The predictive value of diaphragm ultrasound for weaning outcomes in surgical intensive care unit

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Abstract

Introduction: Multiple studies have shown that diaphragmatic ultrasound can better predict outcome of weaning. The purpose of this study was to investigate the predictive value of two diaphragmatic ultrasound indices, diaphragmatic thickening (DTF) and excursion (DE) for weaning outcomes in surgical intensive care unit (ICU).

Patients and Methods: The study included 60 cases whose mechanical ventilation (MV) time was >48 hours, and all eligibles were divided into either the weaning success group (n=45) or the weaning failure group (n=15). Diaphragm thickness, diaphragmatic excursion (DE) and diaphragmatic thickening fraction (DTF) were measured in the zone of apposition. The rapid shallow breathing index (RSBI) was also recorded.

Results: The ventilatory treatment time (p=0,002) and length of ICU stay (p=0,005) in the weaning failure group was longer than the success group. Cut-off values of diaphragmatic measures associated with successful weaning were ≥ 30% for DTF and ≥ 14 mm for DE giving a sensitivity (Se), a specificity (Sp) of 84,4%; 73,3% and 83,3%; 83,3%, respectively.By comparison, RSBI < 80 had a sensitivity of 93,3%, a specificity of 70% for determining weaning success. The areas under the ROC curves for DTF, DE and RSBI were 0,843; 0,807 and 0,873, respectively.

Conclusions: Ultrasound evaluation of diaphragmatic excursion (DE) and diaphragmatic thickness fraction (DTF) could be a good predictor of weaning outcome in a surgical intensive unit. It is recommended to consider the use of these parameters with RSBI consequently to improve weaning outcomes.

Introduction

Weaning from mechanical ventilation is an important issue that is of particular concern to resuscitators. The appropriate time for patients to stop mechanical ventilation is still controversial, if weaning is given too early, 25% of patients will need to be mechanically restarted 1 and conversely, delaying weaning will increase the risk of ventilator-associated complications such as barotrauma, pneumonia, and ventilator-associated diaphragmatic atrophy [2].

The use of tools to predict whether weaning success or failure is of great significance to physicians because it is more objective than depends on the clinician's clinical experience. Currently, there are many clinical and paraclinical indicators to assess the possibility of leaving the ventilator such as minute ventilation, maximum inspiratory pressure, respiratory rate, and shallow tachypnea index (RSBI,respiratory rate/tidal volume) can be used in clinical practice, but these indicators have limitations in assessing when weaning can be performed.

The diaphragm is an important respiratory muscle whose function impairment is commonly observed in mechanically ventilated patients. The impaired diaphragmatic function has even been observed in patients with successful spontaneous breathing trial (SBT) [3]. Diaphragm ultrasound allows direct assessment of the diaphragm and its functioning, and allows assessment of both motion and diaphragm thickness parameters to help predict the patient's weaning outcome. Diaphragm ultrasound uses two indices, DE and DTF, to assess the mobility and function of the diaphragm [4].

The indicators to evaluate the function of the diaphragm through ultrasound in predicting the success of weaning have been studied in the world for the past few years. However, in Vietnam, there are no studies specifically evaluating the role of this index in weaning on surgical resuscitation patients. Therefore, we carried out this study with the aim: to evaluate the prognostic value of weaning based on some diaphragmatic ultrasound indices in surgically resuscitated patients.

Patients and methods

Patients

This prospective study was conducted in the surgical intensive care unit of VietDuc University Hospital. Study subjects included 60 consecutive patients between March 2021 and September 2021, who were aged more than 18 years. The institutional ethics committee of the hospital approved the study protocol. The patients or guardians of the eligible patients provided written informed consent.

All patients who received MV support for ≥ 48h and met the standard criteria for weaning readiness based on the European Society of Resuscitation guidelines on weaning in 2007 [5] (improvement in the cause of primary disease, body temperature < 38^0C, hemoglobin ≥ 8g/dl, no electrolyte disturbances, blood sugar; have an adequate cough reflex; ý Glasgow score ≥ 9 and consciousness improved after sedation was stopped; hemodynamically stable (heart rate 60-140 beats/min), systolic blood pressure 90-160 mmHg, absence of vasopressors or low-dose vasopressors; PaO_2/FiO_2 ≥ 150 mmHg with PEEP ≤ 8cm H_2O and FiO_2 ≤ 40%). If patients experienced a known neuromuscular disease (Guillain Barre, myasthenia gravis), cervical spinal cord injury, patients or patient representatives refused to participate in the study, suspected or confirmed diaphragmatic paralysis, pregnant women, muscle relaxants within 48 hours prior to the study, then that patient was excluded from the study.

