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TO ASSESS THE DIAPHRAGMATIC AND LUNG USG TO PREDICT THE OUTCOME OF WEANING PROCESS

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ABSTRACT

Aim: The aim of the present study was to assess the diaphragmatic and lung USG to predict the outcome of weaning process.

Methods: The proposed study has been conducted on critically ill post-surgical patients on mechanical ventilation aged between 18-65 years, in intensive care unit of Department of Anaesthesiology and CCM, Nehru hospital, B.R.D. Medical College, Gorakhpur, Uttar Pradesh from December 2020 to November 2021. 110 patients were included in the study.

Results: There was significant difference observed in failure rate of extubation among different age groups as age increases the rate of failure also increases significantly ($p<0.0001$). There was no significant difference observed in success rate of extubation across gender (success rate: male vs female: 88.2% vs 86.8%, $p=0.839$). Failure rate of extubation was significantly higher in those patients who had any comorbidities as compared to those who had no comorbidities. Mean LUS Score on CPAP was significantly lower in success group as compared to failure group. Mean LUS Score after extubation was significantly lower in success group as compared to failure group. Mean DTF on CPAP was significantly higher in success group as compared to failure group. Mean DTF on T piece was significantly higher in success group as compared to failure group. Mean DTF after Extubation was significantly higher in success group as compared to failure group. Likewise, Mean E on CPAP was significantly higher in success group as compared to failure group. Mean E on T piece was significantly higher in success group as compared to failure group. Mean E after extubation was significantly higher in success group as compared to failure group.

Conclusion: The weaning outcome can be predicted by LUS score, diaphragmatic thickness fraction (DTF), diaphragmatic excursion (E) in mechanically ventilated patients. A value of LUS score on T-piece ≤10 predicts the successful weaning final outcome. A value of DTF on T-piece ≥31% predicts the successful weaning final outcome. Similarly, a value of E on T-piece ≥18mm also predicts a successful weaning outcome. Increased rate of weaning failure observed in older age group, patients with co-morbidities and high SOFA score. Also prolonged duration of mechanical ventilation caused failure in weaning.

Keywords: diaphragmatic, lung USG, predict, outcome, weaning process

1. INTRODUCTION

Weaning from mechanical ventilation (MV) is a challenging decision, it means complete transition from mechanical breathing support to patient's own respiratory drive support. This transition is very critical and needs accurate, intense, confident decision based on trusted validated clinical, radiological and laboratory parameters to avoid the risk of weaning failure.[1] The patient's failure to accomplish this or to withstand 48 h of spontaneous breathing is defined as a weaning failure. Weaning failure is a disappointing event that, in relation to he comorbidities and other reported complications, impacts all ICU staff and patient families and costs patient exposure to reintubation risk.[2] The readiness of the patient for weaning depends globally on the respiratory muscles' power that faces the burden of breathing. Unbalance between the power and the burden leads to weaning failure, including any factor that impairs the respiratory muscle function as ICU acquired neuromuscular dysfunction which is either due to prolonged mechanical ventilation, prolonged sedation or any other potential cause.[3] Although the validated respiratory parameters which are assessed during weaning process are appropriate for weaning, however, the proficiency of these parameters to detect the power of the respiratory muscles to carry on the burden of breathing may be deficient.[4]

The diaphragm is the principal muscle in the process of respiration. MV for long durations may lead to its atrophy and subsequent impairment of its functions. This atrophy and subsequent dysfunction are the main causes of difficult weaning and subsequently weaning failure.[5] The role of Ultrasound (US) in assessment of diaphragmatic function has been conducted in many studies[6], where it can detect the normal and abnormal movements of diaphragm in many different conditions.[7] Also, lung US can be used in the evaluation of the lung condition which is beneficial during making the decision of weaning as it gives us an idea about its aeration and so we can expect if respiratory distress will occur after weaning or not.[8]

The process of weaning from mechanical ventilation remains one of the most critical challenges in patients undergoing mechanical ventilation in the intensive care unit (ICU)[9] the multidisciplinary team must study the optimal time for weaning from the mechanical ventilator as premature weaning may lead to weaning failure and thus increase the risk of hospital acquired infections, costs in care, ICU length of stay, hospital length of stay and diaphragmatic dysfunction.[10-11] Current guidelines recommend several indices applied at the bedside to predict successful weaning from mechanical ventilation. However, they have yet to prove ideal[12] probably due to the heterogeneity of critically ill patients, which limits the predictive ability of these indices in diferent patient subgroups[13]. A spontaneous breathing trial (SBT) is an appropriate way to prepare the patient for extubation [14] however, even after successful SBT, failure rates and subsequent reintubation can exceed 20% in the highest-risk patients.[15]

The aim of the present study was to assess the diaphragmatic and lung USG to predict the outcome of weaning process.

