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Original Article

Lung Ultrasound and Non-Invasive Ventilation Outcome in Acute Respiratory Failure

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ABSTRACT

Objective: This study aimed to evaluate the dysfunction of the diaphragm in critically ill non-intubated patients admitted to respiratory critical care unit with acute respiratory failure.

Methods: This was a prospective study on 200 mechanically ventilated patients. The following data were collected: demographic characteristics, anthropometric measurements. Disease severity and hemodynamics. In addition, ICU length of stay, duration mechanical ventilation, outcome and duration of hospital stay. Besides, parameters of MV like (PaO2 / FiO2 Ratio), and respiratory rate were noticed. The laboratory workup included arterial blood gases, Na+, K+, Mg++, Ca++, PH, PCO2, HCO3-. The ultrasound was performed before and after weaning and included the diaphragmatic excursion and diaphragmatic thickness traction. The patients were split into two categories regarding their reaction to weaning attempts: ***Category A*** represented successful weaning. ***Category B*** represented unsuccessful weaning followed by reintubation and mechanically ventilated.

Results: The weaning success was reported for 123 patients (61.5%) and mortality was reported for 28 patients (14.0%). Weaning success was associated with male gender, younger age, and slightly higher BMI. Obstructive airway disease showed a significant increase in success than failure (25.2% vs 11.7% respectively). Weaning failure was significantly associated with increased septic shock and pneumonia. The muscle thickness in inspiration was significantly increased in success than failure (25.56 vs 24.08 respectively). DE before weaning was the most sensitive indicator at cut-off value > 15 followed by DE after weaning at cutoff value >17; while DTF after weaning was more sensitive than DTF before weaning (93.55% and 80.65% respectively) at cutoff points > 20.4 and > 18.5, respectively.

Conclusions: Assessment of DTF and DE by diaphragm ultrasound is an easy to obtain a new weaning index that can be used as a bedside technique in daily clinical practice with promising prediction of success or failure of weaning.

Keywords: Ultrasonography; Pulmonary; Intensive Care Unit; Respiratory Failure; Outcome.

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INTRODUCTION

Acute respiratory failure (ARF) is a common complaint of patients in ED (emergence department), and the key presentation of respiratory disorders due to lung parenchyma (gas-exchanging organ), and the pump [(1)]. Hypoxemic ARF is a condition associated with an increased work of breathing; however, energy availability is decreased due to hypoxemia, resulting in muscle fatigue and ventilation failure due to imbalance between the demand and supply [(2)]. Point-of-care lung ultrasound (LUS) has been suggested as an alternate to chest CT and chest radiography (CXR) for the diagnosis and monitoring of interstitial pneumonia and acute respiratory distress syndrome, with the advantages of the ability to use it as bedside method, easy repeated, of short duration with low cost [(3)]. In the respiration process, the diaphragm is the chief muscle. Several diseases have been linked to diaphragmatic weakness (e.g., sepsis, shock, hypoxia, and post-surgical settings), creating a "multiple-hit mechanism". This described as the combination of different factors, collectively induce changes in respiratory mechanics with subsequent respiratory failure [(4)].

The diaphragmatic dysfunction (DD) in respiratory failure has often been neglected. It is prevalent in critically ill patients needing invasive mechanical ventilation (MV) reaching up to 60% [(5)]. It is associated with weaning failure from MV, prolonged stay in respiratory critical care unit (RCU) and higher mortality [(6)]. Diaphragm excursion and thickness are the most common studied parameters. This is recognized as an echographic measurement of the inspiratory downward displacement of the hemi-diaphragm and diaphragmatic thickness [(7)]. Diaphragmatic excursion and thickness have been affected in patients admitted due to ARF [(8)].

Diaphragm thickness fraction correlates strongly with diaphragm strength and Diaphragmatic atrophy associated with diminished thickness; and associated with increase duration of intubation which is directly correlated to the level of inspiratory effort [(9)].

THE AIM OF THE WORK

This study will be assessing the diaphragmatic dysfunction in critically ill non-intubated patients admitted to respiratory critical care unit with acute respiratory failure.

.PATIENTS AND METHODS

This was a prospective cohort study which was conducted on 200 MV patients who were admitted at Al-Azhar University Hospitals in Damietta during February 2022 till 2023.

The inclusion criteria were age ranging from 18 to 60 years, who admitted to the ICU, RCU or mechanically ventilated, readiness for weaning from MV as the cause of respiratory failure had been released, stable hemodynamics and no requirement for vasopressor or neuro-muscular Blockers > 24hrs and fulfill the weaning from mechanical ventilation criteria.

