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Chest Ultrasound in Predication of Weaning Failure

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Abstract

AIM: Failure of weaning from mechanical ventilation (MV) is a common problem that faces the intensivist despite having some prediction indices. Application of chest ultrasonography (US) may help in weaning and prediction of its outcome.

METHODS: 100 patients on invasive MV fulfilling criteria of weaning shifted to spontaneous breathing trial (SBT) (using PSV 8 cm H2O) for 1 hour. Weaning failure was defined as; Failed SBT, reintubation and/or ventilation or death within 48 hours. Echocardiography was used to get Ejection fraction, E/A ratio, Doppler tissue imaging (DTI) &, lung ultrasound (LUS) was used to assess LUS score, diaphragm ultrasound was used to assess diaphragmatic thickening fraction (DTF).

RESULTS: Mean age 57.1 ± 14.5, 62% were males. Weaning was successful in 80% of patients. LUS score was significantly higher in the failed weaning group: (10.8 ± 4.2) vs (16.5 ± 4.2 cm), (p: 0.001). (DTF) Was significantly higher in the successful weaning group: (43.0 ± 10.7) vs (28.9 ± 2.8 cm), (p: 0.001). DTF can predict successful weaning using Receiver operating characteristic (ROC) curves with the cutoff value: ≥ 29.5 with sensitivity 88.0% and specificity 80.0% with a p-value < 0.001.LUS score can predict weaning failure by using a ROC curve with cutoff value: ≥ 15.5 with sensitivity 70.0% and specificity 82.5 % with a p-value < 0.001.)

CONCLUSION: The use of bedside chest US (to assess lung and diaphragm) of great benefit throughout the weaning process.

Introduction

Mechanical ventilation (MV) is one of the most common interventions in critical care. Weaning failure from MV occurred in 10-20% of patients [1], [2].

Timing is crucial when deciding if a patient can be successfully extubated. Both premature discontinuation and unnecessary delay of MV weaning have associated with poor outcome [3].

One of the major causes of weaning failure is the imbalance between the load on the diaphragm and its ability to cope with it [4], [5], [6], [7]. There is rising evidence that diaphragmatic dysfunction has a critical role in ventilator dependency. Diaphragm thickness calculated at end inspiration is related to maximal inspiratory pressure. Diaphragm US can be used to evaluate diaphragmatic dysfunction [7], [8], [9], [10]. Shifting a patient from MV to spontaneous breathing may be associated with lung aeration loss(derecruitment), which can cause weaning failure, [11], [12]. Lung ultrasound is an emerging and increasingly used tool to investigate both in a semi-quantitative and quantitative way lung aeration during MV [12].

Patients and Methods

A prospective observational study was conducted on one hundred patients admitted to the department of critical care medicine, faculty of medicine, Cairo University, from January 2016 to July 2017. The study was approved by the Ethical committee of Cairo University. Written informed consent was obtained by first degree relatives.

Patients

One hundred consecutive mechanically ventilated patients for more than 48 hours were included when the underlying cause that had required intubation was resolved, making the patient candidate to a first 1-hour SBT [10]. Exclusion criteria were patients aged < 18 years, patients with tracheostomy, cardiac arrhythmias, Left ventricular systolic dysfunction (LVEF < 50%) [22], diaphragmatic paralysis Neuromuscular disorders for example: Guillain barre syndrome and Myasthenia gravis, Severe ICU-acquired neuromyopathy, chronic obstructive pulmonary disease with forced expiratory volume < 50% of the predicted value and history of pneumonectomy or chronic lung disease

Methods

All patients were subjected to the following:

1-Detailed history is taking. Full physical examination and Laboratory investigations (Complete blood count, Coagulation profile, Arterial blood gases, Liver functions (ALT), Kidney functions (creatinine), blood glucose), bedside twelve leads ECG and chest x-ray.

2-Mechanical ventilation. All patients were intubated and mechanically ventilated under volume controlled ventilation using a Puritan Bennet 840 ventilator, and they were observed till improvement of their conditions and became eligible to enter the SBT for weaning [23]. Patients were included in the weaning trial if they met the weaning criteria [11].

3-SBT protocol. Patients were put on PS/CPAP trial (pressure support 8 cm H_2O, CPAP 5 cm H_2O for one hour and they were extubated if they have succeeded in the trial. Failure of the weaning process was defined as a failed SBT or the need for reintubation within 48 hours following extubation [11], [24], so all patients included in the study were observed for 48 hours after the SBT. The following weaning indices were recorded for all patients during the SBT: Tidal volume (TV), Respiratory rate (RR), ABG: Po_2, So_2 % and Po_2/Fio_2, Rapid shallow breathing index: (RSBI (f/VT) = Respiratory rate/tidal volume [25]. A threshold of ≤ 105 is a must to continue the SBT [25].

Indicators of weaning failure were recorded:

a) objective indices: tachycardia more than 140 beats/min, tachypnea more than 35 breaths/min, use of accessory respiratory muscles, systolic arterial pressure more than 200 or less than 80 mmHg, hypoxemia: SO_2 less than 90%, acidosis, Arrhythmia [11];

b) subjective indices: Agitation, disturbed conscious level, increased work of breathing. SBT without the presence of the above signs was considered successful, and patients were extubated [11].

