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TRANSTHORACIC ECHOCARDIOGRAPHY AND TISSUE DOPPLER IMAGING AS PREDICTORS FOR WEANING CRITICALLY ILL PATIENTS FROM MECHANICAL VENTILATION

By

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ABSTRACT

Background: The use of invasive mechanical ventilation (MV) sometimes is an inevitable lifesaving step in management of critically ill patients. However, being associated with numerous complications, the invasive MV should be discontinued at the earliest possible time in the course of a patient's illness. Successful, timely weaning and extubation of critically ill patients has a considerable bearing on ultimate outcome .

Objective: To evaluate the use of transthoracic echocardiography (TTE) and tissue Doppler imaging (TDI) in predicting failure of weaning of critically ill patients from mechanical ventilation due to cardiac origin.

Patients and Methods: This study was done on ninety adult patients of both sexes admitted to the units of anesthesia intensive Care Department at Al-Hussein and Bab El-Sharia Hospitals, Al-Azhar University. The included patients were selected from those who were mechanically ventilated for more than 48 hours, TTE & pulsed tissue Doppler imaging (TDI) performed at the lateral mitral annulus just before initial spontaneous breathing trial and E/E' index should be calculated in patient eligible for weaning. The study conducted during the period from December 2018 to December 2020.

Results: Cardiogenic pulmonary edema was the most frequent cause (65.4%) for weaning failure among the studied population and mainly among patients with systolic dysfunction. There were no statistical significant differences between successfully weaned and failed weaning groups regarding demographic data, positive pressure used for ventilation, and the use of diuretics within 48 hours before the SBT .

Conclusion: TTE and pulsed wave tissue Doppler imaging performed at the lateral mitral annulus before initiating the spontaneous breathing trial (SBT) were considered a useful bedside tool helping predict failure of weaning from mechanical ventilation in critically ill patients due to cardiac origin .

Keywords: Mechanical Ventilation, tissue Doppler imaging.

INTRODUCTION

The first formal description of the use of ultrasound to assess cardiac function was published 50 years ago. Since then echocardiography has allowed an increasingly sophisticated understanding of myocardial structure and function. Pulsed Doppler systems were developed

in the 1970s, followed by phased array scanners in the 1980s which allowed the accurate display of the temporal and spatial relationships between cardiac structures and the Echocardiogram (M-mode). Improvements in microprocessor technology enabled non-invasive assessment of intra-cardiac pressures and velocities. Eventually, two-dimensional echocardiography coupled to color Doppler permitted the real-time imaging of blood velocities in a picture immediately recognizable as the heart. The use of mechanical ventilation (MV) sometimes is inevitable lifesaving step in management of critically ill patients. Mechanical ventilation should be discontinued at the earliest possible time in the course of a patient's illness. Thus, both prolonged duration of mechanical ventilation and premature extubation are associated with increased morbidity and mortality *(Konomi et al., 2016).*

Discontinuation of mechanical ventilation is a two-step process. First, evaluation of systems should be done to determine whether causes of respiratory failure have been resolved. This includes: Patient should be conscious, with no or minimal need for sedation. Patient should have adequate oxygenation.

Second, patients who may be ready to wean are identified using various predictors of weaning outcome. Predictors of weaning outcome can help prevent unnecessary prolongation of mechanical ventilation by identifying the earliest time that a patient is able to resume and sustain spontaneous ventilation and can also prevent a premature weaning attempt that could result in cardiovascular, respiratory, or psychological distress *(Windisch et al., 2017).*

There is a growing evidence to suggest that transthoracic echocardiography (TTE) should be used to identify a cardiac origin of respiratory weaning failure. Tissue Doppler is a technique that directly measures myocardial velocities. The early diastolic mitral annulus velocity (E') has been shown to be a relatively load independent measure of myocardial relaxation. When E' is combined with pulsed Doppler mitral flow in early diastole E, the resulting E/E' ratio is closely correlated with the measured invasive left ventricular filling pressure *(Chew et al., 2018).*

The aim of the present study was to evaluate the use of TTE and tissue Doppler imaging (TDI) in predicting failure of weaning of critically ill patients from mechanical ventilation due to cardiac origin.

PATIENTS AND METHODS

This study was done on ninety adult patients of both sexes admitted to the units of Anesthesia Intensive Care Department at the Al-Hussein and Bab El-Sharia Hospitals, Al-Azher University. The included patients were selected from those who were mechanically ventilated for more than 48 hours and were considered eligible for weaning the study conducted during during the period from December 2018 to December 2020.

Inclusion Criteria: A clear improvement or resolution of the condition that initially necessitated mechanical ventilation. Adequate cough, absence of excessive tracheo-bronchial secretion. Adequate arterial blood gases and acid base values.

Adequate oxygenation (partial pressure of arterial oxygen (PaO2)/ fraction of inspired oxygen (FiO2) ≥200 on PEEP ≤8 cmH2O). Stable cardiovascular status (heart rate ≤120/ min, systolic blood pressure higher than 90 mmHg and lower than 160 mmHg) with no or low dose vasopressors or inotropes. Adequate pulmonary functions (respiratory rate ≤35 breathes/min, tidal volume > 5 mL/kg, no significant respiratory acidosis, RSBI< 105 breaths/min/L.). On no or only light sedation with stable neurological status. Electrocardiogram (ECG) showing normal sinus rhythm.

Exclusion Criteria: Patients suffering any type of dysrhythmias or atrioventricular conduction abnormalities. Patients with temporary or permanent pace-maker. Technical difficulty in getting an apical four chamber view as reported in cases of chronic obstructive pulmonary disease (COPD) and obese patients. Patients with mitral stenosis, heavy mitral annular calcification or prosthetic mitral valve where E/E' measurement is not validated for estimation of left ventricular filling pressure in such cases. Patients with constrictive pericarditis.