2. MATERIALS AND METHODS

The proposed study has been conducted on critically ill post-surgical patients on mechanical ventilation aged between 18-65 years, in intensive care unit of Department of Anaesthesiology and CCM, Nehru hospital, B.R.D. Medical College, Gorakhpur, Uttar Pradesh from December 2020 to November 2021. 110 patients were included in the study.

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The permission of ethical committee has been taken. Written informed consent has been taken from guardian of patients before conducting the study.

The exclusion criteria of this study:

- Patients aged < 18 years & > 65 years
- Any patient with known neuromuscular disorder or recent CVA
- Any patient with primary US revealed unilateral/bilateral absent diaphragmatic mobility
- Any patient with post esophageal or thoracic surgeries due to intra-operative diaphragmatic manipulation
- Patients with cardiac diseases
- Patients with poor LUS view window (obese, multiple rib fracture with surgical emphysema)

Patients who are on mechanical ventilator >48 hours are taken for the studies. All the patients switched over to CPAP mode of ventilation after assessing reversal of underlying pathology and clinical improvement and were kept on same mode for next 3 hours.

The patients who fulfilled the above criteria have been disconnected from the ventilators to allow spontaneous breath trial (SBT) by using T-piece with oxygen supply @ 5L/min and observed for 1 hour for the same targets explained above.

When the above criteria are fulfilled, patients extubated and observed for next 2 hours for any distress. ABGs are repeated in all three phases to assess the target criteria. Simultaneously all patients underwent diaphragmatic or lung ultrasound examination on 3 stages - first during CPAP mode, second during T piece trial and third 2 hours after extubation. And at all these three stages SOFA score is noted simultaneously for all patients.

Method of diaphragmatic US:

- USG machine and probe: SONOSITE II, and linear probe, covered with tegaderm to maintain sterility.
- Patient position: Semi-recumbent position.
- Diaphragmatic thickness fraction (DTF) assessment: The linear US probe was placed intercostally perpendicular to the chest wall in the 8th or 9th intercostals space between the anterior and mid axillary line. The diaphragm appeared as three-layered structure (two parallel echogenic lines representing the pleura and the peritoneum with central hypoechoic space representing the diaphragmatic muscle). The diaphragmatic thickness was measured from the middle of the pleural line to the middle of the peritoneal line. The thickness was measured during the end inspiration and the end expiration. This was repeated to take the average followed by DTF calculation = (Thickness at the end inspiration – thickness at the end expiration)/Thickness at the end expiration.
- Diaphragmatic excursion (E): The convex probe is placed subcostally parallel to the inetrcostal space to measure the range of the diaphragmatic movement using M-mode method with the cursor crossing the diaphragm and assess the high and low peak points as indicator for the diaphragmatic mobility range.

For lung ultrasound:

- USG machine and probe: SONOSITE II, and curvilinear probe, covered with tegaderm to maintain sterility.
- Patient position: Supine for anterior and lateral lung fields and lateral decubitus position for posterior lung field examination.
- Technique: Lung was divided into 6 regions by drawing four vertical lines at parasternal border, at the point of anterior axillary line, posterior axillary line and last at para-vertebral line

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posteriorly. A horizontal line is drawn starting from xiphisternum to make a total of 12 regions of chest.

- Lung US scan findings were noted into four patterns of aeration.

1. Normal aeration (N): Presence of lung sliding with A lines or fewer than two isolated B lines
2. Moderate loss of lung aeration: Multiple, well-defined B lines (B1 lines)
3. Severe loss of lung aeration: Multiple coalescent B lines (B2 lines)
4. Lung consolidation (C): The presence of a tissue pattern characterized by dynamic air bronchograms.

LUS score was given in following way: N=0, B1 lines=1, B2 lines=2, C=3

We have taken worst finding of each region as representative of that particular region. The LUS score has calculated after summation of all 12 regions. The final score, ranging from 0 to 36, is the sum of the values, from 0 to 3, assigned to the LUS patterns visualized in each of the 12 regions examined.

All patients observed for 48 hours to assess any respiratory distress. Patients who require any respiratory support in the form of non-invasive ventilation or intubation itself or death of the patient considered as failure of this study and the study discontinued for that patient.

