Section: Miscellaneous



Original Research Article

# EVALUATION OF DIAPHRAGMATIC THICKNESS FRACTION (DTF) COMBINED WITH RAPID SHALLOW BREATHING INDEX (RSBI) FOR PREDICTING EXTUBATION OUTCOMES IN MECHANICALLY VENTILATED PATIENTS: A PILOT STUDY FROM A TERTIARY CARE ICU

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## ABSTRACT

**Background:** In the intensive care unit, accurate extubation result prediction lowers morbidity and resource use. Although commonly used, the Rapid Shallow Breathing Index (RSBI) does not directly evaluate diaphragmatic function. Diaphragmatic contractility can be measured dynamically and non-invasively using point-of-care ultrasound's Diaphragmatic Thickness Fraction (DTF). This pilot study assessed whether DTF alone or in conjunction with RSBI enhances extubation success prediction. **Materials and Methods:** Between December 2024 and January 2025, a prospective observational pilot study was conducted in the intensive care unit of Kovai Medical Centre and Hospital – Institute of Health Sciences and Research (KMCH–IHSR), Coimbatore, Tamil Nadu, India. The study included thirty-one adult intubated patients on invasive mechanical ventilation. Using a high-frequency linear ultrasound probe, diaphragmatic thickness was measured every day from the day of intubation to the day of extubation, at end-expiration and end-inspiration at the zone of apposition. The formula for calculating the diaphragmatic thickening fraction (DTF) was DTF = [(Tinsp − Texp) / Texp] × 100. During the SBT, the rapid shallow breathing index (RSBI) was measured. Patients were classified as either successfully extubated (no reintubation within 48 hours) or unsuccessfully extubated (reintubation within 48 hours). The Friedman test for repeated measures, receiver operating characteristic (ROC) curve analysis with area under the curve (AUC), and independent t-test were used for statistical analysis. Statistical significance was defined as a p-value of less than 0.05. **Results:** Within 48 hours, 26 (83.9%) of the 31 patients were successfully extubated, while 5 (16.1%) were reintubated. The success group's mean RSBI (59.5 ± 22.8) was significantly lower than the failure group's (125 ± 45.2, $p < 0.001$). Right DTF was significantly higher in patients who were successfully extubated (23.5 ± 8.1%) compared with those who failed (6.9 ± 3.4%; $p < 0.001$), and a similar trend was observed on the left side (19.7 ± 6.4% vs 10.5 ± 4.8%; $p = 0.005$). The combined DTF (mean of both sides) showed moderate predictive accuracy (AUC = 0.708; $p = 0.08$). Adding DTF to RSBI did not significantly strengthen predictive ability (AUC = 0.71; $p = 0.94$). Serial measurements showed significant day-to-day changes in diaphragm thickness (Friedman $\chi^2 = 87.9$; $p < 0.001$). Over the weaning period, right-sided values showed a progressive decrease, while left-sided values increased, indicating variability in diaphragm behaviour during recovery. Diaphragmatic thickening recorded during the SBT was higher in the success group, suggesting better

tolerance of unsupported breathing. **Conclusion:** RSBI remains a dependable bedside predictor of extubation success, while ultrasound-derived diaphragmatic thickening fraction offers additional physiological assessment, particularly when measured serially and during the spontaneous breathing trial. Although combining DTF with RSBI did not improve predictive accuracy in this small cohort, DTF alone showed meaningful association with extubation outcomes. Larger multicentre studies are needed to show standardized thresholds and confirm its role in routine weaning evaluation.

## INTRODUCTION

Weaning from mechanical ventilation and timely extubation are essential components of critical care management. Failed extubation leads to reintubation, increased incidence of ventilator-associated complications, prolonged ICU stay, and higher mortality. Conversely, premature extubation may result in respiratory failure and need for emergent airway intervention. Therefore, correct bedside predictors that reflect the patient's ventilatory capacity and respiratory muscle function are valuable.

The Rapid Shallow Breathing Index (RSBI), calculated as respiratory rate divided by tidal volume (breaths/min/L), is a widely used predictor of weaning success due to its simplicity and reproducibility.[1,2] However, RSBI evaluates ventilatory pattern rather than specific respiratory muscle performance, and may be influenced by factors such as sedation, metabolic state, and patient cooperation.