The selected patients were subjected to the following: Full history taking as can as possible. Complete physical examination. Relevant laboratory investigations including: Complete blood count (CBC). Liver enzymes (SGOT and SGPT) and serum albumin. Renal function tests (blood urea nitrogen and serum creatinine). Serum electrolytes including sodium and potassium. Arterial blood gases and acid base values.

After approval of ethical committee of the Faculty of Medicine, informed consents were taken from the patient's families.

All patients included in the study were mechanically ventilated according to the policy of our department for mechanical ventilation till criteria of weaning were met. Patients presented with hypotension (systolic blood pressure < 90 mmHg) were managed by inotropes and or vasopressors (dobutamine and noradrenaline) to get appropriate mean arterial blood pressure of more than 65 mmHg. During the study period, the dose of ongoing vasoactive drug infusion, if any, was kept constant. All mechanically ventilated patients were screened for the inclusion criteria daily. Once the inclusion criteria were met the patients were prepared for a spontaneous breathing trial (SBT) with a T-piece. Trans Thoracic Echocardiography (TTE) with the use of tissue Doppler imaging on the lateral portion of the mitral annulus were performed in every patient under pressure support mode (ranging from 7-12 cmH2O) prior to the disconnection from the ventilator on a T-piece. Spontaneous breathing trial: The SBT was performed over a 30-minute period using a T-piece while the patient was in a semi-recumbent position (45°). Heart rate, systolic and diastolic blood pressure, respiratory rate, pulse oxymetry, five-lead electrocardiographic tracing and level of consciousness were closely monitored during the SBT.

SBT failure was defined as the need to connect the patient back to the ventilator prior to its completion due to at least one of the following reasons: Agitation and anxiety or depressed mental status.

Cyanosis, percutaneous oxygen saturation (SpO2) below 90%. Respiratory rate of more than 35 breathes/min. Heart rate above 150 beats/min or cardiac arrhythmia, systolic blood pressure above 180 mmHg or below 90 mmHg. If the SBT was successful, the planned extubation was performed. The attending physician in charge of the patient was blind to TTE results. All patients were included at the time of their first SBT. Failure to wean a patient from the ventilator was defined as a failed SBT or the need for a re-intubation within 48 hours following extubation. In the latter case, medical records were reviewed to identify the cause of weaning failure and to exclude an underlying cardiogenic pulmonary edema based on clinical and radiological criteria. The following signs or information were used and were assumed to be suggestive of weaning induced pulmonary edema: previous history of heart disease, exclusion of other causes of respiratory failure, early onset of respiratory distress after suppression of positive pressure ventilation, the presence of frothy secretions and bilateral crackles and onset of newer bilateral infiltrates on chest x-ray .

Measurements of transthoracic echocardiography and tissue Doppler imaging which was done prior to disconnection from the ventilator on a T-piece:

In the apical four-chamber view, left ventricular ejection fraction (LVEF) was measured using the modified Simpson's method. Both the right ventricular (RV) and LV end-diastolic areas (EDA) were measured to calculate the RVEDA/LVEDA ratio. A dilated right ventricle was defined by a ratio of more than 0.6. Color Doppler mapping was used to detect the presence of a relevant mitral regurgitation and to assess its severity semi-quantitatively (grade I versus to grade II-IV) *(Buonanno et al., 2020).*

LV inflow velocity: Pulsed-wave Doppler applied at the tip of the mitral valve leaflets was used to record LV inflow velocities. Maximal flow velocities during early diastole (E wave) and during atrial systole (A wave) were measured, and the E/A ratio was computed. The deceleration time of the E wave (DTE) was measured by extending the deceleration slope from the peak wave velocity to the zero-velocity baseline.

Tissue Doppler imaging: By using pulsed-wave tissue Doppler at the lateral portion of the mitral annulus, the maximal velocity of its displacement during early diastole (E' wave) was measured, and the E/E' ratio was computed.

LV stroke volume was measured using difference between end systolic volume (ESV) and end diastolic volume (EDV).

The pulmonary capillary occlusion pressure (PCOP) and the left ventricular filling pressure was estimated using the following equation:

PCOP= 1.9 + 1.24 x (E/E') *(Donal et al., 2017)*

- All measurements were performed in triplicate and averaged.
- TTE was performed using vivid 3 device (General Electric®, Norway).
- All the above parameters were compared in the patients who were successfully weaned and those who

failed to wean, to get the most significant and sensitive echocardiographic parameters predicting weaning failure of cardiac origin.

Statistical analysis:

Data were fed to the computer using IBM SPSS software package version 20.0. Qualitative data were described using number and percent. Comparison between different groups regarding categorical variables was tested using Chi-square test. When more than 20% of the cells have expected count less than 5, correction for chi-square was conducted using Firsher's Exact test. The distributions of quantitative variables were tested for normality using Shapiro-Wilk test. Quantitative data were described using mean and standard deviation. Comparisons between two independent populations were done using independent t-test. Agreement of the different predictive with the outcome was used and was expressed in sensitivity, specificity, positive predictive value, negative predictive value and accuracy. Receiver operating characteristic curve (ROC) was plotted to analyze a recommended cutoff, the area under the ROC curve denotes the diagnostic performance of the test. Significance test results were quoted as two-tailed probabilities. Significance of the obtained results was judged at the 5% level.

RESULTS

Ninety patients were included in this study, males were 52 (57.8%) whereas females were 38 (42.2%). Their ages ranged from 22-75 years with median of 61 and mean value of 58.07 ± 12.21 years **(Table 1)**.

