Echocardiography During Weaning From Mechanical Ventilation

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Abstract: Weaning of patients from the ventilator remains a crucial issue. The incidence of weaning failure, which is defined as a failed spontaneous breathing trial (SBT) or the need for a re-intubation in the 48 hours following extubation, reached 31%. Weaning failure remains a clinically relevant challenge because it may result in significant morbidity (prolonged duration of mechanical ventilation, re-intubation) and may influence mortality . Even if its actual incidence is unknown, cardiac dysfunction is a leading cause of weaning failure. Although echocardiography allows the noninvasive assessment of cardiac function and LV filling pressures, its clinical value in the setting of ventilator weaning has yet to be determined. The aim of the present work was to evaluate the ability of transthoracic echocardiography (TTE) to detect the effects of spontaneous breathing trial (SBT) on central hemodynamics and to identify predictive indices of cardiac-related weaning failure. This study was conducted on 40 patients on mechanical ventilation admitted to The Critical Care Department of Alexandria Main University Hospital and to intensive care unit in Gamal Abdel Naser Hospital in Alexandria-Egypt. Trans thoracic echocardiography (TTE) was under taken just before and at the end of a 30-min SBT in patients fulfilling weaning criteria. Values of TTE parameters were compared between baseline (before weaning) and SBT (after weaning) in all patients. Clinical and ECHO parameters were compared between patients who succeed the weaning trial and those who failed. Ejection fraction (EF) was 50.2±4.25% before weaning and decreased significantly to 41.1±4.88% after weaning in the failure group (p=0.01). The deceleration time of the E wave of the mitral flow (DTE) decreased significantly from 178.1± 10.5 milliseconds (ms) before weaning to 160.4±10.2 ms after weaning in the failure group (p=0.042). We concluded from this study that EF and DTE could be used as predictive indices of cardiac-related weaning failure while right ventricular end diastolic area / left ventricular end diastolic area(RVEDA/LVEDA) and the pulmonary flow acceleration time did not show any predictive value. Further studies are needed to evaluate the impact of the echocardiography as a screening strategy on the weaning process and patient outcome.

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1. Introduction

Ventilatory support includes non-invasive or invasive mechanical ventilation. Non-invasive positive pressure ventilation (NIPPV) has been shown to reduce the need for intubation, decrease length of stay in the Intensive Care Unit (ICU) and may reduce mortality but it requires more careful monitoring than for invasive ventilation as well as it is not suitable for all patients in need of mechanical ventilation, e.g.: unconscious or shocked patients [(1)] .

Invasive mechanical ventilation entails the use of ventilator to assist the patient's ventilation through endotracheal or tracheostomy tube. Invasive mechanical ventilation is associated with numerous life threatening complications and it should be discontinued at the earliest possible time in the course of patient's illness [(2)]. So, weaning of patients from mechanical ventilation is one of the most challenging problems faced by physicians working in the ICU [(3)].

Weaning from mechanical ventilation is the process of abruptly or gradually withdrawing ventilator support when the cause of acute respiratory failure is under resolution [(3)].

Weaning failure remains a clinically relevant challenge because it may result in significant morbidity (prolonged duration of mechanical ventilation, re-intubation) and may influence mortality [(4, 5)].

Within the cardiovascular system, cardiac dysfunction has been flagged as a cause of failure in weaning patients off mechanical ventilation[(6-9)].

Even if its actual incidence is unknown, cardiac dysfunction is a leading cause of weaning failure [(10)].Breathing in the context of weaning was described as a physical exercise [(11)]. The abrupt cessation of positive pressure ventilation increases venous return and left ventricular (LV) afterload [(12)]. Decrease LV compliance [(7)] and may even induce cardiac ischemia which may present in the form of S-T segment changes in electrocardiogram [(13)].All these factors tend to increase LV filling pressure and may subsequently result in pulmonary edema. [(7)]

The reduction in oxygen delivery and subsequent hypoxemia seen in weaning may be due to worsening of ventilation perfusion ratios, or weaning induced pulmonary edema, especially in those with left heart disease. The hypoxemia and respiratory acidosis during weaning may cause reduction in oxygen delivery to the myocardium.[14,15]

