International Journal of Multidisciplinary Research and Development
Online ISSN: 2349-4182, Print ISSN: 2349-5979; Impact Factor: RJIF 5.72
Received: 22-06-2019; Accepted: 24-07-2019
www.allsubjectjournal.com
Volume 6; Issue 9; September 2019; Page No. 186-191

Role of chest ultrasound in assessment of diaphragmatic motion for discontinuation of patients from mechanical ventilation

Hamdy Meligi[1], Maha EL-kholy[2], Ibrahim Shalan[3], Abd El- Aziz Aboul Ela[4]
[1-4] Chest Department AL Azhar Assiut University, Egypt

Abstract
Introduction: Predicting extubation outcome and preventing extubation failure is an important task. We hypothesized that patients who fail a trial of weaning develop diaphragmatic fatigue. The prediction rate of various weaning parameters may not be satisfactory. Accordingly we suggest that ultrasonographic evaluation of diaphragmatic excursion during spontaneous breathing trials may be a good predictor for extubation outcome.
Objective: The aim of the work was to determine the value of diaphragmatic motion measured by B- mode of chest ultrasound as a predictor tool for discontinuation of patients from mechanical ventilation.
Patients and Methods: The patients (60 patients) were classified into a success group (SG) or failure group (FG) according to the extubation outcome. Weaning parameters including RSBI, VTspon, and maximum inspiratory Force were measured and ultrasonographic measurement of diaphragmatic excursion was performed within 6 h before extubation. The maximal liver and spleen displacements among 10 respiratory cycles were recorded. The final mean value of liver displacement and spleen displacement (MD) was calculated.
Results: The present study included 60 patients, 48 of whom (80%) were in the SG and 12 patients (20%) FG. The baseline data were similar for these two groups. All the weaning parameters were significantly better in the SG and highest significance with the diaphragmatic movement also recorded. Using a cutoff value of 1 cm, the sensitivity and specificity to predict successful extubation were 95.2% and 88.9%, respectively, better than traditional weaning parameters in this study.
Conclusion: It is obvious that diaphragmatic movement more sensitive and specific parameter than volume associated weaning parameter in predicting extubation outcome. Assessment of diaphragmatic movement measured by real time ultrasonography is a good predictor of extubation outcome.

Keywords: diaphragm, chest ultrasound, weaning, mechanical ventilation

Introduction

Ultrasonography is a noninvasive technique, which has proved to be an accurate, safe, easy to use bedside modality, overcoming many of the standard limitations of imaging techniques. Bedside ultrasonography has become a valuable tool in the management of intensive care unit patients [1]. The diaphragm is the principal respiratory muscle, and its dysfunction predisposes to respiratory complications and can prolong the duration of mechanical ventilation [2]. Sonographic evaluation of the diaphragm has recently started to gain popularity in the ICU as specific needs for assessing diaphragmatic function arise in many clinical situations. Abnormal diaphragmatic motion is observed in conditions such as phrenic nerve injury, neuromuscular diseases [3], After abdominal or cardiac surgery and in critically ill patients under mechanical ventilation [4]. Mechanical ventilation is a life-saving intervention, but it is also associated with complications. Therefore, it is desirable to liberate patients from mechanical ventilation as soon as the underlying cause that led to the mechanical ventilation has sufficiently improved and the patient is able to sustain spontaneous breathing and adequate gas exchanges [5]. Weaning from mechanical ventilation is an essential and universal element in the care of critically ill intubated patients receiving mechanical ventilation [6]. There is uncertainty about the best methods for conducting weaning, which will generally require the cooperation of the patient during the phase of recovery from critical illness. This makes weaning an important clinical issue for patients and clinicians [7]. Difficulties in discontinuing ventilatory support are encountered in 20% to 50% of all mechanically ventilated patients with approximately 40% of total ventilation time spent in weaning [8]. US (B-mode) has been recently shown to be capable of quantifying diaphragm movements [9]. Recent preliminary data suggest that sonographic assessment of the diaphragm can provide a noninvasive measurement of excursion or paradoxical movements and can diagnose severe diaphragmatic dysfunction (DD) [10].

