Original Article

# Evaluation of abdominal expiratory muscle thickness pattern, diaphragmatic excursion, diaphragmatic thickness fraction and lung ultrasound score in critically ill patients and their association with weaning patterns: A prospective study

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## Abstract

**Introduction:** Weaning of patient from ventilator and finally extubation is a challenge, especially in critical care setup. Though many parameters are available, based on which, the decision of extubation is taken but still many times, there is failure of weaning.
**Aim:** We conducted a prospective observational study to look for diaphragm and abdominal muscle thickness, contraction, and lung ultrasound as indicator for weaning and extubation.
**Material and Methods:** Patients of either gender aged between 20-50 years, who were on invasive mechanical ventilation for more than 48 hrs. and put on spontaneous breathing trial. A bedside ultrasound examination was performed. Abdominal expiratory muscle thickness, diaphragmatic excursion (DE), diaphragmatic thickness fraction (DTF) and lung ultrasound score (LUS) were measured.
**Results:** 12 patients had simple weaning pattern whereas 5 patients had difficult weaning and 8 patients had prolonged weaning. The mean value of DE was 1.97 cm, DTF- 2.3 mm. The mean value of SOFA score is significant between simple, difficult, prolonged weaning (2.24, 4.56, 7.33 respectively). The DE, which is 2.52, 1.26, 1.81 in simple difficult and prolonged weaning respectively is highly significant. The mean value of LUS was 8.34 and is significant in all weaning patterns. The highest sensitivity is found for SOFA score (84.62) with AUC of 0.88.
**Conclusion:** Evaluation of patient with diaphragm thickness fraction (mean DTF of 26%) and diaphragm excursion (2.52 cm) with mean LUS score of 4.67 opens a new dimension to predict weaning in critically ill patients who are put on spontaneous breathing trial. The sequence of thickness of abdominal expiratory muscles adds to accuracy in successful weaning. Larger muti-center trials are required to make these parameters as a standard practice for weaning patients in critical care setup.

**Keywords:** Critical care weaning, diaphragmatic exertion, diaphragmatic thickness fraction, expiratory abdominal muscle thickness, lung ultrasound score, SOFA score, weaning failure, weaning from ventilation

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## Introduction

Weaning from mechanical ventilation is one of the major challenges faced by intensivists. Weaning includes the entire process of liberating the patient from mechanical ventilatory support and the endotracheal tube, including relevant aspects of tertiary care.[1] With difficult weaning being encountered in 20 to 30% of patients, extubation becomes an art. Premature weaning leads to increased cardiovascular and respiratory stress, carbon dioxide retention, and hypoxemia, whereas delay in weaning is also deleterious.[2] The action of the diaphragm is usually quantified in terms of force generation (measured by inspiratory pressures) or its shortening (measured by lung volume change or displacement of chest wall structures).[3] Fluoroscopic examination has been recognized as the gold standard for the evaluation of diaphragm movement but has limited feasibility in the intensive care unit (ICU).[4]

The RSBI is an important weaning index; however, its validity and reliability are doubtful in critically ill patients.[5] Ultrasound (US) is a non-invasive, widely available, and easy-to-use modality that can be performed by intensivists to predict weaning by studying various respiratory muscles and lung pathologies. Apart from mechanical ventilation, immunity, sepsis, and brain injury are factors contributing to diaphragm atrophy leading to respiratory failure.[6] The role of the expiratory muscles assumes significance whenever there is increased work of breathing on the inspiratory muscles, such as in critically ill patients with sepsis, those undergoing weaning, or during strenuous physical activities in healthy individuals. The activation of abdominal expiratory muscles during weaning improves the clearance of secretions from the airways, improves cough, and prevents premature alveolar and airway closure by placing the diaphragm in a more cranial position before the next inspiration and assists in the development of more negative inspiratory pressure. However, the parameters used to date to test expiratory abdominal muscle strength are often difficult to perform in critically ill ventilated patients. The transversus abdominis (TA) muscle thickness measured using the US has been validated to correlate with pressure developed during the expiratory effort and also the extent of electrical activity generated in the muscle.[7] Lung ultrasound score (LUS) is a rapid, reliable, and accurate method to detect intravascular lung water and also quantify the degree of regional lung aeration loss. It has been postulated that a LUS of more than 17 (at the end of spontaneous breathing trial [SBT]) is highly predictive of post-extubation distress and hence weaning failure.[6] This study was undertaken principally to measure the mean value of abdominal expiratory muscles thickness, diaphragmatic excursion (DE), and diaphragmatic thickness fraction (DTF) in patients with simple, difficult, and prolonged weaning along with LUS and SOFA scores in critical patients. The combined contribution of each of these parameters makes their simultaneous assessment important.