Echocardiography is being used routinely in some intensive care units (ICUs). It permits direct observation of all cardiac structures and the patient's hemodynamics, allowing immediate intervention related to volume replacement and the use of inotropic agents. [16,17] In patients on MV, its use can explain some cardiac morphological and functional analyses that may influence weaning from MV, particularly when weaning is difficult or there is refractory hypoxemia that cannot be explained by lung disease alone[18]. Nevertheless, there are few descriptions in the literature of bedside studies of these cardiorespiratory changes during weaning from MV using echocardiography.[19,20]

2. Material and Methods

This study was conducted on 40 adult patients of both sex on mechanical ventilation and who were admitted to The Critical Care Department of Alexandria Main University Hospital and to intensive care unit in Gamal Abdel Nasser Hospital in Alexandria-Egypt. Informed consent was taken from every patient or from the next of kin as well as approval from local ethical committee.

Inclusion Criteria:

All patients mechanically ventilated for more than 48 hours are eligible if they fulfilled the following weaning criteria:

- Resolution of the acute episode for which the patient was placed on ventilator.
- Pressure support ventilation ≤12.
- Adequate cough.
- Stable cardiovascular status (heart rate ≤120/min, systolic blood pressure ≥90 mmHg and lower than 160 mmHg).
- Adequate oxygenation (partial pressure of arterial oxygen (PaO_2)/fraction of inspired oxygen (FiO_2) ≥150).
- PEEP ≤8 cmH_2O.
- Adequate pulmonary function (respiratory rate ≤35 breathes/min, tidal volume > 5 mL/kg, no significant respiratory acidosis).
- No sedation or stable neurological status.

Exclusion criteria:

Patients are ineligible if:

- They are not in sinus rhythm.
- Have atrioventricular conduction abnormalities.
- They have a pace-maker.
- An apical four-chamber view is not possible to obtain.
- The intensivist experienced in echocardiography is unavailable.

The aim of the present work was to evaluate the ability of transthoracic echocardiography (TTE) to detect the effects of spontaneous breathing trial (SBT) on central hemodynamics and to identify predictive indices of cardiac-related weaning failure.

A) Patient selection:

All patients in the study were subjected to the following:

1. History:

- Personal data: name, age, gender and occupation.
- Drug history.
- Past history of cardiac, pulmonary and neurological diseases.
- Smoking.
- Detailed information for the cause of respiratory failure.

2. Clinical examination: complete physical examination was done with emphasis on:

- Vital signs; (Blood pressure, Heart rate and rhythm, Temperature and Respiratory rate).
- Oxygenation status (e.g. presence of peripheral or central cyanosis).
- Pattern of breathing (e.g. use of accessory muscles of respiration).
- Level of consciousness.
- Signs of right-sided heart failure (e.g. congested neck veins, lower limb edema).

3. Severity of illness: was assessed by Acute Physiology and Chronic Health Evaluation (APACHE) II Score. It was done on admission and before discharge from the ICU.

4. Laboratory evaluation:

- The following routine investigations were done to all patients on admission and whenever indicated during the course of the ICU stay :
  - Complete Blood Count (CBC).
  - Plasma Sodium and potassium.
  - Blood Urea and serum Creatinine.
  - SGOT, SGPT.
  - PT, PTT, INR.
- Arterial Blood Gases(ABG) was assessed using arterial blood gases analyzer(Chiron diagnostics-Model348-UK):
  - On admission.
  - Whenever indicated during the course of mechanical ventilation.
  - At time of weaning.

5. Radiological evaluation:

- Chest X-ray was done on admission and as needed.

B) Management: all selected patients were managed as follows:

1. monitoring:

All patients were monitored for the following parameters during study period:

- Vital signs: including blood pressure, heart rate, temperature and respiratory rate were recorded every two hours during the ICU stay.
- Oxygen saturation (SaO2) using pulse oximetry were continuously recorded.
- Continuous ECG monitoring and 12- lead ECG were done on admission and every 24 hours.

