ADDITION OF DIAPHRAGMATIC ULTRASOUND PARAMETERS TO CONVENTIONAL WEANING CRITERIA ON SUCCESSFUL WEANING OF MECHANICALLY VENTILATED PATIENTS IN ICU

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ABSTRACT

Introduction: Weaning patients from mechanical ventilation is a challenging task. Both unnecessary delay and premature discontinuation of mechanical ventilation may cause deleterious effects to the patients. Therefore, weaning indices are used to determine the optimal timing. The goal of this study was to find out whether diaphragm dysfunction is part of the cause of weaning failure and using both diaphragm USG parameters and RSBI together with clinical weaning criteria could reduce the weaning failure rate in ICU.

Aim: To study the addition of diaphragmatic ultrasound parameters to conventional weaning criteria on successful weaning of mechanically ventilated patients in ICU

Methods: The study design was a comparative randomized prospective study. This study was carried out in patients who was completed a spontaneous breathing trial with RSBI < 105 during the study period. Total 220 patients who met the inclusion and exclusion criteria were randomized whether to use additional diaphragmatic ultrasound parameters (Group A) or conventional parameters only (Group B). Arterial blood gas parameters, clinical parameters such as SBP, HR, RR and SpO2 between the two groups and the success rate of weaning were evaluated.

Results: The ABG parameters were not significantly different between both groups. Among the clinical parameters, RR and SpO_2 at 4 hours and 8 hours after extubation were statistically ($p<0.05$) but not clinically significant. There was more success rate of weaning in the diaphragmatic USG added to conventional parameters than using conventional alone [100 (90.9%) Vs 88 (80%)] ($p = 0.035$).

Conclusion: This study concluded that the use of diaphragmatic USG parameters combined with conventional weaning parameters can provide a more success rate of weaning in patients undergoing weaning from mechanical ventilation in ICU.

Keywords: Diaphragm ultrasound, Weaning

INTRODUCTION

Mechanical ventilation (MV) is one of the supportive therapies for respiratory failure. It is a two-edged sword. Prolonged mechanical ventilation is associated with the ventilator-associated pneumonia (VAP), ventilator-induced lung injury (VILI), digestive hemorrhage and deep venous thrombosis due to prolonged immobilization. To reduce the incidence of complications due to prolonged mechanical ventilation, the intensivists try to wean from mechanical ventilation as soon as the resolution of acute illness. On the other hand, premature discontinuation of mechanical ventilation increases the cardiovascular and respiratory stress and requiring reinstitution of ventilator support which in turn prolonged ventilation. Moreover, the psychological impact of the failed weaning and reintubation of the patients could be one of the reasons for difficult weaning. Therefore, timing is critical when determining if a patient can be successfully extubated.

Attempts have been ongoing to devise tools that can accurately determine the ideal timing of extubation. Among these tools, RSBI is the most extensively studied predictors, as it appears to be most accurate, is independent of patient effort or cooperation, and can be easily measured at the bedside.[5] Despite using objective and subjective weaning criteria and weaning index in weaning protocol at YGH ICU, approximately 35% of patients were failed to wean from mechanical ventilation at first attempt in 2016. There are many possible causes of weaning failure. Among them, the ventilator induced diaphragm dysfunction during MV could not be fully recovered at the time of weaning and could be part of the weaning failure. As the diaphragm is the principle muscle of respiration and its contribution in respiration is about 70%, the study of diaphragm function before extubation could get more success rate of weaning from MV.

Ultrasound can provide a simple, non-invasive method of quantifying diaphragmatic movement in a variety of normal and pathological conditions. Ultrasonography can assess the characteristics of diaphragmatic movement such as amplitude, force and velocity of contraction, special patterns of motion and changes in diaphragmatic thickness during inspiration.

The study done by Osman and Hashim (2017) showed diaphragmatic excursion, diaphragm thickness at end inspiration; at end expiration and diaphragm thickness fraction (DTF) % were significantly higher in the successful group compared to those who failed extubation. In the systematic review done by Zambon et al (2017) the optimal cut off values for diaphragmatic parameters associated with weaning success were more than 10mm for diaphragm excursion (DE) and more than 30% for diaphragm thickness fraction (DTF). This study was carried out to find out whether diaphragm dysfunction is part of the cause of weaning failure and using both diaphragm USG parameters and RSBI together with clinical weaning criteria could reduce the weaning failure rate in ICU.