Table (1): Demographic data of the studied population

Number / Demographic data	(n = 90)	
	Number	**%**
Gender		
Male	52	57.8
Female	38	42.2
Age: (years)		
22-30	5	5.6
30-<40	5	5.6
40-<50	5	5.6
50-<60	23	25.6
60-75	52	57.8
Range	22-75	
Mean ± SD	58.07 ± 12.21	

Reasons for intubation were mostly due to septic shock which was encountered in 26 patients (28.8%), other reasons includes pneumonia in 15 patients (16.7%), neurological disorders in 15 patients (16.7%); seven patients suffered from acute ischemic stroke and 8 patients suffered trauma; cardiogenic shock in 13 patients (14.4%), cardiogenic pulmonary edema in ten patients (11.1%), ARDS in

six patients (6.7%) and cardiac arrest in five patients (5.6%).

History of hypertension was recorded in 32 patients (35.5%) and history of COPD was recorded in 17 patients (18.9%), 15 of those patients were intubated due to acute on top of chronic respiratory failure while one of the remaining two patients was intubated due to cardiogenic shock and the other due to depressed consciousness with acute ischemic stroke.

Fourteen patients (15.6%) at time of the study were still in a need for vasopressor therapy namely norepinephrine and they required doses ranging from 2-6 µg/min with a mean value of 3.86 ± 1.35. Ten patients required inotrope therapy support namely dobutamine with doses ranging from 3-6 µg/kg/min and a mean value of 4.4 ± 1.17. Four of those patients were also on norepinephrine.

Diuretics were prescribed by the treating physicians within 48 hours before initiating the spontaneous breathing trials for 17 patients (18.9%).

Duration of the mechanical ventilation before initiating the trials ranged from 2-10 days with a mean value of 4.84 ± 1.66 days and a median value of 5 days.

All the studied patients were mechanically ventilated before initiating the spontaneous breathing trials using pressure support ranging from 7-12 cmH2O, with a mean value of 8.76 ± 1.12, and using PEEP ranging from 4-8 cmH2O with a mean value of 5.41 ± 1.12. Mortality in the studied population was recorded in 16 patients (17.8%) **(Table 2)**.

Table (2): Clinical characteristics of the studied population

Number **Clinical characteristics**	**(n = 90)**
Cause of intubation (One or more)	Number (%)
Cardiac arrest	5 (5.6)
Cardiogenic pulmonary edema	10 (11.1)
Cardiogenic shock	13 (14.4)
Septic shock	26 (28.8)
Neurological disorders (stroke and trauma)	15 (16.7)
Pneumonia	15 (16.7)
ARDS	6 (6.7)
▪ Medical history:	
• Hypertension	32 (35.5)
• COPD	17 (18.9)
▪ Use of diuretics within 48 hours before the trial	17 (18.9)
▪ Need for vasopressors/inotropes	
• Norepinephrine	14 (15.6)
• Dobutamine	10 (11.1)
▪ Duration of mechanical ventilation (days)	
Range	2-10
Mean ± SD	4.84 ± 1.66
▪ Mechanical ventilation data	
Pressure support (CmH2O)	
Range	7-12
Mean ± SD	8.76 ± 1.12
▪ PEEP (CmH2O)	
Range	4-8
Mean ± SD	5.41 ± 1.12
	Number (%)
Mortality	16 (17.8%)

COPD = chronic obstructive pulmonary disease, PEEP= positive end expiratory pressure

Patients were classified according to their weaning outcome into two groups (successful and failed). Successful weaning is defined by successful passing of the trial and successful extubation for 48 hours, whereas failure of weaning is defined as either failure to pass the trial or need for reintubation within 48 hours of extubation.

Causes of failed weaning show 17 patients developed post extubation pulmonary edema, 6 patients were due to increase amount of secretions, two patients due to stridor & one patient due to hypoventilation **(Table 3)**.

Table (3): Causes of weaning failure in studied population

Causes of failure \ Number	(n=26)	%
Cardiogenic pulmonary edema	17	65.4
Excessive airway Secretions	6	23.1
Stridor	2	7.7
Hypoventilation	1	3.8

In successfully weaned group, age ranged from 25-75 years with a mean value of 58.86 ± 11.82 years. 37 patients were males and 27 patients were females. In failed to wean group, age ranged from 22-69 with a mean value of 56.12 ± 13.17 years. 15 patients were males and 11 patients were females. There were no statistically significant differences as regards age and sex between both groups (p>0.05) **(Table 4)**.

Table (4): Comparison between the successful and the failed weaning groups regarding their demographic data

Demographic data \ Groups	Successful (n = 64)		Failed (n = 26)	
	Number	%	Number	%
Gender				
Male	37	57.8	15	57.7
Female	27	42.2	11	42.3
x^2 **p**	0.992			
Age Range	25 – 75		22 – 69	
Mean ± SD	58.86 ± 11.82		56.12 ± 13.17	
t p	0.337			

p: p value for comparing between the two studied group
χ2: Chi square test
t: Student t-test

Reasons for intubation in successfully weaned group were mostly due to septic shock that was noticed in 21 patients (32.8%). Other reasons includes pneumonia in 13 patients (20.3%), neurological disorders in 11 patients (17.2%); five patients suffered from acute ischemic stroke and six patients suffered trauma; cardiogenic pulmonary edema in eight patients (12.5%), cardiogenic shock in seven patients (10.9%), ARDS in three patients (4.7%) and cardiac arrest in one patient (1.6%).