4-Echocardiographic study. Transthoracic Doppler echocardiographic examination was 30 minutes after the start of the SBT using TOSHIBA ACUSON X 300, with a probe 3.5 MHZ was used to assess the LV systolic function using 2D and modified Simpson's method. LV diastolic function was assessed by measuring mitral inflow velocity E and A waves and velocities of mitral annulus (Ea) using Doppler tissue imaging.

5-Lung ultrasound. (LUS) Was performed using a 2- to 4-MHz convex probe [16]. LUS was performed by the same trained physician at the end of the SBT. An LUS score has been produced to provide quantifiable comparable measures of changes in aeration [17], [18]. This score originates from the conversion of LUS patterns into numeric values, Four aeration patterns by ultrasound were defined [17], [18]: 1) normal aeration (N): presence of lung sliding with A-lines or less than two isolated B lines; 2) moderate loss of lung aeration: multiple B lines (B1 lines); 3) severe loss of lung aeration: multiple fused B lines (B2 lines); and 4) lung consolidation (C), the presence of a dynamic air bronchograms and tissue pattern , N = 0, B1 lines = 1, B2 lines = 2, C = 3. The final score, ranging from 0 to 36, is the sum of the values, from 0 to 3, assigned to the LUS patterns visualised in each of the 12 regions examined.

6-Diaphragmatic ultrasound. Diaphragm ultrasound was performed using a 10 MHz linear probe; Each diaphragm was evaluated by B-mode and M-mode after 30 min of the SBT [26]. The diaphragm was seen by placing the transducer, in the eighth intercostal space, perpendicular to the chest wall between the anterior axillary and the mid axillary lines, to see the zone of apposition of the muscle below the costophrenic sinus [27], [28]. The diaphragm was imaged as a structure with three layers, including two parallel echoic lines (the peritoneal membrane and the diaphragmatic pleura) and a hypo echoic structure between them (the muscle itself) [27], [28]. The patient was then instructed to perform maximum deep inspiration and then maximum exhalation [27], [28]. On each frozen B-mode image, the diaphragm thickness was measured from the middle of the pleural line to the middle of the peritoneal line. Then, the diaphragmatic thickening fraction (DTF) was calculated as a percentage from the following formula: Thickness at end inspiration − Thickness at end expiration/Thickness at end expiration [27], [28]. The same steps were done using the M mode.

Statistical methods

Data were coded and entered using the statistical package SPSS (Statistical Package for the Social Science; SPSS Inc., Chicago, IL, USA) version 22. Data were summarised using mean and standard deviation in quantitative data and using frequency (count) and relative frequency (percentage) for categorical data. Comparisons between quantitative variables were made using the non-parametric Mann-Whitney tests. For comparing serial measurements within each patient in each group, the non-parametric Wilcoxon signed rank test was used. ROC curve was constructed with an area under curve analysis performed to detect the best cutoff value for detection of the success of 1st SBT. P-values less than 0.05 were considered as statistically significant.

Results

The studied patients were divided into two groups: group 1, 80 patients with successful weaning; group 2, 20 patients with failure of weaning.

Table 1: Patients characteristics

	Group 1	Group 2	P value
Demographic data			
Age (years)(mean)	56.4	59.9	0.383
Sex (male/female)	80 (52/28)	20 (10/10)	0.301
Causes of mechanical ventilation:			
Respiratory failure (62%)	14	48	
Cardiac cause (12 %)	2	10	0.542
DCL (16%)	4	12	
Hemodynamic support (10%)	0	10	
2D echocardiographic data:			
LVEDD (mm)(mean)	48.5	52.6	0.25
LVESD (mm) (mean)	38	39	0.82
LVEF (%) (mean)	56.2%	52.7%	0.06
Ventilator parameters before the SBT in both groups:			
Frequency	20.7 ± 3.6	24 ± 3.9	0.012
Tidal volume	484.2 ± 69.1	409.0 ± 82.7	.005
Minute ventilation	9788.2 ± 1438.6	9725.0 ± 1191.2	.899
Ventilator parameters before the SBT in both groups:			
Frequency	25.4 ± 2.3	29.6 ± 3.6	0.001
Tidal volume	416.4 ± 70	346 ± 76.9	0.008
Minute ventilation	10387 ± 1479	9898 ± 1441	0.351
Baseline hemodynamic data (pre-SBT):			
Systolic BP (mmHg)			
Heart rate (beats/min)	123 ± 15.9	122.5 ± 30.4	0.934
	97.9 ± 6.9	106.7 ± 5.6	0.001

LVEDD left ventricular end-diastolic diameter, LVESD left ventricular end-systolic diameter, LVEF left ventricular ejection fraction.

LUS score was significantly lower in the group (1) than group (2) (10.8 ± 4.2 vs 16.5 ± 4.2 cm, P: 0.001). DTF was significantly higher in group (1) than group (2) (43.0 ± 10.7vs 28.9 ± 2.8 cm, P: 0.001).Duration of mechanical ventilation was significantly higher in-group (2) than group (1) (8.8 ± 0.6 vs 6.0 ± 1.4 cm, P: 0.001).