2. Echocardiography (study and grouping):

- TTE was under taken just before and at the end of a 30-min SBT in patients fulfilling weaning criteria. Values of TTE parameters were compared between baseline (pressure support ventilation before weaning) and SBT (after weaning) in all patients.
- Clinical and echocardiographic data were compared between the group who succeed weaning and the other group who failed.
- Echocardiography was done with an ESAOTE echocardiography with 2.5 MHz cardiac probe with pulsed, continuous and color-coded Doppler.

C) Measurements:

TTE was initially performed in a patient under pressure support prior to the disconnection from the ventilator on a T-piece, and subsequently at the end of the SBT (i.e., before the planned extubation or before the reconnection to the ventilator required by the deterioration of respiratory status). The following parameters were recorded.

- Left ventricular ejection fraction (LVEF) using either the Simpson's rule or the M mode.
- Right ventricular (RV) and Left ventricular (LV) end-diastolic areas (EDA) were measured to calculate the RVEDA/LVEDA ratio. [21]
- The deceleration time of the E wave of the mitral flow (DTE) was measured in extending the deceleration slope from the peak wave velocity to the zero-velocity baseline[22] .
- Pulmonary flow acceleration time.

All measurements were performed in triplicate at end-expiration and averaged.

3. Results

The study was done on 40 patients who were mechanically ventilated for more than 48 hours and fulfilled the weaning criteria. 28 patients (70%) were successfully weaned while 12 patients (30%) suffered from failed weaning.

Table (1) shows Demographic data and basic characteristics of the studied patients**.** 28 patients (70%) were males and 12 (30%) were females. There was no significant stastisical difference between the success and failure group regarding the gender (p= 0.106). The age was ranging from 28 to 61 with a mean of 43.6±12.5 in the success group versus 38 to 65 with a mean of 45.6±11.85 in the failure group with no significant statistical difference between the 2 groups (p= 0.311). The age distribution of the studied group was 2 patients (5%) less than 30 years, 4 patients (10%) were from 30-40 years, 15 patients (37.5%) were from 40-50, 10 patients (25%) were from 50-60 years and 9 patients (22.5%) were aged more than 60. Regarding smoking, 13/28 patients of the studied population who succeed weaning were smokers versus 6/12 in the failure group with no significant statistical significant difference between the 2 groups (p=0.112). Regarding the past history of cardiac problems, 4 patients (10%) were suffering from mild ischemia controlled on oral medications with no past history of previous admissions with acute coronary syndrome or coronary catheterization. Two of them succeed in weaning while the other two failed (p=0.098). The APACHE II score was 18.11±2.71 in the success group versus 17.98±2.64 which did not show an statistical value (p=0.226).

Regarding the vital signs of the patients (table 2). Both groups (success and failure weaning) showed significant rise in their heart rate , both systolic and diastolic pressure during spontaneous breathing trial. Heart rate was 82.5±6.02 before weaning and increased to 87.6±5.98 after weaning (p= 0.036) in the success group while it was 81.5±5.85 and increased to 94.7±5.22 (p=0.0152) in the failed weaning group. Systolic blood pressure increased from 115.5± 4.25 to 122.5± 6.25 (p=0.041) in the success group and from 112.6 ±5.25 to 128.7± 5.98(p= 0.015) in the failure group. Also, diastolic blood pressure increased significantly from 78.9 ±5.98 before weaning to 85.2± 6.25 after weaning in the success group (p=0.025) and increased from 80.1 ±5.85 to 96.1±7.01 in the failure group(p=0.004). while the basic values before weaning of heart rate, systolic and diastolic pressures did not differ significantly between the success and failure group (p>0.05). Significant difference was noticed in the values post weaning between the 2 groups. The p values were (p=0.001, p=0.013, p=0.0012) respectively for the heart rate, systolic blood pressure and diastolic blood pressure. As regards the oxygen saturation it was 98.0±0.36 in the success group before weaning and it increased to 99.0±0.08 after weaning while it was 98.2±0.12 before weaning and increased to 99.1±0.41 after weaning in the failure group. There was no any significant statistical difference between the readings of oxygen saturation before and after weaning in both groups and no difference also between the failure and success weaning in all readings (p1 >0.05 and p2 >0.05).