In the failed group reasons for intubation were mostly due to cardiogenic shock that was noticed in six patients (23.1%), Other reasons includes septic shock in five patients (19.2%), neurological disorders in four patients (15.4%); two patients suffered from acute ischemic stroke and two patients suffered trauma, cardiac arrest in four patients (15.4%), ARDS in three patients (11.5%), cardiogenic pulmonary edema in two cases (7.7%) and pneumonia in two patients (7.7%) **(Table 5)**.

Table (5): Comparison between the successful and the failed weaning groups as regard causes of intubation

Groups / Causes of intubation	Successful (n = 64)		Failed (n = 26)		^{t}p
	Number	%	Number	%	
Cardiac arrest	1	1.6	4	15.4	0.372
Cardiogenic pulmonary edema	8	12.5	2	7.7	
Cardiogenic shock	7	10.9	6	23.1	
Septic shock	21	32.8	5	19.2	
Neurological disorders	11	17.2	4	15.4	
Pneumonia	13	20.3	2	7.7	
ARDS	3	4.7	3	11.5	

p: p value for comparing between the two studied groups
t: Student t-test

There are statistically significant difference between two groups as regard duration of ventilation and mortality. There is no statistically significant difference between two groups as regard mechanical ventilation data and use of diuretics **(Table 6)**.

Table (6): Comparison between the successful and the failed weaning groups as regard use of diuretics, mortality, duration of mechanical ventilation and mechanical ventilation data

Groups / Clinical criteria	Successful (n = 64)		Failed (n = 26)		$^{FE}p/^{t}p$
	Number	%	Number	%	
Use of diuretics within 48 hours before the trial	9	14.1	8	30.8	0.08^{FE}
• **Mortality**	4	6.3	12	46.2	$<0.001^{*FE}$
• **Duration of mechanical ventilation (days)** Range Mean ± SD	2-9 4.61 ± .48		2-10 5.42 ± 1.94		0.034^{*t}
• **Mechanical ventilation data** • Pressure support (CmH_2O) Range Mean ± SD	7-12 8.67 ± .12		7-12 8.96 ± 1.11		0.271^{t}
• **PEEP (CmH2O)** Range Mean ± SD	4-8 5.65 ± 1.15		4-8 5.19 ± 1.02		0.167^{t}

p: p value for comparing between the two studied groups, FE: Fisher Exact test, t: Student t-test

There were no statistically significant differences as regards complete blood count values and liver functions tests values **(Table 7)**.

Table (7): Complete blood count and Liver function tests values among both groups

Groups / Laboratory investigations	Successful (n = 64)	Failed (n = 26)	P
	Mean ± SD	Mean ± SD	
Hb (g/dl)	11.06 ± 1.51	11.25 ± 1.66	0.589
WBCs $\times 10^3$ (cells/mm^3)	8.45 ± 1.71	8.25 ± 1.53	0.61
Platelets $\times 10^4$ (/mm^3)	23.31 ± 8.06	21.10 ± 5.58	0.140
ALT (IU/L)	33.28 ± 12.78	35.88 ± 11.49	0.258
AST (IU/L)	39.69 ± 14.56	41.65 ± 12.67	0.452
Albumin (g/L)	3.18 ± 0.39	3.13 ± 0.31	0.530

p: p value for Student t-test for comparing between the two studied group
p: p value for comparing between the two studied groups
MW: Mann Whitney test, t: Student t-test

There were no statistically significant differences as regards renal functions tests values and serum electrolytes values **(Table 8)**.

Table (8): Renal function tests, Serum sodium and potassium levels among both groups

Groups / Laboratory investigations	Successful (n = 64)	Failed (n = 26)	P
	Mean ± SD	Mean ± SD	
BUN (mg/dl)	22.67 ± 12.89	31.12 ± 23.65	0.086
Serum creatinine (mg/dl)	0.99 ± 0.46	1.12 ± 0.57	0.078
Na (mEq/L)	138.34 ± 4.44	136.92 ± 4.40	0.171
K (mEq/L)	4.0 ± 0.36	4.08 ± 0.45	0.414

BUN: Blood urea nitrogen
p: p value for Mann Whitney test for comparing between the two studied groups

There were no statistically significant differences as regards acid base values obtained before the trial between both groups (p>0.05) **(Table 9)**.

Table (9): Acid base values among both groups

Groups / Values	Successful (n = 64)	Failed (n = 26)	P
	Mean ± SD	Mean ± SD	
pH	7.36 ± 0.03	7.37 ± 0.03	0.906
$PaCO_2$ (mmHg)	41.72 ± 10.25	41.0 ± 9.62	0.760
HCO_3 (mEq/L)	24.48 ± 3.58	24.31 ± 5.51	0.858
PaO_2 (mmHg)	96.02 ± 14.81	97.08 ± 17.24	0.770
SaO_2 (%)	97.03 ± 2.52	97.19 ± 2.43	0.782
Lactate(mmol/L)	1.00 ± 0.23	1.10 ± 0.20	0.056
RBS (mg/dL)	160.37 ± 23.20	170.55 ± 22.21	0.059

p: p value for Student t-test for comparing between the two studied groups
RBS: random blood sugar

Ejection fraction values in successfully weaned patients ranged from 30 – 70 with a mean of 50.34 ± 11.5 %, while in the failed to wean patients it ranged from 26-60 with a mean of 44.42 ± 12.95%. Ejection fraction values were significantly lower in the failed to weaned group than in successfully weaned patients (p=0.036). Systolic dysfunction was defined as ejection fraction below 50% and the number of patients with systolic dysfunction in the successfully weaned group was 29 (45.3%) while in the failed to wean group was 13 (50%). No significant difference between the two groups was noticed regarding number of patients with systolic dysfunction **(Table 10)**.