## Material and Methods

The present prospective observational study was carried out in the Department of Anesthesiology and Critical Care, from October 2022 to March 2024. Approval from the Institutional Ethics Committee (IEC) was taken vide CTRI number-CTRI/2023/04/052044.

Patients of either gender and aged between 20 and 50 years, on invasive mechanical ventilation for more than 48 h, and put on spontaneous breathing trial (SBT) for weaning with a fraction of inspired oxygen ($FiO_2 < 0.5$), positive end-expiratory pressure (PEEP < 5 cm $H_2O$), partial pressure of oxygen in arterial blood ($PaO_2/FiO_2 > 200$ mmHg), a respiratory rate less than 35/min, tidal volume more than 5 mL/kg, minute ventilation less than 10 L/min, no abnormality in electrolyte parameters, absence of hemodynamic instability, resolution of the initial cause of ventilator requirement, and patients awake with the ability to cough were included in the study. Patients with refusal of consent, chest or abdominal trauma, obesity, localized fluid collections in the abdomen, pregnancy, known diaphragmatic paralysis, or diaphragmatic surgery were excluded from the study. The SBT was terminated if rapid shallow breathing index (RSBI) was 105 breaths/min/L, respiratory rate was more than 35/min, or $SpO_2$ dropped to less than 90%. Our estimated sample size was based on diaphragmatic excursion in patients on mechanical ventilation. For the sample size calculation, we had a defined mean difference of 0.6 (with 0.75 standard deviation [SD]). We calculated the sample size with a 95% confidence interval, 80% power, and an alpha level of 0.05. The sample size was taken as 25.

**Data collection method-** A bedside US examination was performed using ESAOTE S.p.A machine (Via Enrico Melen 77, 16152, Geneva, Italy).

**Measurement of expiratory abdominal muscle thickness-** All measurements were performed on the right side (except LUS). A linear probe (high frequency) was used for the US examination.

Assessment of rectus abdominis (RA) muscle: A US probe was placed horizontally about 2 to 3 cm above the umbilicus and 2 to 3 cm away from the midline.

For external oblique (EO), internal oblique (IO), or TA muscle assessment, a linear probe was placed horizontally at the anterior axillary line, approximately at the mid-point of the coastal margin and iliac crest.[7]

**Diaphragmatic excursion (DE) –** A low-frequency convex probe (1–5 MHz) was placed first below the coastal margin on the mid-clavicular line with a dot marker facing the left of the patient. Starting depths were adjusted to 16 cm. M mode was applied in the middle of the image passing through the dome of the diaphragm and an M mode trace was obtained to capture a few inspiratory cycles. Two acoustic windows allowed us to examine the diaphragm:

1. At the zone of apposition, between the 8th and 10th intercostal spaces in the mid-axillary or anteroaxillary line, 0.5–2 cm below the costophrenic sinus-less echogenic structure between the two parallel echogenic layers was taken as the diaphragm thickness.
2. The liver or spleen was used as acoustic windows in the subcostal region, between the mid-clavicular and anterior axillary lines: It is necessary to utilize an abdomen or cardiac probe (2–5 MHz). The diaphragm is distinguished during inspiration by a hyperechoic line that approaches the probe (generated by the pleura firmly adhering to the muscle). It is simple to measure the inspiratory excursion in the M-mode. The difference between the highest crest and the lowest trough was taken as DE.[8]

**Diaphragmatic thickness fraction (DTF):** After freezing the M mode trace, the thickness of the diaphragm at end inspiration (thickest) and end expiration (thinnest) was measured.[7] DTF fraction was calculated as:

$$\frac{\text{Diaphragmatic thickness (end inspirationat - end expiration)}}{\text{Diaphragmatic thickness at end expiration}} \times 100$$

**Lung Ultrasound Score (LUS)** was calculated after examination of six lung regions on each side [Figure 1]. The maximum score was 36 (as described by Bouhemad *et al.*6). The LUS was calculated as follows:

Score 0: Normal lung aeration, A-lines

Score 1: Moderate loss of lung aeration, B-lines which are well-separated

Score 2: Severe loss of lung aeration, coalescent B-lines

Score 3: Complete loss of lung aeration, lung consolidation.

