ORIGINAL ARTICLE

Diaphragmatic Excursion: Does it Predict Successful Weaning from Mechanical Ventilation?

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ABSTRACT

Objective: To measure the diaphragmatic excursion and its outcome on weaning from mechanical ventilation.
Study Design: Cross-sectional comparative study.
Place and Duration of Study: Medical Intensive Care Unit (ICU), Military Hospital (MH), Rawalpindi, Pakistan, from January to December 2014.
Methodology: Diaphragmatic excursion (DE) in cm was measured through ultrasound by marking liver and spleen displacement in patients who fulfilled the criteria of removal from ventilatory support. The patients were followed up for 48 hours and classified according to the outcome as successful weaning and weaning failure.
Results: Out of 100 cases, 76 patients had a successful weaning while 24 had a failed weaning outcome. At a diaphragmatic excursion of 1.2 cm and more, out of 67 cases, 60 had a successful weaning (89.55%) while 7 cases (10.45%) had a weaning failure. At an excursion of less than 1.2 cm, 17 out of 33 cases (51.5%) had successful weaning while 16 (48.48%) had weaning failure. At this cut off point (1.2 cm), the sensitivity and specificity for successful weaning were 78.95% and 70.83%, respectively. The positive and negative likelihood ratio (LR) for these values being 2.70 and 0.29, respectively. The positive predictive value was 82.35% and negative predictive value 60.00%.
Conclusion: Ultrasonographic measurement of diaphragmatic excursion is a good method for predicting weaning outcome from mechanical ventilation.

Key Words: *Mechanical ventilation. Weaning. Diaphragmatic excursion. Ultrasound.*

INTRODUCTION

Unnecessary delay in weaning from mechanical ventilation in a critically ill patient increases the risk of ventilator associated lung injury and ventilator associated pneumonias. Similarly, an untimely extubation is associated with significant morbidity and mortality. The process of weaning from ventilatory support takes almost 40% of the time spent on ventilator.[1] Weaning indices like spontaneous tidal volumes, minute ventilation and rapid shallow breathing index (RSBI), have been used extensively in clinical practice for weaning purposes.[2] These parameters measure the overall respiratory volumes produced by the muscles of breathing and do not take into account the independent contribution of the diaphragm.[3] During resting, the main muscle of breathing is the diaphragm which is a major determinant to delayed weaning, highlighting the significance of diaphragmatic assessment.[4]

Assessment for diaphragmatic dysfunction can be done by a number of methods including measurement of transdiaphragmatic pressure, diaphragmatic electromyography & phrenic nerve stimulation, fluoroscopic examination of the diaphragm, pulmonary function tests, MRI, chest radiographs and CT scans.[5,6] However, all of them require transport of the critically ill to the radiology department and pose a risk of ionizing radiation.[7] Ultrasonographic assessment of the diaphragmatic dysfunction in the critical care unit has lately earned admiration by measuring its excursion during quite spontaneous breathing, prevailing over the common constraints of methods of imaging.[8]

This study aimed to assess the diaphragmatic excursion – an ultrasonic parameter and its outcome on successful weaning and extubation.

METHODOLOGY

It was a prospective observational study performed at MH ICU between January and December 2014. The Institutional Ethic Committee approved the study.

The sampling technique was convenient purposive. The diaphragmatic excursion was measured in patients who fulfilled the criteria to be removed from ventilatory support and the outcome classified as successful weaning and weaning failure (including both the primary and the secondary weaning failure). Weaning success was defined as the patient preserving their breathing for at least 48 hours without the need of any amount of ventilatory support. The requirement of mechanical ventilation including non-invasive ventilation (NIV) within

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48 hours of self-breathing defined primary weaning failure; and if required after 48 hours, defined secondary weaning failure.

A mixed subset of patients was included in the study. However, being a medical ICU, surgical cases were not available for inclusion. Majority of the patients had respiratory failure due to neuromuscular conditions, pneumonias and COPD. Patients were included in the study if they were alert and cooperative with stable hemodynamics in the absence of vasoactive agents, FiO_2 <0.5, Psupport $\leq$8 cm H^2O, PEEP $\leq$5 cm H^2O, PaO_2/FiO_2 >200, PCO_2 normal or base line except for permissive hypercapnia and respiratory rate <30 breaths per minute. To keep the patients calm, sedatives were allowed (Ramsay score 3). Patients with injury to the cervical spine were excluded from the study.