MATERIALS AND METHODS

The study was comparative randomized prospective study, performed between January, 2018 and August, 2019 in ICU of Yangon General Hospital after the approval of Research and Ethics Committee of University of Medicine (1), Yangon. Mechanically ventilated patients due to acute respiratory failure for more than 48 hours who meet the criteria for spontaneous breathing trial in ICU were recruited for the study. Any patient with known neuromuscular disorder, cervical spine injuries and post esophageal or thoracic surgeries due to intra-operative diaphragmatic manipulation were excluded.

When the criteria for spontaneous breathing trial (SBT) are reached, SBT was attempted for 2 h with CPAP of 5cmH2O. The clinical weaning parameters such as SBP, HR, RR, SpO2, and EtCO2 were monitor continuously. The rapid shallow breathing index (RSBI) was recorded at 30min of SBT. If RSBI is < 105, the SBT was continued for next one hour and thirty minutes. After completion of two hours SBT with RSBI < 105 and stable clinical parameters, the patients were allocated into two groups according to block randomization table.

The patients in group B were extubated after passing SBT for 2 hour. For group A patients, right hemi-diaphragm ultrasound scans were performed with patients lying down at a semi-recumbent position (30°) using an Ultrasonix ultrasound system. A linear array 10-MHz transducer probe is placed at the anterior axillary line, with the transducer positioned to

obtain a sagittal image at the intercostal space between the 7th and 8th, or 8th and 9th ribs. On 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 DTF was calculated as percentage from the following formula:

$$\frac{\text{Thickness at end inspiration} - \text{Thickness at end expiration}}{\text{Thickness at end expiration}}$$

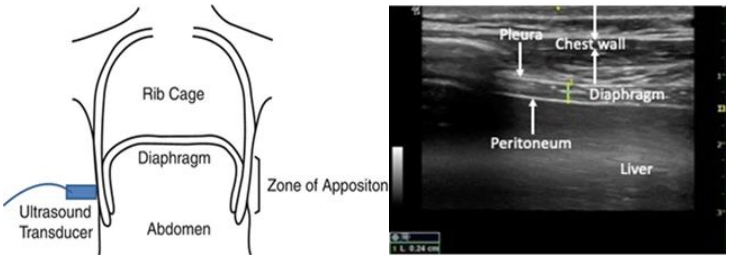

Figure (1) Diaphragm Thickness at Zone of Apposition (Cardenas et al, 2018)

The evaluation of diaphragmatic excursion was done using a low frequency curvilinear transducer placed between the mid-clavicular and anterior axillary lines, in the anterior subcostal region. The amplitude of diaphragmatic excursion was measured on the vertical axis of the tracing from the base line to the point of maximum height of inspiration on the graph. The maneuvers were repeated at least three times and the average was taken. The duration of the maneuver was about15min.Then, the extubation was done when DTF % > 30% and DE > 10 mm together with RSBI < 105 and fulfillments of other weaning criteria for extubation.

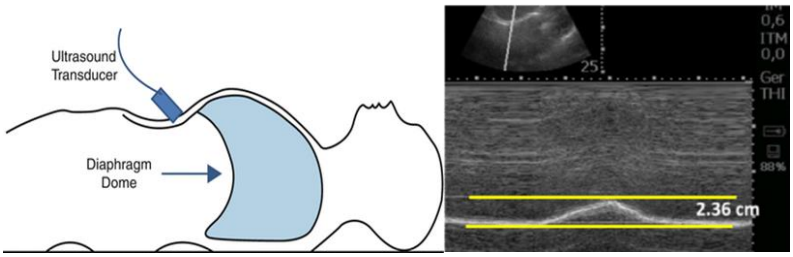

Figure (2): Diaphragm Excursion in Anterior Subcostal View (Cardenas et al, 2018)

Arterial blood gas (ABG) was done at 30min and 24 hours after extubation and compared in both groups. The clinical parameters were monitored closely in both groups and recorded four hourly after extubation for 48 hours and compared. When the following criteria such as: change in mental status, onset of discomfort, respiratory rate (RR) >35

breaths/min, hemodynamic instability (heart rate >140, systolic blood pressure >180 or <90 mmHg), SpO2<90% or signs of increased work of breathing occurs during the weaning process and/or within 48 hours after extubation in both groups, resumption of ventilatory support with non- invasive ventilation (NIV) and/or reintubation was done and assumed as weaning failure.