Study design

When this criterion is met, the patient is removed from the ventilator and conducted a spontaneous breathing test (SBT) through a T-tube with O_2 5 liters/min. SBT is done in 2 hours. If the patient responds to SBT, they will be extubated and receive a 28-40% O_2 mask and monitored for 48 hours after extubation. Extubation is successful if the patient is able to maintain spontaneous breathing for more than 48 hours after extubation. Intubation fails if the patient is unable to maintain spontaneous breathing for at least 48 hours, requires noninvasive mechanical ventilation, or requires reintubation.

Indicators of circulation, respiration, diaphragmatic index on ultrasound, and rapid shallow breathing index (RSBI) were recorded at the time before removing the ventilator, after performing SBT 30 minutes and after 48 hours. Diaphragm

indicatorsand RSBI were measured 3 times, the average value of 3 measurements was calculated.

Diaphragm ultrasound measurement

Diaphragm ultrasound: evaluate two indices, diaphragm excursion (DE) and diaphragmatic thickness fraction (DTF).

All patients were placed in a semi-recumbent position with the head of the bed at a 30-degree angle. In the present study, only the right hemidiaphragm was measured because the right hemidiaphragm was more feasible and repeatable compared with the left hemidiaphragm. Using a high frequency ultrasound probe of 7-10 MHz placed in the 8-9 intercostal space between the anterior and middle axillary lines with M-mode to assess the thickness of the diaphragm during inspiration (Tdi, diaphragm thickness at end inspiration) and diaphragm thickness at end expiration (Tde, diaphragm thickness at end expiration). The diaphragmatic ultrasound image was a hypoechoic structure between two echoic lines (the diaphragmatic pleura and the peritoneal membrane). DTF (%)= (Tdi-Tde)/Tde. Using a 3.5MHz low frequency ultrasonic transducer placed under the right lower quadrant of the midclavicular line in M-mode obtained the index of diaphragmatic excursion (DE), in mm.

The shallow tachypnea index is calculated as respiratory rate divided by tidal volume, in breaths/min/L.

Statistical analysis

Analyses were carried out using IBM SPSS Statistics for Windows, Version 22.0. Depending on whether distribution was normal or non-normal, continuous variables were described as mean ± SD or median (interquartile range). Continous variables were compared with Students t-test or Mann-Whitney U test. To determine the best cut off for DE, DTF and RSBI, the area under the receiver operating characteristic(ROC) curve was calculated. For all final comparison, a p-value less than or equal to 0,05 was considered statistically significant.

Results

Results of weaning from mechanical ventilation and patient characteristics

In our study conducted on 60 patients, 45 patients were successfully weaned from mechanical ventilation (accounting for 75%) and 15 patients failed (accounting for 25%). The average age of the study patients was 48.95 ± 20.25 years old (the lowest was 18 years old - the highest was 86 years old). The male/female ratio in our study was 52/8.

Table 1. Characteristics of successful and failed weaning patients

	Successful weaning (n=45) ($\bar{X}$ ± SD)	**Failed weaning (n=15) ($\bar{X}$ ± SD)**	**p**
Age	47,18 ± 20,03	54,27 ± 20,66	p>0,05
BMI	21,25 ± 1,69	21,48 ± 1.79	p>0,05
APACHEII	8.58 ± 3,39	9,13 ± 2.75	p>0,05
Length of MV until SBT (days)	8,91 ± 3,41	13,87 ± 10,89	p>0,05
Duration of MV (days)	8,91 ± 3,41	21,87± 13,05	p<0,05*
ICU length of stay (days)	12,96 ± 7,68	26,00 ± 15,18	p<0,05*
Hospital length of stay (days)	23,89 ± 9,87	37,67 ± 12,72	p<0,05*

(BMI: body mass index, APACHE: acute physiology and chronic health evaluation)

We found that the length of stay in the ICU and the hospital stay of the successful group was significantly shorter than that of the failed mechanical weaning group (p<0.05). The time of weaning of the successful group was also statistically significantly shorter than that of the failure group (8.91 ± 3.41 versus 21.87 ± 13.05 days with p<0.05). The distributions by mean age, body mass index (BMI) and APACHEII did not differ between the two groups (p>0.05).

In 60 patients, 50% of patients had central nervous system damage (due to traumatic brain injury, cerebrovascular accident, and brain tumor); 26.7% of patients with multiple trauma, 16.7% of patients with gastrointestinal surgery, 4% of urological surgery, and 2.7% of orthopedic trauma.