Table (10): Ejection fraction values and systolic dysfunction among both groups

Groups / Values	Successful (n = 64)		Failed (n = 26)	
	No.	**%**	**No.**	**%**
EF (%)				
<50 %	29	45.3	13	50
≥ 50 %	35	54.7	13	50
^{x2}**p**	0.686			
EF (%)				
Mean ± SD	50.34 ± 11.5		44.42 ± 12.95	
^{t}**p**	0.036*			

EF: Ejection fraction, p: p value for comparing between the two studied group, χ2: Chi square test, t: Student t-test,

Successfully weaned group showed one patient with grade II- IV to severe mitral regurge and 11 patients with grade I mitral regurge, while the remaining 52 patients showed no mitral regurge. Failed to wean group showed four patients with grade II-IV to severe mitral regurge and eight patients with grade I mitral regurge, while the remaining 14 patients showed no mitral regurge. Successfully weaned group showed significantly more patients without mitral regurge when compared to the failed weaning group (p= 0.008), also prevalence of grade II-IV to severe mitral regurge was significantly higher among the failed weaning group when compared to the successfully weaned group (p= 0.023) **(Table 11)**.

Table (11): Degrees of mitral regurge (MR) among both groups

Groups / Parameters	Successful (n = 64)		Failed (n = 26)		P
	No.	**%**	**No.**	**%**	
MR					
No	52	81.2	14	53.8	^{x2}**p**= 0.008*
Grade I	11	17.2	8	30.8	^{x2}**p**= 0.152
Grade II, III, IV	1	1.6	4	15.4	^{FE}p = 0.022*

p: p value for comparing between the two studied group, χ2: Chi square test, FE: Fischer Exact test,

DTE values in successfully weaned patients ranged from 114-225 with a mean value of 167.37 ± 19.36 ms while in the failed to wean patients they ranged from 96-212 with a mean value of 157.5 ± 30.99 ms. There were no statistically significant differences between both groups (p>0.05) as regards deceleration

time of E wave (DTE) values obtained just before the trial. E/A values in successfully weaned patients ranged from 0.83-1.22 with a mean value of 1.05 ± 0.08 while in the failed to wean patients they ranged from 0.9-1.36 with a mean value of 1.09 ± 0.09. There were no statistically significant differences between both groups (p>0.05) as regards E/A ratio values obtained just before the trial. A wave values in successfully weaned patients ranged from 58-113 with a mean value of 77.42 ± 11.96 cm/sec while in the failed to wean patients they ranged from 59-99 with a mean value of 78.88 ± 11.53 cm/sec. There were no statistically significant differences between both groups (p>0.05) as regards left ventricle inflow velocity during atrial systole (A wave) values obtained just before the trial. E wave values in successfully weaned patients ranged from 66-115 with a mean value of 81.39 ± 11.18 cm/sec while in the failed to wean patients they ranged from 69-110 with a mean value of 86.27 ± 13.77 cm/sec. There were no statistically significant differences between both groups (p>0.05) as regards left ventricle inflow velocity at early diastole (E wave) values obtained just before the trial **(Table 12)**.

Table (12): E wave velocities, A wave velocities, E/A ratio, DTE and E' values and diastolic dysfunction incidence among both groups

Groups / Parameters	Successful (n = 64)		Failed (n = 26)		^{t}p
	Mean ± SD		Mean ± SD		
E (cm/sec)	81.39 ± 11.18		86.27 ± 13.77		0.103
A (cm/sec)	77.42 ± 11.96		78.88 ± 11.53		0.613
E/A	1.05 ± 0.08		1.09 ± 0.09		0.0533
DTE (ms)	167.37 ± 19.36		157.5 ± 30.99		0.115
E' (cm/sec.)	9.35 ± 1.25		8.37 ± 1.89		0.010*
Diastolic dysfunction	**No.**	**%**	**No.**	**%**	
≤ 8 cm/sec	16	25	17	65.4	
>8 cm/sec	48	75	9	34.6	<0.001*

DTE: Deceleration time of E wave, p: p value for comparing between the two studied group, t: Student t-test, *:

E/E' values in successfully weaned patients ranged from 6.09-13.2 with a mean value of 8.86 ± 1.71 while in the failed to wean patients they ranged from 6.27-16.92 with a mean value of 10.95 ± 3.38. E/E' values were significantly higher in the failed to wean patients when compared to values obtained in the successfully weaned patients just before the trial. (p = 0.005). PCOP values in successfully weaned patients ranged from 9.45-18.27 with a mean value of 12.89 ± 2.12 mmHg while in the failed to wean patients they ranged from 9.67-22.88 with a mean value of 15.84 ± 4.19 mmHg. PCOP values were significantly higher in the failed to wean patients when compared to values obtained in the successfully weaned patients just before the trial. (p = 0.005) Cardiac output values in successfully weaned patients ranged from 4.8-6.3 with a mean value of 5.58 ± 0.37 L/min while in the failed to wean patients they ranged from 3.7-6.4 with a mean value of 5.33 ± 0.68 L/min. There were no statistically significant differences between both groups (p>0.05) as regards cardiac output values obtained just before the trial. RV/LVEDA values in successfully weaned patients ranged from 0.43-0.63 with a mean value of 0.47 ± 0.03 while in the failed to wean patients

they ranged from 0.44-0.62 with a mean value of 0.49 ± 0.04. There were no statistically significant differences between both groups (p>0.05) as regards RV/LVEDA values obtained just before the trial **(Table 13)**.

