

Evaluation of Abdominal Expiratory Muscle Thickness Pattern, Diaphragmatic Excursion, and Lung Ultrasound Score in Critically Ill Patients and Their Association with Weaning Patterns: A Prospective Observational Study

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ABSTRACT

Introduction: The expiratory muscles are an indispensable component of respiratory function in critically ill patients, yet is often overlooked. We evaluated the association of abdominal expiratory muscles thickness pattern with weaning.

Materials and methods: This was a single-center, prospective observational study done on 81 adult mechanically ventilated patients who underwent the weaning process.

Results: Sixteen patients had simple weaning and 65 patients had either difficult or prolonged weaning. The mean and standard deviation (SD) of the thickness of expiratory abdominal muscles—rectus abdominis (RA), internal oblique (IO), external oblique (EO), and transversus abdominis (TA) were significantly more in patients with simple weaning than those with difficult or prolonged weaning. The receiver operating curve (ROC) of expiratory muscles showed RA, IO, EO, TA cut-offs 0.638, 0.492, 0.315, and 0.253 cm, respectively, to predict simple weaning. The pattern of expiratory muscle thickness RA > IO > EO > TA was maintained in both simple and difficult/prolonged weaning groups ($p = 0.362$). The ROC of diaphragmatic excursion (DE) for predicting simple weaning had cut-off 1.79 cm. The lung ultrasound score (LUS) was 5.75 ± 3.32 in the simple weaning group, compared to 9.71 ± 5.18 in the difficult/prolonged weaning group ($p = 0.005$).

Conclusion: Abdominal expiratory muscles were significantly thicker in patients with simple weaning compared to those with difficult or prolonged weaning. The pattern of expiratory muscle thickness followed the pattern of RA > IO > EO > TA in both simple weaning and difficult or prolonged weaning groups. DE > 1.79 cm predicted simple weaning and LUS was significantly lesser in patients with simple weaning (CTRI/2020/11/028895).

Keywords: Diaphragmatic excursion, Expiratory abdominal muscles, Expiratory muscle thickness pattern, External oblique, Internal oblique, Rectus abdominis, Transversus abdominis.

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INTRODUCTION

Expiratory muscles consist of the rib cage muscles (internal intercostals and triangularis sterni) and the abdominal muscles—rectus abdominis (RA), internal oblique (IO), external oblique (EO), and transversus abdominis (TA).¹ Even though literature is replete with studies on inspiratory muscles, especially diaphragm and its role in weaning, the expiratory muscles have often been overlooked.¹⁻³ The role of the expiratory muscles assumes significance whenever there is an increased work of respiration on the inspiratory muscles, like in critically ill sepsis patients, those undergoing weaning or during strenuous physical activities in healthy individuals.¹ Whenever there is an increased demand on the inspiratory muscles, like in patients in the intensive care unit (ICU), the expiratory muscles of the abdomen are recruited.^{1,4} These muscles are recruited for the expiratory work in a particular order. The TA is the first abdominal expiratory muscle to be recruited.^{1,5} Thereafter, the IO is recruited, then the EO, and finally the RA.^{1,5} In noncritically ill patients, the thickness of the expiratory abdominal muscles has a definite order, RA > IO > EO > TA.¹ The thickness of TA muscle correlates to the expiratory pressure developed as well as the electrical activity generated in the muscle.¹ We wanted to determine if there was a difference in the expiratory muscle thickness and the pattern of this thickness (RA > IO > EO > TA) in patients with simple weaning vs difficult or prolonged weaning. The

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hypothesis is that patients with simple weaning will have thicker abdominal expiratory muscles and have the thickness pattern of RA > IO > EO > TA maintained, as compared to patients with difficult or prolonged weaning. The research question which we

wanted to address is whether the abdominal expiratory muscles are significantly thicker and the pattern of thickness with the order RA > IO > EO > TA is different in patients with simple weaning as compared to those with difficult or prolonged weaning.

