally assessed.

All included patients underwent a spontaneous breathing trial (SBT) according to standard ICU protocol. At the fifth minute of the SBT, the rapid shallow breathing index (RSBI) and diaphragm thickening fraction (DTF) were measured simultaneously. RSBI was calculated as the ratio of respiratory rate to tidal volume (breaths/min/L), using a cutoff value of <105 breaths/min/L to predict weaning success. Diaphragm ultrasound was performed on the right hemidiaphragm using a high-frequency linear transducer placed at the zone of apposition. Diaphragm thickness was measured at end-expiration and end-inspiration, and DTF was calculated as follows: DTF (%) = [(thickness at end-inspiration − thickness at end-expiration) / thickness at end-expiration] × 100.

An initial cutoff value of DTF ≥26% was applied based on previous literature. The reference standard was the clinical outcome of weaning. Weaning success was defined as successful extubation without the need for reintubation, noninvasive ventilation, or death within 48 hours after extubation. Patients requiring ventilatory support or reintubation within this period were classified as weaning failure.

Statistical analysis was performed using STATA software. Categorical variables are presented as frequencies and percentages. Diagnostic accuracy of RSBI and DTF was assessed by calculating sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy. Receiver operating characteristic (ROC) curve analysis was used to determine the area under the curve (AUC) and to identify the optimal cutoff value for diaphragm thickening fraction. A p-value <0.05 was considered statistically significant.

Results

A total of 56 patients receiving mechanical ventilation and undergoing the weaning process were included in the analysis. The study population consisted of equal numbers of male and female patients (28 each). Successful weaning was achieved in 41 patients (73.2%), while 15 patients

(26.8%) experienced weaning failure within 48 hours after extubation. No significant difference in sex distribution was observed between patients with successful weaning and those with weaning failure.

Table 1. Diagnostic Test of the Diaphragm Thickening Fraction

		Weaning Success		Total
		Success	Failure	
DTF(%)	≥ 26%	38	4	42
	< 26%	3	11	14
Total		41	15	56

The diagnostic performance of diaphragm thickening fraction (DTF) for predicting weaning success is presented in Table 1. Using a cutoff value of ≥26%, DTF demonstrated a sensitivity of 95.4% and a specificity of 75.0%. The positive predictive value was 93.3%, and the negative predictive value was 81.8%, resulting in an overall diagnostic accuracy of 91.0%.

Receiver operating characteristic (ROC) curve analysis showed an area under the curve (AUC) of 0.79, indicating good discriminative ability. Further analysis identified a higher cutoff value of ≥33% as the optimal threshold, providing a better balance between sensitivity and specificity for predicting successful weaning (Table 2 and Figure 2).

Table 2. Optimal Cutoff Value of Diaphragm Thickening Fraction

Cutoff (%)	Sensitivity	Specificity
≥ 26	95.4%	75.0%
≥ 33	95.5%	100.0%

The diagnostic performance of the rapid shallow breathing index (RSBI) is summarized in Table 2. Using a cutoff value of <105 breaths/min/L, RSBI demonstrated a sensitivity of 97.5% and a specificity of 80.0%. The positive predictive value and negative predictive value were 93.0% and 92.3%, respectively, with an overall diagnostic accuracy of 92.0%. ROC curve analysis demonstrated an AUC of 0.88 for RSBI, indicating superior discriminative performance compared with DTF (Figure 1).

Comparative ROC analysis showed that RSBI had a higher AUC than DTF (0.88 vs 0.79), suggesting better overall diagnostic performance. However, the statistical significance of the difference between AUC values was not evaluated (e.g., using the DeLong test), and confidence intervals for AUC were not calculated.

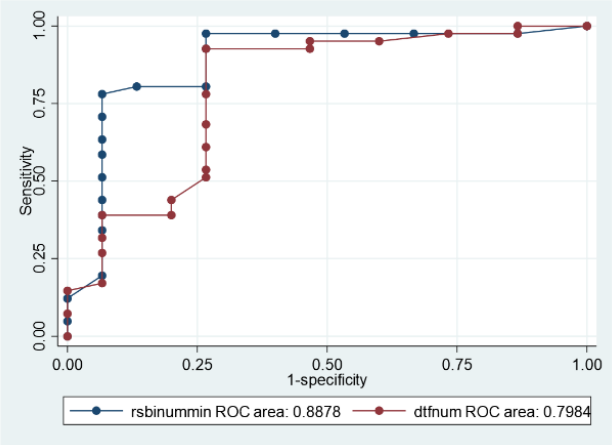

Figure 1. ROC Graph of RSBI and DTF

Discussion

This study aimed to evaluate the diagnostic accuracy of diaphragm thickening fraction (DTF) compared with the rapid shallow breathing index (RSBI) in predicting weaning success in mechanically ventilated ICU patients. The main findings indicate that both parameters demonstrated high sensitivity and acceptable diagnostic accuracy. RSBI showed superior overall discriminative ability, as reflected by a higher area under the ROC curve, whereas DTF may serve as a clinically useful adjunct in assessing readiness for weaning.