Table (13): E/E' values, Calculated pulmonary capillary occlusion pressure (PCOP), Cardiac output (CO) values and right/left ventricle end diastolic area (RV/LVEDA) ratio among both groups

Groups / Parameters	Successful (n = 64)	Failed (n = 26)	t p
	Mean ± SD	Mean ± SD	
E/E'	8.86 ± 1.71	10.95 ± 3.38	0.001*
PCOP (mmHg)	12.89 ± 2.12	15.48 ± 4.19	0.001*
CO (L/min.)	5.58 ± 0.37	5.33 ± 0.68	0.044
RV/LVEDA	0.47 ± 0.03	0.49 ± 0.04	0.114

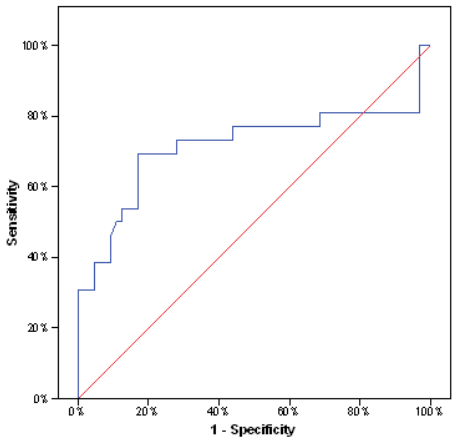
p: p value for comparing between the two studied group, t: Student t-test

Area under receiver operating characteristic (ROC) curve was 0.685 for E', while for E/E' was 0.714 (p= 0.005) in predicting weaning failure when measured just before the SBT. For E/E' a cut off value more than or equal to 10.25 was associated with the highest diagnostic accuracy (78.89) with sensitivity of 69.23% and specificity of 82.81% with a positive predictive value of 62.07% and a negative predictive value of 86.89% **(Table 14 & Figure 1)**.

Table (14): Diagnostic performance of E/E'

Diagnosis / E/E'		Successful (n=64)	Failed (n=26)	AUC	P	Sensitivity	Specificity	PPV	NPV	Accuracy
E/E'	**≤10.25**	53	8	0.714*	0.005	69.23	82.81	62.07	86.89	78.89
	>10.25	11	18							

AUC: area under the curve.
P: p value.
PPV: positive predictive value
NPV: negative predictive value



	AUC	p
E/E'	0.714*	0.005

Figure (1): Receiver operating curve (ROC) curve for E/E' in the studied groups

The studied population, 48 patients (53.3%) were with normal systolic function, 24 patients (26.7%) were with mild-moderate systolic dysfunction and 18 patients were with severe systolic dysfunction (20%). From the 48 patients with normal systolic function (EF ≥50%), 35 (72.9%) patients underwent successful extubation and 13 (27.1%) patients failed to be weaned. From the 24 patients included in subgroup of patients with mild to moderate systolic dysfunction (EF 30-<50%), 19 (79.2%) of them underwent successful extubation and five (20.8%) patients failed to be weaned. From the 18 patients included in the third subgroup (EF <30%), 10 (55.6%) of them underwent successful extubation and eight patients (44.4%) failed to be weaned. There were no statistical significant differences regarding degree of systolic dysfunction when comparing between successfully and failed weaning groups **(Table 15)**.

Table (15): Degrees of systolic dysfunction in patients of both groups

Groups / Parameters	Successful (n = 64)		Failed (n = 26)		p
	No.	%	No.	%	
EF (Ejection fraction)%					
A- ≥ 50	35	54.7	13	50.0	0.686
B- 30 – <50	19	29.7	5	19.2	0.309
C- <30	10	15.6	8	30.8	0.104

p: p value for comparing between the two studied group, $\chi 2$: Chi square test

Cardiogenic pulmonary edema was recorded in six patients (46.1%) in those who failed to wean in subgroup A, four patients (80%) in subgroup B and seven patients (87.5%) in subgroup C. Excessive airway secretions was recorded in four patients (30.8%) in those who failed to wean in subgroup A, one patient (20%) in subgroup B and one patient (12.5%) in subgroup C. Stridor was recorded in two patients (15.4%) in those who failed to wean in subgroup A. It was not recorded either in group B or group C. Hypoventilation was recorded in only one patient (7.7%) in the subgroup A **(Table 16)**.

Table (16): Causes of weaning failure among the three subgroups

Ejection fraction / Causes of failure	A- ≥50		B- 30 – <50		C- <30	
	(n = 13)	%	(n = 5)	%	(n = 8)	%
Cardiogenic pulmonary edema	6	46.1	4	80	7	87.5
Excessive airway secretions	4	30.8	1	20	1	12.5
Stridor	2	15.4	0	0	0	0
Hypoventilation	1	7.7	0	0	0	0

DISCUSSION

It is desirable to have accurate objective predictors of weaning outcome that can be applied early in a patient's clinical course. When assessed early in a patient's clinical course, predictors of weaning outcome can help prevent unnecessary prolongation of mechanical ventilation by identifying the earliest time that a patient is able to resume and sustain spontaneous ventilation *(Gunther et al., 2021)*. Conversely, by identifying patients

who are likely to fail weaning, predictors of weaning outcome can prevent a premature weaning attempt that could result in cardiovascular, respiratory, or psychological distress. Finally, the predictors may provide insight into the reasons for ongoing ventilator dependence *(Chakupurakal and Cardasis, 2021).* Numerous measures have been proposed as predictors of weaning outcome.

In our current study, the most common cause of intubation came in agreement with *Caille et al. (2010)* and *Moschietto et al. (2012),* and *disagreement with Schifelbain et al. (2011),* where was the neurological disorders are the most common causes by 33% and not between the trauma patients according to randomize control trial.

