



Diaphragmatic dysfunction evaluation using ultrasonography as a predictor of weaning for patients with Acute Exacerbation of Chronic Obstructive Pulmonary Disease from mechanical ventilation

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Abstract

Introduction: Diaphragmatic Excursion (DE) was used as a predictor for weaning of mechanical ventilation (MV) but not for acute exacerbation of chronic obstructive pulmonary disease (AECOPD) patients.

Objectives: To correlate between Diaphragmatic dysfunction (DD) and outcome of mechanically ventilated AECOPD patients.

Materials and Methods: 60 wean able mechanically ventilated patients with AECOPD were prospectively enrolled. M-mode U/S evaluation of the diaphragm was done using convex probe 3.5-5 MHZ in the supine position at the start of spontaneous breath trial on T-piece. Patients were randomized into two groups; DD (< 1 cm excursion) and non-DD (> 1 cm excursion). Outcomes of the ICU stay were determined.

Results: Ten patients with DD had primary weaning failure versus two in the non-DD group, while six patients with DD had secondary weaning failure. There was significant reduction in duration of weaning, ICU and hospital length of stay in favor of non-DD group (2.5, 5 and 6 days, respectively; $p < 0.001$). For predicting weaning failure, the test showed 88.89% sensitivity, 97.62% specificity, 94.12% positive predictive value and 95.35% negative predictive value.

Conclusions: DD detected by M-mode U/S was associated with prolonged duration of mechanical ventilation, ICU, hospital stay, and weaning failure in AECOPD patients.

Key words: Acute exacerbation of COPD, Diaphragmatic dysfunction, Ultrasonography, Diaphragmatic excursion, weaning failure, and Rapid Shallow Breathing Index.

Introduction

Acute Exacerbation of COPD is defined as “acute event characterized by a worsening of the patient's respiratory symptoms that is beyond normal day to day variations and leads to a change in medication”.⁽¹⁾

Weaning from mechanical ventilation (MV) is defined as “the process of abruptly or gradually withdrawing ventilatory support”.⁽²⁾

Unnecessarily hazards due to delay in weaning off MV can happen, for instance trauma to the airway, ventilator-associated pneumonia, sedatives and

other ICU medications side effects, and increased cost of health-care.^(3,4)

Weaning off MV depend on respiratory mechanics.⁽⁵⁾

Various insults such as sepsis, hypoxia, and hypotension, which are common in intensive care unit (ICU) patients, can affect the diaphragm which is the main muscle of respiration.^(6,7)

COPD as a special category has a major effect on diaphragmatic function.^(8,9)

Furthermore, diaphragmatic dysfunction (DD) can be induced by MV through reduction of the diaphragmatic capability of force generation; this is known as ventilator induced diaphragmatic dysfunction.^(10,11)

Ultrasonography as an easy and accurate bedside diagnostic modality with advantage of lacking radiation hazards makes it suitable for critically ill patients with no need for transportation.⁽¹²⁾

Degree of diaphragmatic muscle thinning assessed by ultrasound in mechanically ventilated patients had been studied although no relationship with the diaphragm strength, atrophy nor pulmonary function.⁽¹³⁾

Others studied the dynamics of the diaphragm using ultrasound but also poorly quantified pulmonary function.⁽¹⁴⁾

However, many studies were done lately to use the diaphragmatic assessment by US in prediction of the weaning from mechanical ventilation but none in our knowledge for the COPD mechanically ventilated patients.^(15,16)

The diaphragmatic assessment using ultrasound had been found to provide functional information about the muscle and can be repeated if required.⁽¹⁷⁾

M-mode US is an easy to perform. The M-mode US has been recently shown to be capable of quantifying diaphragm movements.^(18,19)

Aim of the Work

The aim of the work was to determine the correlation between diaphragmatic dysfunction and patients with acute exacerbation of chronic obstructive pulmonary disease on mechanical ventilation as regard:

1. Duration of weaning.
2. Total duration of mechanical ventilation.
3. Weaning failure either primary or secondary.
4. ICU length of stay.
5. Hospital length of stay.
6. Hospital mortality.

Methodology

This was a prospective observational study approved by the institutional ethics committee as well as an informed consent from the patients' next of kin.

Study Subjects

We evaluated 60 AECOPD patients receiving mechanical ventilation in our medical ICU.

Only patients who were prepared for liberation of mechanical ventilation and extubation were evaluated on t-piece. The decision for extubation was made by the attending physicians, according to the clinical condition, weaning parameters, and results of the SBT of the patients were recorded. The attending physicians were blinded to the results of sonographic measurements. Either patients with accidental extubation, prepared for extubation with SBT other than t-piece (CPAP, Adoptive supportive ventilation) were excluded orthose with failed SBT were excluded.