**Weaning**

**Simple weaning:** Patients who proceeded from the initiation of weaning to successful extubation on their first SBT without any difficulty.

**Difficult weaning:** Patients who failed initial weaning and required up to 3 SBT or as long as 7 days from the first SBT to achieve successful weaning.

**Prolonged weaning:** Patients who failed at least three weaning attempts or required 7 days of weaning after the first SBT.[1]

**SOFA Score-** The respiratory, cardiovascular, hepatic, coagulation, renal, and neurological systems were each given a score between 0 and 4, with an increasing score indicating increased organ dysfunction.[9]

## Results

Table 1 shows the age and sex distribution of study cases along with the diagnosis and the way they were ventilated (endotracheal tube or tracheostomy). Table 2 shows various US measurements performed on patients

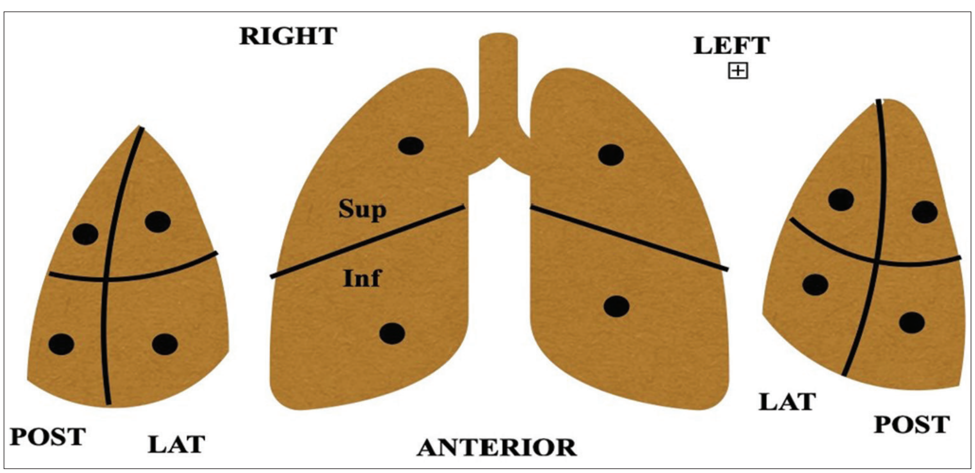


**Figure 1:** Diagrammatic representation of lung ultrasound points where scoring was measured

and SOFA scores of patients included in the study. Table 3 shows various US scores and statistical comparisons of these with a difficulty level of weaning. Table 4 shows various US measurements and their statistical significance with cut-off values. A comparison of the SOFA score and different levels of weaning is represented in the bar chart [Figure 2], and the SOFA scores compared with different US methods are presented in the bar chart [Figure 3].

## Statistical analysis

For the sample size calculation, we had a defined mean difference of 0.6 with 0.75 Standard Deviation. We calculated sample size with 95% confidence interval, 80% power and alpha level of 0.05. Hence the sample size was taken as 25. The data was coded and entered into Microsoft Excel spreadsheet. Analysis was done using SPSS version 20 (IBM SPSS Statistics Inc., Chicago, Illinois, USA) Windows software program. Descriptive statistics included computation of percentages, means and standard deviations. The data were checked for normality before statistical analysis using Kolmogorov Simonov test. The ANOVA test (for quantitative data to compare two and more than two observations) and Multiple Comparisons Tukey HSD test were applied. A p-value of <0.05 was considered significant. The receiver operating characteristic (ROC) curves of the continuous variables helpful in predicting weaning to calculate the area under the curve (AUC) were plotted with cut-off thickness of the abdominal expiratory muscles.