In our current study, the history of hypertension was recorded in 35.5% which was close to results of *Caille et al. (2010), Schifelbain et al. (2011)* and *Moschietto et al. (2012).*

In our current study, the history of COPD was record in 18.9% which was close to result of *Caille et al. (2010)* and *Moschietto et al. (2012).*

In our current study, the demographic data were close to that of *Caille et al. (2010)* and *Schifelbain et al. (2011)* and *Vignon (2018).* This study disagreed with *Ehab et al. (2012)* where the patient's age was lower approximately 44 years (35%).

In our current study, no significant differences between successful and failed weaning groups, regarding CBC values, liver function tests (ALT, AST and serum albumin), renal function test (BUN and serum creatinine), serum electrolytes (sodium and potassium) and acid base values and this was in agreement with *Moschietto et al. (2012).*

In our current study, the use of vasoprossor therapy in 15% as 2-6 µg/kg/min for norepinephrine and intropes 3-6 µg/kg/min for dobutrex which was similar to *Caille et al. (2010).*

In our current study, the use of diuretics before initiating spontaneous breathing trials 18.9% was close to results obtained by *Caille et al. (2010)* about 12% of their cases.

In our current study, the duration of ventilation before the initial trials ranged between 2-10 days with median of 5 days which was similar to *Caille et al. (2010),* and shorter than *Schifelbain et al. (2011)* who showed median 13 days. The mechanical ventilation data was similar to *Caille et al. (2010)* and *Moschietto et al. (2012).*

In our current study, the mortality in studied population was 17.8%, which was similar to *Moschietto et al. (2012)* where mortality about 16% and the mortality in our study was slightly higher than the mortality recorded by *Caille et al. (2010)* where were about 10%.

In our current study about 28.9% of the studied population had met criteria of weaning failure. This was similar to the studies done by *Schifelbain et al. (2011), Ehab et al. (2012)* and *Moschietto et al. (2012).* This percentage was higher when compared to that recorded by *Caille et al. (2010)* which were 19.6% .

In our current study, the most common cause for failure of weaning in the present study was cardiogenic pulmonary edema accounting for 65.4%. This was similar to the results obtained by *Caille et al. (2010)*

which accounting for 80% and *Moschietto et al. (2012)* which accounting for 70%.

In our current study by comparing the two groups (successful and failed weaning) regarding their demographic data, we found no statistical significant difference between them. This was similar to results obtained by *Caille et al. (2010), Ehab et al. (2012)* and *Moschietto et al. (2012).*

In our current study we can recognize that, collectively, cardiac causes for intubation in our study were accused in most of our cases either in the successful or in the failed weaning group. This was similar to results of *Caille et al. (2010)* and disagreement with *Moschietto et al. (2012).*

Duration of mechanical ventilation before initiating the trials in the successfully weaned group ranged from 2-9 days with a mean value of 4.61 days ± 1.48 and a median of 4.5 days. While in the failed to wean group it ranged from 2-10 days with a mean value of 5.42 days ± 1.94 and a median of 5 days, successfully weaned patients in our study showed a significant shorter duration of mechanical ventilation before initiating the SBTs when compared to the failed to wean group. This was relatively similar to results obtained by *Moschietto et al. (2012).*

There were no statistically significant differences in the present study regarding mechanical ventilation data recorded before initiating the SBTs between both groups in agreement with *Caille et al. (2010).*

There was no significant difference between two groups as regard using diuretics within 48 hours before initiating the spontaneous breathing trials in agreement with *Moschietto et al. (2012).*

Mortality in successfully weaned patients in our study was recorded in 6.3% compared to 46.2% in the failed to wean group. Mortality was significantly higher in the failed to wean group. This was similar to results obtained by *Moschietto et al. (2012).*

In our current study, there was no significant difference as regard systolic dysfunction between two groups which was in agreement with *Caille et al. (2010), Moschietto et al. (2012), Ehab et al., (2012)* and *Vignon (2018).*

Our current successfully weaned group significantly showed more patients without mitral regurge when compared to the failed weaning group. Also, prevalence of moderate to severe mitral regurge was significantly higher among the failed weaning group when compared to the successfully weaned group. This finding was similar to that obtained by *Caille et al. (2010).*

In our current study, there was no statistically significant difference between two groups as regard E wave velocities and E/A ratio which were in agreement with *Caille et al. (2010), Moschietto et al. (2012)* and *Vignon (2018).*

In our current study, there was no statistically significant difference between two groups as regard DTE which was in agreement with *Caille et al. (2010), Ehab et al (2012)* and *Moschietto et al. (2012).*

In our current study, E' values were significantly lower in those who failed wearing in agreement with *Moschietto et al. (2012).*

In our current study, E/E' values in the failed wearing group were significantly higher compared to those in the successfully weaned group in agreement with *Caille et al. (2010)* and *Moschietto et al. (2012)* and disagreement with *Vignon (2018)* where there was no statistical significant differences between two groups as regard E/E' values.

In our current study, area under receiver operating characteristic (ROC) curve was associated with the highest diagnostic accuracy 78.89% with sensitivity of 69.23% and specificity of 82.81% with a positive predictive value of 62.07% and a negative predictive value of 86.89% this was similar to results obtained from *Moschietto et al. (2012).*

In our current study, calculated cardiac output values using TTE showed no statistical significant between two groups this was in agreement with results obtained by *Caille et al. (2010).*

CONCLUSION

Weaning induced cardiogenic pulmonary edema is a common cause for failure of weaning from mechanical ventilation in critically ill patients with lower incidence among those with normal systolic function (EF ≥50%). Among TTE and tissue Doppler imaging parameters, ejection fraction, mitral regurge, E' and E/E' index can be used as predictors for failure of weaning critically ill patients from mechanical ventilation due to cardiac origin. Systolic dysfunction did not seem to influence weaning outcome, whereas diastolic dysfunction is closely associated with weaning failure. E/E' index is considered the most significant parameter in predicting weaning failure due to cardiac origin using cut off value of 10.25 cm/sec. However, it is not a good predictor among patients with normal systolic function (EF ≥50%). Deceleration time of E wave (DTE) can help in predicting failure of weaning due to cardiac origin in patients with marked systolic dysfunction (EF <30%).