On the other side, exclusion criteria were relative's refusal, pre-existing neurologic disease, patients under treatment with neuromuscular blockers, presence of any mass or mechanical factor in chest or abdomen interfering with the diaphragmatic mobility, pregnant women, presence of ascites, colonic distension, presence of lung collapse, fibrosis or pleural effusion and surgical dressings over the right lower rib cage which would preclude ultrasound examination.

Study Procedure

Consent was obtained from the 1st degree relatives. Study well done on 200 patients in the ICU at Al Azhar University planned for noninvasive ventilated and fulfilled inclusion and exclusion criteria. The following data were collected from the clinical examination. These included demographic data, anthropometric measurements with calculation of body mass index (BMI). The general clinical examination included measurement of heart rate, blood pressure and Glasgow coma scale (GCS). The cause of ICU admission, severity of illness assessed by APACH-II score, length of ICU stay, duration mechanical ventilation, outcome and duration of hospital stay were documented. In addition, parameters of MV like (PaO_2 / FiO_2 Ratio), and respiratory rate were noticed. The laboratory workup included arterial blood gases, Na^+, K^+, Mg^{++}, Ca^{++}, PH, PCO_2, HCO_3-. The ultrasound was performed before and after weaning and included the diaphragmatic excursion and diaphragmatic thickness traction.

Ultrasound technique to detect the diaphragmatic thickness: the probe was 10–12MHz. the procedure completed while the patient was positioned perpendicularly over the 9th–10th intercostal space in the anterior axillary line. The window for diaphragmatic thickness was the part of the zone of apposition of diaphragm to rib cage and to evaluate the thickness of the diaphragm.

Procedure for Detection of Diaphragmatic Excursion: the probe was 3.5–5 MHz probe, inserted below the rib cage at the level of the mid-clavicular line. The window was from the right hemidiaphragm, via the hepatic window, directing the ultrasound beam perpendicularly toward the posterior third of the right hemidiaphragm and done during inspiratory phase of spontaneous ventilation. The parameters were the diaphragm mobility studies (as a sign of diaphragm activity), diaphragm thickness (as a sign of atrophy), and variation in diaphragm thickness.

Diaphragm mobility (Excursion): Normal values in healthy patients differ between men (18±3 mm) and women (16±3 mm). In MV patients, DD is defined as an excursion of less than 10mm or a negative excursion (or paradoxical movement). These values are also good predictors of failure to wean.

Diaphragm Thickness: Diaphragm thickness can be quantified using ultrasound, through the right hemidiaphragm, via the hepatic window. This is preferred than the left as it is more accessible. A probe of 10-12MHz was used to determine diaphragmatic thickness. It is positioned over the right 9th – 10th intercostal space in perpendicular manner in the anterior axillary line. The apposition of the diaphragm to the rib case had been observed. In this situation, the diaphragm is seen as 3 parallel layers of variable density (pleura, diaphragm, and peritoneum). Diaphragm thickness is measured by M-mode or with a 2D image during non-forced expiration. The normal thickness of the diaphragm in ventilated patients is 2.4±0.8mm. Atrophy is defined as values below 2 mm. Ratios of 1.0 are considered normal, with a lower accepted limit of 1.2.

Diaphragm Thickness Fraction: Variations in the thickness of the diaphragm can be calculated using ultrasound M-mode. The variation in the diaphragm thickness can be used as an indicator of diaphragm capacity to generate pressure**.** A variation of < 20% was suggested as a predictor for failure to wean.

The patients were categorized into two categories according to their reaction to weaning attempts: ***Category A*** for successful weaning. ***Category B*** for unsuccessful weaning followed by reintubation and MV.

Ethical consideration: The written informed consent was obtained from all patients or their first-degree relatives after describing the study aim and procedures. The local research and ethics committee of the DFM faculty (Damietta, Egypt) approval was obtained.

Statistical analysis: The collected data were managed and analyzed using SPSS program version 24 (IBM® Inc., Armonk, USA). Qualitative data were summarized by their frequencies and percentages. Chi square test (χ^2) or Fisher exact was used to test association between qualitative variables. Quantitative data were summarized by their mean and standard deviation, or medians and interquartile range (IQR). Independent samples "t" test, or Mann Whitney "U" test was used to calculate difference between two groups. The Wilcoxon test used to compare the changes of the same variable over time. Receiver operation characteristic (ROC) curve was constructed to test predictive power of selected tests. Areas under the curve (AUC) were determined. A higher AUC indicates superior test performance, the values 0.5 or less indicate non-discriminatory test. The optimal cutoff point was established at the point of maximum accuracy. For all tests, p value < 0.05 was considered significant.