The diaphragm is the principal muscle of inspiration and a major determinant of weaning success. Prolonged mechanical ventilation causes diaphragmatic disuse atrophy and dysfunction, termed ventilator-induced diaphragmatic dysfunction (VIDD).[3,4] Diaphragm ultrasound is an accessible point-of-care tool for assessing diaphragmatic structure and function, including diaphragm excursion and diaphragmatic thickness fraction (DTF). DTF, defined as the percentage increase in diaphragmatic thickness from end-expiration to end-inspiration, correlates with diaphragmatic contractile activity and has been studied as a predictor of extubation outcomes.[5-9]

Evidence to date is mixed, some studies report that DTF reliably predicts extubation success, while others find limited incremental benefit when added to conventional indices. Furthermore, interindividual variability, differing measurement protocols, and small sample sizes limit broad generalizability. This prospective pilot study aims to evaluate the predictive accuracy of DTF measured by ultrasound, both alone and combined with RSBI, for extubation outcomes in a tertiary-care intensive care unit.

## MATERIALS AND METHODS

**Study design and setting:** This prospective observational pilot study was conducted in the adult intensive care unit of KMCH–IHSR, Coimbatore, India between December 2024 and January 2025. The institutional ethics committee approved the study (Approval No. 63/IHEC/2024; Date: 5.11.24.), and written informed consent was obtained from patients or their legal surrogates.

**Inclusion Criteria:** Adult patients (age≥ 18 years) who had been mechanically ventilated were eligible.

**Exclusion Criteria:** Known diaphragmatic paralysis, neuromuscular disease, pregnancy, and inability to obtain adequate sonographic images included.

**Ultrasound Protocol:** Diaphragmatic thickness measurements were performed using a point-of-care ultrasound machine with a linear probe (7–12 MHz). The diaphragm was visualized in the zone of apposition at the anterior or mid-axillary line. Thickness measurements were taken at end-expiration (Texp) and end-inspiration (Tinsp) over three consecutive respiratory cycles, and the mean values recorded. DTF was calculated as DTF (%) = [(Tinsp − Texp)/Texp] × 100. Daily measurements were taken bilaterally. Trained single operators performed all ultrasound measurements to minimize interobserver variability.

**RSBI and clinical assessment:** RSBI was calculated as respiratory rate divided by tidal volume in liters. Standardized criteria for readiness to extubate were followed, including adequate oxygenation, hemodynamic stability, and proper mentation. All patients underwent an SBT as part of routine weaning protocol. The SBT outcome was documented as pass or fail based on clinical tolerance (absence of respiratory distress, stable vital signs, and acceptable gas exchange). However, SBT failure was not used as an absolute contraindication to extubation; in selected cases, extubation proceeded based on overall clinical judgment.

**Outcome measures**: The primary outcome was extubation success, defined as the patient being still free from invasive ventilatory support for at least 48 hours post-extubation. Extubation failure was defined as reintubation within 48 hours of extubation for respiratory failure, hypoxemia, or hypercapnia.

**Statistical Analysis:** Data was analyzed using SPSS v25. Continuous variables were reported as mean ± standard deviation (SD) or median (IQR) as proper,


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categorical variables as counts and percentages. Independent-samples t-tests compared continuous variables between groups. Receiver operating characteristic (ROC) curves were generated to calculate area under the curve (AUC) for DTF, RSBI, and combined indices. Repeated measures analyses were performed using the Friedman test for day-to-day DTF changes. A p-value < 0.05 was considered statistically significant.

## RESULTS

A total of 31 mechanically ventilated patients were enrolled, of whom 26 (83.9%) were successfully extubated and 5 (16.1%) failed and required reintubation. Baseline demographic and clinical parameters, including age, sex, and comorbidities, were comparable between the two groups. However, patients in the failure group had a significantly longer duration of mechanical ventilation (10.1 ± 3.4 vs 7.2 ± 2.5 days, p = 0.04), longer ICU stay (12.0 ± 3.5 vs 9.1 ± 3.0 days, p = 0.03), and total hospital stay was increased in failure group (16.8 ± 4.6 vs 13.2 ± 3.8 days, p = 0.02). These findings suggest delayed recovery and prolonged ventilatory dependence among patients with extubation failure, consistent with the adverse physiological effects of extended mechanical ventilation (3).