Objective

The aim of the work was to determine the value of diaphragmatic motion measured by B- mode of chest ultrasound as a predictor tool for discontinuation of patients from mechanical ventilation.

Patients and methods

This was a prospective observational study approved by the institutional ethics committee. This study was carried out on 60 intubated patients receiving mechanical ventilation who were scheduled to be extubated in the respiratory intensive care unit (RICU) of Assiut University Hospital. The diaphragmatic Excursion was measured by ultrasonography before extubation. The patients (60 patients) were classified into a success group (SG) or failure group (FG) according to the extubation outcome. The baseline data and organ displacements in these two groups were analyzed. The sensitivity and specificity for the mean organ displacements and weaning parameters to predict successful extubation were calculated. Weaning parameters including RSBI, VTspon, and maximum inspiratory Force were measured and ultrasonography was performed within 6 h before extubation. All patients were in a supine position with discontinuing of ventilator and shifting to T-piece spontaneous breathing. An ultrasound scanner (Aloka Echo Camera SSD-3500; Aloka Prosound; Japan) equipped with a3.5-MHz sonar probe was used. The probe was placed along the right anterior axillary line and the left posterior axillary line for measurement of liver and spleen displacement in cranio-caudal aspects, respectively (Figure I&II). A mark for measurement was placed on the image at the location of the most caudal margin of the liver or spleen at the end of expiration. With the probe fixed on the chest wall during respiration, the image of sonography was frozen at the end of inspiration, and a second mark was placed on the new location of the most caudal margin of the liver and spleen. The distances between the two marks were then measured. The maximal liver and spleen displacements among 10 respiratory cycles were recorded. The final mean value of liver displacement and spleen displacement (MD) was calculated.

Fig 1: RT hemidiaphragm (liver displacement)

Fig 2: Left hemidiafragm (spleen displacement)

(Figure I&II): Ultrasonographic measurements of liver displacement and spleen displacement in a cranio-caudal direction, with liver displacement is 1.75 cm and spleen displacement is 1.42cm.

Statistical analysis

MD and weaning parameters were presented as means ± SD. Independent sample t test was used for evaluating weaning parameters and MD in the SG and the FG. The cutoff point for MD was determined by the receiver-operated characteristic curves. The sensitivity and specificity of MD and weaning parameters to predict successful extubation were calculated; $p < 0.05$ was considered statistically significant.

Results

The present study included 60 patients, 48 of whom (80%) were in the SG. The baseline data are similar for the two groups BUT all the weaning parameters were significantly better in the SG if compared with those in the failure group and highest significance ($p < 0.001$) was recorded with the diaphragmatic movement. The sensitivities and specificities to these weaning parameters for predicting successful extubation were calculated and summarized in table (6). Using a cutoff value of 1cm, the sensitivity and specificity to predict successful extubation were 95.2% and 88.9%, respectively, better than traditional weaning parameters in this study. Receiver operator characteristic (ROC) curve for MD is shown in Figure (2).

Table 1: Demographic data of the studied patients

	N	%
Age (Mean± SD)		
	SD (62.5 ± 13.18)	
Sex		
Male	42	70
Female	18	30
Residence		
Rural	17	28.33
Urban	43	71.67
Occupation		
Worker	10	16.67
Farmer	32	53.33
House wife	18	30
Smoking habits		
Passive Smoker	19	31.67
Active Smoker	25	41.67
EX_ Smoker	16	26.66

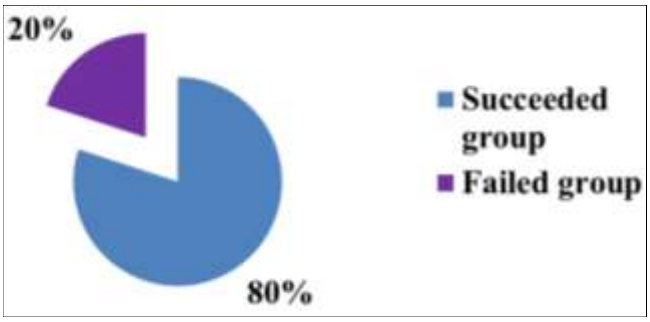

Fig 1: Percentage of patients

Table 2: Laboratory findings of studied patients at weaning from mechanical ventilation in relation to extubation outcome