Aim

To assess the expiratory abdominal muscle thickness pattern, diaphragmatic excursion (DE), diaphragmatic thickening fraction (DTF), and lung ultrasound score (LUS) in critically ill patients and their association with weaning pattern.

Objectives

The primary objective of the study is to determine the abdominal expiratory muscle thickness, the order of the thickness of abdominal expiratory muscles, diaphragmatic excursion and lung ultrasound score in patients undergoing weaning in the intensive care unit. The secondary objective was to estimate cut-off values of abdominal expiratory muscle thickness and diaphragm excursion distance to predict simple weaning.

MATERIALS AND METHODS

Study Design

It was a single-center, prospective, cross-sectional observational study.

Ethics

Before the commencement of the study, Institutional Ethical Committee clearance was obtained (IEC:465/2020). Approval from the Clinical Trial Registry of India (CTRI) was then obtained (CTRI/2020/11/028895) before the first recruitment. Informed consent was taken from the patient's relative or legally authorized representative before recruitment.

Study Population

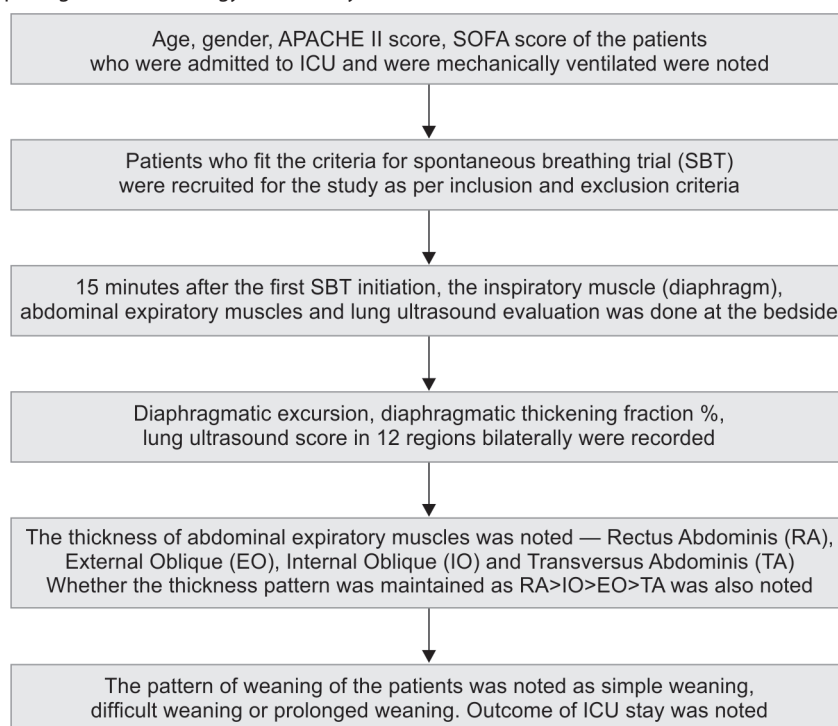
Eighty one patients aged between 18 and 80 years were included. Patients of either gender, who were on invasive mechanical ventilation and were put on spontaneous breathing trial (SBT) for the weaning process, were included. Patients who met the following criteria were put on SBT—Fraction of inspired oxygen ($\text{FiO}_2 < 0.5$), positive end-expiratory pressure (PEEP) ≤ 5 cm H_2O , partial pressure of oxygen in arterial blood (PaO_2)/ $\text{FiO}_2 > 200$ mm Hg, respiratory rate < 35 /minute, tidal volume > 5 mL/kg, minute ventilation < 10 L/minute, 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.

Exclusion criteria included patients < 18 years, patients with chest or abdominal trauma, distorted abdominal wall anatomy, patients with damage to the abdominal wall, patients with localized fluid collections in the abdomen, hernias, abdominal wall hematomas, inguinal masses, femoral hernias, abdominal surgeries, patients with any neuromuscular weakness, patients with any diaphragmatic disorders, pregnant patients. The SBT was terminated if rapid shallow breathing index was > 105 breaths/minute/L, RR > 35 /minute, SpO_2 drop to $< 90\%$, the patient had evidence of respiratory distress with increased work of breathing, increase in heart rate $> 20\%$ from baseline or increase in systolic blood pressure > 180 mm Hg or < 90 mm Hg. A flowchart describing the methodology is depicted (Flowchart 1).

