

## Diaphragmatic Excursion Assessment by Ultrasound versus Volume Associated Weaning Parameters as A Prediction in Extubation in Critically Ill Patients

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### ABSTRACT

**Background:** Liberating a patient from ventilator is a continuous process as with any disease condition which starts with recognition of patient being ready to be weaned from ventilator by letting the patient breathe on T-piece and, if successful proceeding to SBT followed by extubation, if it is tolerated well (simple weaning). Otherwise letting patient on ventilator till next such trial being successful. Difficulty in weaning from mechanical ventilation is one of the most frequently encountered problems in MICU. An estimated 20% of mechanically ventilated patients face failed extubation (requiring reintubation within 48 h of extubation).

**Aim of the study:** This study was designed to assess the value of the excursion of diaphragm tested by ultrasonography to predict weaning from mechanical ventilation versus volume associated weaning parameters in medical intensive unit's patients.

**Patients and Methods:** A prospective study was carried out on 30 patients ready for weaning. All patients were divided into two equal groups. Group A (successful weaning group) and Group B (failed weaning group).

**Results:** Of the entire group of 30 patients, 21 patients (70%) had succeeded extubation and 9 patients (30%) failed. By applying cut-off level 1cm determined in our study the sensitivity and specificity of mean liver and spleen displacement were 95.2% and 88.9% respectively, which is higher than Pi max (85.7% and 77.8%) by cut-off level  $\leq 20$  cm H<sub>2</sub>O,  $f/VT$  (85.7% and 66.7%) by cut-off level  $\leq 105$  breath/min/l.

**Conclusions:** The present study concluded that ultrasonographic measurement of liver and spleen displacement during SBT before extubation is a good method for predicting extubation outcome.

**Keywords:** Bedside ultrasonography , Critically ill , Diaphragmatic dysfunction.

### key messages

What is the key question?

1. Can ultrasound measurements of diaphragmatic excursion during inspiration provide a measure of extubation success or failure?
2. What is the bottom line?

We found that measurements of diaphragmatic excursion outperform standard measures of extubation outcome.

3. Why read on?

Learn the rationale for using ultrasound measures of diaphragmatic excursion to predict extubation outcomes, how these measures compares with other measures used to predict extubation success or failure.

### INTRODUCTION

Bedside ultrasonography has become a valuable tool in the management of intensive care unit patients. This is especially true in emergency situations where an adequate imaging technique is frequently limited by a variety of factors, including difficulty of patient transportation to the radiology department due to illness severity. Ultrasonography is a noninvasive technique, which has proved to be an accurate, safe, easy to use bedside modality, overcoming many of the standard limitations of imaging techniques<sup>(1)</sup>.

The diaphragm is the principal respiratory muscle, and its dysfunction predisposes to respiratory complications and can prolong the duration of mechanical ventilation. Sonographic evaluation of the diaphragm has recently started to gain popularity in the ICU as specific needs for assessing diaphragmatic function arise in many clinical situations. Abnormal diaphragmatic motion is observed in conditions such as phrenic nerve injury, neuromuscular diseases after

abdominal or cardiac surgery<sup>(2)</sup> and in critically ill patients under mechanical ventilation<sup>(3)</sup>.

Since diaphragmatic motion plays a prominent role in spontaneous respiration, observation of the diaphragm kinetics seems essential. The use of tools previously available for this purpose is limited due to the associated risks of ionizing radiation (fluoroscopy or computed tomography) or due to their complex and/or highly specialized nature, requiring a skilled operator (trans diaphragmatic pressure measurement, diaphragmatic electromyography, phrenic nerve stimulation and magnetic resonance imaging)<sup>(4)</sup>.

Sonography receives increasing recognition as a fast, easy and accurate method of noninvasively evaluating diaphragmatic function at the bedside. In the ICU population, it can quantify normal and abnormal movements in a variety of clinical conditions<sup>(5)</sup>.

## PATIENTS AND METHODS

Type of the study: prospective study. This prospective study was carried on 30 patients ready for weaning.

**The study was approved by the Ethics Board of Al-Azhar University.**

Selection of the patients: thirty patients were admitted

to medical intensive care unit at Al-Hussien University

Hospital between August 2017 and April 2018.

Patients were divided into two groups: **Group A**

were successfully

weaned, and **Group B** were failed weaning.

### *Inclusion criteria*

Patients are on mechanical ventilation who fulfilled criteria of weaning.