Data analysis

A statistical analysis was performed using the Statistical Package for Social Sciences software, version 16.0 (SPSS). Continuous variables were presented as mean ± SD for normally distributed data set. Categorical variables such as patient's gender and weaning outcomes were expressed as actual numbers and percentages and were analyzed using the chi-square test. Comparison between two independent mean groups for parametric data such as age, admission score was done between student t tests. The repeated measure ANOVA test was used for SBP, HR, RR and SpO2. The probability of error at 0.05 was considered significant while at 0.01 and 0.001 are highly significant.

RESULTS

Duration the study period, total 220 patients were enrolled. Ultrasound examination was feasible in all patients. There was no participant who withdrew from the study. Table 1 summarizes the main clinical demographic characteristic of the population enrolled in the study.

In comparison of weaning success rate between two study groups, in group A, 100 (90.9%) of patients were successfully extubated while in group B, 88 (80%) of patients were successfully extubated. P value was <0.05 and it was statistically significant in comparing the success rate of weaning between two groups.

The ABG parameters did not significantly differ between the both groups. Among the clinical parameters, RR and SpO2 at 4 hours and 8 hours after extubation were statistically ($p<0.05$) but not clinically significant.

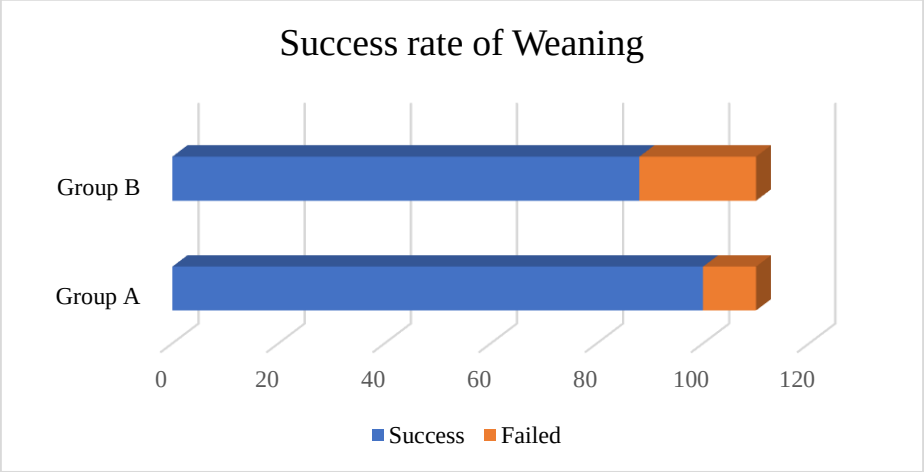

Figure (3) Comparison of success rate of weaning between two groups

Table (1) Demographic characteristic of patients

		Group A		Group B		P Value
		N	%	N	%	
Sex	Male	71	64.55	73	66.36	0.77
	Female	39	35.45	37	33.64	
Co-morbidities	Hypertension	18	16.36	24	21.81	0.68
	Heart disease	6	5.45	5	4.54	
	COPD	17	15.45	16	14.54	
	DM	7	6.36	7	6.36	
Type of ICU admission	Medical	55	50	57	51.82	0.79
	Emergency Surgery	53	48.18	50	45.45	
	Elective Surgery	2	1.82	3	2.73	
Reason for MV	APO	16	14.55	16	14.55	0.97
	Sepsis	17	15.45	15	13.64	
	Pneumonia	10	9.02	19	17.28	
Reason for MV	Post-op respiratory failure	7	6.36	9	8.18	
	Tetanus spasm	17	15.45	16	14.55	
	Trauma	30	27.27	29	26.36	
	Others	12	10.9	6	5.45	
		Mean ± SD		Mean ± SD		
Age		44.13 ± 16.3		44.95 ± 17.1		0.71
IBW (kg)		57.55 ± 7.54		57.82 ± 6.48		0.77
APACHE II		17.43 ± 5.93		18.3 ±6.34		0.29
Duration of MV until SBT(Hr)		151.35±112.72		149.91± 115.77		0.46

