Ventilator induced Diaphragmatic Dysfunction assessed by Ultrasonography and its impact on Weaning outcome

Thesis
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By

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Abstract

Background: Ventilator induced diaphragmatic dysfunction (VIDD), as a loss of diaphragmatic force generating capacity due to the use of mechanical ventilation. Difficulties in discontinuing ventilatory support are encountered in 20–25% of mechanically ventilated patients, with a staggering 40% of time spent in the intensive care unit being devoted to weaning. M-mode ultrasonography is now an accepted qualitative method of assessing diaphragmatic motion in normal and pathological conditions. In this study, we evaluated whether diaphragmatic excursion (DE) as measured by M-mode sonography can be a predictor of weaning and diagnosis of VIDD.

Aim: The aim of this study is to determine the presence of ventilator induced diaphragmatic dysfunction (VIDD) diagnosed by M-mode ultrasonography and its impact on weaning outcome.

Methodology: This study was conducted prospectively in critical care unit in Ain Shams Hospital, a university-affiliated, tertiary referral center in Cairo, Egypt. Study subjects included 78 patients between August 2017 to August 2018. who required mechanical ventilation ≥72hrs. who fulfilled the spontaneous breath trial (SBT) criteria, at the start of a 1-hr SBT, each hemidiaphragm was evaluated M-mode sonography with the patient in the supine position. Rapid shallow Breathing index (RSBI) was simultaneously calculated at the bedside. Ultrasonographic Diaphragmatic Dysfunction (DD) was diagnosed if an Diaphragmatic Excursion (DE) was <10 mm or negative, the latter indicating paradoxical diaphragmatic movement.

Results: Diaphragmatic Dysfunction (DD) among the eligible 78 patients was 48% (n = 37). DD group had longer weaning time [39,2 (26-56) hrs. vs. 22.3 (30-16) hrs. p = 0.001) in DD vs. NDD group respectively and total ventilation time [140 (130-150) hrs. vs. 130 (120–140) hrs. $p > 0.05$) in DD vs. NDD group respectively. Weaning failure was (45.8% vs. 30.8%, p=0.01) in DD vs. NDD group respectively. In NDD group Rt. DE, mean 25.4 ±4.1 mm. While Lt. side was 25.3±4.6 mm, 11.25mm and 22mm (45-15) respectively. In DD group Rt. DE, mean 7.6 ±2.02mm, IQR 2.4 mm and median 8.2mm (10-1.9). While Lt. side was 9.2±0.8mm, 4.3mm and 8.9mm (9.8-5.7) respectively. The area under the receiver operating characteristics curve (ROC) of ultrasonographic criteria in predicting

weaning failure was near similar to that of rapid shallow breathing index. Hypercapenic acidosis in NDD group might protect them from VIDD

Conclusions: DD is present in a significant percentage 48% (nearly half) of our medical ICU patients on MV ≥72hrs which largely account for weaning failure. DD was associated with a significant longer weaning time, and ICU stay, with no significant difference in 30 day mortality

Recommendations: DE by US measurements is a valuable tool and is recommended as an adjunctive weaning index to aid prediction of weaning outcome. Evaluating the role of spontaneous ventilation modes and advanced ventilation modes as PAV and NAVA effects on decreasing VIDD versus controlled modes.

