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Diaphragmatic ultrasonography as a predictor of weaning from the ventilator.

[1]Dr. Vidya Shree, MBBS, MD, Senior resident, department of Anaesthesiology, Institute of kidney diseases and research centre, Ahmedabad, India.

[2]Dr. Geeta Parikh, MBBS, MD, Professor, department of Anaesthesiology, Institute of kidney diseases and research centre, Ahmedabad, India.

[3]Dr. Kaushalya bhabhor, MBBS, MD, Senior resident, department of Anaesthesiology, Institute of kidney diseases and research centre, Ahmedabad, India.

Corresponding Author: Dr. Geeta Parikh, MBBS, MD, Professor, department of Anaesthesiology, Institute of kidney diseases and research centre, Ahmedabad, India.

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Abstract

Introduction: Current guidelines for weaning recommend the implementation of a spontaneous breathing trial (SBT) as a tool to predict weaning outcome. However, 13 to 26% of patients who are extubated following a successful SBT need to be reintubated within 48 hours. Successful liberation from MV depends on several factors, as patients must be haemo dynamic ally stable, have an adequate ventilation-perfusion ratio, have the ability to generate a strong cough and expectorate endo tracheal secretions. Diaphragmatic dysfunction remains the main cause of weaning difficulty or failure. Its prevalence ranges from 33 to 95%. Diaphrag matic dys function among patients hospitali zed in the intensive care unit (ICU) is commonly attributed to critical illness poly neuro pathy and myopathy. Mechanical ventilation, even after a short period of time, can also induce dia phrag matic dysfunction by reducing the force that generates the capacity of the diaphragm, which may cause weaning difficulty. Weaning failure defined as the requirement of invasive or non-invasive mechanical ventilation within 48hours after extubation, extremely common. About 20% of mechanically ventilated patients confront weaning failure and require reintubation. Weaning failure is associated with prolonged mechanical ventilation and ICU stay, as well as increased hospital mortality. Several conventional ventilatory parameters, including the rapid shallow breathing index (RSBI), vital capacity (VC), and maximum peak inspiratory pressure (PIMAX), are routinely used to predict weaning failure from mechanical ventilation none of shown great pro gnostic accuracy.

More recently, lung and diaphragm ultrasound methods have been introduced, assessing pulmonary airway patterns and diaphragm function for weaning from the ventilator. Although fluoro scopic examination of the diaphragm remains the gold standard for evaluation of diaphragmatic movement, it cannot be performed in icu patient.

Aims and objectives.

Bedside diaphrag matic ultra sono graphy provides real time assessment of qualitative and quantitative function of diaphragm which helps to diagnose diaphrag matic weakness and respiratory load.

Primary aim

- To assess the accuracy of diaphrag matic ultra sono graphic parameters as predictor of weaning from the ventilator. The parameters are,

a) Diaphragmatic excursion (DE) (mm)

b) time to peak inspiratory amplitude (TPIA) (seconds)

- To compare conventional ventilatory parameters with diaphragmatic ultrasonographic parameters in successful weaning group

Secondary aim

To compare conventional ventilatory parameters with diaphragmatic ultra sonographic parameters in successful weaning group

Materials and methods

Study design

It is a prospective observational study. The study was ap proved by Ethical committee. We enrolled 43 adult patients aged >18 years, who were admitted to intensive care unit and intubated for more than 48hours. We conducted the study from December 2019 to December 2020. All patients were provided with written consent prior to study. When the patients was unable to provide consent because of consciousness disturbance, the next kin provided written consent

Inclusion criteria

1. Intubated patient >48 hours
2. Age >18years
3. Readiness for weaning from mechanical ventilation as defined by recovery from the cause of respiratory failure.
4. Stable haemodynamic status, no requirement of Vaso pressors and ionotropes
5. No administration of sedative agents and neuro muscular blocking agents >24 hours.
6. Patients who tolerated the spontaneous breathing trial for more than 2 hours with respitaory rate <35, heart rate <100, oxygen saturation >95%.

Exclusion criteria

1. Pneumothorax, pneumome diastinum, pleural lesion
2. History of neuromuscular disease
3. Thoracic surgery
4. Presence of tracheostomy
5. Spinal cord injury higher than T8
6. Pregnancy

Methods

Patient who are ready for extubation given spontaneous breathing trial (SBT) for 2 hours and parameters recorded. The parameters recorded are RR (respiratory rate), tidal volume (TV), minute ventilation (MV), rapid shallow breathing index (RSBI), vital capacity (VC), peak inspiratory pressure (PImax) at minimal (<5 mmhg) supports on ventilator. RSBI <105 breaths/litre/min is con sidered as a good discriminator of weaning success and failure. Rapid shallow breathing index (RSBI) is calculated by number of respiratory breaths per minute divided by tidal volume in litres.