Inclusion criteria were: Patients on ventilatory support for at least 48 hours who met the definition of acute exacerbation of AECOPD on mechanical ventilation and who met the criteria for weaning from mechanical ventilation, which include: Patients able to breathe spontaneously, presence of adequate cough reflex, respiratory rate <35/min, temperature <38.5°C, no vasopressors for blood pressure control, peak end-expiratory pressure <5 cm H₂O, oxygen saturation ≥90% with fraction of inspired oxygen (F_iO₂) not >60%, rapid shallow breathing index(RSBI) <105.

Exclusion criteria were:

1. Patients who received certain drugs as amino glycosides, the ophylline or steroid therapy before admission.

2. Advanced liver, renal or cardiac disease except for pulmonary hypertension.
3. Electrolyte imbalance as hyponatremia, hypernatremia, hyperkalemia, hypokalemia and hypophosphatemia.
4. History of diaphragmatic palsy, cervical spine injury, neuromuscular disease (myasthenia gravis, Guillain-Barre´ syndrome, amyotrophic lateral sclerosis).
5. Presence of thoracotomy, pneumothorax, or pneumomediastinum.

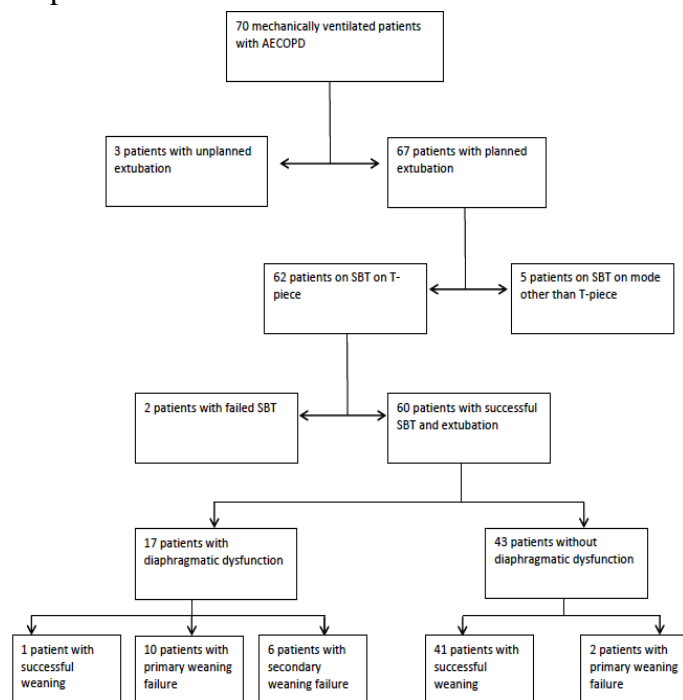


Figure (1) showing flow chart for selection of the patient. SBT: Spontaneous breath trial

Study Design and Methods

History taking, clinical examination, laboratory investigations were taken. Weaning parameters were measured on mechanical ventilator for the patients on mechanical ventilation for at least 48hour then Ultrasonographic evaluation of the diaphragm at the start of a 1 hour of spontaneous breath trial on T-piece using ultrasound unit Digital ultrasonic imaging system model DP-3300, Shenzhen mindray biomedical electronics .co. ltd, with macro convex probe 3.5-5 MHZ. US was performed in the supine position with the probe position between the midclavicular and the anterior axillary line, during inspiration the diaphragm

moved caudally toward the probe, the ultrasound beam was directed to the hemi diaphragmatic domes, the liver and spleen were used as a window for each hemi diaphragm. Two-dimensional mode was used to discover the best site for application of M-mode for each hemi diaphragm then either liver or spleen displacement was recorded throughout 10 subsequent quite breathings and the maximum excursion of the diaphragm was recorded.

Diaphragmatic dysfunction was considered if < 1 cm in supine position.⁽¹⁸⁾

Patients were randomized according to US findings into two groups: Group I: Who had DD encountered (excursion less than 1 cm) and Group II: Who had non-DD encountered (excursion more than 1 cm).

Statistical analysis of the data

Data were fed to the computer using IBM SPSS software package version 20.0. The distributions of quantitative variables were tested for normality. Quantitative data were described using mean and standard deviation for normally distributed data while abnormally distributed data was expressed using median. For normally distributed data, comparison between group I and group II were done using independent t-test; while abnormally distributed data was assessed using Mann-Whitney Test. Agreement of the different predictive values of the outcome was used and was expressed in sensitivity, specificity, positive predictive value and negative predictive value. Significance test results are quoted as two-tailed probabilities. Significance of the obtained results was judged at the 5% level.