RESULTS

Primary outcome

In the current work weaning success was reported for 123 patients (61.5%) and mortality reported for 28 patients (14.0%). Weaning success was associated with male gender, younger age and slightly higher BMI. But the difference between failed and succeed weaning was statistically non-significant. In addition, weaning success and failure showed no significant difference regarding hypertension, diabetes mellitus, hypothyroidism, and cerebrovascular stroke. However, obstructive airway disease showed a significant increase in success than failure (25.2% vs 11.7% respectively). Weaning failure was significantly associated with increased septic shock and pneumonia (Table 1). CVP was significantly lower in failed than success weaning (11.74±6.57 vs 13.70±5.6, respectively). However, weaning success was associated with significant increase of albumin, magnesium, Vt, PaCO2, PaO2, SaO2, and significant reduction of serum creatinine, PS, FiO2, and RR (Table 2).

In the current work, there was no significant difference between weaning failure and success regarding muscle thickness during inspiration and expiration. However, thickness in inspiration was significantly increased in success than failure (mean 25.56 vs 24.08 respectively) (Table 3).

In the current work, there was no significant difference between weaning failure and success regarding ICU stay, weaning hours, and pneumonia as complication. However, duration of mechanical ventilation was significantly decreased in success than failure (4.09 vs 5.54 respectively), complication was significantly decreased in success than failure in ARDS (0.8% vs 22.1% respectively), effusion was significantly decreased in success than failure (3.3% vs 27.3% respectively) and death was significantly decreased in success than failure (5.7% vs 27.3% respectively) (Table 4).

Secondary outcome:

In the current work, there was no significant difference between mortality and patient demographics. In addition, there was no significant difference between mortality and Hypertension, Diabetes mellitus, Hypothyroidism, and Cerebrovascular stroke.

However, mortality was significantly decreased in COPD (3.6 vs 22.7 respectively). In addition, there was a significant difference between mortality and admission cause, where mortality was significantly increased in patients admitted with pulmonary edema and pneumonia (Table 5). Furthermore, there was no significant difference between mortality and laboratory finding. However, ABG finding, albumin, creatinine, leucocyte, and heart rate were significantly increased in success than failure respectively) (Table 6). There was no significant difference between mortality and muscle thickness during inspiration and expiration. However, excursion of diaphragm after ventilation was significantly increased in success than failure (mean 9.16 vs 5.81 respectively), excursion of diaphragm before ventilation was significantly increased in success than failure (mean 9.65 vs 5.45 respectively). thickness in inspiration was significantly increased in success than failure (mean 25.62 vs 21.12 respectively), thickness in expiration was significantly increased in success than failure (mean 19.70 vs 16.03 respectively) (Table 7).

In the current work, there was no significant difference between mortality and ICU stay and duration of mechanical ventilation and weaning. However, complication was significantly decreased in success than failure, ARDS (4.7% VS 35.7%), pneumonia (5.2 % VS 17.9%), and effusion (6.4% VS 25%) respectively. Also, there was no significant difference between mortality and laboratory finding. However, HCT was significantly increased in success than failure (mean 38.03 vs 34.39 respectively), CRP was significantly increased in success than failure (mean 47.81 vs 36.43 respectively) (Table 8).

DE before weaning was the most sensitive indicator at cut-off value > 15 followed by DE after weaning at cutoff value >17; while DTF after weaning was more sensitive than DTF before weaning (93.55% and 80.65% respectively) at cutoff points > 20.4 and > 18.5, respectively (Table 9).

Table (1): Association between weaning outcome and patient demographics

Variable		Failed weaning (n=77)	Weaning success (n=123)	P value
Gender (n,%)	Male	45(58.4%)	57 (46.3%)	0.10
	Female	32 (41.6%)	66 (53.7%)	
Age (years)	Mean±SD	52.55±18.20	51.25±16.19	0.60
BMI (kg/m^2)	Mean±SD	24.25±4.89	25.44±3.97	0.06
Chronic medical Disease (n,%)	Hypertension	48(62.3%)	75 (61.0%)	0.84
	Diabetes mellitus	55 (71.4%)	83 (67.5%)	0.56
	Obstructive airway disease	9 (11.7%)	31 (25.2%)	***0.020****
	Hypothyroidism	12 (15.6%)	13 (10.6%)	0.29
	Cerebrovascular stroke	11 (14.3%)	14 (11.4%)	0.54
Cause of Admission	Diabetes mellitus	1(1.3%)	10(8.1%)	0.054
	Hypothyroidism	31(40.3%)	46(37.4%)	0.76
	COPD	4(5.2%)	29(23.6%)	***0.001****
	Stroke	13(16.9%)	11(8.9%)	0.12
	Septic shock	6(7.8%)	0(0.0%)	***0.003****
	Liver cell failure	4(5.2%)	14(11.4%)	0.29
	Pulmonary edema	6(7.8%)	3(2.4%)	0.15
	pneumonia	12(15.6%)	4(3.3%)	***0.006****
	Renal failure	0(0.0%)	6(4.9%)	0.08