The Rapid Shallow Breathing Index (RSBI) was significantly lower in the successful group (59.5 ± 22.8) compared to the failure group (125 ± 45.2, p < 0.001). ROC curve analysis demonstrated an AUC of 0.87 (95% CI: 0.72–0.98) with a sensitivity of 88.5% and specificity of 80.0%, confirming that lower RSBI values are predictive of successful weaning, in line with the foundational studies by Yang and Tobin (2) and Ely et al. (1).

Ultrasound-derived diaphragmatic thickening fraction (DTF) showed superior predictive performance. The right DTF was significantly higher among successfully extubated patients (23.5 ± 8.1%) than in those who failed (6.9 ± 3.4%, p < 0.001), with an AUC of 0.91. The left DTF was also higher in successfully extubated patients (19.7 ± 6.4% than those in failed (10.4 ± 4.8%), with an AUC of 0.83, showing good discriminative power. Mean combined DTF showed moderate accuracy (AUC = 0.71, p = 0.08). These results align with earlier work showing DTF as a robust and reliable indicator of diaphragmatic function (4–7, 11).

When diaphragmatic thickening fraction values recorded during the spontaneous breathing trial (SBT) were analyzed, patients who were successfully extubated showed significantly higher DTF values (mean 24.73%) compared with those who later failed extubation (mean 15.45%; p = 0.012). Because these measurements were taken during minimal ventilatory support rather than controlled ventilation, they are true diaphragm effort during spontaneous breathing, suggesting that stronger diaphragmatic performance during the SBT is associated with a higher likelihood of extubation success.

When RSBI and DTF were analyzed together, there was no improvement in predictive accuracy compared to either parameter alone (AUC = 0.71, p = 0.94), likely reflecting the small sample size and overlap between the two measures, which is consistent with findings reported by Smargiassi et al. (8). Serial assessment showed significant variation in diaphragm behavior over the weaning period (Friedman $\chi^2$ = 87.9, p < 0.001). Over repeated recordings, a gradual decrease in right sided DTF (approximately 32% reduction from ~34% to ~23%, p < 0.001) and a gradual increase on the left side (approximately 25% rise from ~35% to ~44%, p < 0.001) were observed. Although the mechanism for this asymmetry cannot be decided from this pilot dataset, the results suggest that diaphragm performance during weaning may not change uniformly between hemidiaphragms."

**Table 1: Baseline Demographic and Clinical Characteristics (n = 31)**

| Characteristics | Mean ± SD / n (%) |
|---|---|
| AGE(YEARS) | 56 ± 11 |
| < 45 | 5(16) |
| 45-54 | 8(26) |
| 55-64 | 9(29) |
| >65 | 9(29) |
| GENDER | |
| Male | 18(58.1) |
| Female | 13(41.9) |
| COMORBIDITY | |
| No Comorbidity | 10 (32.3) |
| Diabetes | 8 (25.8) |
| Hypertension | 7 (22.6) |
| Chronic kidney disease | 3 (9.7) |
| Chronic obstructive pulmonary disease | 2 (6.5) |
| Other | 1 (3.2) |
| Duration of stay in mechanical ventilation (day) | 7.8 ± 2.9 |
| ICU stay (days) | 9.4 ± 3.1 |
| Hospital stays (days) | 13.6 ± 4.2 |
| EXTUBATION OUTCOME | 26 (83.9) |
| Successful extubation | 5 (16.1) |
| Reintubation | |


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**Table 2: Comparison of Baseline and Clinical Parameters According to Extubation Outcome**

| Variable | Successful (n = 26) Mean ± SD / n (%) | Failed (n = 5) Mean ± SD / n (%) | p Value |
|---|---|---|---|
| Age (years) | 56.8 ± 13.2 | 59.4 ± 14.9 | 0.67 |
| Gender<br>Male<br>Female | <br>15<br>11 | <br>3<br>2 | 0.89 |
| Comorbidities<br>No Comorbidity<br>One or more comorbidity | <br>9 (34.6)<br>17 (65.4) | <br>1 (20)<br>4 (80) | 0.61 |
| Duration of mechanical ventilation(days) | 7.2 ± 2.5 | 10.1 ± 3.4 | 0.04 * |
| ICU stay (days) | 9.1 ± 3.0 | 12.0 ± 3.5 | 0.03 * |
| Hospital stays (days) | 13.2 ± 3.8 | 16.8 ± 4.6 | 0.02 * |
| RSBI (on extubation day) | 59.5 ± 22.8 | 125 ± 45.2 | < 0.001 *** |
| Right DTF (%) | 23.5 ± 8.1 | 6.9 ± 3.4 | < 0.001 *** |
| Left DTF (%) | 19.7 ± 6.4 | 10.5 ± 4.8 | 0.005 ** |
| Mean DTF (%)<br>DTF During SBT (%) | 21.6 ± 7.2<br>24.73 ± 5.5 | 8.7 ± 4.1<br>15.45 ± 3.9 | 0.08<br>0.012 ** |