When the aforementioned criteria were fulfilled, the patients were removed from ventilatory support and extubated (provided they were able to protect their airway and did not require frequent suctioning). Supplemental oxygen was administered to keep the saturations in the target range. The diaphragmatic excursion was then measured through ultrasound using a low frequency curvilinear probe (3.5 MHz) placed along the left posterior and right anterior axillary line and measuring the displacements of the liver and spleen, respectively. To reduce observer bias, the assessment was done by two ICU physicians trained in the ultrasound of the lung and the diaphragm, interobserver variability being 1-3 mm. Marks were placed at the most caudal margins of the liver and spleen at end expiration and inspiration. Distance between them defined the diaphragmatic excursion (DE) of the spleen and liver. The mean DE was calculated in cm after recording the maximal displacements in five breathing cycles. All measurements were performed in the supine position during quiet breathing, excluding occasional deep or shallow breaths. The patients were followed up for 48 hours and outcome classified as successful weaning and weaning failure. Re-instituting mechanical ventilatory support was based on at least one of the following criteria: sweating, anxiety, agitation, deterioration in neurological status, abdominal paradox, usage of accessory muscles, breathing rate exceeding 30/min, arterial CO2 > 55 mm Hg and pH < 7.25, arterial PO2 < 70 mm Hg at an FIO2 of > 0.5, systolic blood pressure above 180 mm Hg or below 90 mm Hg, heart rate > 140 beats/min, a sustained 20% increase or decrease in heart rate, and unstable hemodynamics (arrhythmia or shock).

The data was analysed using STATA version 13 by the author. Test of normality (Shapiro-Wilk) was applied for age and duration of ventilation. P value for duration of ventilation and age were 0.003 and 0.008, respectively, which showed that this variables data was nonparametric. Median with interquartile range (IQR) was calculated for age and duration of ventilation as it was nonparametric data. Frequencies with percentages were calculated for gender and weaning outcomes. Other parameters evaluated included sensitivity and specificity, likelihood ratios (LR), and positive and negative predictive values.

RESULTS

The median age of the study population was 40.50 years with an IQR of 25.75 years. Sixty-eight were males (68%) and 32 females (32%). The most common reason for ventilation was respiratory illnesses in 73 cases (73%), followed by neurological conditions and others in 27 cases (27%). The median duration of ventilation was 7.50 days with an IQR of 12.00 days.

A total of 100 cases were studied. The number of successful and failed weanings at each diaphragmatic displacement is summarized in Table I.

Out of 100 cases, 67 cases were at or above the diaphragmatic excursion of 1.2 cm while 33 cases were below this value. Out of these 67 cases, 60 had a successful weaning (89.55%) while only 7 cases (10.45%) had a weaning failure. Best results were seen at a DE of 1.4 and 1.5 cm. Out of the 33 cases with a diaphragmatic excursion below 1.2 cm, only 17 (51.5%) had successful weaning while 16 (48.48%) had weaning failure.

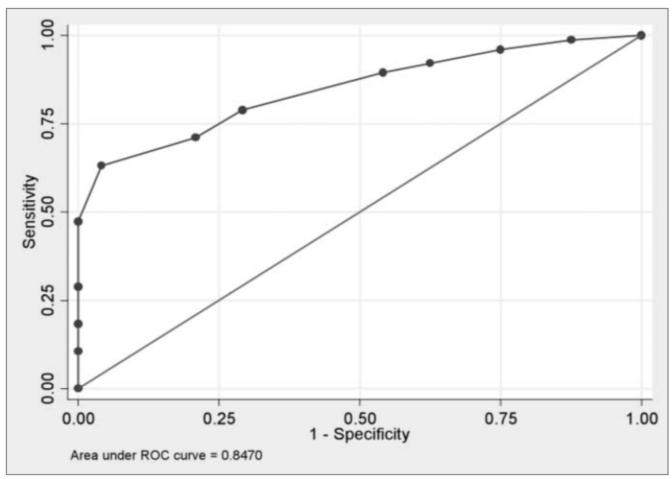

Figure 1: Cut off point for sensitivity and specificity.

Table I: Weaning outcomes at various DE (n=100).

	Displacement (cm)											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8
No. of failures	3 (3%)	3 (3%)	3 (3%)	2 (2%)	6 (6%)	2 (2%)	4 (4%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
No. of successful weaning	1 (1%)	2 (2%)	3 (3%)	2 (2%)	8 (8%)	6 (6%)	6 6%)	12 (12%)	14 (14%)	8 (8%)	6 (6%)	8 (8%)
Total	4 (4%)	5 (5%)	6 (6%)	4 (4%)	14 (14%)	8 (8%)	10 (10%)	13 (13%)	14 (14%)	8 (8%)	6 (6%)	8 (8%)

At the cut off point (1.2 cm), the sensitivity and specificity for successful weaning were 78.95% and 70.83%, respectively. The positive and negative likelihood ratio for these values being 2.7068 and 0.2972, respectively. The positive predictive value was 82.35% and negative predictive value 60.00%.