Outcomes and definitions:

1. Duration of weaning (which represents the time spent in partial support mode such as pressure support or continuous positive airway pressure).⁽¹⁵⁾
2. Total duration of mechanical ventilation (the period between the start and end of mechanical ventilation).⁽¹⁵⁾
3. Weaning failure either primary (defined as a requirement for mechanical ventilation within 48 hours of self-breathing) or

secondary (defined as a requirement for mechanical ventilation after a successful weaning i.e. respiratory failure occurring past the 48 hours of self-breathing).⁽¹⁵⁾

4. ICU length of stays in days.
5. Hospital length of stays in days.
6. Hospital mortality.
7. Sensitivity: the probability of a test correctly identifying those patients who have the specified condition.
8. Specificity: the probability of a test correctly identifying those patients who do not have the specified condition.
9. Positive predictive value: the probability that a patient with a positive test result really does have the condition for which the test was conducted.
10. Negative predictive value: the probability that a patient with a negative test result really is free of the condition for which the test was conducted.

Results

There was no significant difference between the two groups as regard the demographic data, neither the vital signs, the electrolytes, arterial blood gases nor the mean hypoxemia index at the time of weaning at the start of the SBT as shown in table 1.

Table (1): Baseline characteristic table at the time of the *beginning of spontaneous breath trial*:

Variables on the start of SBT	Group I (n = 17)	Group II (n = 43)	p
Age	62.29 ± 5.17	60.19 ± 6.08	p= 0.213
Temperature	37.46 ± 0.36	37.40 ± 0.34	p= 0.582
Heart rate	98.12 ± 11.54	95.58 ± 8.76	p= 0.361
MAP	80.0 ± 7.50	76.51 ± 7.76	p= 0.119
Respiratory rate	18.82 ± 0.88	18.65 ± 1.25	P= 0.606
Potassium	3.86 ± 0.23	3.83 ± 0.25	p= 0.683
Magnesium	1.96 ± 0.18	1.91 ± 0.17	p= 0.345
Phosphorus	3.19 ± 0.13	3.21 ± 0.30	p= 0.638
pH	7.40 ± 0.05	7.42 ± 0.04	p = 0.248
PaCO2	51.96 ± 8.91	49.23 ± 7.5	p = 0.193
HCO3	32.62 ± 4.79	30.74 ± 3.90	p = 0.402
HI	200.12 ± 34.76	217.16 ± 43.39	p = 0.137

MAP: mean arterial pressure, PaCO2: arterial carbon dioxide tension; HCO3: bicarbonate level, HI: hypoxemia index.

As regard the excursion of the diaphragm there was statistical difference between the two groups being

higher in the non-DD group with median of 1.9 on the right side compared to 0.66 in the DD group and 1.95 on the left compared to 0.67 in DD group.

In the DD group there were ten patients with primary weaning failure and six patients with secondary weaning failure while in the non DD group there were two patients with primary weaning failure and all the rest were successfully weaned as shown in Figure 2.

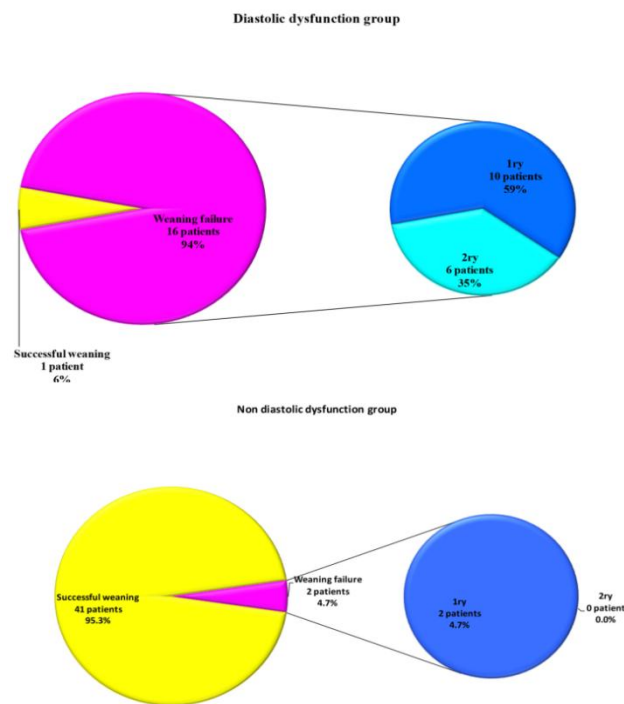


Figure (2) showing the weaning failure in both groups as regard the 1^{ty}: primary and 2^{ty}: secondary weaning failure.

There was 60 hours Reduction in the median duration of weaning time by in favor of the non-DD group with reduction in the median total duration of mechanical ventilation by 120 hours in favor of the non-DD group. as shown in table 2.

There was significant reduction by 5 days in the median of the ICU stay as well as 6 days in the median of the length of the hospital stay in favor of the non-DD group as shown in table 2.