Table (2): Association between weaning success and heart rate, CVP, laboratory investigations, arterial blood gases and hemoglobin concentration

	Success		Failed weaning		P
	Mean	SD	Mean	SD	
HR	94.15	15.34	97.12	23.99	0.2
CVP	13.70	5.60	11.74	6.57	0.02*
Leucocytes	13831.71	5943.87	15592.2	9694.88	0.113
Album.	3.93	0.79	3.24	0.93	<0.001*
Urea	90.09	80.49	100.03	52.18	0.33
Cr.	1.54	1.92	2.28	1.61	0.006*
NA	134.06	7.81	131.84	10.16	0.08
K	4.17	0.95	4.20	1.17	0.881
Ca	9.58	1.33	9.53	1.31	0.80
Mg	2.67	0.72	2.44	0.75	0.032*
PS	8.13	2.43	9.81	0.97	<0.001*
FiO2	0.35	0.05	0.42	0.05	<0.001*
Vt	501.87	134.11	398.26	128.38	<0.001*
RR	22.67	5.12	24.7	4.00	0.003*
pH	7.38	0.10	7.36	0.10	0.102
PaCO2	40.15	11.16	35.40	7.47	0.01*
HCO3	24.64	4.26	20.53	5.93	<0.001*
PaO2	118.74	9.18	113.39	10.99	<0.001*
SaO2	98.51	2.47	97.14	2.79	<0.001*
Hb	14.26	17.52	10.56	1.74	0.06

Table (3): Association between weaning success and muscle

	Weaning success		Failed weaning		p
	Mean	S.D	Mean	S.D	
Excursion of diaphragm_after	9.71	9.52	8.02	7.19	0.182
Excur_before	9.07	8.77	8.10	7.01	0.415
Thickness_exp	19.44	3.20	18.78	3.81	0.188
Thickness_insp	25.56	4.31	24.08	4.43	**0.020***
P IT_left_after	0.44	0.09	0.46	0.10	0.293
PIT_right_before	0.45	0.04	0.46	0.03	0.154
PIT_left	0.37	0.06	0.35	0.05	0.072
PIT_right	0.35	0.04	0.34	0.04	0.074
Rectus_left_after	65.67	4.79	65.58	4.76	0.897
Rectus_right_after	65.50	5.6	65.42	4.65	0.917
Rectus_left	56.54	3.56	55.81	3.52	0.157
Rectus_right	55.60	4.36	55.91	4.20	0.623

Table (4): Association between weaning success, ICU stay and duration of mechanical ventilation and complication

		Weaning failure		Success weaning		P
		Mean	SD	Mean	SD	
ICU (days)		8.30	3.59	8.79	5.33	**0.43**
Ventilation (days)		5.54	2.51	6.90	4.09	0.004*
Weaning (hours)		32.83	27.86	41.22	34.06	**0.06**
Complications	**ARDS**	17(22.1%)		1 (0.8%)		<0.01*
	Pneumonia	3 (3.9%)		11 (8.9%)		**0.17**
	Effusion	14 (18.2%)		4 (3.3%)		<0.001*
Death		21 (27.3%)		7 (5.7%)		<0.001*

Part II: Secondary outcome

Table (5): Association between death (mortality) and patient demographics

		No (n=172)	Yes (n=28)	P value
Gender (n,%)	**Male**	85(49.4%)	17 (60.7%)	0.26
	Female	87 (50.6%)	11 (39.3%)	
Age (years)	**Mean±SD**	52.22±16.47	48.89±19.82	0.34
	Min. – Max.	19- 84	19- 84	
BMI (kg/m²)	**Mean±SD**	25.09±4.20	24.29±5.34	0.37
	Min. – Max.	18-35	18-34	
	Hypertension	103(59.9%)	20(71.4%)	0.24
Associated chronic disease	**Diabetes mellitus**	115(66.9%)	23 (82.1%)	0.11
	Obstructive airway disease	**29 (22.7%)**	**1 (3.6%)**	**0.019***
	Hypothyroidism	21 (12.2%)	4 (14.3%)	0.76
	Cerebrovascular stroke	23 (13.4%)	2 (7.1%)	0.35
Admission cause	**Diabetes mellitus**	11 (6.4%)	0 (0.0%)	<0.001*
	Hypothyroidism	68 (39.5%)	9 (32.1%)	
	COPD	29 (16.9%)	4(14.3%)	
	Stroke	22 (12.8%)	2 (7.1%)	
	Septic shock	4 (2.3%)	2 (7.1%)	
	Liver cell failure	18 (10.5%)	0 (0.0%)	
	Pul edema	5 (2.9%)	4 (14.3%)	
	pneumonia	10 (5.8%)	6 (41.4%)	
	Renal failure	5 (2.9%)	1 (3.6%)	

