The role of diaphragmatic rapid shallow breathing index as a predictor of weaning from mechanical ventilation using transdiaphragmatic ultrasonography

Thesis

Submitted for Partial Fulfillment of the Master Degree in Chest Diseases

By

Mahmoud Mohamed Kotb Kotb

M.B.,B.Ch.

Under Supervision of

Prof. Dr. Aya Mohammed Abdel Dayem

Professor of Chest Diseases

Faculty of Medicine, Ain Shams University

Assist. Prof. Dr. Ashraf Abbas El-Maraghy

Assistant Professor of Chest Diseases

Faculty of Medicine, Ain Shams University

Faculty of Medicine

Ain Shams University

2019

سورة البقرة الآية: ٣٢

Acknowledgment

First and foremost I feel always indebted to ***Allah****, the Most Beneficent and Merciful.*

I would like first to express my unlimited gratitude and thankfulness to my ***Prof. Dr. Aya Mohammed Abdel Dayem,*** *Professor of Chest Diseases, Faculty of Medicine, Ain Shams University, for her acceptance to supervise my work and for her continuous support, her valuable advices and encouragement. Without her encourage and help, I would not have been able to finish this work.*

Many thanks to ***Assist. Prof. Dr. Ashraf Abbas El-Maraghy,*** *Assistant Professor of Chest Diseases, Faculty of Medicine, Ain Shams University, who showed me the way and the first steps for going on into this work, who helped me much by his continuous guidance, patience and follow up in every step in this work.*

Finally, thanks to my ***Parents*** *and my* ***Wife*** *for their continuous support and encouragement.*

Mahmoud Mohamed Kotb Kotb

List of Contents

List of Abbreviations

Abbrev.		Full-term
A/C	**:**	Assist control
ABG	**:**	Arterial blood gases
AE	**:**	Acute exacerbation
ARDS	**:**	Acute respiratory distress syndrome
AUC	**:**	Area under the curve
CBC	**:**	Complete blood count
CI	**:**	Confidence interval
CINMA	**:**	Critical illness neuromuscular abnormalities
CLD	**:**	Chronic liver disease
CLT	**:**	Cuff leak test
Cm	**:**	Centimeter
CMV	**:**	Controlled mechanical ventilation
COPD	**:**	Chronic obstructive pulmonary disease
CPAP	**:**	Continuous positive airway pressure
CROP	**:**	Compliance, rate, oxygenation and maximal pressure integrated index
C_{rs}	**:**	Dynamic respiratory system compliance
CT	**:**	Computed Tomography
CXR	**:**	Chest x-ray
DD	**:**	Diaphragmatic displacement
DM	**:**	Diabetes mellitus
DPLD	**:**	Diffuse parenchymatous lung disease
D-RSBI	**:**	Diaphragmatic rapid shallow breathing index
DT	**:**	Diaphragmatic thickness
DTF	**:**	Diaphragmatic thickening fraction
FIO2	**:**	Fraction of inspired oxygen
FRC	**:**	Functional residual capacity
GCS	**:**	Glasgow coma scale

Hb	**:**	Hemoglobin
HTN	**:**	Hypertension
IBW	**:**	Ideal body weight
ICU	**:**	Intensive care unit
IMV	**:**	Intermittent mandatory ventilation
MHz	**:**	Megahertz
MIP	**:**	Maximal inspiratory pressure
MRI	**:**	Magnetic resonance imaging
MV	**:**	Mechanical ventilation
MVV	**:**	Maximal voluntary ventilation
NIV	**:**	Non-invasive ventilation
NPV	**:**	Negative predictive value
P value	**:**	Probability value
$P_{0.1}$	**:**	0.1 second after onset of inspiration
$P_{0.1}$/MIP	**:**	Airway Occlusion Pressure /Maximum Inspiratory Pressure Ratio
PA	**:**	Postero-anterior
PA-aO_2	**:**	Alveolar arterial oxygen tension difference
$PaCo_2$	**:**	Partial pressure of carbon dioxide in the arterial
P_aO_2	**:**	Partial pressure of arterial oxygen
P_AO_2	**:**	Alveolar oxygen tension
Pdi	**:**	Trans-diaphragmatic pressure
PE	**:**	Pulmonary embolism
PEEP	**:**	Positive end expiratory pressure
PEEPi	**:**	Intrinsic Positive end expiratory pressure
pH	**:**	Potential of hydrogen
Pimax	**:**	Maximal inspiratory pressure
PO2	**:**	Partial pressure of oxygen
PPV	**:**	Positive predictive value
PRVC	**:**	Pressure regulating volume control
PS	**:**	Pressure support
PSV	**:**	Pressure support ventilation

RBS	**:**	Random blood sugar
RF	**:**	Respiratory failure
ROC	**:**	Receiver operating characteristics
RR	**:**	Respiratory rate
RSBI	**:**	Rapid shallow breathing index
RV	**:**	Residual volume
SaO2	**:**	Oxygen saturation
SBT	**:**	Spontaneous breathing trial
SD	**:**	Standard deviation
SIMV	**:**	Synchronized intermittent mandatory ventilation
SPSS	**:**	Statistical package for Social Science
TCD	**:**	Total compartmental displacement
Tdi	**:**	Diaphragm thickness
TF	**:**	Thicknening fraction
Tinsp	**:**	Inspiratory time
TLC	**:**	Total lung capacity
Ttot	**:**	Total respiratory time
TUS	**:**	Transthoracic ultrasound
US	**:**	Ultrasound
VC	**:**	Vital capacity
V_E	**:**	Minute ventilation
VT/TV	**:**	Tidal volume
WOB	**:**	Work of breathing
ZAP	**:**	Zone of apposition

List of Tables

List of Figures

Abstract

Background: Minimizing the duration of mechanical ventilation (MV) is of a paramount importance for all critical care physicians. Therefore, deciding the appropriate time of weaning from MV is crucial, as delayed weaning and extubation is associated with longer intensive care unit (ICU) stay, inappropriate utilization of health care resources, and greater morbidity and mortality.