Prognostic value of the diaphragmatic index in weaning from mechanical ventilation

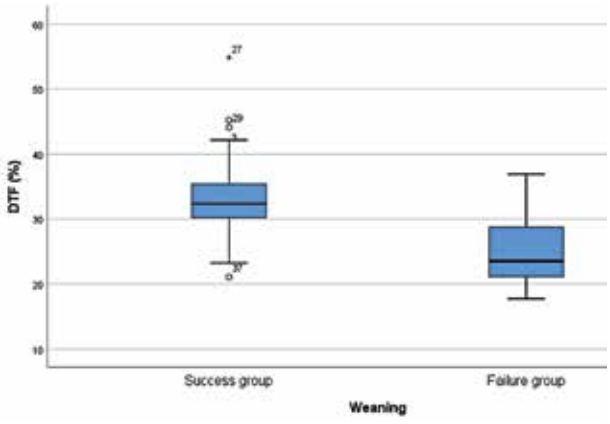

Figure 1. Mean value of DTF index of two groups

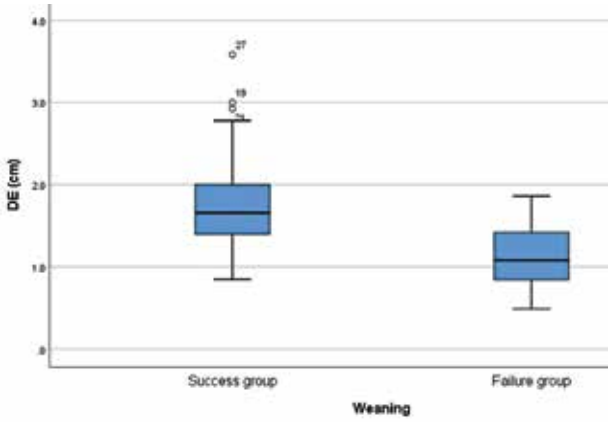

Figure 2. Mean value of DE index of two groups

The results in chart 1 and chart 2 show that the mean DE value of the successful group is 17.51 ± 5.74 mm, which is statistically significantly higher than that of the unsuccessful weaning group, which is 11.33 ± 4.27 mm (p<0.001). The mean DTF value of the successful group was higher than that of the failed group (33.23 ± 6.01 % and 25.07 ± 5.73%); The difference was statistically significant with p<0.001.

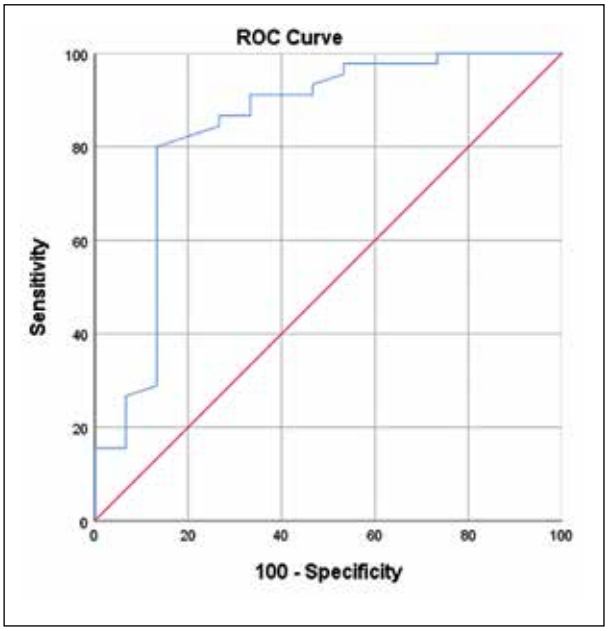

Figure 3. Area under receiving operating characteristic curve for DTF% to predict weaning success.

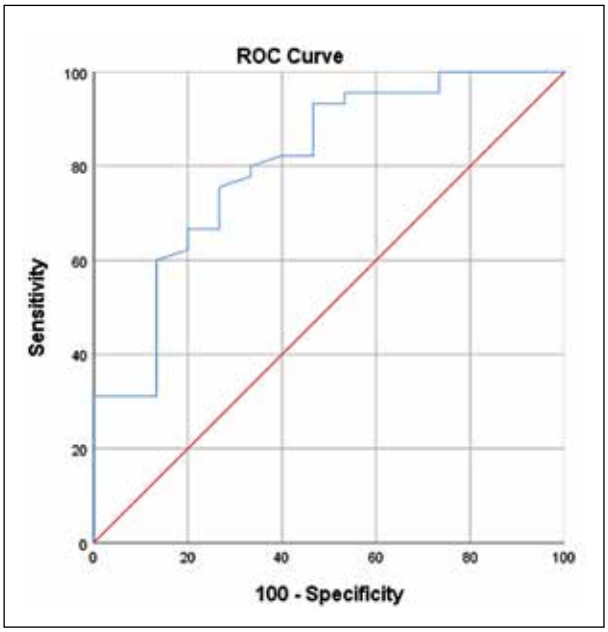

Figure 4. Area under receiving operating characteristic curve for DE(cm) to predict weaning success.