A total of 12 patients had a simple weaning pattern, 5 patients had difficult, and 8 patients had prolonged weaning. The mean value of DE and DTF along with abdominal muscle thickness is shown in Tables 2 and 3. The mean value of SOFA score was significant between simple, difficult, and prolonged weaning (2.24, 4.56, and 7.33, respectively). The DE was 2.52, 1.26, and 1.81 in simple, difficult, and prolonged weaning, respectively, which was statistically and highly significant. LUS score was also statistically significant in all weaning patterns. The highest sensitivity was found for the SOFA score (84.62) with an area under the curve (AUC) of 0.88 as shown in Table 4. Also, 91.7% of patients with simple weaning had SOFA scores between 2 and 4 and 100% of patients with prolonged weaning had SOFA scores between 5 and 8, as shown in Figure 2, which shows a comparison of SOFA scores and different levels of weaning.

Figure 3 shows SOFA scores compared with different ultrasound methods.

**Table 1: Distribution of age, sex, ventilation type, weaning, and abdominal muscle thickness patterns**

| | Study variables | *n*=25 |
|---|---|---|
| Mean age (in years) | 34.96±9.77 | |
| Gender | Male | 16 |
| | Female | 9 |
| Diagnosis | Head injury | 13 |
| | Others | 12 |
| Conduit | Intubation | 14 |
| | Tracheostomy | 11 |
| Weaning pattern | Simple | 12 |
| | Difficult | 5 |
| | Prolonged | 8 |
| Abdominal muscle thickness pattern | Simple (maintained/not maintained) | 12/0 |
| | Difficult and prolonged (maintained/not maintained) | 9/4 |

# Discussion

The primary objective of our study was the estimation of DE and DTF in patients undergoing SBT in the ICU. Secondarily, we determined the order of abdominal expiratory muscle


**Figure 2:** Comparison of SOFA score and different levels of weaning (pink color bar with SOFA score 2–4 and purple color bar with SOFA score 5–8)

**Table 2: Various ultrasound measurements included in the study**

| Study variable | Minimum | Maximum | Mean | Std. deviation |
|---|---|---|---|---|
| Diaphragmatic excursion (DE) in cm | 0.23 | 3.90 | 1.97 | 0.84 |
| Diaphragmatic thickness fraction (DTF) | 0.10 | 0.37 | 0.23 | 0.07 |
| LUS (lung ultrasound score) (max 36) | 3 | 19 | 8.32 | 4.67 |
| Rectus abdominus (RA) thickness | 0.64 | 2.80 | 1.24 | 0.46 |
| Internal oblique (IO) muscle thickness | 0.20 | 0.52 | 0.45 | 0.14 |
| External oblique (EO) muscle thickness | 0.27 | 0.32 | 0.28 | 0.32 |
| Transversus abdominus (TA) muscle thickness | 0.18 | 0.28 | 0.23 | 0.35 |
| SOFA | 2 | 8 | 4.56 | 1.91 |

thickness as well as LUS in patients undergoing weaning. According to the hypothesis published by Jiang *et al*.,[10] a cutoff value of 1.1 cm can be used to forecast a successful extubation. We found a lower cut-off for DE (1.04 cm) to predict simple weaning when taking diaphragm activity into account. In an earlier study, the authors concluded that a DE of more than 1.79 cm has a high probability of weaning success.[7] However, the cut-off values provided in previous studies are variable and range from 1.0 to 1.5 cm of DE in normal tidal breathing and from 20% to 36% for DTF. A tidal excursion of less than 10 mm or a thickening fraction of less than 20% has traditionally been used to define diaphragmatic dysfunction (DD).[11] Kim *et al.*[12] studied adult patients requiring mechanical ventilation in the ICU and discovered that paradoxical movement or DE less than 10 mm is linked to weaning failure. In our study, the mean DE was 1.97 ± 0.84 and the mean value of DE in simple weaning was 2.52 ± 0.67, 1.26 ± 0.73 in prolonged weaning, and 1.81 ± 0.29 in difficult weaning, which was statistically significant and in accordance with the above studies.