Table (6): Association between mortality and heart rate, CVP, laboratory investigations, arterial blood gases and hemoglobin concentration

	Yes (n=28)		No (n=172)		p
	Mean	SD	Mean	SD	
HR	106.89	21.83	93.41	18.03	<.001*
CVP	14.21	8.18	12.74	5.63	0.232
WBC	17792.8	10165.3	13975	7033.45	0.014*
Alb.	3.32	1.11	3.72	0.86	0.031*
Urea	116.79	58.52	90.19	72.25	0.066
Cr.	2.72	2.70	1.67	1.64	0.007*
NA	131.61	6.44	133.47	9.15	0.303
K	4.33	1.35	4.16	0.98	0.415
Ca	9.71	1.39	9.54	1.31	0.515
Mg	2.62	0.79	2.58	0.73	0.795
PS	9.11	1.95	8.72	2.19	0.381
FiO2	0.40	0.06	0.37	0.06	0.049*
Vt	442.39	126.60	465.17	143.27	0.429
RR	24.29	3.53	23.34	4.99	0.338
pH	7.38	0.11	7.37	0.10	0.828
PaCO2	35.1	6.51	38.83	10.55	0.077
HCO3	20.14	6.14	23.53	5.07	0.002*
PaO2	112.2	9.70	117.4	10.1	0.014*
SaO2	96.36	2.93	98.25	2.55	0.001*
Hb	10.03	1.89	13.29	14.90	0.250
APACH II	12.6 (11-13.6)	12.8 (11-14.0)	12.6 (11-14)	12.8 (11-14.0)	0.949
PaO2/FiO2	250 (230-258)	243 (230-255)	246 (230-258)	243 (230-255)	<0.001
RR	21 (18-28)	20 (18-29)	20 (18-29)	20 (18-29)	0.074

Table (7): Association between mortality and muscle

	Yes (n=28)		No (n=172)		P
	Mean	SD	Mean	SD	
Excur_after	5.45	7.74	9.65	8.74	0.018*
Excur_before	5.81	7.98	9.16	8.08	0.043*
Thickness_exp	16.03	2.91	19.70	3.26	<0.001*
Thickness_insp	21.12	4.64	25.62	4.04	<0.001*
PIT_left_after	0.47	0.08	0.45	0.09	0.25
PIT_right_before	0.46	0.03	0.45	0.04	0.428
PIT_left	0.35	0.06	0.36	0.06	0.629
PIT_right	0.34	0.04	0.35	0.04	0.747
Rectus_left_after	66.64	4.91	65.48	4.74	0.231
Rectus_right_after	65.71	4.58	65.42	5.40	0.788
Rectus_left	56.25	3.79	56.26	3.52	0.994
Rectus_right	56.82	4.31	55.54	4.27	0.143

Table (8): Association between mortality and ICU stay, duration of mechanical ventilation, complications and laboratory investigations.

		Yes (n=28)		No (n=172)		P
		Mean	SD	Mean	SD	
ICU (days)		9.50	7.22	8.33	3.67	0.18
Ventilation (days)		6.82	4.31	5.94	3.07	0.18
Weaning (hours)		43.29	39.84	34.88	28.78	0.17
Complications	**ARDS**	10 (35.7%)		8(4.7%)		***0.001****
	Pneumonia	5 (17.9%)		9(5.2%)		0.015*
	Effusion	7 (25.0%)		11 (6.4%)		***0.001****
HCT		34.39	9.92	38.03	8.75	0.046*
ESR		57.00	35.38	54.86	34.87	0.764
CRP		36.43	20.38	47.81	25.86	0.028*
Plt		396.64	130.53	375.69	141.41	0.464
Lymph_		1615.36	605.89	1732.33	977.90	0.540
PNL		10241.07	6578.96	10825.35	4953.24	0.582
INR		1.43	0.67	1.37	0.53	0.555
D dimer		868.57	543.33	1101.16	853.38	0.165
ALT		46.86	18.00	51.95	25.22	0.306
AST		44.57	13.43	51.18	19.04	0.079
LDH		592.93	994.98	447.69	502.99	0.232
S ferritin		316.79	136.90	357.35	425.65	0.618

Table (9): The validity of DE and DTF% before and after weaning with area under the ROC curve (AUC) as a predictor for weaning success.