No mortality was found in the non-DD group while there was one (5.9%) patient in the DD group there was no significant difference between the two groups.

Table (2): Comparison between the two groups according to the outcome parameters

Median(IQR) of	Group I (n = 17)	Group II (n = 43)	P value
Duration of weaning (hours)	96(84-120)	36(24-48)	<0.001
Total duration of MV(hours)	192(168-204)	72(72-72)	<0.001
LOS in ICU (days)	10.0 (9-13)	5.0 (4-5)	<0.001
LOS in hospital (days)	12.0 (12-15.5)	6.0 (5-6)	<0.001

Data are presented as median (interquartile range) or n (%).LOS: length of stay, MV: mechanical ventilation, ICU: intensive care unit.

As regard the sensitivity, specificity, positive predictive value and negative predictive value of ultrasonographically assessed DD in predicting primary weaning failure, the test had more accurate results for prediction of secondary weaning failure than in primary weaning failure as shown in table 3.

Table (3): showing the sensitivity, specificity, positive and negative predictive value of the test in detecting weaning failure either primary or total weaning failure.

	Sensitivity	Specificity	PPV	NPV
For detection of the primary weaning failure	83.33	85.42	58.82	95.35
For detection of weaning failure either primary or secondary	88.89	97.62	94.12	95.35

PPV: positive predictive value, NPV: negative predictive value.

Discussion

In continuation of many previous studies on the usefulness of the US assessment of the diaphragm as a tool to predict weaning from mechanical ventilation, this study was done for patient with AECOPD requiring mechanical ventilation who were planned for discontinuation of mechanical ventilation.

The excursion of the diaphragm was higher in the non-DD group.

The lower limit excursion during quiet breathing was estimated to be 1 cm as recorded by M-mode Ultrasonography.

The supine position was applicable to mechanically ventilated patients with minimum error of measurement though previous study proved

greater diaphragmatic excursion for the same inspired tidal volume in the supine position in comparison with sitting position.⁽²⁰⁾

3 patients were excluded as they had unplanned extubation, 5 others were extubated using other weaning methods; 3 on adoptive supportive ventilation and 2 CPAP while 2 patients had failed SBT and were excluded, both were volume overloaded and received diuretics before weaning and were weaned on adoptive supportive ventilation.

In the present study, there was statistically significant reduction by 62.5% in both the percent of the median for weaning duration and the total mechanical ventilation duration in favor for the non-DD group.

Statistically significant reduction was also found by 50% in both the median of the ICU days of stay and the total hospital days of stay in favor of the non-DD.

The longer duration of total mechanical ventilation duration, weaning duration, the ICU stay and the total hospital stays in the DD group could be explained by progressive declining in the diaphragmatic excursion in the DD group due to vicious circle of respiratory muscle fatigue and increased respiratory demands leading to a decrease in the tidal volume and a compensatory increase in the respiratory rate, together with hypoxemia adding to the load imposed on the respiratory muscles and eventually, respiratory failure with the need for resuming mechanical ventilation.

In agreement with other studies,^(15,16) good diaphragmatic excursion had correlation with all the outcomes.

Weaning failure either primary or secondary was found to be higher in the DD group. On the other hand, there were no patients of secondary weaning failure in the non-DD group versus six patients (35.5%) in the DD group as shown in figure 2. those with the weaning failure were successfully weaned and extubated in the succeeding trial.

On applying the test on weaning failure either primary or secondary in comparison to that of primary weaning failure yielded more accurate results thus stressing upon the usefulness of the

method to predict weaning failure even within 48 hours after mechanical ventilation weaning.

Limitations in our study:

- The study did not take in consideration the intra-abdominal pressure that may affect the diaphragmatic excursion.
- COPD patients have hyperinflated chest that on deep inspirations cause obscuring the view of the diaphragm by the decent of the lung requiring more skills to overcome that problem and required long duration of examination to determine the most adequate view to calculate the diaphragmatic excursion especially in assessing the left diaphragmatic hemisphere that caused some patients to be annoyed.
- Weaning modes on mechanical ventilation without t-piece as CPAP and adaptive supportive ventilation can alter the results and the contribution of the diaphragmatic excursion may be doubtful.
- The study did not also consider the diaphragmatic thickness in relation to weaning parameters thus more studies may consider both the thickness and the excursion together to make more accurate results.
- Incorporating other comorbidities which may be commonly associated with long standing COPD can alter the results or change the cutoff point thus further studies with larger number of patients should be studied.

Conclusion

We concluded that there is a correlation between diaphragmatic dysfunction, detected by using M-mode Ultrasonography, in the weaning of patients with AECOPD from mechanical ventilation, and weaning failure, duration of weaning, duration of mechanical ventilation, ICU stay, and hospital stay and it is helpful screening tool for weaning off mechanical ventilation.

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