**Table 3: Various ultrasound scores and statistical comparison of these with difficulty levels of weaning**

| Weaning pattern and study variable | | Mean | Std. deviation | *P* |
|---|---|---|---|---|
| SOFA | Simple | 2.24 | 1.3 | 0.001 (S) |
| | Prolonged | 4.56 | 1.8 | |
| | Difficult | 7.33 | 1.5 | |
| Diaphragmatic excursion (DE) | Simple | 2.52 | 0.67 | 0.001 (S) |
| | Prolonged | 1.26 | 0.73 | |
| | Difficult | 1.81 | 0.29 | |
| Diaphragmatic thickness fraction (DTF) | Simple | 0.26 | 0.06 | 0.18 |
| | Prolonged | 0.195 | 0.07 | |
| | Difficult | 0.24 | 0.09 | |
| LUS (Lung ultrasound score)(max36) | Simple | 4.67 | 1.55 | 0.002 (S) |
| | Prolonged | 10.63 | 4.37 | |
| | Difficult | 13.4 | 2.79 | |
| Rectus abdominus (RA) thickness | Simple | 1.12 | 0.31 | 0.81 |
| | Prolonged | 1.27 | 0.43 | |
| | Difficult | 1.27 | 0.54 | |
| Internal oblique (IO) muscle thickness | Simple | 0.50 | 0.67 | 0.02 (S) |
| | Prolonged | 0.41 | 0.35 | |
| | Difficult | 0.34 | 0.26 | |
| External oblique (EO) muscle thickness | Simple | 0.27 | 0.08 | 0.19 |
| | Prolonged | 0.19 | 0.44 | |
| | Difficult | 0.13 | 0.26 | |
| Transversus abdominus (TA) muscle thickness | Simple | 0.508 | 0.61 | 0.53 |
| | Prolonged | 0.43 | 0.28 | |
| | Difficult | 0.390 | 0.28 | |

The diaphragm is the main inspiratory muscle and the inverse relation of length to contraction holds true. The mean DTF was 23% ± 7% and the mean value of DTF in simple weaning was 26% ± 6%, 19.5% ± 7% in prolonged weaning, and 24% ± 9% in difficult weaning. This was not statistically significant. Di Nino *et al.*,[2] in their study on patients who were on mechanical ventilation, predicted a cut-off value of 30% for best outcome at weaning. In a study by Amara *et al.*[7] conducted on mechanically ventilated patients who underwent the weaning process, the mean DTF% was 44% for the simple weaning group. The reason might be that we had strict measurement criteria. Moreover, we did not include extremes of age in our study population.[9] The fact that all readings were taken by a single observer makes our results more reliable and reproducible. According to a study by Tenza-Lozano *et al.*,[13] a single diaphragmatic indicator may not be a perfect predictor. They demonstrated that DTF, when used as a single predictor, has an area

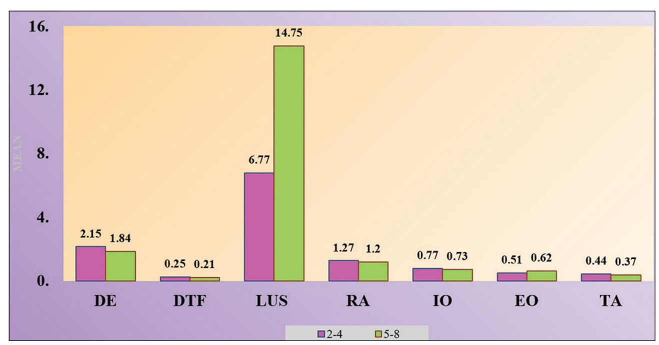


**Figure 3:** SOFA score compared with different ultrasound methods. (DE: diaphragmatic excursion, DTF: diaphragmatic thickness fraction, LUS: lung ultrasound score, RA: rectus abdominis, IO: internal oblique, EO: external oblique, TA: transversus abdominis)

**Table 4: Various ultrasound measurements and their statistical significance with the cut-off values**

| | AUC | Cut-off | *P* | Sensitivity | Specificity | PPV | NPV | Diagnostic accuracy |
|---|---|---|---|---|---|---|---|---|
| DE | 0.56 | 1.04 | 0.009 (S) | 52.17 | 50 | 92.31 | 89.4 | 52 |
| DTF | 0.67 | 15.75 | 0.135 | 47.62 | 25 | 76.92 | 80.33 | 44 |
| LUS (max 36) | 0.75 | 3.5 | 0.04 (S) | 54.17 | 68.4 | 74.8 | 87.33 | 56 |
| RA | 0.49 | 0.6 | 0.11 | 55.3 | 74.1 | 76.5 | 85.6 | 58.9 |
| IO | 0.64 | 0.52 | 0.11 | 47.62 | 25 | 76.92 | 80.33 | 44 |
| EO | 0.55 | 0.27 | 0.466 | 59.17 | 76.5 | 80.11 | 85.7 | 60.8 |
| TA | 0.44 | 0.18 | 0.72 | 56.2 | 60.2 | 90.2 | 90.5 | 53.9 |
| SOFA score | 0.88 | 3 | 0.002 (S) | 84.62 | 91.67 | 91.67 | 84.62 | 88 |