	Cut- off	Sensitivity	Specificity	PPV	NPV	AUC	P
DE before weaning	>15	100	58.06	70.5	100	0.823	**<0.001**
DE after weaning	>17	96.77	64.5	73.2	95.2	0.822	**<0.001**
DTF before weaning	>18.5	80.65	77.42	78.1	80	0.785	**<0.001**
DTF after weaning	**>20.4**	**93.55**	**93.55**	**93.5**	**93.5**	**0.939**	**<0.001**

DISCUSSION

This was a prospective cohort study which was conducted on 200 mechanically ventilated patients who were admitted at Al-Azhar University Hospitals in Damietta during February 2022 till January 2023 to assess weaning failure and related factors. The current study show, there was Weaning success was higher among males, younger in age with slightly higher BMI. However, the difference between failed and weaning success was statistically non-significant. In addition, there was no significant difference between mortality and patient demographics.

Similarly, **Varon-Vega *et al*.** [10] study found no statistically significant association between age, gender, and weaning failure with p-value >0.05.

Keyal *et al*. [11] study reported no significant association between the patient's age and failure of weaning.

In contrast to **Jaber *et al*.** [12] studied 1541 patients undergoing weaning in 26 ICUs and reported a significant association between weaning failure and patient gender. Fames had a higher rate of weaning failure (p=0.009).

Yonaty *et al*. [13] reported a significant correlation between weaning failure and patient's age. Older patients had higher rate of weaning failure, and when age advances, the rate of failure increases (p =0.03).

In line of results of the current work, **Zamzam *et al*.** [14] reported a higher rate of male gender, with mean age of 58.47±8.2 years. There was no significant difference between groups regarding age or sex.

In addition, **Venkatram *et al*.** [15]**,** demonstrated that the failure noninvasive mechanical ventilation (NIMV) and the need for invasive mechanical ventilation (IMV) in the older age. This was attributed to the association of poor nutrition (manifested by low BMI) and old age. In addition, reduced muscle power, weak cough reflex, retained excessive secretions are additional risk factors for the failure of NIMV and the need for invasive ventilation.

Furthermore, **Anjalee and Sanjay** [16] and **Kaur *et al*.** [17] reported that, higher BMI was significantly associated with weaning failure (p = 0.033)

On the other side, **Huang *et al*.** [18] included 40 patients planned for weaning to assess utility of M mode US on ventilator weaning outcomes in elderly patients and revealed statistically no significant difference between weaning failure and weaning success as regards BMI.

In the current work, there was no significant difference between weaning failure and success regarding admission cause. However, obstructive airway disease was significantly increased in success than failure (23.6% vs 5.2% respectively). Also, there was no significant difference between mortality and Hypertension, Diabetes mellitus, Hypothyroidism, and Cerebrovascular stroke. However, mortality was significantly decreased in COPD (3.6 vs 22.7 respectively)

This agrees with studies by **Kubler *et al*.** [19] which showed that men account for more than half of the patients receiving MV in ICU. They explained this by the commonest etiology of respiratory failure and so-often MV was COPD which is more prevalent in males than females. However, in the study of **Anjalee and Sanjay** [16] the primary causes for IMV were acute kidney injury, sepsis, neurological, respiratory, malignancy and poisoning. The commonest causes were chronic kidney disease (CKD) (reported among 17.23%) and coronary artery disease (CAD) (reported among14.65%) followed by hypertension (12.27%) and diabetes (11.68%).

The results agree with **Zamzam *et al*.** [14] as, who reported that COPD (45.0%) was the commonest diagnosis, followed by interstitial lung disease (25%), and bronchial asthma (13.5%).

Kubler *et al*. [19] reported the same situation regarding COPD (29%) followed by other causes (e.g., ARDS, pneumonia, and cardiogenic pulmonary edema). However, **Frutos-Vivar *et al*.** [20] reported that pneumonia was the commonest reason for initiating MV, and it was an independent risk factor for the failure of weaning.

Another study by **Jaber *et al*.** [12] demonstrated that the cause of ICU admission was significantly associated with the failure of weaning especially in post-surgery patients (with p-value=0.0009), and neurological causes (with p-value=0.001).

In the current work, there was no significant difference between mortality and ICU stay and duration of mechanical ventilation and weaning. However, complication was significantly decreased in success than failure, ARDS (4.7% VS 35.7%), pneumonia (5.2 % VS 17.9%), and effusion (6.4% VS 25%) respectively.

