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ORIGINAL ARTICLE

Cardiac Function During Weaning Failure: The Role of Systolic & Diastolic Dysfunction

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Abstract

Background: **Patients are at risk for grave outcomes due to weaning failure and early reintubation. The most prevalent reason why an attempt to wean fails is cardiac dysfunction.**

Aim of study: **The key objectives of this prospective research is:**

To examine the connection between heart function and weaning outcomes at the beginning of the procedure and before extubation.

Patients and methods: **The study included finally 100 subject collected in critical care unit at internal medicine department in Al-Hussein university hospital from July 2019 until July 2021. Echocardiography performed, systolic & diastolic functions were measured at baseline ventilator setting and before extubation & compared to the outcome of weaning process.**

Results: **After analyzing data from 100 individuals (50%) with successful weaning and (50%) patients with unsuccessful weaning, we discovered a high correlation between diastolic dysfunction and the weaning failure group of patients (p0.01 for each).**

Conclusion: **Failure to wean is linked to a problem with left ventricular relaxation.**

Keywords: Weaning failure, Systolic dysfunction, Diastolic dysfunction

1. Introduction

Weaning is the process of reducing the mechanical ventilator's assistance for the patients so that their job of breathing increases. Evaluation of the likelihood that mechanical ventilation may be effectively stopped is the goal.[1]

Spontaneous breathing trials (SBTs), gradual reductions in the level of pressure support during pressure support ventilation (PSV), and gradual reductions in the number of ventilator-assisted breaths during intermittent mandatory ventilation (IMV) are all examples of traditional weaning techniques.[2]

A spontaneous breathing experiment is the most effective approach to assess if mechanical ventilation can be stopped. There are three different ways to accomplish this:* putting the patient on a minimum pressure support and positive end expiratory pressure (PEEP), such as 5–7 cm H2O PS/ 5 cm H2O PEEP performing mechanics; *extubating using continuous positive airway pressure (CPAP) alone; or *using a T-piece.[3]

Weaning failure has been linked to cardiogenic pulmonary edema often. The right heart catheterization was suggested as the reference technique in this case since the final diagnosis is still challenging. A spontaneous breathing test (SBT) caused the left ventricular filling pressure (LVFP), which is a major factor in weaning failure, to increase. Transthoracic echocardiography (TTE) should be utilized to determine the cardiac cause of respiratory weaning

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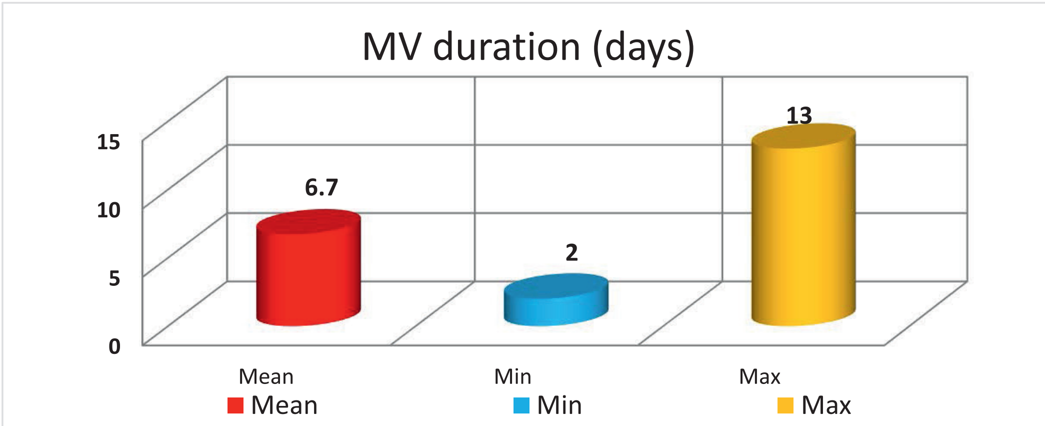

Fig. 1. Description of MV duration in all studied patients.

failure since the insertion of a pulmonary artery catheter is still an intrusive and possibly hazardous operation.[4–6]

2. Patients and methods

One hundred of patients were admitted to intensive care units and underwent mechanical ventilation at critical car unit of internal medicine departments under study of our research.

All patients of our study under go:

Full history taking, Full clinical examination including cardiac examination was done, Full laboratory examinations:-such as Complete blood count, Renal function, Liver function,PT, PTT, INR, serum electrolytes including(sodium, potassium, calcium and chloride) and Imaging: such as X-ray chest &heart and electrocardiogram.

Echocardiography was done to all patients for evaluation of cardiac state.

Patients study was classified into two groups:

Patients with successful weaning Patients with failed weaning.

A computer-driven automated weaning system was used to ventilate the patient, and the pressure support level was progressively dropped to standardize the weaning process (while maintaining the patient within a zone of respiratory comfort). Extubation was carried out as quickly as feasible once the Automated weaning system determined the patient was ready for separation, providing the patient satisfied all other known extubation requirements.

If the patient was still on ventilation and not ready for separation, a daily weaning experiment was conducted for the set of patients for whom echocardiography availability permitted serial evaluations. The low pressure support experiment was the main component of the weaning study, which ran for 30 min to 2 h.