*DE: diaphragmatic excursion, DTF: diaphragmatic thickness fraction, LUS: lung ultrasound score; RA: rectus abdominus thickness, IO: internal oblique muscle thickness, EO: external oblique thickness, TA: transversus abdominus thickness* under the receiver operating characteristic (ROC) curve of 0.71. With an AUC of 0.83, the performance of DTF in conjunction with lung ultrasonography (USG) enhanced the prognosis of successful weaning. The diagnosis of interstitial–alveolar syndrome, pleural effusion, or lung consolidation can be made quickly and accurately with LUS evaluation. Lung consolidation or pleural effusion is most common in dorsal or dependent regions. Normal aeration is defined by lung sliding and A-lines.[14] The group that experienced a difficult or prolonged weaning process had a significantly higher LUS in our study as well as in some previous studies. However, the score (10.63 ± 4.37) in prolonged and (13.4 ± 2.79) difficult weaning in our study was significantly lower than the score (16.5 ± 4.2) reported by Soliman *et al.*[15] in a group of mechanically ventilated patients who failed to wean from mechanical ventilation. This disparity in the score might be because we included a huge range of medical, surgical, and neurosurgical patients in our study with diffuse pathologies affecting the diaphragm. With less diaphragmatic excursion, the patients may accept an even lower lung US score for successful weaning, which could explain why our difficult or prolonged weaning patients had lower lung US scores.[15]

The effect of the highest SOFA scores on patients admitted for 1 week in the ICU after a complicated surgery was examined by Moreno *et al.*,[16] who found a strong correlation between rising scores and mortality. As a discriminator of survival status at ICU discharge, the score fared well. Currently, no available studies exist on the SOFA score in patients put on SBT; however, our study has shown the highest AUC of 0.88 of the SOFA score, which is statistically significant. The mean SOFA score is 4.56 ± 1.91 in our study. The sensitivity the specificity of the SOFA score were 84.62 and 91.67, respectively. The mean LUS of patients with SOFA scores between 2 and 4 (13 patients) was 6.77 ± 3.320 and between 5 and 8 was 14.75 ± 4.475 (12 patients) with a $P$ value of 0.001 (statistically significant). Therefore, there is a high correlation between the LUS score and the SOFA score. This instigates the importance of future studies where these two parameters will play an important role in predicting weaning success in critically ill patients.

Theerawit *et al.*[4] discovered that the diaphragmatic characteristics on the right and left did not change significantly. Ultrasonic measurements of TA thickness have been verified to correlate with both the level of electrical activity produced in the muscle and the pressure created during the expiratory effort. Previous studies have demonstrated a positive correlation between the diaphragm's thickness and strength as well as a concurrence between the EO's thickness and the peak expiratory flow rate. According to previous research on healthy persons, the usual sequence of the expiratory abdominal muscles' decreasing muscular thickness is RA > IO > EO > TA.[7] The mean values for EO, IO, and TA were reported by De Troyer *et al.*[17] to be 7.2, 11.5, and 4.6 mm, respectively, whereas we recorded the mean values for RA, EO, IO, and TA to be 12.4, 2.8, 4.5, and 2.3 mm, respectively. In our study, however, all patients of simple and the majority (69%) of the patients of difficult and prolonged weaning groups were able to maintain this arrangement. The discrepancies between our findings and those of De Troyer *et al.* could be attributed to minute variations in the subjects' body mass, degree of fitness, or inter-individual measurement variations. According to Strohl *et al.*,[18] the three upper abdominal wall muscles' combined relaxed thickness ranged from 11 to 20 mm; these findings corroborated with those of the present study.