Of the 24 cases of weaning failure, Non-invasive Ventilation (NIV) was required in 15 cases (5, i.e. 20.8% primary and 10, i.e. 41.66% secondary wearing failures), and reintubation was required in 09 (37.5%) cases.

DISCUSSION

The study highlights that DE is a more precise and better than the traditional volume-based weaning parameters, such as spontaneous tidal volumes and rapid shallow breathing index in foreseeing weaning failure or success.[9] All patients who qualified for weaning had good and similar tidal volumes before extubation. However, immediately before failure, shallow breathing was noticed in patients with DE less than 1.2 cm. This is because the tidal volumes generated represent the combination of the effort generated by all respiratory muscles: Diaphragm and the accessory muscles combined, without measuring the individual input from the diaphragm. Those cases, who acquire input from the accessory muscles of breathing before extubation but have a poor diaphragmatic excursion, were more likely to have a weaning failure due to subsequent fatigue in contrast to patients with good spontaneous tidal volume and diaphragmatic movements.[10]

The study draws attention to the fact that patients with diaphragmatic excursions $\geq$1.2 cm can be extubated safely with a low risk of weaning failure. Hence, they may be transferred out of the ICU with a very low risk of reintubation. Patients with DE less than 1.2 cm are at a higher risk of weaning failure and need a closer follow-up in the ICU setup. After extubation, they should be supported with NIV, especially if they had a shallow breathing at the end of the trial. Another option could be to defer the extubation for a later time and meanwhile building up of respiratory muscle strength. Secondly, cases of secondary weaning failures can esp be successfully managed with NIV and might not require reintubation.

In a similar study by Jiang, *et al*., the sensitivity and specificity to predict successful extubation was 84.4% and 82.6%, respectively, using a mean cut off value of 1.1 cm of spleen and liver displacement. It was better than many of the traditional weaning parameters used in the trial.[1] Kim, *et al*. used M mode and studied 88 ICU cases. Using a vertical excursion of 10 mm, diaphragmatic dysfunction prevalence of 29% was found. Where there was a diaphragmatic dysfunction, the patients took longer time to wean than patients without diaphragmatic dysfunction. This emphasizes that ultrasonography of the diaphragm may be useful in predicting weaning failures.[11] In this study, displacements of the spleen and liver served as alternatives for diaphragmatic movements.[12] They were used because they were easier to locate compared to direct visualization of the diaphragm, especially in patients with irregular breathing patterns.[13]

The normal movement of the diaphragm during inspiration is caudal as the diaphragm moves towards the probe; while the expiratory motion is cranial, as the diaphragm moves away from the probe.[14] The diaphragm inspiratory excursion is the amplitude between the foot of the inspiration slope and the apex of this slope. It is always greater in men than in women and greater in the supine position than in the sitting or the standing positions. There is no significant correlation with age. The normal range of diaphragmatic excursion during quiet breathing is 1.8 ±0.3 cm in males and 1.6 ±0.3 cm in females. During deep breathing, the normal range in males increases to 7.0 ±0.6 cm and in females it increases to 5.7 ±1.0 cm.[15]

To evaluate diaphragmatic excursion, a brief recording (5-10 min) during spontaneous breathing and disconnection from the ventilator is necessary.[16] A low frequency, curvilinear probe is used. It is placed immediately below the right or left costal margin in the mid-clavicular line, or in the right or left anterior axillary line and is directed medially, cephalad and dorsally. B-mode ultrasound is used to visualize and M-mode to measure. To enhance reproducibility, the cursor for diaphragmatic excursion measurements in M-mode should always be as strictly perpendicular with regards to the middle or posterior part of the diaphragm.[17]

There are a few bars to this method of predicting weaning outcomes, and some rules that need to be considered.[18,19] One limitation reported to occur in 2 and 10 % of cases, is a poor acoustic window, especially in ICU patients.[20] Secondly, the ribs and lungs can obscure the images in patients who have greater chest wall movements due to an increased respiratory effort.[21] Lastly, a smaller splenic window on the left causes the hemidiaphragm to be visualized less easily than the one on the right because of a larger liver window.[22]

CONCLUSION

Ultrasonographic assessment of DE can be a valuable method to predict results of extubation. It is easily available and non-invasive. However, more research is required on the subject.

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