### *Exclusion criteria*

- Intubation for elective surgery or due to upper airway obstruction.
- Mechanical ventilation via a tracheostomy tube.
- History of peritonitis or intraabdominal operation.
- Empyema, pleurodesis, plural effusion or ascites.
- Patients who are prepared to be extubated without an SBT.
- Failure of SBT:
  1.  $P_{aO_2} \leq 60$  mmHg on  $F_{iO_2} \geq 0.4$  or  $S_{aO_2} < 90\%$ .
  2.  $P_{aCO_2} > 50$  mmHg or an increase in  $P_{aCO_2} > 8$  mmHg.
  3.  $pH < 7.32$  or a decrease in  $pH \geq 0.07$  pH units.
  4.  $RR > 30$  breaths/min or increased by  $\geq 50\%$ .
  5. Systolic BP  $> 160$  mmHg or increased by  $> 20\%$ , Diastolic BP  $< 90$  mmHg.
- Patients with delayed extubation, ie, not extubated within 6 h after measurement of weaning parameters or ultrasonography.

### *Methods*

**All patients underwent the following:**

- Full history taking.
- Thorough clinical examination.
- Investigations:
  - 1) **Laboratory investigations:**  
Routine investigations:-
    - Complete blood picture.
    - Fasting and post prandial blood sugar.
    - Hepatic and renal profiles.
    - Blood coagulopathy profiles.
    - Erythrocyte sedimentation rate (ESR).
    - Serum electrolyte (Na, K).
    - Arterial blood gases.
  - 2) **Electrocardiogram.**
  - 3) **Radiological examinations: Chest x-ray.**
- Daily follow up during mechanical ventilation until

traditional weaning parameters becomes accepted and the patient become weanable.

- Spontaneous breathing trails either T-piece or spontaneous mood on mechanical ventilation with pressure support 3-5 cmH<sub>2</sub>O.
- Measurement of rapid shallow breathing index, maximal inspiratory pressure (specific weaning predictors) after successful SBT within one hour before extubation.
- Ultrasonographic measurement of liver and spleen displacements after successful SBT within one hour before extubation.

### **Method of ultrasonic evaluation:**

#### **Ventilation:**

- All patients were discontinuing of ventilator and shifting to T-piece spontaneous breathing.

**Position of the patient:** All patients were in a supine position.

#### **Time:**

- 1st measurement: After successful T-piece spontaneous breathing one hour before extubation.
- 2nd measurement: 5 min later.

#### **Device:**

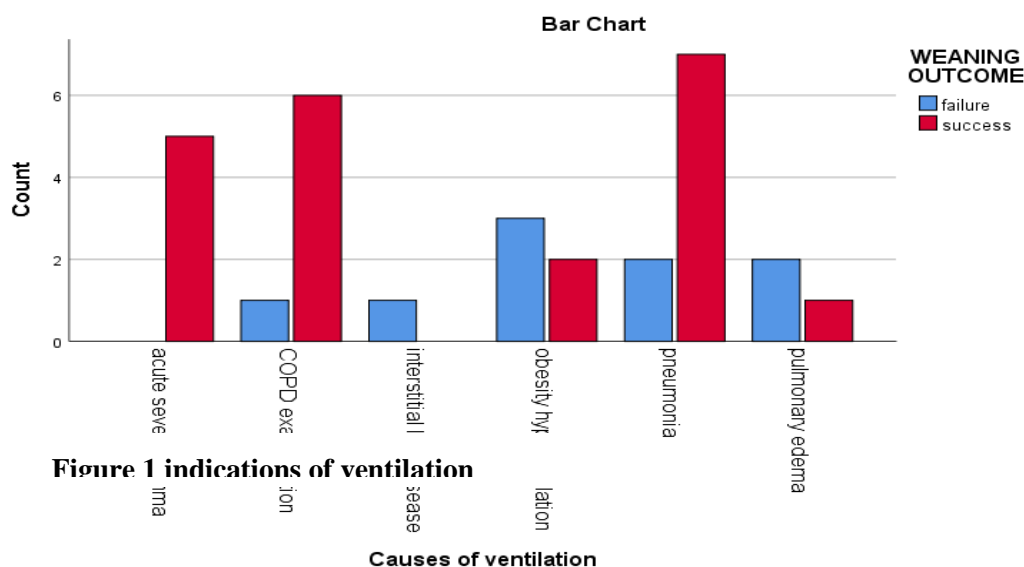
- An ultrasound scanner (ACUSON X 300 -SEMENS) equipped with a (CH5-2) curved sonar probe was used.

## RESULTS

This study included 30 patients admitted to MICU whom mean age was  $50.32 \pm 18.06$  years old. Patients with pneumonia accounted for 30% of cases followed by acute exacerbation of COPD who accounted for 23.3% of cases, then obesity hypoventilation and acute severe asthma who accounted for 16.7% of cases. Acute pulmonary edema accounted for 10%. Interstitial lung disease were the least frequent diagnosis with 3.3 % of the studied patient as shown in figure 1 (as p value 0.08). As regards sex, females were (26.7%) while males were (73.3%) as shown in table 1. In regard to occupation workers were (82.4%) Not working (17.6%). As regards marital status, they were divorced (0.8%), married (61.8%), single (13.0%) and widow (24.4%).