Variable (Mean ± SD)	Succeeded	Failed	T test	P value
WBCs (/mm^3)	11.30 ± 4.54	10.69 ± 4.38	0.620	0.537
Haemoglobin(g/dl)	11.83 ± 2.27	12.25 ± 2.08	0.595	0.554
Platelet (/mm^3)	207.42 ± 75.72	244.58 ± 111.79	1.375	0.174
Na (mEq/l)	137.56 ± 5.36	137.2 ± 2.66	0.243	0.809
K (mEq/l)	3.86 ± 0.61	3.98 ± 0.45	0.604	0.548
Mg (mEq/l)	2.03 ± 0.32	2.08 ± 0.23	0.547	0.586
Creatinine (mg/dl)	0.90 ± 0.56	0.83 ± 0.26	0.455	0.651
Albumin (g/dl)	2.24 ± 0.54	1.53±0.57	4.014	0.000

Table 3: Diagnosis of studied patients in relation to extubation outcome

Diagnosis	Succeeded no. (48) (%)	Failed no. (12) (%)	X_2	P value
COPD 36 (100)	29 (80.6%)	7 (19.4%)	11.575	0.171
Overlaps 11 (100)	10 (90.9%)	1 (9.1%)		
ILD 5 (100)	2 (40 %)	3 (60 %)		
Bronchopneumonia 1 (100)	1 (100 %)	0 (0%)		
Asthma 2 (100)	2 (100%)	0 (0%)		
Pneumonia 2 (100)	2 (100%)	0 (0%)		
Pulmoary embolism 1 (100)	1 (100%)	0 (0%)		
Alveolar HAGE. 1 (100)	0 (0 %)	1 (100%)		
Bronchiectasis (1) (100)	1 (100%)	0 (0%)		

Table 4: Vital signs of studied patients as a weaning parameter in relation to extubation outcome:

Variables (Mean ± SD)	Succeeded (no=48)	Failed (no=12)	T test	P value
Systolic blood pressure (mmHg)	122.08 ± 14.87	125.83 ±15.05	0.780	0.439
Diastolic blood pressure (mmHg)	74.9 ± 8.47	75.83 ± 6.69	0.356	0.723
Heart rate (beat/min)	90.52 ± 11.66	94.08 ± 12.09	0.940	0.351
Temperature (°C)	37.59 ± 0.63	37.57 ± 0.32	0.133	0.895
RR (Breath/min)	26.43 ± 4.19	34.7± 4.92	6.65	<0.001

Table 5: Mean measures of both liver & Spleen displacement of studied patients as a weaning parameter before extubation

Variables	Succeeded (no=48)	Failed (no=12)	P value
Liver displacement (mean measure (cm))	1.47 ± 0.32	0.78 ± 0.35	<0.001
Spleen displacement (mean measure (cm))	1.46 ± 0.35	0.75± 0.35	<0.001

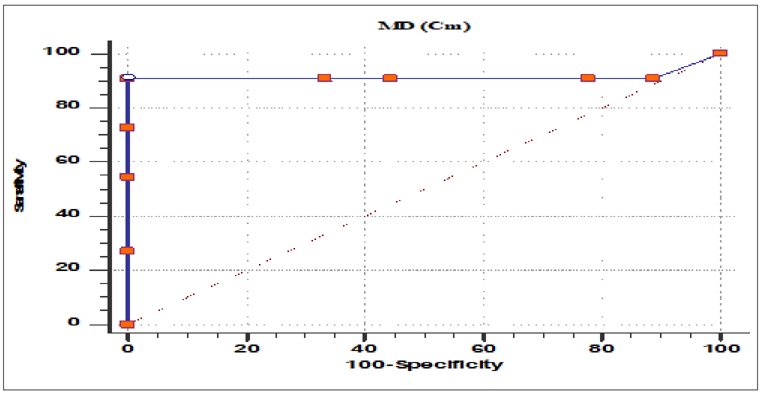

Fig 2: Sensitivity, specificity for MD OF liver and spleen

Table 6: Sensitivity, specificity, predictive values & accuracy of specific weaning parameters for prediction of extubation outcome