Keywords: Ventilator Induced Diaphragmatic Dysfunction, ICU, US, CMV

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LIST OF ABBREVIATIONS

Akt : Activation of Protein Kinase
ASV : Adaptive Support Ventilation
ATC : Automatic Tube Compensation
B-mode : Brightness Mode
CMV : Controlled Mechanical Ventilation
COPD : Chronic Obstructive Pulmonary Disease
CPAP : Continuous Positive Airway Pressure
CROP : Index of Compliance, Rate,OxygenationPressure
CT : Computed Tomography
CVP : Central Venous Pressure
DD : Diaphragmatic Dysfunction
DE : Diaphragmatic Excursion
DM : Diabetes Mellitus
F : Breathing frequency
FOXO1 : Forkhead box protein O1
IAP : Intra-Abdominal Pressure
IQR : Interquartile Range
IVC : Inferior Vena Cava
IWI : Integrated Weaning Index
KD : Kilo Daltons
M-mode : Motion Mode
MRI : Magnetic Resonance Imaging
mRNA : Messenger m Ribonucleic Acid
mTOR : Mammalian Target Of Rapamycin
MV : Mechanical Ventilation
NADPH : Nicotinamide Adenine Dinucleotide Phosphate
NAVA : Neutrally Adjusted Ventilatory Assist
P0.1 : Airway Occlusion Pressure 0.1s
PAV : Proportional Assist Ventilation
PEEP : Positive End Expiratory Pressure
PImax : Maximum Inspiratory Pressure
PPB : Positive Pressure Breathing

ROS : Reactive Oxygen Species
ROC : Receiver Operator Characteristic Curves
RSBI : Rapid Shallow Breathing Index
RV : Residual Volume
SBT : Spontaneous Breathing Trial
Sens : Sensitivity
Spec : Specificity
TLC : Total Lung Capacity
VE : Minute Ventilation
VIDD : Ventilator-induced diaphragmatic dysfunction
VT : Tidal Volume
Fio2 : Fraction of inspired oxygen
PO2 : Arterial oxygen partial pressure
NDD : Non Diaphragmatic Dysfunction

INTRODUCTION

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 ***(Kim et al., 2011).***

The diaphragm, the principal respiratory muscle in humans, is susceptible to various insults such as hypotension, hypoxia, and sepsis, all of which are common in intensive care unit patients.

Mechanical ventilation in controlled mode and possibly with high levels of partial ventilatory assist can also result in ventilator-induced diaphragm dysfunction (VIDD) (***Hudson et al., 2012***).

A landmark study demonstrated that 18 hrs to 69 hrs of controlled mechanical ventilation (CMV) resulted in a decreased diaphragm fiber cross-sectional area of 57% and 53%, respectively, in type I and type II fibers ***(Levine et al., 2008).***

Patients with adequate spontaneous tidal volume but poor diaphragmatic excursion are more likely to fail a breathing trial compared to patients with adequate spontaneous tidal volume and good diaphragmatic movement. This can be explained by the fact that spontaneous tidal volume represents the result of the

combined activation of all respiratory muscles used without specifically measuring the contribution of the diaphragm, whereas diaphragmatic excursion represents the final result of combined diaphragmatic strength, intra-thoracic and intra-abdominal pressures, diaphragmatic movement is a more sensitive and specific parameter than volume-associated weaning parameters in predicting extubation outcome. Patients who recruit accessory respiratory muscles to maintain adequate tidal volumes may therefore experience more difficulties to sustain spontaneous breathing and fail extubation more often ***(Jiang et al., 2004)***.

Motion mode (M-mode) US has been recently shown to be capable of quantifying diaphragm movements ***(Kim et al., 2011)***.

Recent preliminary data suggest that sonographic assessment of the diaphragm can provide a noninvasive measurement of a maximal positive vertical excursion ≤ 10 mm or paradoxical movements, and excursion of ≤ 25 mm can diagnose severe diaphragmatic dysfunction (DD) ***(Dimitrios et al., 2013).***

Ultrasound by cardiac intensivists showed a sensitivity 100 % and specificity 100% and the interobserver and interobserver reproducibility (intra-class correlation coefficients) of the diaphragmatic excursion measurements reported in ICU patients were found in the same range, between 88 and 99 % ***(Kim et al., 2011)***.

AIM OF THE WORK

The aim of this study is to determine the presence of ventilator induced diaphragmatic dysfunction (VIDD) diagnosed by M-mode ultrasonography and its impact on weaning outcome.