Data Collection

In the patients who were put on spontaneous breathing trial (SBT) for weaning, data of age, gender, diagnosis, Acute Physiology, and Chronic Health Evaluation (APACHE II) score on intensive care unit (ICU) admission, Sequential Organ Failure Assessment (SOFA) score on admission were noted.

Flowchart 1: Flowchart depicting the methodology of the study



Ultrasound Examination

The bedside ultrasound examination was performed using Phillips machine model CX 50 (Phillips Healthcare, 3000 Minuteman Road, Andover, USA). A linear probe was used for calculating the thickness of expiratory abdominal muscles—RA, IO, EO, and TA. Ultrasound examination of RA was done by placing the linear probe horizontally about 2–3 cm above the umbilicus and 2–3 cm away from the midline.¹ Ultrasound examination of the EO, IO, and TA was done by placing the linear probe horizontally at the anterior axillary line, approximately at the mid-point of the right costal margin and the iliac crest¹ (Figs 1 and 2). Curvilinear probe was used for DE measurements (right side). The probe was placed in subcostal space in a horizontal fashion to measure the movement in M-mode. Lung ultrasound examination to calculate the LUS after examination of six lung regions on each side, with a maximum score of 36, as described by Bouhemad et al.⁶ The LUS for each region was as follows:⁶

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

A linear probe was used for DTF, at the zone of apposition between pleura and diaphragm at the mid-axillary line between the 8th and 10th intercostal space on the right side.⁷ The DTF percentage (DTF%) was calculated as:

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

Primary outcome was the weaning patterns which the patient had—simple, difficult, or prolonged. Weaning was categorized as simple weaning (initiation of weaning to successful extubation after first SBT), difficult weaning (patients failing initial SBT and requiring up to three SBTs or up to 7 days from first SBT for successful weaning), or prolonged weaning (requiring more than three SBTs and requiring 7 days after first SBT).^{7,8} Secondary outcomes were in terms of survival of ICU stay. The primary endpoint was the pattern of weaning, whether it was simple, difficult, or prolonged.

Statistical Analysis

Sample size calculation was done considering a proportion of 70% patients having simple weaning.^{9,10} Considering 10% relative error of proportion, confidence interval of 95 and 80% power of the study, sample size of 81 was calculated as follows:

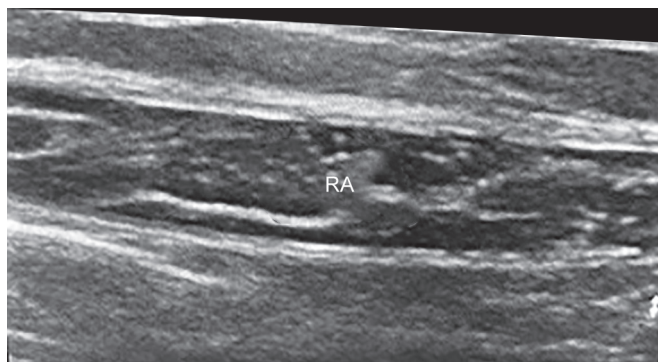


Fig. 1: Ultrasound depicting the rectus abdominis muscle (RA)