After 2 hours of Spontaneous breathing trial (SBT) dia phrag matic ultrasonographic parameters were recorded. Transthoracic ultrasonography was performed at bedside with Philips USG machine. The examination was per formed in both B and M modes. All examinations were carried out with patient in supine position. We obtained dia phrag matic ultrasound values from three consecutive tidal breaths and the average values were used for ana lysis. The diaphragmatic inspiratory excursion (DE) of each hemi dia phragm, and time to peak inspiratory

amplitude of the diaphragm (TPIA dia) of each hemi dia phragm (right TPIA dia and left TPIAdia) were measured in M-mode using 1-5MHz ultrasound transducer during tidal breathing. The measurement was performed via sub costal approach in both right and left midclavicular line and anterior axillary line. The liver and spleen were identified as a window for each hemidiaphragm. The ultrasound probe was placed in the direction in which the ultra sound beam reached the posterior third of the cor responding hemi diaphragm perpendicularly. During in spiration, the normal diaphragm moved caudally toward the ultrasound transducer, which was recorded as the upward motion of the M-mode tracing. The amplitude of the diaphragmatic inspiratory excursion was measured as the point of the maximal height of inspiration in the M-mode tracing. The TPIAdia was defined as the time to the maximal 2526 amplitude of diaphragmatic inspiratory excursion as measured from the M-mode tracing.

Table 1:

Measurement	Evaluation in m-mode
Diaphragmatic excursion (DE, cm)	Excursion amplitude from start of contraction to maximum inspiration
Time to peak inspiratory amplitude (TPIAdia, seconds)	Time to peak inspiratory amplitude (TPIAdia, seconds)

Figure 1: (A) shows intercostal approach (left up), sub costal approach (left down), (B) ultrasound image of the diaphragm using intercostals (left up) and subcostal (left down) approach.

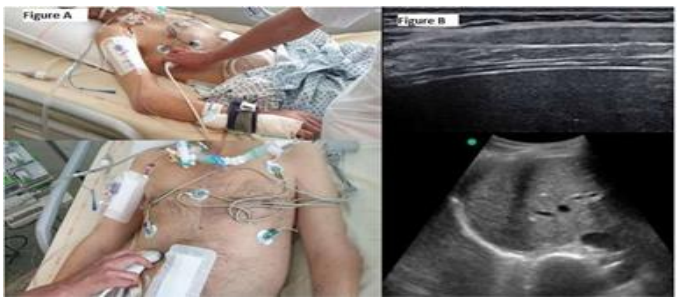


Figure 2: Ultrasound image of the dome of the diaphragm in brightness-mode (B-mode; left panel) and motion-mode (M-mode; right panel).

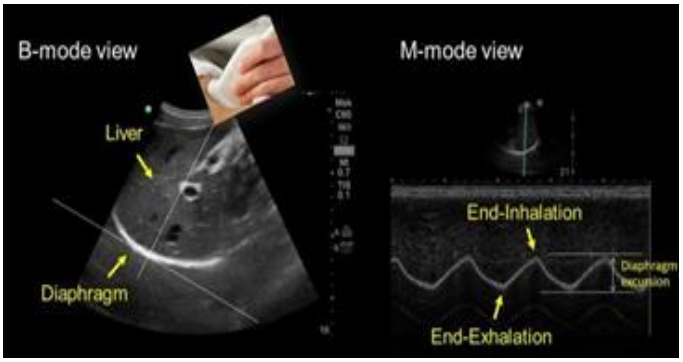
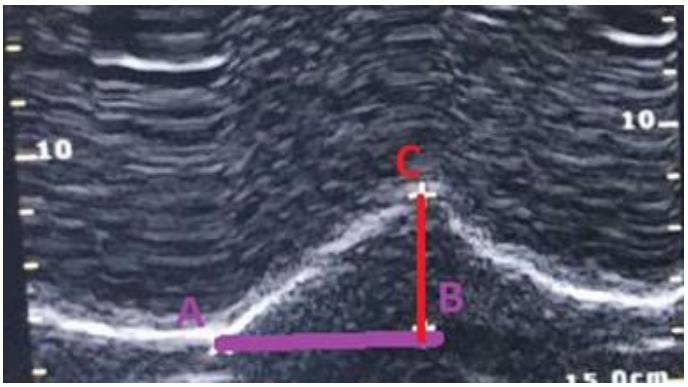


Figure 3: showing diaphragmatic parameters in M-mode A-B = Time to peak inspiratory amplitude (seconds) B-C= Diaphragmatic excursion (mm)



Results and discussion

Patients were divided into two groups after extub ation

- Successful group- patient weaned from ventilation, ability to tolerate spontaneous breathing at least 48 hours without any assisted ventilation.
- Failed group- patient requiring inavsive or non-invasive mechanical ventilation within 48 hours of extubation.