**Table (1) shows Comparison of the studied groups as regarding sex.**

		WEANING OUTCOME			P value	
		failure	success	Total		
Total groups		Count	9	21	30	0.374
		% within WEANING OUTCOME			100%	
SEX	Female	Count	1	7	8	0.374
		% within WEANING OUTCOME	11.1%	33.3%	26.7%	
	Male	Count	8	14	22	0.374
		% within WEANING OUTCOME	88.9%	66.7%	73.3%	

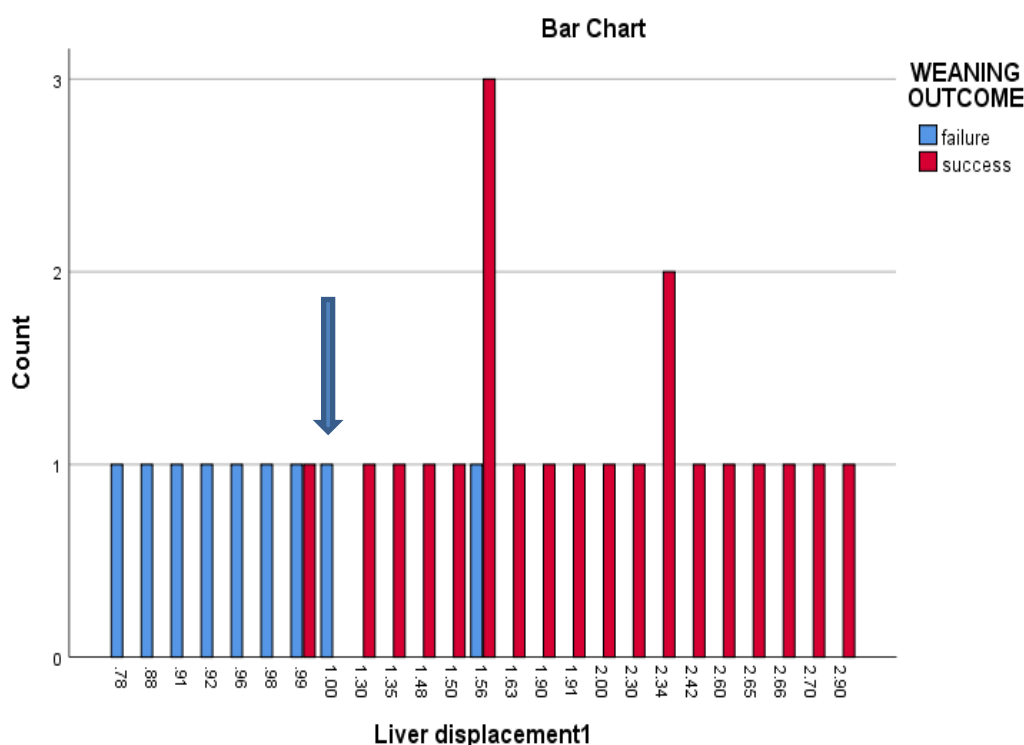


As regards comorbidities associated with the two groups there was significant statistical difference for HTN as p value was 0.05. Regarding pulse, there was significant statistical difference as p value was 0.03. In addition, there was highly significant statistical difference between the two groups as regarding the ICU stay/day and the time in MV ( $p < 0.0001$ ) with increasing successful weaning with decreasing ICU stay and duration of mechanical ventilation. Results showed also that PH and PCO<sub>2</sub> (mmHg) before and after weaning had significant statistical difference (p

value 0.03 and  $<0.001$  respectively). There was correlation between the ultrasound diaphragmatic parameter before and after weaning as p value was  $<0.0001$ . The study showed that by applying cut-off level 1cm determined in our study the sensitivity and specificity of mean liver and spleen displacement were 95.2% and 88.9% respectively as shown in (figure 2) and table 2 , which was higher than Pi max (85.7% and 77.8%) by cut-off level  $\leq 20$ cm H<sub>2</sub>O, f/VT (85.7% and 66.7%) by cut-off level  $\leq 105$  breath/min/l as p value  $< 0.05$ .

**Table (2) comparison of the studied groups as regarding diaphragmatic excursion:**

DE/cm	Failed cases	Successful cases	Specificity% of DE >1cm	Sensitivity% of DE >1cm
<i>Below 1 cm</i>	8	1		
<i>Above 1cm</i>	1	20		
Total cases	9	21	<b>88.89</b>	<b>95.24</b>

**Figure 2:** liver and spleen displacement

## DISCUSSION

The diaphragm is a fundamental respiratory muscle whose dysfunction may be very common in patients undergoing mechanical ventilation. Diaphragmatic dysfunction is associated with prolonged mechanical ventilation and weaning failure <sup>(6)</sup>.