Tests	cut-off level	Sensitivity %	Specificity %	PPV %	PNV %	Accuracy %
MD of both liver & spleen (cm)	>1	95.2	88.9	95.2	88.9	93.3
Pimax cm H_2O	≤ -20	85.7	72.2	87.8	68.4	81.7
ƒ / VT	≤ 105	83.3	66.7	85.4	63.2	78.3
VTspont ml/Kg	>5	78.6	66.7	84.6	57.1	75

Discussion

Evaluating the strength of the respiratory muscles is important, since the imbalance between respiratory demand and supply will lead to weaning failure through the development of respiratory muscle fatigue. There have been studies evaluating diaphragmatic function to predict weaning outcomes, including Pimax, P0.1, Pdi, lung volume and inspiratory flow rate. However, some of these methods are limited by their invasive nature and dependency on maximal voluntary efforts of the patients [11]. Practitioners' decision for Extubation is a challenging task that involves a complete knowledge of a great number of clinical parameters, as well as its evolution in time [12]. Recently, an increasing interest on respiratory pattern variability as an extubation readiness indicator has appeared [13]. Moreover, as weaning from mechanical ventilation is a complex process requiring assessment and interpretation of both objective and subjective clinical parameters, for many years, automated computerized systems for various medical processes, including respiratory management, have been proposed to optimize decision-making and reduce variation amongst clinicians. The measurement of the movements of the liver and spleen served as surrogates for diaphragmatic Excursion. The Pdi, a similar tool previously used to represent the strength of the diaphragm, lacks the information concerning volume change contributed by the diaphragm. In another way, weaning parameters containing a volumetric factor, as seen in VTspon or RSBI, measure the volume change generated by the respiratory muscles as a whole without specifically measuring the contribution of the diaphragm [14]. The used technique application appears promising because the diaphragm plays a pivotal role of respiratory muscle endurance. If fatigue of the diaphragm occurs, the velocity of movement is slowed, and amplitude of movement is decreased [12]. Diaphragmatic movement is a final result of diaphragmatic strength, intrathoracic and intraabdominal pressure. Among the various causes of extubation failure, poor endurance is probably the most difficult to predict. Evaluation of the diaphragmatic movements by ultrasonography therefore may be an important tool to evaluate the endurance of the patient. In this study, the most diagnostic cases were COPD accorging to patients admitted at RICU in period of collection of cases and this agree with Makhlouf, 2008 [15]. In this study, the liver and spleen displacements measured by ultrasound in the cranio-caudal aspect are reproducible because the reference points are easier to find compared to direct sonographic visualization of the diaphragm. The displacements may be contributed by two components: movement caused by diaphragmatic contraction and movement of the chest wall as well as the probe [16]. Successful extubation was 80% in our patients, a value which is higher than the previously reported [17], in the literature. The explanation of that is lower mean age of our patients, few comorbidity and they must fulfill all the weaning parameters cut off points including RSBI, VTspon, and maximum inspiratory Force in addition to stable good level of oxygenation before trial of extubation. All parameters before extubation—including VTspon, RSBI, maximum inspiratory force and MD—were significantly better in the SG than in the FG. We identified a cutoff point for MD of 1 cm according to receiver operated characteristic curve. The sensitivity and specificity for successful extubation by MD 1 cm are better than by traditional weaning parameters, including the VTspon, maximum inspiratory force and RSBI. The sensitivity and specificity of these traditional weaning parameters are similar to that described in previous reports [18, 19]. In the failure group (FG), inspite all of them had significantly lower values than the SG group and higher RSBI, their values