In agreement with **Baptistella *et al*.** [21] study which was conducted on 110 patients who were planned for weaning to identify respiratory and non-respiratory parameters of weaning outcome and found statistically significant increased length of ICU stay with patients with weaning failure (13 days in weaning failure vs 7 days in weaning success) with p- value=0.005.

In contrast to **Yu *et al*.** [22] found no significant difference between weaning failure and weaning success regarding the length of ICU stay (p =0.166). However, **Yonaty *et al*.** [13] revealed that the longer duration of hospital stay duration in associated with weaning failure (p <0.01).

In addition, **Spadaro *et al*.** [23] conducted a study on 51 patients to assess the role of diaphragmatic US to assess weaning and found significant increase of the length of hospital stay in weaning failure p =0.001).

In contrast to **Tenza-Lozano *et al*.** [24] study revealed no significant difference between weaning failure and success as regards the length of hospital stay (p-value = 0.08). The small number of MV patients in their study could explain these results.

Jaber *et al.* [12] reported that the length of MV is significantly associated with weaning failure (p=0.025).

Baptistella and colleges [21] confirmed these results and indicated that the duration of MV represents one of predictors for weaning failure (p=0.045). This can be explained by the diaphragmatic inactivity and MV, leading to atrophy of the diaphragm myofibers. This atrophy can be developed as early as after the first 18 hours of invasive ventilation [25]. In contrast, another Egyptian research by **Baess *et al.*** [26] found no significant association between duration of MV and weaning outcome (p=0.06). However, they included only 30 patients, and this could explain the differences in results.

The current study revealed no significant association between APACHE II score and exubation failure. This agrees with **Varon-Vega *et al.*** [10] who found no significant association between weaning outcome and APACHE II score (p=0.52).

In contrast **Chen *et al.*** [27] reported a significant association between lower APACHE II score and weaning failure. In addition, **Zamzam *et al.*** [14] reported that the APACHE II score was significantly associated with weaning outcome. This was confirmed by **Venkatram *et al.*** [15] who demonstrated that the mean admission APACHE II score was significantly lower in NIMV than IMV group.

The current study revealed that high PaQ2/FiO2 was significantly associated with weaning failure with p-value <0.001. In agreement with **Fahmy *et al.*** [28] study which was performed on 53 patients to evaluate the role of the diaphragm and lung ultrasonography in the prediction of weaning outcome in MV patients and revealed statistically significant lower PaO2/FiO2 in weaning failure group with p-value <0.001. The same was reported by **Chen *et al.*** [27] study which was conducted on 92 patients who were mechanically ventilated to assess the related factors for weaning failure and found statistically significant higher PaQ2/FiO2 with weaning failure group compared to weaning success group with p- value=0.01.

In the current work, significant reduction of HCO3 and PO2 were significantly associated with weaning failure (p< 0.001). These confirmed the results of **Dodgen *et al.*** [29] who included 164 patients on MV mechanically and there was significantly lower PaO2 in weaning failure (p=0.006).

In contrast, **Rizzo *et al.*** [30] conducted a study on 851 ventilated patients and revealed no significant association between PaO2 and weaning failure (p=0.2). This confirmed by **Zamzam *et al.*** [14], who reported that the admission ABG was lowest in failure than success weaning. This matches with **Shirakabe *et al.*** [31] who showed that the significant reduction of PH increases the risk of weaning failure in invasive or noninvasive ventilation. On the other side, this disagrees with **Chu *et al.*** [32] who included patients with severe acidaemia needing NIMV. However, they only included patients with COPD exacerbations with different chest diseases that makes the comparison not completely applicable.

Our results are in line with **Zamzam *et al.*** [14] who reported that PO_2 significantly reduced in weaning failure than weaning success. This was confirmed in the study of **Confalonieri *et al.*** [33] who reported severe hypoxemia as a significant risk factor for weaning failure of Invasive or non-invasive ventilation. **Zamzam *et al.*** [14] **and Confalonieri *et al.*** [33] also reported high $PaCO_2$ level is predictive of weaning failure in NIMV and this indicating the shift to IMV.

On the other side, **Venkatram *et al.*** [15] showed no significant association between mean $PaCO_2$ values and weaning outcome. In addition, **Vanani *et al.*** [34] showed that the admission levels of HCO3 were significantly higher in patients who failed NIPPV, and values of $PaCO_2$ has a direct relation with weaning success and it depends on the individual's ability to compensate.