In this study, most patients were successfully weaned, and no significant difference in sex distribution was observed between the successful and failed weaning groups. These findings are consistent with previous reports suggesting that demographic factors alone have limited predictive value for weaning outcomes. Variations in weaning success rates across studies may be attributable to differences in patient characteristics, duration of mechanical ventilation, and local weaning protocols.[7]

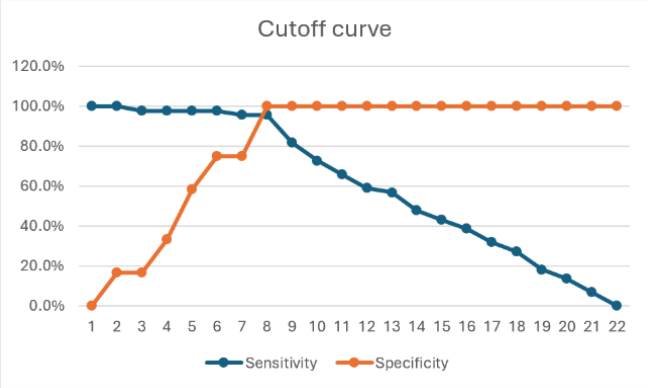

Figure 2. Cutoff Curve of RSBI and DTF

RSBI is widely used as a simple and sensitive predictor of weaning success, and its performance in the present study is consistent with previous studies.[4,5] The high sensitivity and relatively high AUC observed support its role as a primary screening tool in routine ICU practice. However, RSBI may be influenced by non-respiratory factors such as fever, sepsis, anxiety, and patient positioning, which may reduce its reliability in certain clinical settings.[4] These limitations underscore the need for complementary tools that more directly assess respiratory mechanics.

Diaphragm ultrasound has increasingly been used to evaluate respiratory muscle function at the bedside. In this study, DTF demonstrated high sensitivity and good diagnostic accuracy, consistent with previous observational studies.[6,8] The optimal cutoff value identified (≥33%) suggests that greater diaphragmatic contraction is associated with successful spontaneous breathing. Variability in reported cutoff values across studies may be explained by heterogeneity in patient populations, ventilator settings, and ultrasound measurement techniques.[9,10] The novelty of this study lies in the direct comparison of DTF and RSBI within the same patient population during the weaning process, highlighting the role of DTF as an adjunct rather than a replacement for RSBI. Although RSBI demonstrated superior overall diagnostic performance, DTF provides additional physiological insight by directly reflecting diaphragm function, which is often impaired in critically ill patients after prolonged mechanical ventilation. Previous studies have suggested that combining diaphragm ultrasound parameters with conventional indices may improve clinical decision-making, particularly when RSBI results are inconclusive.[11,12] The findings of this study support the role of DTF as a complementary tool to enhance weaning assessment in selected patients.

The relatively lower discriminative performance of DTF compared with RSBI observed in this study may be explained by several physiological factors. Although DTF directly reflects diaphragmatic contractility, it is influenced by patient effort during spontaneous breathing trials, ventilatory support settings, and measurement variability. In contrast, RSBI integrates respiratory rate and tidal volume, thereby indirectly reflecting the balance between respiratory load and muscle capacity.

From a practical perspective, diaphragm ultrasound requires operator expertise, specialized equipment, and additional time compared with RSBI, which may limit its

routine use in all ICU settings. However, DTF may be particularly useful in selected patients in whom RSBI results are inconclusive or when diaphragmatic dysfunction is suspected. The optimal cutoff value identified in this study (≥33%) was derived from the same dataset and may therefore be subject to overfitting; external validation in larger and more diverse populations is warranted before clinical implementation.

Several limitations should be acknowledged. The absence of a formal sample size calculation may limit statistical power, particularly for comparisons between diagnostic parameters. Although ultrasound measurements were performed by an operator not involved in clinical decision-making, incomplete blinding may introduce observational bias. In addition, subgroup analyses based on underlying diagnoses were not performed. Larger multicenter studies with standardized ultrasound protocols are needed to better define the role of diaphragm thickening fraction in predicting weaning outcomes. Furthermore, detailed data on causes of weaning failure, such as indications for reintubation or causes of mortality, were not systematically collected. The lack of comprehensive baseline clinical characteristics, including severity scores (e.g., APACHE II or SOFA) and primary diagnoses, limits the assessment of potential confounding factors.

Conclusion

Both diaphragm thickening fraction and the rapid shallow breathing index demonstrated high sensitivity and acceptable diagnostic accuracy for predicting weaning success in mechanically ventilated ICU patients. RSBI showed superior overall discriminative performance and remains a practical primary tool for routine weaning assessment.

Nevertheless, diaphragm thickening fraction provides additional physiological insight by directly assessing diaphragm function and may serve as a complementary parameter, particularly when the reliability of RSBI is limited.

Further multicenter studies with larger patient populations and standardized ultrasound protocols are needed to clarify the role of diaphragm ultrasound as an adjunct in weaning prediction. The optimal cutoff value identified in this study requires external validation before widespread clinical application.

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Conflict of Interest

The author(s) report no conflict of interest.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Author's Contributions

Conceptualization: IGNMA, DASD. Methodology: IGNMA, DASD, and DT. Investigation: DT. Data curation: DT. Formal analysis: DT. Writing – original draft: DT. Writing – review & editing: IGNMA, DASD, and DT. Supervision: IGNMA. All authors approved the final manuscript.

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