Table 2: demographic data

	Success Group(n=35)	Failure Group(n=8)	P value
Male: Female	25:10	7:1	0.347
Age (years)	38.6±9.73	43.7±13.13	0.219 (NS)

Table 3: Reason for intubation

Reason for Intubation	No. of patients(n=43)	Percentage (%)
Pneumonoia	10	24
Septic shock	8	19
Pulmonary edema	7	16
Heart disease	4	10
Copd exacerbation	8	18
Post operative Condition	6	13

Table 4: mean distribution of vitals in success group and failure group before extubation

Vitals (mean ± SD)	Success group(n=35)	Failure group (n=8)	P-value
Heart rate (bpm)	91.8±8.46	87.12±31.09	0.429
SBP (mmhg)	122.22±13.59	134±31.09	0.098
DBP (mmhg)	83.85±8.14	83.87±7.42	0.995
Oxygen Satur ation (%)	95.45±1.60	93.87± 1.88	0.019

there was no significant difference in vitals distribution in both groups (P>0.05).

Table 5: Comparision of conventional ventilatory wean ing parameters in success group and failure group.

Parameters	Success group(n=35)	Failure group (n=8)	P-value	95% ci
Respiratory Rate (breaths/min)	22.12 ±3.53	33.85± 2.31	<0.0 001*	-13.90 to -8.59
Tidal volume {ml)	468.25 ±69.24	345.62 ±34.43	<0.0 001*	71.46 to 173
Rsbi (breaths/min/ litre)	48.08 ±16.31	99.12 ±13.72	<0.0 001*	-63.62 to -38.45
Vital capacity (litres)	3.15±0.69	1.96±0. 53	<0.0 001*	-0.660 to 1.72
PI max (mmhg)	25.71±3.0 3	22.75± 4.96	0.03 37	0.239 to 5.680

As per the table Respiratory rate, tidal volume, vital capacity were significant in success group compared to failure group (p <0.005), where PImax is insignificant (p > 0.005).

The RSBI in spontaneously breathing patient was significantly lower in the weaning success group than failure group (P<0.0001) with mean of 48 breaths/ litre/ min.

Table 6: Comparision of diaphragmatic ultra sonographic parameters in success and failure group

Parameters	Success group(n=35)	Failure group (n=8)	P-value	95% CI
DE (mm) RIGHT	18.23±4.81	11.55±1.2 0	0.004 *	3.19 to10.16
DE (mm) LEFT	18.13±5.33	11.55±1.3 4	0.001 4*	2.74 to 0.44
TPIAdia(se c) RIGHT	1.16±0.27	0.90±0.16	0.013 *	0.05 to 0.46
TPIAdia(se c) LEFT	1.18±0.25	0.85±0.11 7	0.000 7*	0.15 to 0.51

Respiratory rate, tidal volume, vital capacity were signifi cant in success group compared to failure group (p <0.005), where PImax is in significant (p> 0.005).

The RSBI in spontaneously breathing patient was signifi cantly lower in the weaning success group than failure group (P < 0.0001) with mean of 48 breaths/ litre/ min.

Table 7: sensitivity and specificity of ultra sono graphic parameters i, e., TPIAdia and diaphragmatic excursion and rapid shallow breathing index of weaning success

	Cutt-off Value	Sensitivity	Specificity
RSBI (breaths/litre/min)	<100	94.29%	75.00%
TPIAdia(sec)	>0.8	94.41%	85.70%
DE (mm)	>12.5	91.18%	55.56%

The above table summarise that, RSBI cut-off value <100 gives sensitivity of 94.29% and specificity of 75. 00 %, TPIAdia cut-off value > 0.8seconds gives sensiti vity of 94.41% and specificity of 85.70% and diaphrag matic excursion (DE) cut-off value of 12.5mm gives sensiti vity of 91.18% and specificity of 55.56% in successful weaning group.