The area under the ROC curve of the DTF index in the prognosis of successful weaning from mechanical ventilation is AUC = 0.84; 95% confidence interval CI = [0.706;0.98]. From the ROC curve, we determined that the cut-off point of the DTF index in the prognosis of successful weaning is >30%. For the DE index, the area under the ROC curve for the prognosis of mechanical weaning was AUC=0.807; 95% CI=[0.676;0.937]. From this curve, it is shown that the cutoff of DE in the prognosis of successful weaning is 14mm. Meanwhile, the RSBI index has an AUC of 0.873 ; 95% CI=[0.784-0.963].

The predictive value of two indices of diaphragm and RSBI in weaning is presented in Table 2 below:

Table 2. Predictive values of DE, DTF and RSBI in weaning

	Threshold	Se	Sp	PPV	NPV
DTF (%)	>30%	84,4%	73,3%	90,5%	61,1%
DE (mm)	>14mm	83%	83%	83%	83%
RSBI (breaths/min/L)	<80	93,3%	70%	75,5%	91,3%

Discussion

Weaning and extubation is not an esay mission in resuscitation and should be planned to assess patient readiness criteria as soon as possible. Although the failure rate for planned extubation is about 15% [6], in our study the rate was 25%, explaining this rate as different studies performed in different studies. Patient populations and disease distribution, different age.

In our study, the DE value of the successful weaning group was significantly higher than that of the failure group (17.51 ± 5.74 mm vs 11.33 ± 4.27 mm, p< 0.001). This result is similar to that of Farghaly et al (16 ± 3.3mm vs 9.8 ± 1.4 mm, p<0.0001) [7]. We found the optimal cut-off point for DE value in predicting successful weaning from mechanical ventilation to be 14mm with a sensitivity of 83% and a specificity of 83%. Our results are quite similar to the results of other studies such as those of Spadaro et al. confirmed the DE cut-off point of 14mm with sensitivity and specificity of 88.2% and 61.8%, respectively [8] ; Kim et al confirmed a DE cut-off of 14mm, but lower sensitivity and specificity (60% and 76%) for predicting successful weaning from mechanical ventilation. In addition, in evaluating diaphragmatic movement as a predictor of weaning failure, Kim et al. indicated that DE <10 mm during spontaneous breathing was associated with weaning failure [9].

In this study, we found that DTF of the successful group was significantly higher than that of the failure group (33.23 ± 6.01% vs 25.07) ± 5.73%, p<0.001). A DTF >30% is considered to have a sensitivity of 84.4% and a specificity of 73.3% for the prognosis of successful weaning. This result is similar to DiNino et al., indicating that a DTF >30% has a sensitivity and specificity of 88% and 71%, respectively [10]. Whereas Ferrari et al found that a DTF >36% was associated with a successful spontaneous breathing test with a sensitivity of 82% and a specificity of 88%, however this study focused on predicting spontaneous breathingis more successful than the outcome of extubation [11].

We determined the AUC value of the ROC curve for DE and DTF values in the prognosis of successful weaning from mechanical ventilation. The two indices of diaphragmatic ultrasound have a relatively good predictive effect on successful abandonment with an AUC for DE of 0.807 and a DTF of 0.84. This result is similar to many authors such as Spadaro et al., whose AUC of DE is 0.82 [8]; Farghaly et al. showed that the AUC of DE and DTF were 9.879 and 0.708, respectively [7]. DiNino et al.'s study showed that the AUC of the DTF value of 0.79 was slightly lower than our study, possibly partly because the authors performed weaning from mechanical ventilation on both methods performed SBT and PS (pressure support) while our study followed the spontaneous breathing test [10].

Compared with the prognostic value of RSBI, the AUC of 0.873 was higher than that of the diaphragmatic

echocardiographic index and had a sensitivity and specificity for a cut-off point of 80 breaths/min/L 93.3% and 70% respectively. According to our study, the ultrasound index of the diaphragm has a higher specificity than RSBI, this result is similar to the author Farghaly et al. One possible explanation is that RSBI is not specific for diaphragmatic efforts, it reflects the force of all respiratory muscles (including accessory and diaphragmatic inspiratory muscles). In the case of patients with diaphragmatic failure, accessory respiratory muscles may increase effort during inspiration to ensure adequate tidal volume during the short duration of spontaneous breathing, but this effort may not be sustained for long periods of time. and therefore appear unresponsive to extubation despite passing spontaneous breathing. Therefore, thanks to the combination of RSBI sensitivity and specificity of DE, DTF index on diaphragmatic ultrasound, the author Farghaly et al suggest using RSBI to monitor patients ready to wean from mechanical ventilation and use other diaphragm ultrasound index for patients who passed that weaning test for the best results [7].

Conclusion

Our study shows that the indices on the diaphragmatic ultrasound: diaphragm excursion (DE) and diaphragmatic thickening fraction (DTF) are indicators with good predictive value in predicting the weaning outcome of patients in surgical intenive care unit. It is recommended to use these indices with RSBI to improve weaning outcomes.

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