Regarding echocardiographic parameters (table3), Ejection fraction (EF%) (figure 1) was 51.2±6.27 before weaning and decreased significantly to 47.1±6.11 after weaning in the success group (p=0.021). While it was 50.2±4.25 before weaning and decreased to 41.1±4.88 after weaning in the failure group (p=0.01). No significant statistical difference in the baseline values before weaning between both groups (p>0.05) while a significant decrease in the EF% in the failure group in comparison with the success group after weaning was noticed (p=0.031).

RVEDA/LVEDA was 0.5211±0.068 in the successful weaning group before weaning and it was 0.53±0.041 after weaning with no significant statistical difference (p=0.103). In the failure to wean group the RVEDA/LVEDA was 0.548±0.033 before weaning and 0.549±0.025 after weaning with no significant difference (p=0.36). Also, no significant difference was noticed while comparing the two groups (p=0.098, p=0.44) before and after weaning respectively.

The deceleration time of the E wave of the mitral flow (DTE) in millisecond (figure 2) was 180.6±11.6 before weaning and it showed non-significant decrease to 178.7±9.2 after weaning in the success group (P>0.05) while the DTE decreased significantly from 178.1± 10.5 before weaning to 160.4±10.2 after weaning in the failure group (p=0.042). The baseline value of DTE did not show significant difference between the two groups before weaning (p>0.05) but significantly lower value was recorded in failure group post weaning (p=0.048). The pulmonary flow acceleration time in millisecond was 102.6±24.2 before weaning in the success weaning group and it decreased to 95.6±8.98 post weaning (p>0.05), also non-significant decrease in the failure group was recorded from 108.6±9.65before weaning to 101.3±11.2 after weaning (p>0.05). No statistical significant difference was noticed between the success and failure group regarding The pulmonary flow acceleration time in both pre and post weaning readings (p>0.05).

Table (1): Demographic data and basic characteristics of the studied patients.

	Success patients ("n=28/40")		Failed patients ("n=12/40")		P
	No.	%			
Sex					
Male	20	71.4	8	66.7	
Female	8	28.6	4	33.3	0.106
Age					
< 30	2	7.1	0	0.0	
30 – 40	2	7.1	2	16.7	
40 – 50	10	35.7	5	41.7	
50 – 60	7	25.0	3	25.0	
60 or more	7	25.0	2	16.7	
Range	28 – 61		38 - 65		
Mean	43.6		45.6		0.311
S.D.	12.5		11.85		
Smoking					
Yes	13	46.4	6	50.0	0.112
No	15	53.6	6	50.0	
Past history of Cardiac diseases	2	7.1	2	16.7	0.098
APACHE II	18.11±2.71		17.98±2.64		0.226

Table (2): Vital signs before and after weaning in success and failed weaning patients.

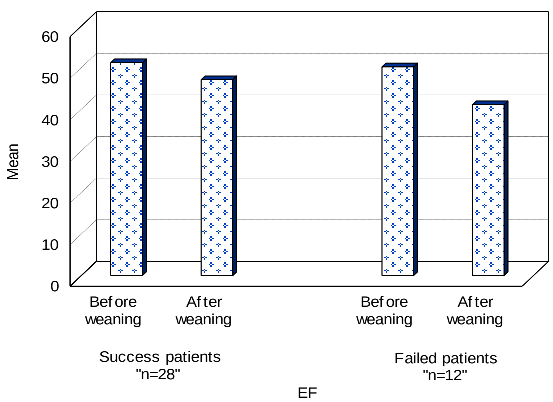
	Success patients ("n=28/40")		Failed patients ("n=12/40")	
	Before weaning	After weaning	Before weaning	After Weaning
Heart rate(bpm)	82.5±6.02	87.6±5.98	81.5±5.85	94.7±5.22
P1	0.036*		0.0152*	
P2			>0.05	0.001*
Systolic blood pressure (mmhg)	115.5±4.25	122.5±6.25	112.6±5.25	128.7±5.98
P1	0.041*		0.015*	
P2			>0.05	0.013*
Diastolic blood pressure(mmhg)	78.9±5.98	85.2±6.25	80.1±5.85	96.1±7.01
P1	0.025*		0.004*	
P2			>0.05	0.0012*
Oxygen saturation(%)	98.0±0.36	99.00±0.08	98.2±0.120	99.1±0.41
P1	>0.05		>0.05	
P2			>0.05	>0.05