**p < 0.05 significant; ** p < 0.01; *** p < 0.001.*

**Table 3: Predictive Accuracy of RSBI and DTF for Successful Extubation (n = 31)**

| Variable | Mean ± SD (Success) | Mean ± SD (Failure) | p Value | Cut-off | AUC (95% CI) | Sens (%) | Spec (%) | PPV (%) | NPV (%) |
|---|---|---|---|---|---|---|---|---|---|
| RSBI | 59.5 ± 22.8 | 125 ± 45.2 | < 0.001 | ≤ 64 | 0.87 (0.72–0.98) | 88.5 | 80.0 | 95.8 | 57.1 |
| Right DTF (%) | 23.5 ± 8.1 | 6.9 ± 3.4 | < 0.001 | ≥ 20 % | 0.91 (0.78–0.99) | 92.3 | 86.7 | 96.0 | 72.2 |
| Left DTF (%) | 19.7 ± 6.4 | 10.5 ± 4.8 | 0.005 | ≥ 17 % | 0.83 (0.65–0.96) | 80.8 | 73.3 | 91.3 | 52.4 |
| Mean DTF (%) | 21.6 ± 7.2 | 8.7 ± 4.1 | 0.08 | ≥ 18 % | 0.71 (0.52–0.89) | 76.9 | 66.7 | 88.0 | 44.4 |
| RSBI + DTF (Combined) | | | 0.94 | | 0.71 (0.50–0.86) | | | | |

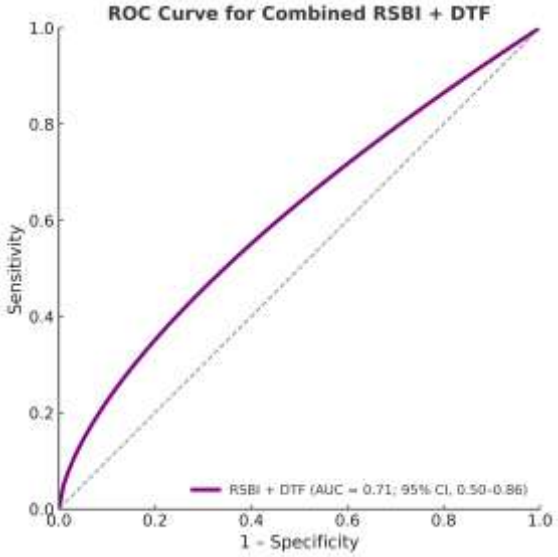



**Figure 1: Receiver-operating-characteristic (ROC) curves of combined indices for prediction of extubation success**

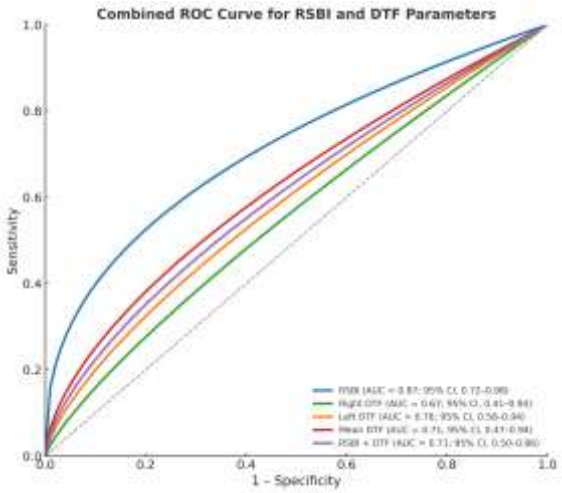



**Figure 2: Receiver-operating-characteristic (ROC) curves of RSBI, right DTF, left DTF**

## DISCUSSION

This pilot study showed that both diaphragmatic thickening fraction (DTF) and the Rapid Shallow Breathing Index (RSBI) were significantly associated with extubation outcomes, with DTF showing particularly strong predictive value. These findings reinforce the growing role of diaphragmatic ultrasound as a physiological assessment tool during weaning.