Finally, we compared LUS score and diaphragmatic study findings in successfully extubated patients and extubation failure patients to assess its predictability in weaning trials.

All the data thus observed during lung and diaphragmatic ultrasonography recorded and further statistical analysis have done accordingly.

Statistical analysis was performed included profiling of patients on different demographic, clinical, laboratory and radiological findings. Descriptive analysis of quantitative parameters was expressed as means and standard deviation. Categorical data was expressed as absolute number and percentage. Independent Student t – test was used for testing of mean between independent groups whereas Paired Student t – test used for paired observation. Cross tables were generated and Chi square test used for testing of associations. Pearson correlation used to assess the strength of relationship between two variables. The diagnostic accuracy of diaphragmatic indices and LUS in predicting extubation success was assessed by receiver operating characteristic (ROC) curve analysis. P-value <0.05 was considered statistically significant. All analysis were done using SPSS software, version 24.0.

3. RESULTS

Table 1: Patient characteristics

Age (Years)	**Success (n=96)**	**Failure (n=14)**	**Total (n=110)**
<20	14 (100%)	0 (0%)	14 (100%)
21-30	47 (97.8%)	1 (2.1%)	48 (100%)
31-40	17 (94.4%)	1 (5.6%)	18 (100%)
41-50	9 (81.8%)	2 (18.2%)	11 (100%)
51-60	8 (66.7%)	4 (33.3%)	12 (100%)
>60	4 (57.1%)	3 (42.9%)	7 (100%)
Gender			

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Male	30 (88.2%)	4 (11.8%)	34 (100%)
Female	66 (86.8%)	10 (13.2%)	76 (100%)
Inotropic Support			
Yes	42 (76.4%)	13 (23.6%)	55 (100%)
No	54 (98.2%)	1 (1.8%)	55 (100%)

There was significant difference observed in failure rate of extubation among different age groups as age increases the rate of failure also increases significantly (p<0.0001). There was no significant difference observed in success rate of extubation across gender (success rate: male vs female: 88.2% vs 86.8%, p=0.839). There was significant lower success rate was observed in patients who were on inotropic support (76.4%) as compared to those patients who were not on inotropic support (98.2%).

Table 2: Success rate of extubation among patients with pre – existing comorbidities

Comorbidities	Success (n=96)	Failure (n=14)	Total (n=110)	Chi Square Value	p - value
Alcoholic					
Yes	1 (33.3%)	2 (66.7%)	3 (100%)	8.078	0.004*
No	95 (88.8%)	12 (11.2%)	107 (100%)		
COPD					
Yes	2 (28.6%)	5 (71.4%)	7 (100%)	23.192	0.0001*
No	94 (91.3%)	9 (8.7%)	103 (100%)		
Hypertension					
Yes	1 (25%)	3 (75%)	4 (100%)	14.492	0.0001*
No	95 (89.6%)	11 (10.4%)	106 (100%)		
Severe Anaemia					
Yes	1 (20%)	4 (80%)	5 (100%)	21.342	0.0001*
No	95 (90.5%)	10 (9.5%)	105 (100%)		
Severe Sepsis					
Yes	0 (0%)	1 (100%)	1 (100%)	6.920	0.009*
No	96 (88.1%)	13 (11.9%)	109 (100%)		
Type II DM					
Yes	1 (25%)	3 (75%)	4 (100%)	14.492	0.0001*
No	95 (89.6%)	11 (10.4%)	106 (100%)		

Failure rate of extubation was significantly higher in those patients who had any comorbidities as compared to those who had no comorbidities (p < 0.05).

Table 3: Mean value of LUS Score on CPAP mode and success of extubation and LUS score on T-piece trial and LUS score after success or failure of extubation of patients among study population

	Success (n=96)	Failure (n=14)	Mean ± Std.	95% CI of the Difference	t – value	p – value

			Error Mean	Lower	Upper		
LUS Score on CPAP	6.8 ± 2.2	10 ± 2.2	-3.2 ± 0.6	-4.4	-2	-5.141	<0.0001*
LUS score on T-piece	8.5 ± 2.1	12.6 ± 2.6	-4.1 ± 0.6	-5.4	-2.9	-6.502	<0.0001*
LUS after Extubation	9.4 ± 2.6	15.5 ± 3.4	-6.1 ± 0.8	-7.6	-4.6	-7.952	<0.0001*

Mean LUS Score on CPAP was significantly lower in success group as compared to failure group. Mean LUS Score on T-piece was significantly lower in success group as compared to failure group. Mean LUS Score after extubation was significantly lower in success group as compared to failure group.