were accepted for trial of weaning but all of them required CPAPor reintubation again. The only parameter which considered of poor value is the degree of hemidiaphragm movement and in turn the degree of liver and spleen displacement. We noticed that all patients in the FG group had a rapid shallow breathing index which nearly doubles that of the SG patient. Moreover individual analysis found fairly low Vtspon in some cases of FG. This indicate that high RSBI and fairly low VTspon in patients with poor MD more likely to suffer from failed extubation. Jiang *et al* in 2003 [14] detected that VTspon in those patients with poor MD seems more likely to become small and to lead to respiratory failure than those with better MD and similar VTspon, as in the SG, before extubation. Diaphragm movement and other respiratory muscles contribute to VTspon together. Although diaphragm movement is only one component for VTspon, it seems that the measurement of MD is a more sensitive and specific parameter than the initial VTspon before extubation in predicting deterioration of VTspon, which leads to extubation failure, especially in patients with poor endurance. Patients who maintain tidal volumes by recruiting accessory respiratory muscles before extubation usually fatigue and fail extubation. This is why MD is better than VTspon or RSBI for predicting successful extubation. This means that accurate quantification of respiratory muscle strength is important in assessing patients with respiratory muscle dysfunction and respiratory failure. The simplest method is measuring the PImax, but wide range of normal values have been reported; these are closely related to voluntary effort (which is difficult to evaluate in uncooperative patients) [20]. The PImax relates more to diaphragm contractile strength in deep respiration than in quiet respiration. We evaluated diaphragm movement in quiet respiration by liver and spleen displacement, which is a better predictor than traditional weaning parameters for predicting successful extubation, especially in patients with poor endurance. Rapid respiratory rate will increase the loading of the respiratory muscles, and therefore may lead to fatigue of the diaphragm, resulting in impaired endurance [21]. One of the pathophysiologic causes of extubation failure includes an imbalance between respiratory muscle capacity and work of breathing. Compared with patients who tolerate extubation, those who require reintubation have a higher incidence of hospital mortality, increased length of ICU and hospital stay, prolonged duration of mechanical ventilation, higher hospital costs, and an increased need for tracheostomy. Given the lack of proven treatments for extubation failure, clinicians must be aware of the factors that predict extubation outcome to improve clinical decision making. So, correcting liver and spleen displacements with respiratory rate during spontaneous breathing may, therefore, enhance the sensitivity and specificity for predicting successful extubation [22, 23]. It was reported that albumin level had significant lower in failure cases than success one. and this agree with Zhao *et al*. (2016) [24] mention that: Serum albumin is a good predictor for duration of weaning in patients with long-term mechanical ventilation. Several limitations of the study could be limit the value of the MD as it is an observational study and the diaphragm was the only among the respiratory muscles assessed, and we did not evaluate the correlation between liver and spleen displacements and Pdi or pressure in the esophagus. Late expiratory strain of the abdominal muscles, as would be seen in patients with expiratory flow obstruction or increased ventilatory demand, may result in caudal displacement of the liver and spleen when the abdominal muscles relax. Therefore, the "neutral" positions of the abdominal organs need to be judged by the ultrasound operator; meanwhile, some patients are not suitable for this position. It might be difficult to evaluate patients with an irregular respiratory pattern with high breath-by-breath variability of liver and spleen displacement.