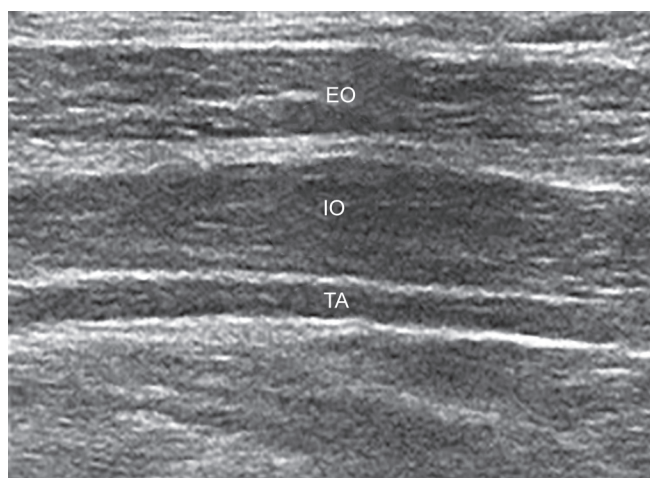


Fig. 2: Ultrasound depicting the external oblique (EO), internal oblique (IO), and transversus abdominis muscle (TA)

$Z(\alpha/2) = 1.96$ for a confidence interval of 95%, relative error (E) is 10% Sample size (n) = $[Z(\alpha/2)/E]^2 \times P \times (1 - P) = (1.96/0.1)^2 \times (0.7) \times 0.3 = 80.67$, rounded off to 81.

Data analysis was done using statistical software IBM SPSS (Statistical Package for the Social Sciences) software (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, version 22.0 Armonk, New York: IBM). Continuous variables were analyzed as mean and standard deviation (SD). To calculate the statistical differences in continuous variables between the simple weaning vs the difficult or prolonged weaning group, Independent Student's t -test was used. To calculate the statistical difference between categorical variables between two groups, Pearson's Chi-square test was used. A p -value of <0.05 was considered significant. The receiver operating characteristic (ROC) curves of the continuous variables helpful in predicting simple weaning to calculate the area under the curve (AUC) were plotted. The cut-off thickness of the four abdominal expiratory muscles—RA, IO, EO, TA, the DE, and DTF% was derived from ROC curves, and sensitivity, specificity, 95% confidence interval, positive predictive value, negative predictive value, and diagnostic accuracy were calculated.

RESULTS

Sixteen patients had a simple weaning pattern; 35 patients had a difficult weaning pattern and 30 had prolonged weaning. The age, APACHE II score, SOFA score on the day of admission to ICU and the mean and SD of all patients' ultrasound parameters on the day of first SBT are depicted (Table 1). There was a significant difference between the thickness of the abdominal expiratory muscles, RA, IO, EO, and TA between the patients in the simple weaning group and those in the difficult or prolonged weaning group (Table 2). There was a significant difference in the DE and LUS between the patients who had simple weaning and those who had either difficult or prolonged weaning (Table 2). The APACHE II score and SOFA score on admission were also significantly different between those with simple weaning and difficult/prolonged weaning (Table 2). Even though the DTF% was more in those with simple weaning compared to those with difficult or prolonged weaning, it was not statistically significant (Table 2).

Regarding the pattern of abdominal expiratory muscle thickness following the order: RA > IO > EO > TA, the pattern was present in

Table 1: Depiction of the mean and standard deviation (SD) of the age, APACHE II score, SOFA score and various measurements of the patients put on SBT as done by ultrasound

Variables of the patients (N = 81)	Mean ± SD
Age (years)	55.7 ± 15.91
APACHE II	15.43 ± 6.63
SOFA	6.22 ± 3.53
Diaphragmatic excursion (cm)	1.67 ± 0.4
Diaphragmatic thickening fraction %	27.28 ± 7.53
Rectus abdominis thickness (cm)	0.62 ± 0.18
Internal oblique thickness (cm)	0.46 ± 0.18
External oblique thickness (cm)	0.32 ± 0.1
Transversus abdominis thickness (cm)	0.24 ± 0.07
Lung ultrasound score	8.93 ± 5.11

Table 2: Depiction of the difference in mean and standard deviation (SD) of the various parameters between those of difficult/prolonged weaning group versus those of simple weaning group. Independent Student's t test ($p < 0.05$ is significant)