P1 comparison between vital signs before and after weaning in the same group (success or failed weaning)
P2 comparison between the vital signs in the success and failure groups both before weaning and after weaning.

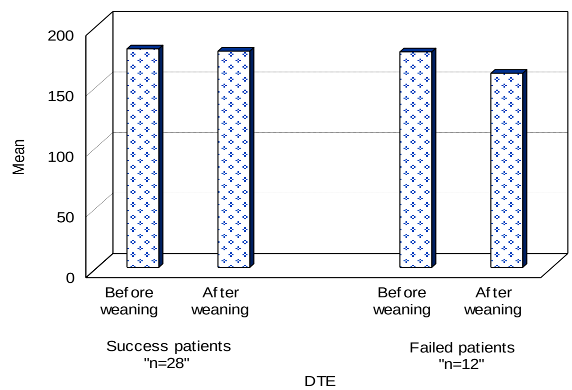
Table (3): ECHO parameters before and after weaning in success and failed patients.

	Success patients "n=28"		Failed patients "n=12"	
	Before weaning	After weaning	Before weaning	After Weaning
1- EF(%)	51.2±6.27	47.1±6.11	50.2±4.25	41.1±4.88
P1	0.021*		0.01*	
P2			>0.05	0.031*
2- RVEDA(mm^2)	26.4±3.08	24.6±2.19	22.6±3.11	26.5±3.01
P1	0.013*		>0.05	
P2			>0.05	0.041*
3- LVEDA(mm^2)	37.8±2.69	42.2±3.22	38.1±3.25	39.5±3.11
P1	0.042*		>0.05	
P2			>0.05	0.01*
4- RVEDA/LVEDA Ratio	0.5211±0.068	0.53±0.041	0.548±0.033	0.549±0.025
P1	0.103		0.36	
P2			0.098	0.44
5- DTE(ms)	180.6±11.6	178.7±9.2	178.1±10.5	160.4±10.2
P1	>0.05		0.042*	
P2			>0.05	0.048*
6- Pulmonary flow acceleration time(ms)	102.6±24.2	95.6±8.98	108.6±9.65	101.3±11.2
P1	>0.05		>0.05	
P2			>0.05	>0.05

P1 comparison between ECHO data before and after weaning in the same group (success or failed weaning)
P2 comparison between ECHO data in the success and failure groups both before weaning and after weaning.



Figure(1): Ejection fraction (EF) before and after weaning in successful and failed weaning groups



Figure(2): deceleration time of E wave (DTE) before and after weaning in successful and failed weaning groups

4. Discussion

Regarding the basic characteristics and demographic data of the patients included in this study, the results showed no significant differences between the baseline status of both the successfully weaned patients (28/40) and the patients who failed in their weaning trial (12/40) regarding the age, sex, past history of smoking, past history of serious cardiac problems and APACHE II score.

The vital signs measurements showed a nearly similar baseline readings when the patients were on mechanical ventilation, while a significant rise in the heart rate and blood pressure was shown in the successfully weaned patients (p=0.036), the group who failed weaning showed a more significant rise in these data (p=0.0152). This can be explained as SBT resulted in a significant increase in heart rate and in cardiac output well-reflecting the greater work of breathing which has been compared with a true exercise, the observed rise in systolic arterial pressure was consistent with greater LV after loading.(11) Positive pressure ventilation decreases both left ventricular preload and after load. Hence while on positive pressure ventilation (PPV), theoretically the left ventricular performance may improve. Hence abrupt weaning can result in both increased cardiac demand and workload on heart(23).