The present study confirmed that RSBI stays a reliable predictor of extubation success, consistent with the foundational trials by Yang and Tobin,[2] and


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Ely et al,[1] who showed that lower RSBI values correlate strongly with successful weaning. Like these earlier studies, the patients who failed extubation in the current study had significantly higher RSBI values, showing increased reliance on rapid, shallow respiratory patterning a known sign of respiratory muscle fatigue and insufficient ventilatory reserve.

DTF showed robust predictive accuracy, aligning with the findings of DiNino et al,[5] Ferrari et al,[10] and Subhash et al,[7] who reported that higher DTF values reflect preserved diaphragmatic contractility and correlate with extubation success. In the current study, DTF was measured daily from intubation until extubation, enabling observation of diaphragm evolution over time rather than a single time-point assessment. This aligns with recommendations from Matamis et al,[6] and Vivier et al,[11] who emphasized routine ultrasound as a method to check dynamic muscle behavior rather than relying solely on single-measurement values.

Notably, the DTF measured specifically during the spontaneous breathing trial (SBT) was significantly higher in successfully extubated patients. This supports the role of diaphragmatic performance under minimal or no ventilatory support as a more physiologically meaningful time point for prediction. Similar conclusions were reported by Ferrari et al,[10] who noted DTF values recorded during unsupported breathing had the strongest discriminatory value for predicting weaning success.

Serial ultrasound tracking revealed non-uniform diaphragm behaviour, with decreasing right-sided DTF and a gradual increase in left-sided values. Although asymmetric trends have been described previously, particularly in the context of ventilator unloading and differential muscle recruitment (Goligher et al,[9]) the exact mechanism remains uncertain. The changes seen here align with theories proposed by Zambon et al,[4] who showed ventilator-induced diaphragmatic dysfunction (VIDD) and suggested that diaphragm adaptation may depend on ventilatory strategy, patient effort, and recovery phase. These findings further support the argument made by Patel et al,[14] and Smith et al,[12] that serial assessment may be more clinically informative than a single measurement, especially in patients with fluctuating respiratory effort.

Despite strong individual performance of RSBI and DTF, combining these indices did not improve predictive accuracy. A similar observation was reported by Smargiassi et al,[8] who noted that diaphragm ultrasound parameters performed well independently but did not offer significant additive benefit when combined with traditional bedside weaning indices in small pilot study. Given the modest sample size in the present study, this lack of improvement may reflect limited statistical power rather than a true absence of synergistic value. Larger multicentre studies (sample size of 100-200) including the meta-analyses by Lee,[13] and the systematic review by Smith,[12] support the potential of integrated models but emphasize the need for adequate patient numbers to confirm thresholds.

Overall, the findings of this study support the role of diaphragm ultrasound particularly DTF measured during spontaneous breathing as a useful adjunct to traditional weaning assessments. When interpreted alongside clinical judgement and SBT tolerance, DTF may help find patients at higher risk of extubation failure and guide decisions on timing of extubation or respiratory muscle strengthening strategies.

**Limitations**

Several limitations should be acknowledged. The small sample size and single-centre design may limit generalizability. Ultrasonographic measurements are operator-dependent, although standardized technique and training were used to minimize variability. Additionally, long-term post-extubation outcomes were not evaluated, and the influence of systemic factors such as nutrition or inflammation on diaphragm performance was not assessed. Despite these limitations, the strength of this study lies in its demonstration of dynamic, asymmetric diaphragmatic adaptation and the superiority of DTF over conventional indices in real-time prediction of extubation success.

## CONCLUSION

This pilot study found that both RSBI and diaphragmatic thickening fraction are useful indicators of extubation readiness, with DTF showing strong association with successful outcomes. Daily monitoring showed that diaphragm function changes over the course of ventilation, and values obtained during the spontaneous breathing trial were particularly informative. Although combining RSBI and DTF did not enhance predictive accuracy in this small sample, DTF is still a practical, non-invasive tool that can support clinical judgement during weaning. Larger studies are needed to confirm best cut-offs and clarify how diaphragm ultrasound can be effectively integrated into routine extubation protocols.

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