Variables of the patients in the study	Difficult or prolonged weaning (N = 65)	Simple weaning (N = 16)	p value
	Mean ± SD	Mean ± SD	
Age	57.2 ± 16.45	49.63 ± 12.14	0.088
APACHE II score	16.42 ± 6.45	11.44 ± 5.96	<0.05
SOFA score	6.68 ± 3.58	4.38 ± 2.71	<0.05
Rectus abdominis thickness (cm)	0.59 ± 0.16	0.73 ± 0.23	<0.05
Internal oblique thickness (cm)	0.43 ± 0.14	0.59 ± 0.23	<0.05
External oblique thickness (cm)	0.30 ± 0.08	0.39 ± 0.14	<0.05
Transversus abdominis thickness (cm)	0.23 ± 0.07	0.27 ± 0.07	<0.05
Lung ultrasound score (global)	9.71 ± 5.18	5.75 ± 3.32	<0.05
Diaphragmatic excursion	1.62 ± 0.4	1.89 ± 0.35	<0.05
Diaphragmatic thickening fraction	0.38 ± 0.49	0.44 ± 0.51	0.703

75% of the patients who had simple weaning and 84.6% patients who had difficult or prolonged weaning, and there was no statistical difference between the two groups ($p = 0.362$, Pearson's Chi-square test) (Table 3). The AUC of the ROC plots and the confidence intervals (CI) of the abdominal expiratory muscle thickness to predict simple weaning were as follows: RA [AUC 0.712, $p = 0.009$, 95% CI (0.561, 0.862), cut-off 0.638 cm, sensitivity 68.8%, specificity 64.6%], IO [AUC 0.715, $p = 0.008$, 95% CI (0.558, 0.872) cut-off 0.492 cm, sensitivity 68.8%, specificity 76.9%], EO [AUC 0.718, $p = 0.007$, 95% CI (0.567, 0.869), cut-off 0.315 cm, sensitivity 68.8%, specificity 66.2%], TA [AUC 0.689, $p = 0.019$, 95% CI (0.557, 0.822), cut-off 0.253 cm, sensitivity 62.5%, specificity 64.6%] (Fig. 3).

The AUC of DE for predicting simple weaning was 0.700, $p = 0.014$, 95% CI (0.552–0.847), cut-off 1.79 cm, sensitivity 68.8%, specificity 67.7% (Fig. 3). The AUC of DTF% for predicting simple weaning was however not significant. (AUC 0.548, $p = 0.553$) (Fig. 3).

Table 3: Depiction of the pattern of abdominal expiratory muscle thickness in the simple weaning versus difficult/prolonged weaning group. (RA, rectus abdominis; IO, internal oblique; EO, external oblique; TA, transversus abdominis). Pearson's Chi-square test

RA > IO > EO > TA thickness pattern	Simple weaning (N = 16)	Difficult/prolonged weaning (N = 65)	p value
Not maintained	4 (25%)	10 (15.4%)	0.362
Maintained	12 (75%)	55 (84.6%)	