Table 4: Mean value of diaphragmatic thickness fraction (DTF) on CPAP mode and success of extubation and DTF on T piece and DTF after success or failure of extubation among study population

	Success (n=96)	Failure (n=14)	Mean ± Std. Error Mean	95% CI of the Difference		t – value	p – value
				Lower	Upper		
DTF on CPAP	32 ± 1.3	29 ± 1	3 ± 0.4	2.3	3.8	8.135	<0.0001*
DTF on T piece	33.1 ± 1.4	29.8 ± 1.4	3.4 ± 0.4	2.6	4.1	8.498	<0.0001*
DTF after extubation	34.1 ± 1.3	30.5 ± 1.7	3.6 ± 0.4	2.9	4.4	9.454	<0.0001*

Mean DTF on CPAP was significantly higher in success group as compared to failure group. Mean DTF on T piece was significantly higher in success group as compared to failure group. Mean DTF after Extubation was significantly higher in success group as compared to failure group.

Table 5: Mean value of E on T-piece and Mean value of E after extubation in success and failure group and SOFA Score of patients on mechanical ventilation and success of extubation and Mean number of days of patients on ventilator and success of extubation

	Success (n=96)	Failure (n=14)	Mean ± Std. Error Mean	95% CI of the Difference		t – value	p – value
				Lower	Upper		
E on T-piece in (mm)	21.7 ± 3.2	13.4 ± 4.3	8.3 ± 1	6.4	10.2	8.685	<0.0001*
E after Extubation in (mm)	24.5 ± 3.6	12.9 ± 6	11.6 ± 1.1	9.4	13.8	10.31	<0.0001*

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SOFA Score	8.3 ± 2	13 ± 3.1	-4.7 ± 0.6	-5.9	-3.5	-7.6	<0.0001*
No of days on Ventilator	4.1 ± 1.3	6.9 ± 2.4	-2.8± 0.4	-3.6	-2	-6.733	<0.0001*

Mean E on T-piece was significantly higher in success group as compared to failure group. Mean E after extubation was significantly higher in success group as compared to failure group. Mean SOFA Score was significantly lower in success group as compared to failure group. Mean of number of days on ventilator was significantly lower in success group as compared to failure group.

4. DISCUSSION

Multiple parameters and indices have developed over time to evaluate about the readiness of extubation. The usual respiratory indices used for weaning are breathing frequency, minute ventilation (Ve), maximum inspiratory pressure (PImax), rapid shallow breathing index (RSBI, i.e., respiratory frequency/tidal volume), tracheal airway occlusion pressure 0.1 sec (P=0.1s), and a combined index called CROP (compliance, rate, O2, pressure index). Among this RSBI shows more predictability of failure in weaning trial.[16] With the increasing familiarity of ultrasound among anaesthesiologist and intensivists and recent introduction of "point of care ultrasound (POCUS)", there has been increased use of lung ultrasound scan (LUS) to predict the success of weaning and readiness for extubation. Ultrasonography can assess the underlying lung pathologies, the characteristics of diaphragmatic movement such as amplitude, force and velocity of contraction, special patterns of motion, changes in diaphragmatic thickness during inspiration.[17]

In present study, there was significant difference observed in failure rate of extubation among different age groups. We found that as the age increases the failure rate also increases ($p<0.0001$). (Table:1) The mean age was significantly lower in patients who had successful extubation as compared to those who had failed extubation (Age: Success vs Failure: 31.1 ± 11.7 vs 56.1 ± 13.2, $p<0.0001$). Similar to our findings, Thille et al[18] also stated in their study that patients with age ≥ 65 years had higher chances of reintubation compared with patients of younger age groups. In this study, success rate of extubation was significantly lower in those patients who had any comorbidities as compared to those who had no comorbidities ($p<0.05$). The study by Shigang Li et al[19] and Thille et al[18] also shows that the extubation success is lower in patients who have comorbidities like pulmonary infection, acute exacerbation of COPD, acute left heart failure and intracranial lesions.