There was no significant changes regarding the oxygen saturation in both groups before and after weaning. This can be simply explained as the fraction of inspired oxygen (FIO2) was titrated to keep the patients secured, away from the deleterious effects of hypoxia through maintaining the same level of arterial oxygen saturation which means that these almost equal readings did not reflect similar clinical conditions rather than an adjusted therapeutic intervention.

The ejection fraction had almost the same values when the patients were on positive pressure ventilation in both groups: 51.2±6.27 in the success group versus 50.2±4.25 in the failure group. But a significant drop happened in the failure group after discontinuation of mechanical ventilation. This results are consistent with the study done by Caille et al [20] which showed an ejection fraction of 51% in the successfully weaned patients versus 36% in the failure group (p= 0.04) . Physiological changes associated with the transition from MV to spontaneous breathing involve an overload of the cardiorespiratory system: increased venous return (preload), increased LV afterload, increase in O2 consumption from 15% to 25% and increased secretion of catecholamines. In patients with preexisting heart disease (coronary artery disease and LV insufficiency), these physiological changes associated with spontaneous breathing can trigger LV failure, which in turn may lead to respiratory failure and unsuccessful weaning.[3,11]

Moreover, In patients with or without coronary artery disease, spontaneous breathing can cause increased oxygen demand, increased cardiac work and subsequent myocardial oxygen demand [24] . Myocardial ischemia has been demonstrated in 22% of those who are weaning failures. This may also be secondary to increased oxygen demand of the respiratory muscles, leading to increased skeletal muscle blood flow with possible risk of critical organ hypo perfusion[25]

RVEDA/LVEDA did not show a significant change in the two groups both before and after weaning. This was in agreement with Caille et al [20] study, as the RV/LV end-diastolic area was similar prior to and at the end of the SBT. This presumably reflects the absence of SBT-induced pulmonary hypertension in the study population, which comprised a low proportion of COPD patients.

DTE did not show significant difference between the two groups before weaning (p>0.05) but significantly lower value was recorded in failure group post weaning (p=0.048). In Caille et al [20] study, DTE was 170 milliseconds in the success group versus 138 in the failure group (p=0.07). In keeping with our results, Mekontso-Dessap and colleagues found that circulating BNP was significantly increased in patients under PS/PEEP who finally failed the weaning process, as a result of an overloaded LV.[26] Similar data was shown in Schifelbain[27] study where DTE was 215±61 in the successful weaning versus 198±35 in the failure group.

No statistical significant difference was noticed between the success and failure group regarding The pulmonary flow acceleration time in both pre and post weaning readings (p>0.05). This can be explained by the non-selective pattern of the patients in the study as we did not categorize patients with COPD with suspected right ventricular failure and pulmonary hypertension, another reason beyond the non-specific reading of the pulmonary flow acceleration time is that the initial measurements were done on pressure support ventilation. However, Pulmonary artery pressures may be increased by weaning due to hypoxemia, acidosis or tachypnoea induced dynamic hyperinflation with compression of alveolar vessels.[12]

We concluded from this study that EF and DTE could be used as predictive indices of cardiac-related weaning failure while RVEDA/LVEDA and the pulmonary flow acceleration time did not show any predictive value. Even in the absence of history of serious cardiac illness or clinical evidence of heart decompensation, subtle ischemic changes may happen in mechanically ventilated patients and hinder weaning. Further studies are needed to evaluate the impact of the echocardiography as a screening strategy on the weaning process and patient outcome.

After assessing the cardiac element in weaning failure and after correcting or excluding other causes of weaning failure like acidosis, infection, hypoxemia etc, the cardiac problem may be managed pharmacologically . Excess LV preload may be corrected with diuretics. Nitrates are also useful when pulmonary edema is secondary to increase in LV preload or myocardial ischemia. When LV after load increase is the cause, vasodilators may be used.

As limitations of this study, we have to consider that the number of patients evaluated was small. In addition, no severe ischemic heart disease or heart failure patients were included, which may explain the absence of ischemia and cardiac dysfunction during weaning.

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