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Original Article

Diaphragmatic and lung ultrasound application as new predictive indices for the weaning process in ICU patients

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A B S T R A C T

Objective: To assess whether the diaphragmatic and lung ultrasound (US) can be used as additive new parameters for the weaning process in intensive care units (ICU) patients in comparison to the traditional weaning parameters.
Patients and methods: 68 patients were included in our study. All patients admitted inside different ICU units-Ain Shams University for different causes mainly post major surgeries. All patients met the traditional criteria for weaning, had diaphragmatic and lung ultrasound after extubation. We measured the diaphragmatic excursion (*E*), diaphragmatic thickening fraction (DTF) as well as the degree of lung aeration. All US results were collected and compared with some of usual weaning parameters namely the arterial blood gases as well as respiratory mechanics. The results were statistically analyzed.
Results: 50 patients showed successful weaning process. Diaphragmatic *E* and TF showed high sensitivity and specificity in correlation with the other parameters. The cut off value was 10 mm for the *E* and 28% for the DTF and 12 for the lung US. A score was put to predict the outcome of weaning process.
Conclusion: For the patients undergoing weaning process, diaphragmatic and lung ultrasound can be used as additive new parameters for prediction of weaning process outcome.

1. Introduction

The mechanical ventilation using pressure-supported technique is widely used in critically ill-patients inside the intensive care units (ICU) [1]. 20% of the patients inside the ICU show difficulties in weaning process while 40% of them experiences much time in ICU during weaning trials [2,3].

Multiple indices were built up to assess the patients' ability to regain spontaneous breathing such as [4,5]:

- Minute ventilation (Ve).
- Maximum inspiratory pressure (MiP).
- Breathing frequency.
- Rapid shallow breathing index (RSBI) = respiratory frequency/tidal volume which is one of the most accurate index.
- Tracheal air way occlusion pressure.
- Compliance, rate, oxygen pressure index (CROP).
- Esophageal and gastric pressure.

The diaphragm is the main respiratory muscle with prolonged mechanical ventilation can lead to impaired diaphragmatic function secondary to atrophy and prolonged dysfunction with subsequent difficult weaning process [1,6].

Preserved diaphragmatic function is very important during weaning process to regain spontaneous breathing process with the usual methods for diaphragmatic assessment like fluoroscopy, phrenic nerve conduction, and trans-diaphragmatic pressure measurements show a lot of limitations and disadvantages especially inside the ICU due to ionizing radiation exposure, not widely available methods and the need for patient transportation [7].

US is a well established bedside radiological tool with multiple trials were done to assess the useful of its use in estimation of the diaphragmatic function [8,9]. Two different parameters have been described for diaphragmatic US namely the diaphragmatic excursion (*E*) during inspiration and diaphragmatic muscle thickening fraction (DTF).

Also, lung US can be used in assessment of lung aeration which can be useful and helpful during the weaning process as it reflect the aeration loss and subsequently predict the post extubation distress [10].

The aim of this work is to assess the ability to use diaphragmatic and lung US as new additive parameters to predict the

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outcome of weaning process in comparison with other weaning parameters.

2. Patients and methods

2.1. Patients

This is a prospective study conducted over 68 patients who admitted in different ICU units – Ain Shams University with different causes with the majority of cases were selected post operatively. All patients were mechanically ventilated through a tracheostomy or endotracheal tube. Written consents were taken from the patients' guardians or their relative to participate in this study according to the rules of ethical committee. The study conducted over the period from August 2015 to August 2016.

2.2. The criteria of weaning

All ICU patients who met the criteria to start weaning process according to Table 1 were included in this study.

2.3. Exclusion criteria

- Patients < 18 years old.
- Any patient with known neuromuscular disorder.
- 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.

2.4. Study design

The patients who selected to start weaning according the criteria shown in Table 1 were disconnected from the ventilators to allow spontaneous breath trial (SBT). Each diaphragm was evaluated to rule out absent diaphragmatic mobility in either side; when detected the patient was excluded from the study. This followed by complete diaphragmatic and lung US.

2.5. Diaphragmatic US

- *US machines:* Logic E9 (GE) and Honda electronics HS-2100 Portable ultrasound machine. 3.5 MHz convex probe as well as 9–11 MHz linear probe were used.
- *Patient position:* Semi-recumbent position.
- *Diaphragmatic thickness 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.

2.6. Lung ultrasound

- *Patient position:* supine and lateral decubitus positions.
- *Technique:* Each lung was divided into 3 zones underwent examination anteriorly and posteriorly using B-mode to assess the degree of lung aeration with total 12 zones to be examined.
- *Image interpretation and lung US score:* (Table 2).

2.7. Analysis of data

The patients were divided into two groups according to their response to weaning trials with group A showed successful weaning (SW) and transferred to the ward while group B showed failed weaning (FW) followed by re-intubation and machine ventilation after 48 h. The diaphragmatic *E*, DTF and lung US measurements were collected for each group and correlated with some selected weaning criteria namely; PaO_2, $PaCO_2$, Respiratory rate (RR), maximum inspiratory force (MiP) and Rapid shallow breath index (RSBI),

The analysis data was done using IBM SPSS (Statistical Program for Social Science version 24.0, IBM Corp., USA, 2016). Data were expressed as Mean ± SD for quantitative parametric measures. The following tests were done:

1. Comparison between two independent mean groups for parametric data using Student *t* test.
2. Pearson correlation test to study the possible association between each two variables among each group for parameteric data.

The probability of error at 0.05 was considered sig., while at 0.01 and 0.001 are highly sig.

3. Diagnostic validity test: diagnostic sensitivity, specificity, negative and positive predictive values (NPV, PPV) and efficacy.

Finally scoring system was put to use diaphragmatic *E*, DTF and lung US during the weaning process.

Table 1
Illustrates the selective criteria to start the weaning for the ICU patients.

Arterial blood gases (ABG)	Respiratory rate	Respiratory mechanics
• PaO_2 > 60 mmHg • Pa CO_2 < 50 mmHg • FiO_2 < 0.5 • PaO_2/FiO_2 > 200 mg • PEEP < 5 CmH_2O	<30–35 breath/min	• Tidal volume (TV) > 5 ml/kg • Vital capacity (VC) > 10 ml/kg • PI max < −15 to −30 CmH_2O • Ve 4–10 L/min • RSBI < 100 breath/min/L • P0.1 < 2 CmH_2O

Table 2
Illustrates the lung US score for detection of the degree of lung aeration (10).

Points for each lung zone (12 zones)	Degree of lung aeration	Pattern
0 point	Normal aeration	Horizontal A-line (no more than two B-line)
1 point	Moderate loss of aeration	Multiple B-line either regularly spaced or irregularly spaced
2 points	Severe loss of aeration	Multiple coalescent B-lines
3 points	Complete loss of aeration	Lung consolidation
Total score	From 0 to 36	