Significant lower success rate of extubation was observed in our study in patients who required inotropic support (76.4%) as compared to those patients who did not require inotropic support (98.2%) ($p<0.001$). Significantly higher mortality rate was observed in patients who were on inotropic support (23.6%). On the contrary, there was no mortality seen in patients with inotropic support ($p<0.0001$). According to Agael et al[20] high early inotrope doses are associated with decreased weaning success and increasing ICU mortality. ICU mortality increased with increasing inotrope dose. In this study mean LUS score on CPAP was significantly lower in success group as compared to failure group. (LUS score on CPAP: Success vs Failure: 6.8 ± 2.2 vs 10 ± 2.2, $p<0.0001$). Mean LUS score on T-piece was significantly lower in success group as compared to failure group. (LUS score on T-piece: Success vs Failure: 8.5 ± 2.1 vs 12.6 ± 2.6, $p<0.0001$). Mean LUS score after extubation was significantly lower in success group as compared to failure group. (LUS score after Extubation: Success vs Failure: 9.4 ± 2.6 vs 15.5 ± 3.4, p<0.0001). In support of our study, Abdel Rahman DA et al[21] revealed that LUS shows a promising role as a predictor of SBT outcome and for expecting the post-extubation distress.

In our study mean DTF on CPAP was significantly higher in success group as compared to failure group. (DTF on CPAP: Success vs Failure: 32 ± 1.3 vs 29 ± 1, p<0.0001). Mean DTF on T piece was significantly higher in success group as compared to failure group. (DTF on T piece: Success vs Failure: 33.1 ± 1.4 vs 29.8 ± 1.4, p<0.0001). Mean DTF after extubation was significantly higher in success group as compared to failure group. (DTF after extubation: Success vs Failure: 34.1 ± 1.3 vs 30.5 ± 1.7, p<0.0001). Similar to our findings, Abhinav Banerjee, et al[22] and Baess et al[23] also found that DTF score was higher in successfully weaned patients. In current study, mean E on CPAP was significantly higher in success group as compared to failure group. (E on CPAP: Success vs Failure: 23.1 ± 3.4 vs 13.4 ± 5, p<0.0001). Mean diaphragmatic excursion (E) on T-piece was significantly higher in success group as compared to failure group. (E on T-piece: Success vs Failure: 21.7 ± 3.2 vs 13.4 ± 4.3, p<0.0001). Mean E after extubation was significantly higher in success group as compared to failure group. (E after extubation: Success vs Failure: 24.5 ± 3.6 vs 12.9 ± 6, p<0.0001). In our study we also observed that T-piece E score was significantly higher in the success group than failure group (p<0.001). In line with our study, Banerjee et al[22] found that mean E was higher in successful weaning patients as compared to the failed ones.

In our study mean sequential organ failure assessment (SOFA) score was significantly lower in success group as compared to failure group. (SOFA Score: Success vs Failure: 8.3 ± 2 vs 13 ± 3.1, p<0.0001). Similarly, in their study, Thille et al[18] observed that SOFA score worsened rapidly in the failure group but continued to improve in the group with successful extubation. The mean number of days on ventilator was significantly lower in success group as compared to failure group. (Number of days on ventilator: Success vs Failure: 4.1 ± 1.3 vs 6.9 ± 2.4, p<0.0001). Similarly, in the study by Li S et al[24] and Umbrello et al[23] the mechanical ventilation time and ICU stay time of the successful weaning group were significantly shorter than those of the failed weaning group. Patients with failed weaning need to be intubated again which increases the probability of repeated treatment and prolongs the time of mechanical ventilation and treatment.

5. CONCLUSION

The present study reported that Mean LUS Score on CPAP was significantly lower in success group as compared to failure group. Mean LUS Score after extubation was significantly lower in success group as compared to failure group. Mean DTF on CPAP was significantly higher in success group as compared to failure group. Mean DTF on T piece was significantly higher in success group as compared to failure group. Mean DTF after Extubation was significantly higher in success group as compared to failure group. Likewise, Mean E on CPAP was significantly higher in success group as compared to failure group. Mean E on T piece was significantly higher in success group as compared to failure group. Mean E after extubation was significantly higher in success group as compared to failure group.

The weaning outcome can be predicted by LUS score, diaphragmatic thickness fraction (DTF), diaphragmatic excursion (E) in mechanically ventilated patients. A value of LUS score on T-piece ≤10 predicts the successful weaning final outcome. A value of DTF on T-piece ≥31% predicts the successful weaning final outcome. Similarly, a value of E on T-piece ≥18mm also predicts a successful weaning outcome.

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Increased rate of weaning failure observed in older age group, patients with co-morbidities and high SOFA score. Also prolonged duration of mechanical ventilation caused failure in weaning. We proposed that LUS and USG guided diaphragmatic study should be made an integral part of training of anaesthetists and intensivists for the care of ICU patients. However, further studies with larger sample sizes of patients are required to establish the true predictive power of these ultrasound techniques in weaning success.

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