Table 8: postive and negative predictive values, positive and negative likelihood ratios in weaning success

	PPV	NPV	Positive Likelihood Ratio (95% CI)	Negative Likelihood Ratio	Accuracy
RSBI (breaths/ litre/mi)	94.29	75.0	3.77 (1.13 to12.56)	0.08	90.70%
TPIAdia(sec)	94.29	75.0	6.61 (1.08 to 40. 65)	0.06	93.02%
DE (mm)	88.50	62.5	2.05 (0.98 to 4.29)	0.16	83.72%

The PPV and NPV of RSBI was 94.29 and 75.0, TPIAdia was 97.10 and 75, DE was 88.50 and 62.5 respectively. The RSBI showing positive likhe lihood ratio 3.77 with 90.70% accuracy, TPIAdia showing 6.61 with 93.02% accuracy, and DE showing 2.05 with 83.72% accuracy respectively.

Table 9: Comparision between group diaphragmatic dys function and non-diaphragmatic dysfunction.

Parameters	Diaphragmatic Dysfunction(n=12)	Diaphragmatic dys function(n=12)	P-value
Tidal volume (mean ± SD, ml)	408.16±77.6	477.2±82.3	0.016*
PImax (mean ± SD, mmhg)	26.1±4.6	24.6±3.1	0.217
Vital Capa city (mean ± SD, litre)	2.8±0.78	2.9±0.79	0.991
RSBI (mean ± SD breaths/ ml/min)	72.9±28.2	53.9±2.35	0.021*
TPIAdia (mean ± sd seconds)	0.98±0.32	1.17±0.23	0.006*

As per the table, patient who developed diaphragmatic dys function had higher RSBI, lower tidal volume, and lower TPIAdia when compared to non-diaphrag matic dys function ($p<0.05$).

Discussion

Since 1991, the RSBI which is calculated as respi ratory rate divided by tidal volume has been used to predict weaning outcomes. It exhibits the best performance compared with the CROP index (comp liance rate oxy genation pressure index), PIMAX, and Minute venti lation. However, the isolated RSBI may not be precise enough to predict weaning out comes in patients undergoing prolonged mecha nical ventilation. The RSBI is a weaning predictor that measures the change in volume gene rated by all respiratory muscles while not specific ally measuring the diaphrag matic contribution.

More recently, lung and diaphragm ultrasound methods have been introduced, assessing pulmonary airway patterns and diaphragm function. Bouhemad et al [1] was the first author to propose lung ultrasound score (LUS) for calcu lating lung aeration patterns in patients with ventilator –associated pneu monia. Later Soummer et al [2], Binet Cet al [3], Shoaer M et al [4], Osman AM et al [5] Modi fied LUS score to predict ultrasound weaning outcome with promising results. Osman AM et al [6], and DiNino E et al [7] proposed several parameters measured through dia phragm ultrasound for predicting weaning outcome. These para meters include diaphragm movement or excur sion during inspiratory cycle, diaphragm thickness and diaphragm thickening fraction.

In our study, we evaluated the role of ultrasound in the assessment of diaphragm function as a predictor of weaning from the ventilator as diaphragm plays a crucial role in respiratory muscle endurance. In our study, we investi gated 43 patients without significant demo graphic and clinical characteristics, who were mechanic ally ventilated for > 48 hours, whereas Yasser Sadek Nassar et [7] considered the patients who were mechanic ally ventilated for >72 hours. In our study most of the patient (90%) presented with medical conditions as the indication for mechanical ventilation as comparable with F. Varon-Vega et a [12] study, where they included 88% patients of the medical condition as an indic ation for mechanical ventilation.