The current study revealed that high DE after weaning was significantly associated with weaning success with p-value <0.001. Similarly, **Mohamed *et al.*** [35] conducted a study on 80 ventilated patients to evaluate real time ultrasound in the evaluation of diaphragm thickening to predict weaning outcomes and revealed statistically significant higher DTF in weaning success group compared with weaning success with p-value <0.001.

In contrast to **Youssef *et al.*** [36] study which found no statistically significant difference between weaning success and weaning failure groups as regards DE after weaning with p-value=0.392. The difference can be explained by different pressure support used during spontaneous breathing trial which obviously affected the diaphragmatic movement, also may be different in population study as regards age and sex [37].

The current study found statistically significant positive correlation between DE before and after weaning with p-value <0.001. This goes in run with **Mostafa *et al.*** [38] study which was conducted on 30 mechanically ventilated patients to assess the value of the excursion of diaphragm tested by ultrasonography to predict weaning from mechanically ventilated patients and found that DE was positively correlated before and after weaning.

The current study revealed that lower DTF before and after weaning was significantly associated with weaning failure with p-value <0.001. This goes in run with **Ferrari *et al.*** [39] which conducted a study on 46 mechanically ventilated patients planned for weaning to evaluate a new weaning index consisting in the diaphragm thickening fraction (DTF) assessed by ultrasound and found statistically significant lower DTF in weaning failure group compared with weaning success with p-value <0.0001. Similarly, **Youssef *et al.*** (36) conducted a study on fifty mechanically ventilated patients to evaluate the value of echo, lung ultrasound and diaphragm ultrasound as a predictor of weaning outcomes compared to clinical weaning criteria and found that DTF before weaning had a highly significantly values in successfully weaned group compared to failed group with p-value <0.001. In agreement with **Samanta *et al.*** (40) which found statistically significant lower DTF in weaning failure group after weaning with p-value <0.001.

The current study found no statistically significant association between weaning failure and mortality with p-value=0.10, which goes in run with **Yonaty *et al.*** (13) study that was conducted on 158 mechanically ventilated patients planned for weaning and revealed no statistically significant association between weaning failure and mortality with p-value =0.33.

The Present Study found that DE before weaning > 15 had 100% sensitivity, 85.06% specificity, 70.5 PPV and 100% NPV with p-value <0.001. This goes in run with **Gok *et al.*** (41) study which revealed that DE at 1.31 had r=0.532, p-value <0.001, 69% sensitivity, 67.5% specificity, 96% PPV, and 27.8% NPV for determination of weaning success. **Farghaly and Hasan** (42) study included respiratory ICU patients to assess diaphragmatic US in evaluation of weaning success and revealed that DE at cutoff point 10.5 mm had 87.5% sensitivity, 71.2% specificity and AUC=0.879.

The Present study found that DTF before weaning > 18.5 had 80.65% sensitivity, 77.42% specificity, 78.1%PPV and 80% NPV with p-value <0.001. This goes in run with **Gok *et al.*** (41) study which revealed cutoff point of DTF at 27.5 had r=0.499, 67.5% sensitivity, 66.6% specificity, 95% PPV, and 24% NPV for determination of weaning success.

Samanta *et al.* (40) included 44 MV patients planned for weaning to assess the diaphragm using US to predict weaning in ICU patients and found that DTF had high sensitivity 97% and 81% specificity with p-value <0.001 for prediction of weaning success.

Ferrari *et al.* (39) study found that DTF >36% was associated with successful weaning with 82% sensitivity, 88% specificity, 92% PPV and 75% NPV.

Another study by **Mohamed *et al.*** (35) found that a cutoff point >32.82% for DTF had 90% sensitivity, 75% specificity, 44% PPV, 97% NPV, and AUC 77% for determination of weaning success.

Fahmy *et al.* (28) found DTF cut off point > 30% with 100% sensitivity, 100% NPV and highest accuracy 89.24% in detection of successful weaning.

Another study by **Eltrabili *et al.*** (43) revealed cutoff point for DTF for weaning success ≥30.7% had 94% sensitivity and 100% specificity with p-value <0.001, while DE at cut off point >10.4 mm had 94% sensitivity and 84% specificity with p-value <0.001.

Conclusion

The present study finally concluded that Assessment of DTF and DE by diaphragm ultrasound is an easy to obtain new weaning index that can be a bedside method in clinical practice with promising predictors of weaning success or failure before and after weaning. And the present study suggests the use of specific risk factors for weaning failure for mechanically ventilated patients including, high BMI, prolonged ICU stay, prolonged hospital stay, high PaO2/FiO2, lower PO2, lower DE before weaning and lower DE after weaning.

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