U/S which is widely available inside the ICU; provide direct, bed side and rapid visualization and assessment of the diaphragmatic mobility and diaphragmatic function as the main respiratory muscle which may be used as indicator for the weaning outcome <sup>(7)</sup>.

The weaning process of ICU patients is a complex process with an estimated 20% failure rate <sup>(8)</sup>. The weaning process start decision depends on multiple

indices and parameters mainly the arterial blood gases and the respiratory mechanics with all parameters reflecting the diaphragmatic function in an indirect manner <sup>(7)</sup>. Wrong decision in weaning leads to cardio-respiratory distress, prolonged ICU admission and increased mortality rates. In addition, the delay in weaning decision increases the risk of ventilator associated pneumonia and diaphragmatic atrophy <sup>(9, 10)</sup>.

The study was conducted upon 30 patients in the MICU at ELHusseini Hospital.

The aim of this work was to study the role of ultrasound in evaluating the movement of the diaphragm and its value in predicting the successful extubation in mechanically ventilated patients.

The patients were divided into two groups according to their response to weaning trials into:

**group A** showed successful weaning (SW)

**group B** showed failed weaning (FW) followed by re-intubation and mechanical ventilation after 48 h.

In the present study, as regard group (A), the number of patients with successful weaning from mechanical ventilation was 21 out of 30 patients (70%), while the number of patients with failure of weaning from mechanical ventilation was 9 out of 30 patients (30%).

In the present study, 9 patients experienced failed weaning trial representing 30% of the study population. This is consistent with **Osman *et al.***<sup>(7)</sup>, **Esteban *et al.***<sup>(13)</sup>, **Saeed *et al.***<sup>(14)</sup> and **Baess *et al.***<sup>(15)</sup> who showed failure rate about 26,5%, 27%, 26.7% and 23.3% respectively. This is in contrast with **Ferrari *et al.***<sup>(6)</sup> who reported 63% failure rate. This is explained by different causes for mechanical ventilation as well as different ventilation periods before starting weaning process, which may affect the outcome of the weaning process.

The ICU stay and time of mechanical ventilation before weaning were with significant statistical difference, meaning less duration of mechanical ventilation and ICU stay and more probability of successful weaning and extubation.

The pulse and diaphragmatic excursion had also significant statistical difference.

The FIO<sub>2</sub>% before and after weaning was with significant difference (p<0.001), pH and PCO<sub>2</sub> (mmHg) before and after weaning had significant statistical difference, pH (p= 0.03), PCO<sub>2</sub> (p<0.001)

There was significant statistical difference before and after weaning in both groups regarding DE only, p=0.02. There was positive correlation between DE before and after weaning.

Sonography may also be of help during weaning from mechanical ventilation by performing a B-mode ultrasonographic evaluation of the diaphragmatic movements by measuring the liver/spleen displacement during spontaneous breathing trials. This examination proved to be a good predictor for extubation outcome. Using a mean cut off value of 1.1

cm of liver and spleen displacement, the sensitivity and specificity to predict successful extubation were 84.4 and 82.6 % respectively. This was consistent with the present study results' sensitivity and specificity were 95.2 and 88.8% that was better than traditional weaning parameters used in the trial of weaning. Patients with adequate spontaneous tidal volume but poor diaphragmatic excursion were more likely to fail a breathing trial compared to patients with adequate spontaneous tidal volume and good diaphragmatic movement. This can be explained by the fact that spontaneous tidal volume represents the result of the combined activation of all respiratory muscles used without specifically measuring the contribution of the diaphragm, whereas diaphragmatic excursion represents the final result of combined diaphragmatic strength, intrathoracic and intra-abdominal pressures<sup>(11)</sup>.

**Kim *et al.***<sup>(12)</sup> studied the amplitude of diaphragm movements. A diaphragm dysfunction was diagnosed by ultrasound if an excursion <10 mm or a paradoxical movement was observed at tidal breathing is indicative of diaphragmatic dysfunction and predictive of weaning failure.

As regards the relationship between the whole criteria of weaning (TV/ml/kg, RR/min, MV/L/min, and RSB index) and the DE/cm before and after weaning. There was a significant positive correlation and significant statistical difference appeared between TV/ml/kg, minute volume and DE/cm, meaning that more diaphragmatic excursion leads to more lung expansion leads to more tidal volume and minute volume.

## CONCLUSIONS

Ultrasonographic measurement of liver and spleen displacement during SBT before extubation is a good method for predicting extubation outcome.

## RECOMMENDATIONS

- Diaphragmatic ultrasound can be used as a predictive parameter to assess the weaning process outcome.
- Prolonged periods of complete diaphragmatic rest should be avoided and diaphragmatic contraction preserved whenever possible.

- Respiratory muscle training may lead to improved weaning success.

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