All patients were extubated after 2 hours of spontaneous breathing trial, successful extubation was achieved in 81% (n=35) of the patients and failed in the remaining 19% (n=8) as comparable with Pondhep Theerawit et al [8] study, where 82% of the patients weaned successful 18% re-intubated within 48 hours of extubation. There were no significant differences between the groups in terms of demo graphic and clinical characteristics. How ever, number of days on ventilator in the patients with failed extubation were longer (mean no. of days =9) compared with successful weaning group (mean no. of days =5) as comparable with Frutos-vivar F et al [8] study. We recorded diaphrag matic ultra sonographic para meters i.e., Time to peak inspiratory amplitude (TPIA dia seconds) which is time from start to diaphrag matic contraction to maximum inspiration and Diaphrag matic excursion (DE, cm) which is excursion amplitude from start of contraction to maximum inspiration, in all the patients before extub ation and compared these para meters with conventional ventilatory parameters in success ful and failed weaning group. In our study, we compared conventional ventilatory parameters in both groups, tidal volume and vital capacity were significantly higher ($p<0.001$), respiratory rate and RSBI were signific antly lower in successful weaning group. There was no significant difference in PImax between two groups ($p>0.05$). Diaphrag matic ultra sonographic parameters were compared between two groups, TPIAdia (> 0.8 seconds) and DE(>12.5mm) significantly higher($p<0.05$) in successful weaning group. We compared ventilatory and USG parameters in both the groups, found that in the successful weaning group, RSBI (<100) had 94% sensiti vity with specificity of 75%, and TPIAdia (>0.8 seconds) had sensitivity of 94% with specificity of 85% and 93% accuracy as shown in the study by Pongdhep Theerawit et al [8], where they proposed a parameter, TPIAdia (> 0.8 seconds) to predict successful weaning from mecha nical ventilation. However, negative predictive value of TPIAdia is 75, hence positive result that predicts weaning failure does not mean that the patient would have delayed weaning, but should be carefully evaluated during the weaning and extubation periods. Therefore, TPIAdia should be interpreted with caution and should be com bined with other parameters. We found that patients with

a longer TPIAdia tend to have more successful weaning from mechanical ventilation, and we found a strong correl ation between the TPIAdia and RSBI as shown in Pongdhep Theerawit et al [8]. This correlation suggests the presence of a relationship between TPIAdia and dia phrag matic strength.

Physio logically, the strength and endurance of the diaphragm are not similar. Diaphragmatic strength refers to the capacity of the diaphragm to generate force, which is dependent on many factors such as diaphragm con tractile activation, excitation–con traction coupling, central drive, nerve conductance, and neuro muscular transmission. Endurance is defined as the ability of the dia phragm to sustain force over time. Our investigation suggests that the TPIAdia is associated with the strength of the dia phragm rather than its endurance. Diaphrag matic dys function is a common condition in the ICU and is associated with prolonged weaning from mecha nical ventilation and weaning failure. Jiang et al. [9] hypo the sized that displacement of the liver/spleen as measured by ultra sono graphy can represent move ment of the hemi-diaphragms. They demonstrated that using a cut-off value of 10 mm can predict successful extubation. In our study, we used cut-off value of <12.5 mm for diaphrag matic excursion for diaphrag matic dys function and showed that the prevalence of diaphragmatic dysfunction in the medical and surgical ICU was 28% (n=12) and, whereas Kim et al. [10], used cut-off value of < 10 mm for diaphragmatic excursion and demonstrated that 29% of patients hospitalized in the medical ICU developed diaphrag matic dysfunction. Our cut-off value differed from Lerolle et al. [11] who used higher cut-off value of >25mm due to the prolonged (<7 days) mechanically ventilated post-cardiac surgery patients. Cardiac surgery is known to cause phrenic nerve injury during harvesting the left side internal mammary artery, which leads to diaphrag matic paralysis. Lerolle et al [11] measured diaphrag matic excursion during maximal voluntary inspi ratory effort in semi-sitting position, whereas we measured diaphragmatic excursion during tidal volume breathing in the supine position. In our study diaphrag matic excursion (>12.5mm) showed sensiti vity of 91% and specificity of 55% with accuracy of 83.72% and negative predictive value of 62. In diaphrag matic dys function group, failed weaning rate was 58 % and in non-diaphragmatic dysfunction group failed weaning rate was 9%. Diaphragmatic excursion (>12.5mm) also showed strong co-relation with RSBI in successful weaning group and could predict re-intubation within 48hours of extubation. Volumetric weaning parameter (like RSBI) mea sures the changes in volume generated by the respi ratory muscles as a whole rather than the gene rated by the diaphragm alone. In this regard, RSBI although easy to obtain, carries an inherent limit ation and does not fully reflect the functional state of this principle respi ratory muscle. Our study is in agreement regarding the use of diaphragmatic ultrasound as mor pho metric index for weaning that shows a promising advantage over con ventional ventilatory parameters.

Summary and conclusion

The present study demonstrated that Diaphragmatic Ultra sono graphy can predict the weaning outcomes in the mechanical ventilated patients. The diaphragmatic para meters time to peak inspiratory amplitude diaphragm (TPIAdia) (>0.8seconds) and diaphragmatic excursion (>12.5 mm) exhibited good performance in predicting weaning outcomes with good sensitivity and specificity and had strong correlation with the RSBI. Diaphragmatic excursion <12.5mm which is diaphragmatic dysfunction can predict re-intubation within 48 hours of extubation.

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