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تخطيط صدي القلب من خلال الصدر والتصوير النسيجي بالدوبلر كأداة توقع فصل الحالات الحرجه من جهاز التنفس الصناعي

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خلفيـــة البحـــث: يعـــد اســـتخدام التهويـــة الميكانيكيـــة فـــي بعـــض الأحيـــان خطـــوة حتميـــة لإنقـــاذ الحيـــاة فـــي إدارة المرضـــى المصـــابين بـــأمراض خطيـــرة. ومـــع ذلـــك ، نظـــرًا لارتباطهـــا بالعديـــد مـــن المضـــاعفات، يجـــب إيقـــاف التـــنفس الصـــناعي فـــي أقـــرب وقـــت ممكـــن و الفطـــام النـــاجح فـــي الوقـــت المناســـب ونـــزع الأنبـــوب للمرضـــى المصـــابين بأمراض خطيرة له تأثير كبير على النتيجة النهائية.

الهـــدف مـــن البحـــث: تقيـــيم اســـتخدام الموجـــات فـــوق الصـــوتية مـــع التصـــوير بالـــدوبلر النســـيجي فـــي توقـــع فشـــل فصـــل الحـــالات الحرجـــة مـــن جهـــاز التـــنفس الصـــناعي بســـبب القلب.

المرضـــى وطـــرق البحـــث: وقـــد أجريـــت هـــذه الدراســـة علـــى ٩٠ مـــن المرضـــى البـــالغين مـــن الجنســـين تـــم دخـــولهم قســـم التخـــدير والرعايـــة المركـــزة بمستشـــفيات جامعـــة الأزهـــر. و تـــم اختيـــار هـــؤلاء المرضـــى ممـــن كـــانوا علـــى جهـــاز التـــنفس الصـــناعي لمـــدة ٤٨ ســـاعة علـــى الأقـــل و كـــانوا يعتبـــروا صـــالحين للفصـــل و كـــان يـــتم عمـــل مســـح لمعـــايير التضـــمين للبحـــث يوميـــا و عنـــد تـــوافر تلـــك المعـــايير يـــتم التجهيـــز لعمـــل محاولـــة للتـــنفس التلقـــائي باســـتخدام قطعـــة (T). و تـــم عمـــل الموجـــات فـــوق الصـــوتية علـــي القلـــب مـــن خـــلال الصـــدر والتصـــوير بالـــدوبلر النســـيجي لحلقـــة الصـــمام الميترالـــي الجانبيـــة فـــي كـــل مـــريض باســـتخدام ضـــغط هـــوائي موجـــب يتـــراوح مـــن ٧ الـــى ١٢ ســـم مـــائي قبـــل فصـــل المريض من جهاز التنفس الصناعي و استخدام قطعة (T).

نتـــائج البحـــث: شـكلت الوذمـــة الرئويـــة القلبيـــة الســـبب الأكثـــر شـــيوعا لـــدى مرضـــى هـــذه الدراســـة لفشـــل عمليـــة الفصـــل مـــن جهـــاز التـــنفس الصـــناعي (65,4%) و بخاصـــة المرضـــى ممـــن لـــديهم قصـــور بالوظيفـــة الانقباضـــية لعضـــلة القلـــب. لـــم يكـــن هنـــاك فـــرق احصـــائي بـــين المجموعـــة الناجحـــة و المجموعـــة الفاشـــلة فـــي الفصـــل مـــن جهـــاز التـــنفس الصـــناعي مـــن حيـــث الجـــنس و العمـــر و نقـــاط وظـــائف الأعضـــاء المبســـطة لـــدى دخـــول المـــريض والضـــغط الموجـــب المســـتخدم فـــي التـــنفس و اســـتخدام مـــدرات البـــول خـــلال ٤٨ ســـاعة قبـــل محاولـــة التـــنفس التلقـــائي. فتـــرة التـــنفس الصـــناعي قبـــل محاولـــة التـــنفس التلقـــائي كانـــت أقـــل فـــي المجموعـــة الناجحـــة مقارنـــة بالمجموعـــة الفاشـــلة فـــي الفصـــل مـــن جهاز التنفس الصناعي.

الأســـتنتاج: يعتبـــر الموجـــات فـــوق الصـــوتية علـــي القلـــب مـــن خـــلال الصـــدر و التصـــوير بالـــدوبلر النســـيجي لحلقـــة الصـــمام الميترالـــي الجانبيـــة قبـــل البـــدء فـــي محاولـــة التـــنفس التلقـــائي أداة مفيـــدة تســـاعد علـــى توقـــع فشـــل فصـــل الحـــالات الحرجـــة مـــن أجهـــزة التـــنفس الصـــناعي بســـبب القلـــب. الوذمـــة الرئويـــة القلبيـــة مـــن الأســـباب الشـــائعة لفشـــل عمليـــة الفصـــل مـــن جهـــاز التـــنفس الصـــناعي فـــي مرضـــى الحـــالات الحرجـــة و تكـــون أقـــل حـــدوثا لـــدي المرضـــى ذوي الوظيفـــة الطبيعيـــة لانقبـــاض عضـــلة القلـــب و المعرفـــة بقيمة جزء الدم المقذوف من البطين الأيسر ٥٠% أو أكثر.

الكلمات الدالة: التنفس الصناعي وتصوير بالدوبلر النسيجي.