Conclusion

It is obvious that diaphragmatic movement more sensitive and specific parameter than volume associated weaning parameter in predicting extubation outcome. Assessment of diaphragmatic movement measured by real time ultrasonography is a good predictor of extubation outcome.

References

1. Dinh Am, Ko V, Rao HS, Bansal R, Smith RC, Kim DD. *et al*. Measuring cardiac index with a focused cardiac ultrasound examination in the ED. The American journal of emergency medicine. 2012; 30(9):1845-1851.
2. Papa GFS, Pellegrino GM, Di Marco, Imeri F, Brochard, G, Goligher L. A review of the ultrasound assessment of diaphragmatic function in clinical practice. Respiration. 2016; 91(5):403-411.
3. Vetrugno L, Guadagnin GM, Barbariol F, Langiano N, Zangrillo A, Bove T. *et al.* Ultrasound imaging for diaphragm dysfunction: a narrative literature review. Journal of Cardiothoracic and Vascular Anesthesia, 2019.
4. Petrof BJ, Jaber S, Matecki S. Ventilator-induced diaphragmaticdysfunction. Current opinion in critical care. 2010; 16(1):19-25.
5. Lee CH, Lee CY, Hsu MY, Lai CL, Sung YH, Lin CY. *et al*. Effects of music intervention on state anxiety and physiological indices in patients undergoing mechanical ventilation in the intensive care unit a randomized controlled trial. Biological research for nursing. 2017; 19(2): 137-144.
6. Boles JM, Bion J, Connors A, Herridge M, Marsh B, Melot C. *et al*. Weaning from mechanical ventilation. European Respiratory Journal. 2007; 29(5):1033-1056.
7. Tobin MJ, Laghi F, Jubran A. Narrative review: ventilator-induced respiratory muscle weakness. Annals of internal medicine. 2010; 153(4):240-245.
8. Hudson MB, Smuder AJ, Nelson WB, Bruells CS, Levine S, Powers SK. *et al*. Both high level pressure support ventilation and controlled mechanical ventilation induce diaphragm dysfunction and atrophy. Critical care medicine. 2012; 40(4):1254.
9. Kim WY, Suh HJ, Hong SB, Koh Y, Lim CM. Diaphragm dysfunction assessed by ultrasonography: influence on weaning from mechanical ventilation. Critical care medicine. 2011; 39(12):2627-2630.
10. Matamis D, Soilemezi E, Tsagourias M, Akoumianaki E, Dimassi S, Boroli F. *et al*. Sonographic evaluation of the diaphragm in critically ill patients. Technique and clinical applications. Intensive care medicine. 2013; 39(5):801-810.
11. Goligher EC, Dres M, Fan E, Rubenfeld GD, Scales DC, Herridge MS. *Et al*. Mechanical ventilation–induced diaphragm atrophy strongly impacts clinical outcomes. American journal of respiratory and critical care medicine. 2018; 197(2):204-213.
12. Kocis KC, Radell PJ, Sternberger WI. Ultrasound evaluation of piglet diaphragm function before and after fatigue. J Appl Physiol. 1997; 83:1654-1659.
13. Casaseca-de-la-Higuera P, Martín-Fernández M, Alberola-López C. Weaning from mechanical ventilation: a retrospective analysis leading to a multimodal perspective. IEEE Trans Biomed Eng. 2006; 53(7):1330-1345.
14. Jiang JR, Tsai TH, Jerng JS. Ultrasonographic Evaluation of Liver/Spleen Movements and extubation outcome. Chest. 2004; 126:179-185.
15. Makhlouf H, Elkholy M, Salama S. Ultrasongraphic evaluation of diaphragmatic movement as a new parameter to predict weaning outcome in mechanically ventilated patients. Egypt J Chest. 2008; 57:115-120.
16. Houston JG, Fleet M, Cowan MD. Comparison of ultrasound with fluoroscopy in the assessment of suspected hemidiaphragmatic movement abnormality. Clin Radiol. 1995; 50:95-98.
17. Bruton A. A pilot study to investigate any relationship between sustained maximal inspiratory pressure and extubation outcome. Heart Lung. 2002; 31(2):141-9.

18. Yang KL, Tobin MJ. A prospective study of indexes predicting the outcome of trials of weaning from mechanical ventilation. N Engl J Med. 1991; 324:1445-1450.
19. Esteban A, Alía I, Tobin MJ. Effect of spontaneous breathing trial duration on outcome of attempts to discontinue mechanical ventilation. Am J Respir Crit Care Med. 1999; 159:512-518.
20. Ueki J, De Bruin PF, Pride NB. In vivo assessment of diaphragm contraction by ultrasound in normal subjects. Thorax. 1995; 50:1157-1161.
21. Vassilakopoulos T, Zakynthinos S, Roussos C. Respiratory muscles and weaning failure. Eur Respir J. 1996; 9:2383-2400.
22. Zeggwagh AA, Abouqal R, Madani N. Weaning from mechanical ventilation: a model for extubation. Intensive Care Med. 1999; 25(10):1077-83.
23. Rothaar RC, Epstein SK. Extubation failure: magnitude of the problem, impact on outcomes, and prevention. Curr Opin Crit Care. 2003; 9:59-66.
24. Zhao ZY, Wu N, Deng SX, Zhou Y, Cao TW. Serum albumin is a predictor for duration of weaning in patients with traumatic brain injury. Int J Clin Exp Med. 2016; 9(2):4041-4046.