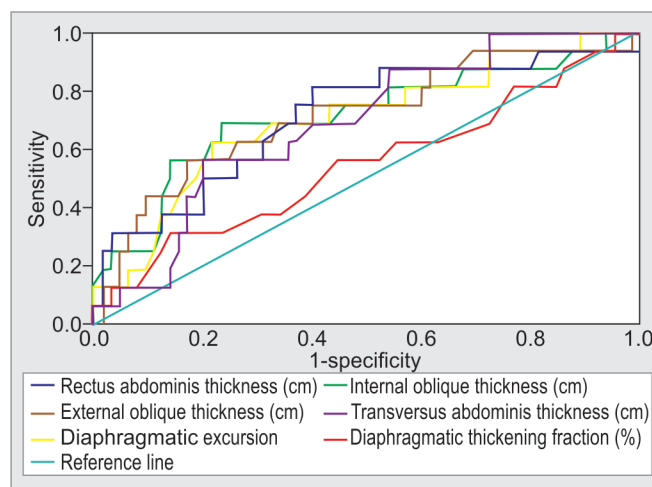


Fig. 3: Depiction of the Area Under Curve (AUC) as per Receiver Operating Characteristic (ROC) curve of the various variables – rectus abdominis (RA), internal oblique (IO), external oblique (EO), diaphragmatic excursion (DE), and diaphragmatic thickening fraction (DTF)% to predict simple weaning. Abdominal Expiratory Muscles—RA [AUC 0.712, $p = 0.009$, 95% CI (0.561, 0.862), cut-off 0.638 cm], IO [AUC 0.715, $p = 0.008$, 95% CI (0.558, 0.872) cut-off 0.492 cm], EO [AUC 0.718, $p = 0.007$, 95% CI (0.567, 0.869), cut-off 0.315 cm], TA [AUC 0.689, $p = 0.019$, 95% CI (0.557, 0.822), cut-off 0.253 cm], DE [AUC 0.700, $p = 0.014$, 95% CI (0.552–0.847), cut-off 1.79 cm], DTF% (AUC 0.548, $p = 0.553$)

The cut-off values, AUC, sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy of the four expiratory abdominal muscles thickness, DE and DTF% to predict simple weaning are depicted in Table 4. The lung ultrasound score was 5.75 ± 3.32 in the simple weaning group, compared to 9.71 ± 5.18 in the difficult/prolonged weaning group ($p = 0.005$). Of the 65 patients in the difficult or prolonged weaning group, 14 patients required tracheostomy and 6 patients had failed to wean, requiring re-intubation. A total of 68 patients survived the ICU stay and 13 patients expired at the end of the ICU stay. The pattern of expiratory muscle thickness pattern RA > IO > EO > TA was maintained both in the survival as well as expired group, and there was no significant difference in the expiratory abdominal muscle thickness pattern between the two groups—those who survived and those expired ($p = 0.160$, Pearson's Chi-Square test).

DISCUSSION

Activation of abdominal expiratory muscles is beneficial during weaning, not only by improving the process of clearance of secretions from the airways, better cough, prevention of premature alveolar and airway closure but also by enhancing the inspiratory



Table 4: Depiction of values of area under curve (AUC) as measured by receiver operating characteristic (ROC) curve, cut-off values for various parameters, 95% confidence interval (CI), sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) diagnostic accuracy of the various parameters predicting simple weaning ($p < 0.05$ is significant)

Variables measured by ultrasound	AUC	Cut-off value (cm) (\geq)	p value	95% CI	Sensitivity	Specificity	PPV	NPV	Diagnostic accuracy
Rectus abdominis	0.712	0.638	0.009	(0.561, 0.862)	68.8%	64.6%	32.4%	89.4%	65.43%
Internal oblique	0.715	0.492	0.008	(0.558, 0.872)	68.8%	76.9%	42.3%	90.9%	75.31%
External oblique	0.718	0.315	0.007	(0.567, 0.869)	68.8%	66.2%	33.3%	89.6%	66.67%
Transversus abdominis	0.689	0.253	0.019	(0.557, 0.822)	62.5%	64.6%	30.3%	87.5%	64.2%
Diaphragmatic excursion	0.700	1.79	0.014	(0.552, 0.847)	68.8%	67.7%	34.4%	89.80%	67.9%
Diaphragmatic thickening fraction	0.548	27.5%	0.553	(0.379, 0.717)	56.3%	55.4%	21.6%	100%	28.40%