DISCUSSION

In the ICU, weaning a patient from mechanical ventilation is an important concern; successful weaning and extubation at the right time avoids weaning failure and mortality. There are various tools to measure patients' readiness to be separated from MV device. Among them, RSBI is important in predicting the weaning indices presented in a study by Yang and Tobin (1991). RSBI is a collaborative reflection of respiratory mechanics and consists of diaphragm and nondiaphragm muscles. Non-diaphragm inspiratory muscles will compensate if the diaphragm is failing in order to preserve the tidal volume; diaphragm weakness may be obscured. However, the non-diaphragmatic muscles are more subject to fatigue and are weaker than the diaphragm; they will not be able to provide sufficient ventilation for long. Moreover, Purro et al (2000) and Vassilakopoulos et al (1998) have also stated that diaphragm weakness is recognized as a major contributing factor to failure to wean from MV.

In this study, DTF% and DE was measured in group A when the patients were fulfilled the

weaning criteria together with RSBI < 105 for 2 hour duration. The patients were extubated when DTF% is > 30% and DE is > 10mm. In group B, the patients were extubated when the weaning criteria were fulfilled together with RSBI < 105 for 2 hours. As a result, 100 (90.9%) of the patients from group A were successfully extubated while only 88 (80%) were successfully extubated in group B (p value was 0.035). The success rate of weaning from mechanical ventilation was higher by using diaphragmatic USG parameters as an additional index to conventional weaning criteria. Therefore, the result of this study has a similar conclusion as the study done by DiNino et al (2014) that there was more success rate of weaning when the weaning was done after fulfillment of the diaphragmatic criteria.

In study done by Ferrari et al (2014), there was more success rate of weaning in the group using the diaphragmatic USG parameters (DTF > 30% and DE > 10mm) as an additional weaning criteria. The study of Mowafy and Abdelgalel (2018) also found that the weaning success rate was higher in the group using both RSBI and DE (73.6%) than in the group using RSBI alone (64.2%). The present study used not only DE but also DTF % as additional parameters to conventional weaning criteria and showed the weaning success rate was higher (90.9%) than using conventional criteria alone.

In study done by Gonzalez-Aguirre et al (2019), 70.6% patients were successfully weaned from MV with DTF > 30%. Soliman et al (2019) also found that 80 out of 100 patients (80%) were successfully extubated with DTF ≥ 29.5%. The findings of the above two studies were consistent with the present study in which the success rate of weaning was higher in the group using both diaphragmatic USG parameters and conventional criteria than in the group using conventional criteria alone.

Regarding causes of weaning failure between the study groups, the increase work of breathing and respiratory failure after extubation was 30% in diaphragm USG added to conventional groups and 54.5% in the conventional group. Therefore, the study could determine that the diaphragm muscle weakness could be one of the causes of weaning failure in ICU.

Some limitations in this study have to be addressed. The ultrasound technique has limitations such as presence of pneumothorax as well as the morbid obesity interfering with best window for diaphragm visualization. Moreover, the mixed types of patients such as surgical and medical patients with various co-morbidities were involved in the present study which could alter the value of the diaphragm parameters used in the study. Therefore, there would be more informative in studying diaphragmatic USG guided weaning in specific population like COPD patients

Based on the results obtained from this study, there was more success rate of weaning in the groups using both diaphragmatic USG and conventional weaning parameters. In monitoring of the extubated patients, the clinical parameters are more indicatives for reinstitution of respiratory support than arterial blood gas. However, the weaning failure can be occurred not only due to ventilator induced diaphragm dysfunction but also due to pulmonary and cardiac problems. Therefore, further studies including lung USG and echocardiogram added to diaphragmatic USG needs to be investigated in weaning from mechanical ventilation. Furthermore, the diaphragmatic USG guided weaning may be useful in the difficult and prolonged weaning like patient with neuromuscular diseases who were excluded in the present study.

Competing interests
The author declare that they have no competing interests.

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