The mean age of patients in our study was 34.96 ± 9.77 years. The majority of patients were males (64%). Although this proportion is arbitrary, it is in accordance with the majority of previous studies.[15]

Out of the total 25 patients in our study, 14 patients (56%) were intubated and 11 (44%) were tracheostomized. Although tracheostomy may improve certain elements of pulmonary mechanics and hence lower the work of breathing, there is no evidence that this is associated with a shorter length of stay or weaning time.[1] Coplin *et al.*[19] described in his study that various factors such as the Glasgow Coma Scale (GCS), and Airway Care Score (ACS) of patients can affect their weaning time and ICU stay length.

In our study, out of 25 patients, 12 (48%) had simple weaning, 5 (20%) had difficult weaning, and 8 patients (32%) had prolonged weaning. This is not in accordance with the study conducted by Amara *et al.*,[7] where 16 (20%) patients had a simple weaning pattern, 35 (43%) patients had a difficult weaning pattern, and 30 (37%) patients had prolonged weaning. The sample size and age disparity in the studies could be the cause of this. However, in the study by Shigang Li *et al.*[20] on elderly patients, 68% had extubation success and 32% had failed weaning, which corroborates with the findings of our study. In a study conducted by Kaur *et al.*[11] on 50 mechanically ventilated patients for sonographic evaluation of diaphragmatic excursion and thickness as indicators of successful weaning, 15 (30%) had SBT failure and 4 had extubation failure.

The abdominal muscles function as a constant volume system. The diameter of muscles is inversely related to the length, and the motor response can be gauged from this. The active muscle shortens and thickens unless activated passively as in mechanical ventilation. The mean thickness of IO in simple weaning is 0.50 ± 0.67, 0.41 ± 0.35 in prolonged, and 0.34 ± 0.26 in difficult, which is statistically significant. However, this conclusion differs from the study conducted by Amara *et al.*,[7] most likely as a result of racial disparities, sample size, and heterogeneity. The sample size needs to be larger to generalize the results. In our study, we found the highest AUC (0.64) of IO thickness for predicting simple weaning, which was more than that of TA; however, the diagnostic accuracy (60.8%) was the highest for EO. In a previous study, the authors reported that for predicting simple weaning, IO thickness had the highest AUC (0.715) and diagnostic accuracy (75.31%), which was even higher than that of TA. B or M-mode can be used to measure diaphragm function with B mode being preferred for diaphragm thickness and M mode reflecting excursion.

The RSBI index is a well-known weaning index and one of the most common clinical indices used to predict weaning outcomes. However, it has some limitations in predicting weaning outcomes. Several previous studies have defined different sensitivities and specificities for RSBI less than 105 to predict weaning success, which may lead to errors in predicting successful weaning. Similarly, the SOFA score measures different outcomes that are not in connection with USG. We emphasize that USG cannot replace RSBI or SOFA score to guide weaning and extubation. Weaning failure is likely to occur if there is an imbalance between the load on the inspiratory muscles and their neuromuscular capacity, the imbalance between the mechanical load imposed on the diaphragm, which is the major muscle of inspiration, and its ability to cope with it. Therefore, evaluating the function of the diaphragm before any weaning trial could be useful in predicting the weaning outcome.[5] The US methods are additive to other markers and help the clinician to guide for extubation in difficult-to-wean patients in a critical care setup.

**Strength of the study:** The fact that the study focused on the abdominal expiratory muscles along with multiple other weaning criteria is one of its strengths. All readings were taken by a single observer. Hence, results are more reproducible. To illustrate the role of the expiratory muscles in patients with a high inspiratory load, such as the critically ill, we also compared the AUC of the expiratory muscles in predicting weaning to the AUC of the DE and DTF%. It was also examined whether critically ill patients follow the same pattern of expiratory muscle thickness that is maintained in healthy people and whether this has an impact on the weaning pattern.

**Limitations of the study:** The fact that the study is performed in a single center is one of its limitations. We did not evaluate each muscle's contribution to the weaning pattern by measuring the abdominal expiratory muscle thickening fraction. Additionally, the expiratory muscle thickness was assessed on the first SBT day rather than at each consecutive SBT. The difference between the thickness of the abdominal expiratory muscles on the day of SBT and the day of admission was not measured. The present sample size estimate and racial differences for evaluating the thickness of the abdominal expiratory muscle and its relationship to the weaning pattern is another drawback of the study. The extrapolation of results is not possible because we included medical, surgical, and neurological patients together.


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## Conflicts of interest

There are no conflicts of interest.


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