muscle capacity.^{1,11-14} The expiratory muscles enhance the inspiratory efforts by placing the diaphragm in a more cranial position before the next inspiration and assist in the development of more negative inspiratory pleural pressure.^{1,4} The abdominal expiratory muscles play a significant role in enhancing maximum expiratory pressure.¹ Maximum expiratory pressure generated in turn has been correlated to expiratory muscle strength.^{1,14-16} Other parameters may also be used to evaluate the expiratory muscle strength, like the amount of gastric pressure developed during expiration (though it more specifically correlates to the strength of TA muscle) and the cough peak expiratory flow.^{1,17,18} However, these tests are often difficult to perform in critically ill ventilated patients to evaluate their expiratory muscle strength. The encouraging fact is that the TA thickness measured using ultrasound has been validated to correlate with pressure developed during the expiratory effort and also the extent of electrical activity generated in the muscle.^{1,19} The positive correlation between the thickness of diaphragm and its strength and the concurrence of the thickness of EO to the peak expiratory flow rate have been proven in previous studies.^{20,21} Thus we measured the thickness of RA, IO, EO, and TA using bed-side ultrasound and evaluated their role in the weaning pattern. The normal pattern of decreasing muscle thickness of the expiratory abdominal muscles bilaterally is RA > IO > EO > TA, which has been found in previous literature in healthy individuals.²²

The order of this thickness of the abdominal muscles is an indicator of the equilibrium or stability within the muscle groups. It has been shown that any deviation from this pattern of muscle thickness may be ascribed to muscle atrophy of a particular expiratory abdominal muscle.²² The abdominal expiratory muscles' stability, equilibrium, and thickness all assist in increasing the abdominal pressure during expiration.^{1,22} This in turn helps in the reduction of the expiratory transpulmonary pressure and optimal lung deflation. This prevents early airway collapse during expiration, assists in effective cough, increases expiratory flow, reduces chances of basal atelectasis.¹ All these factors ultimately aid in successful weaning.¹

We found the highest AUC (0.715) and diagnostic accuracy (75.31%) of IO thickness for predicting simple weaning, which was even more than that of TA (AUC 0.689, diagnostic accuracy 64.2%). IO is the second expiratory abdominal muscle (just after TA) to be recruited for expiratory efforts in critically ill ICU patients, whenever there is an increased workload on the inspiratory muscles.^{1,5} The findings of our study corroborate with that of a recently published study, where the authors found that IO and RA thickening fraction correlated to the expiratory pressure generated.²³ The study

concluded that reduced abdominal muscle thickening during cough leads to an enhanced probability of unsuccessful weaning from the ventilator.²³ The importance of studying the abdominal expiratory muscles, which help in ventilator weaning, has also been emphasized before, where the investigators performed functional electrical stimulation of the abdominal muscles to help accentuate the weaning process.²⁴ The authors had concluded that though functional electrical stimulation did not increase muscle thickness, the maneuver may be beneficial in reducing the length of ICU stay and ventilator days.²⁴ However, another study had shown that electrical stimulation did increase RA thickness, which in turn assisted in weaning.²⁵ The findings of the aforementioned study support the results of our study, where a thicker RA is associated with patients having simple weaning, compared to those with difficult or prolonged weaning.²⁴ Thus, the importance of analyzing expiratory abdominal muscles has to be emphasized in the ICU, apart from our usual inspiratory muscle (mainly diaphragmatic) assessment. In our study, IO had the highest sensitivity (68.8%) and specificity (76.9%) among the abdominal expiratory muscles to predict simple weaning. However, it could not outperform the rapid shallow breathing index (RSBI), and literature shows that RSBI has higher sensitivity (84%) in predicting weaning success, though the specificity is lower (70%).²⁶ The abdominal expiratory muscles are nevertheless an integral component of the respiratory muscle pump complex and should be evaluated during the weaning process.¹

Regarding the pattern of thickness followed by the expiratory abdominal muscles, we did not find any statistical difference between the simple weaning group and the difficult or prolonged weaning group, where the pattern RA > IO > EO > TA was maintained in both groups.

In a study done on six healthy male Italian patients, at FRC, the thicknesses of RA, IO, EO, TA were 11 ± 4.3 mm, 11.1 ± 3.8 mm, 5.5 ± 1.7 mm, and 5.8 ± 1.3 mm, respectively.¹ But cut-off values thickness of the abdominal muscles in our critically ill patients who had simple weaning were significantly lesser, being 6.38, 4.92, 3.15, and 2.53 mm, respectively.