DTF can predict successful weaning with a cut-off point ≥ 29.5 with sensitivity 95.0% and specificity 80.0% with a P: value < 0.001. LUS score is good predictors for weaning failure with a cut-off point ≥ 15.5 with sensitivity 70.0% and specificity 82.5 % with a P: value < 0.001. RSBI also is good predictors for weaning failure, with a cut-off point ≥ 71.5 with sensitivity 80.0% and specificity 70% with a p-value < 0.001.

Discussion

Weaning from MV is one of the most frequently encountered challenges in modern ICUs.

Tools available for determining the optimal timing of weaning and prediction of its outcome are limited. Subjective decisions are usually wrong. Stroetz and Hubmayr found that clinical prediction of extubation success or failure was often incorrect with the decision to extubate biased toward ventilator dependency [29]. The US is well established as a noninvasive widely available, and easy to use can be performed by the intensivist for evaluation and management of mechanically ventilated patients and guide weaning from it. Chest US should include the examinations of the lungs and diaphragm [14]. LUS can accurately detect extravascular lung water and also quantify the degree of regional lung aeration loss. Studies illustrate that LUS can detect extravascular lung water accurately since they compared LUS result with the result of pulse-induced contour cardiac output (PICCO) and pulmonary artery catheter and it was closely similar [30], [31]. An LUS score has been validated to provide quantifiable comparable measures of progressive changes in aeration [18]. This prospective observational study was conducted on 0ne hundred patients underwent SBT weaning from MV shows several findings: SBT is correlated with significant lung derecruitment as assessed by LUS score that was significantly higher in the failed weaning group (P: 0.001), with cut-off value ≥ 15.5 predicted weaning failure with a sensitivity 70% and specificity 82.5%, AUC (0. 836) and P < 0.001. Soummer et al., in their study, concluded that, the lung derecruitment during SBT (assessed by lung u/s) is greater in patients who develop post-extubation distress (irrespective of its primary cause) than in patients who are definitively weaned (p < 0.001), they also concluded that LUS score > 17 (at the end of the SBT) is highly predictive of weaning failure and that derecruitment was made of partial loss of lung aeration rather than appearance of new consolidation [15].

Up till now, all indices that were used to predict extubation failure are indirect measurements of disorders of lung aeration, oxygen saturation defect, conscious level disturbances, hemodynamic instability, and physiological compensatory mechanisms, RSBI, and tachycardia that are patient-dependent [17]. The possibility of quantifying lung aeration directly at the end of an SBT offers an advantage for predicting weaning failure because decreased aeration is one of the critical pathophysiological factors [17].

DTF and weaning

DTF was significantly higher in the successfully weaned group (p 0.001), and with a cutoff value ≥ 29.5, it can predict weaning success with a sensitivity 88.0% and specificity 80.0%, AUC (0.933).

Since its first production [13], diaphragmatic thickening evaluation by the US has been correlated with diaphragm strength and muscle shortening [19], [20], [32]. The volume of diaphragm muscle mass is constant as it contracts. Therefore, as it shortens, it thickens, and measures of its thickening fraction are inversely related to changes in diaphragm length. In support of this concept, the absence of diaphragm thickening has been noted in patients with diaphragm paralysis [19]. Since the diaphragm is the major muscle of inspiration, the presence of diaphragm contraction and shortening should be a prerequisite for successful extubation. Diaphragm thickness may be estimated by B or M-mode [27], [32].

Similar to our results, Ayman I Baess et al., conducted a study on Thirty patients who were planned for weaning after MV, they concluded that diaphragmatic thickening was better than displacement in prediction of weaning outcome, and a cutoff value ≥ 30 can predict successful extubation with sensitivity (69%), specificity (71%) and AUC (0.65) [36]. One of the potential explanations that diaphragm thickening would be a more accurate index of diaphragm contractile activity than excursion during pressure-support ventilation, that thickening can only be influenced by active contraction [34].

DiNino et al. studied 63 intubated patients during the SBT and determined the DTF, They found that a DTF cutoff ≥ 30% was a good predictor for successful weaning with sensitivity and specificity, 88% and 71%, respectively and AUC (0.79) [21].

Limitations: The study is a single centre trial.US is an operator-dependent technique; however, in the current study, the only one trained intensive care physician performed the examination. We only assessed the right hemidiaphragm as it can be easily visualised compared to the left side where imaging is commonly impeded by gastrointestinal gases. However, this limitation is common in other studies on US assessment of diaphragmatic contractile function [33]. For the diaphragmatic us, we did not compare it with the gold standard methods (e.g. Trans-diaphragmatic pressure-time) because of the invasive nature of the procedure and relatively comparable results in previous studies [33], [35]. LUS couldn't confirm the causes of lung derecruitment.

Physiology, practice, and causes of weaning failure support the use of integrated US to predict weaning failure. Chest ultrasound is an integrated bedside examination performed by the intensivist to assess the lung and diaphragm and help to understand the pathophysiological effects of weaning and help to optimise the clinical condition to improve the chances of successful weaning from ventilatory support.

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