Objective: The aim of this study was to compare the ability of the new index diaphragmatic rapid shallow breathing index (D-RSBI) and the traditional rapid shallow breathing index (RSBI) to predict weaning outcome.

Subjects and methods: This was a prospective observational study, conducted at the ICU of Abbassia Chest Hospital, in the period from October 2017 to September 2018. The study included 50 patients and they were enrolled in the study after their informed written consent (by them or by their relatives), and approval of Ethics committee of Hospital was obtained. All patients were subjected to full history taking, full clinical examination, assessment of vital signs, laboratory investigations, diaphragmatic ultrasound, assessment of Tidal Volume (TV), assessment of rapid shallow breathing index (RSBI) = (RR/TV), assessment of Diaphragmatic Displacement (DD) and assessment of Diaphragmatic rapid shallow breathing index (D-RSBI) = (RR/DD).

Results: There was highly statistically significant prolonged ICU length of stay and prolonged maintenance on MV among the patients who failed to be weaned. Regarding the indices in our study; there was no significance in prediction of success or failure of weaning by using RSBI, while there was a very high level of significance in prediction of success or failure of weaning by using both D-RSBI and DD. Regarding logistic regression analysis of association between (RSBI, DD and D-RSBI) and outcome of ventilation; RSBI value 47.7 discriminated individuals with failure of weaning from those with successful weaning, while DD value < 19.85 discriminated individuals with failure of weaning from those with successful weaning and D-RSBI value 1.09 discriminated individuals with failure of weaning from those with successful weaning.

Conclusions: Diaphragmatic ultrasonography provides rapid, bedside and non-invasive tool for prediction of weaning outcome.DD, when combined with RR in an index named D-RSBI (RR/DD), is more accurate than the traditional RSBI (RR/VT) in predicting the weaning outcome. Regarding D-RSBI, a cut-off point of 1.09 is associated with the best sensitivity and specificity.

Key words: Weaning from mechanical ventilation Diaphragmatic mobility

Introduction

Mechanical ventilation is also called positive pressure ventilation. Following an inspiratory trigger, a predetermined mixture of air (ie, oxygen and other gases) is forced into the central airways and then flows into the alveoli. As the lungs inflate, the intraalveolar pressure increases. A termination signal eventually causes the ventilator to stop forcing air into the central airways and the central airway pressure decreases. Expiration follows passively, with air flowing from the higher pressure alveoli to the lower pressure central airways ***(Anthony et al., 2016).***

Liberating a patient from ventilator is a continuous process as with any disease condition which starts with recognition of patient being ready to be weaned from ventilator by letting the patient breathe on T-piece and, if successful, proceeding to SBT followed by extubation, if it is tolerated well (simple weaning), else letting the patient on ventilator till next such trial till being successful ***(Talwa & Dogra, 2016).***

One of the major determinants of weaning failure is the imbalance between the mechanical load imposed on the diaphragm and its ability to cope with it**.** Hence, evaluating diaphragmatic function before any weaning attempt could be of importance ***(Heunks & Hoeven, 2010).***

Rapid shallow breathing index (RSBI) is one of the most used clinical indices to predict weaning outcome, reflects the balance between mechanical load posed on the inspiratory muscles and the inspiratory muscles ability to face it during the weaning attempt ***(Meade et al., 2012).***

RSBI as the ratio of respiratory rate (RR) to tidal volume (VT), with a threshold value of >105 breaths/min/L being highly predictive of weaning failure, while RSBI <105 breaths/min/L is associated with weaning success ***(Yang & Tobin, 1991).***

Chest ultrasonography has many uses, both diagnostic and interventional. It can be used in diagnosis of diseases of the chest wall such as enlarged lymph nodes, rib abnormalities and also diaphragmatic abnormalities like diaphragmatic paralysis. Chest ultrasonography can also be used in interventional procedures of the pleural space such as thoracocentesis and pleural biopsy. In lung cancer, peripheral lung tumors that are in contact with or near the pleural surface can be safely biopsied under US guidance ***(Havelock et al., 2010).***

Diaphragm plays a fundamental role in generating VT in healthy subjects, if the diaphragmatic efficiency is impaired then the accessory inspiratory muscles could contribute to ventilation for a limited period, for example during a SBT. However, since they are by far less efficient and more fatigable than the diaphragm ***(Yan et al., 1993).***

Diaphragmatic dysfunction (defined as DD <10 mm) has been found to be a predictor of weaning failure among patients in medical ICUs ***(Kim et al., 2011).***

Imaging the dome does not directly visualize the diaphragm muscle itself and factors such as breath size, impedance of neighboring structures, abdominal compliance, rib cage or abdominal muscle activity, and ascites will affect regional and global diaphragm motion of the tendonous dome of the diaphragm ***(Miller & Talman, 1967).***

This drawback can be circumvented by ultrasonography of the diaphragm in the zone of apposition (ZAP) as this approach allows for direct visualization of the diaphragm muscle and assessment of its activity ***(McCool & Tzelepis, 2012).***