To the best of our knowledge, there are no studies on critically ill patients in India, elaborating the thickness of abdominal muscles which can predict weaning.

Considering the inspiratory muscle (diaphragm activity), we found a slightly lower cut-off for DE (1.79 cm) to predict simple weaning, than a previous study, where the authors concluded that DE > 2.2 cm has a high probability of weaning success.²⁷ The DTF% cut-off value in our study in the simple weaning was 27.5%, which was similar to previous literature of 28%, but was slightly lesser than

30% as described by DiNino et al.²⁸ DTF% correlates well with the trans-diaphragmatic pressure and diaphragm function.^{29,30}

In our study, a significant finding is that the AUC of three expiratory muscles, RA, IO and EO, was much higher than the AUC of diaphragmatic excursion and diaphragmatic thickening fraction to predict simple weaning. This signifies the role of expiratory muscles in weaning, as it is when the inspiratory muscles are unable to handle the load imposed on them, that the expiratory muscles become more active.¹ This situation is typically appreciated in critically ill patients.

The lung ultrasound score was significantly higher in the difficult or prolonged weaning group. But the score (9.71 ± 5.18) in our study was much lesser than the score of 16.5 ± 4.2 found by Soliman et al., in their patients with failed weaning group.³¹ The lower lung ultrasound score in our difficult or prolonged weaning patients could be because of factors like expiratory muscle thinning, with lesser diaphragmatic excursion may lead to an even lesser lung ultrasound score tolerated by the patients for weaning success. Lung ultrasound score is a reflection of the "lung wettability," and thus the conclusion by Seeley EJ that "A dry lung is a happy lung" is precise in critically ill patients being weaned, where the inspiratory load is high, the diaphragm is weakened, and expiratory muscles have an ever-increasing important role.^{6,32} The fact the diaphragmatic thinning and weakness start within 48 hours of mechanical ventilation is now known, and thinning occurs at a rate of 6% each day.³³ This mandates that we also focus on expiratory muscles to predict weaning patterns.

Strengths of the study include that this was done to assess primarily the role of abdominal expiratory muscles in the weaning pattern, rather than the conventional inspiratory muscle (diaphragm) action only. The expiratory muscles are often overlooked for their role in weaning. We also compared the AUC of the expiratory muscles in predicting simple weaning to the AUC of the DE and DTF% to signify the role of expiratory muscles in patients where the inspiratory load is high, as in critically ill. We also noted if the pattern of expiratory muscle thickness which is maintained in healthy individuals is also followed in the critically ill, and if that has an effect on the weaning pattern. Limitations of the study include that it was a single-center study. We did not measure the abdominal expiratory muscle thickening fraction of each of the muscles and assess their role in the weaning pattern. Also, the expiratory muscle thickness was measured on the day of the first SBT, and not during every subsequent SBT. We did not measure the change in thickness of the abdominal expiratory muscles on the day of SBT, as compared to their thickness on the day of admission. The evaluation of abdominal expiratory muscle thickness does not outperform the simple bedside tests like RSBI to predict simple weaning. Another limitation of the study is that the current sample size calculation is not accurate for the research question of evaluation of the abdominal expiratory muscle thickness and its association with weaning pattern.

CONCLUSION

In patients, mean and SD of the thickness of the abdominal expiratory muscle undergoing weaning in the critical care unit was 0.62 ± 0.18 cm (RA), 0.46 ± 0.18 cm (IO), 0.32 ± 0.10 cm (EO), and 0.24 ± 0.07 cm (TA). Abdominal expiratory muscles thickness of RA, IO, EO, TA being greater than 0.638, 0.492, 0.315, and 0.253 cm, respectively, predicted simple weaning pattern. Abdominal expiratory muscle thickness followed the pattern of RA > IO > EO > TA in both simple weaning and difficult or prolonged

weaning groups. DE > 1.79 cm predicted simple weaning. LUS was significantly lower in the patients who had simple weaning pattern.

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