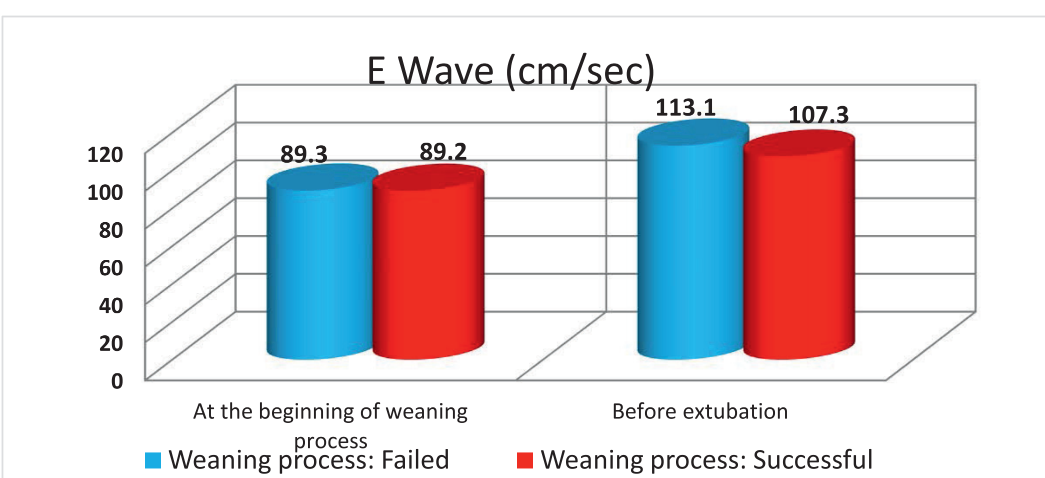

Fig. 2. Comparisons of E wave according to weaning process outcome.

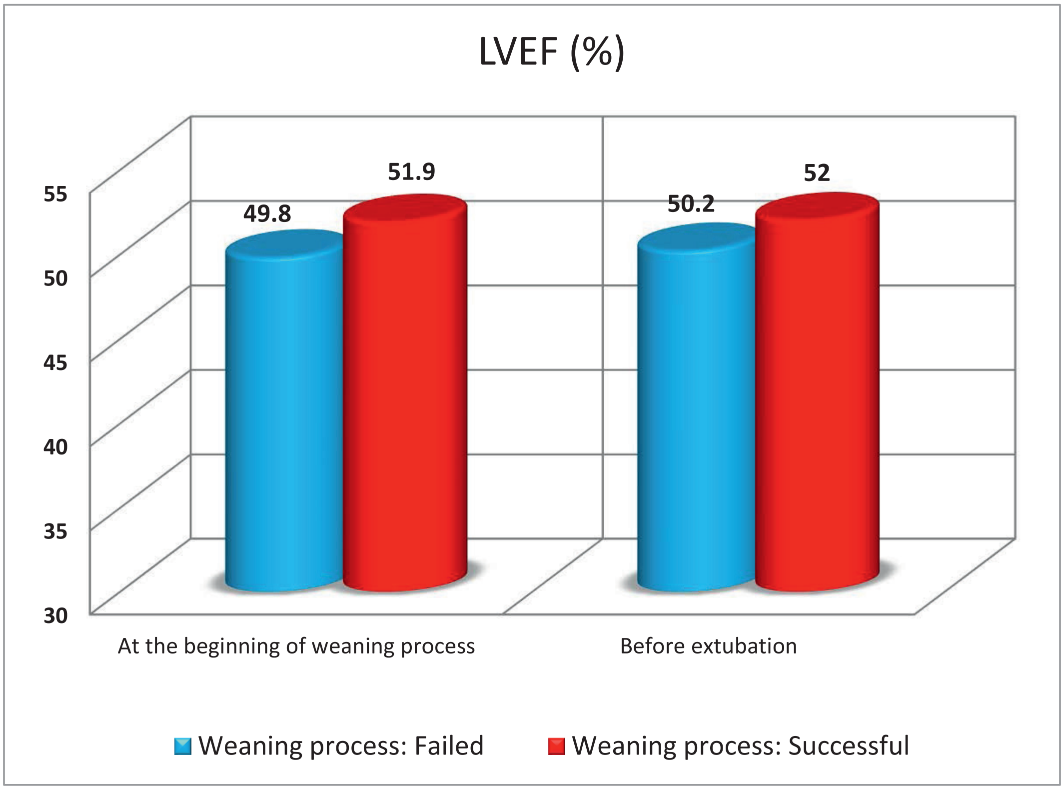

Fig. 3. Comparisons of LVEF % according to weaning process outcome.

Weaning trial failure criteria included diaphoresis and clinical symptoms of respiratory distress, as well as respiratory rate >35 breaths per minute and/or increases in accessory muscle activity, SPO_2<90%, heart rate >140 beats per minute, systolic blood pressure >200 or 80 mmHg.

Echocardiography: In all included patients ($n = 100$), echocardiography was done to assess cardiac function during baseline ventilator setting and just before before extubation. We examined in a subset of patients whether weaning trials could induce change of systolic or diastolic function, independently from their baseline function. All echocardiographic examinations were done by a single trained operator using a transthoracic ultrasound device.

With the patient in a semi-recumbent position, the following echocardiographic views were examined: four chamber and two chamber long axis views to assess left ventricle ejection fraction, computed from

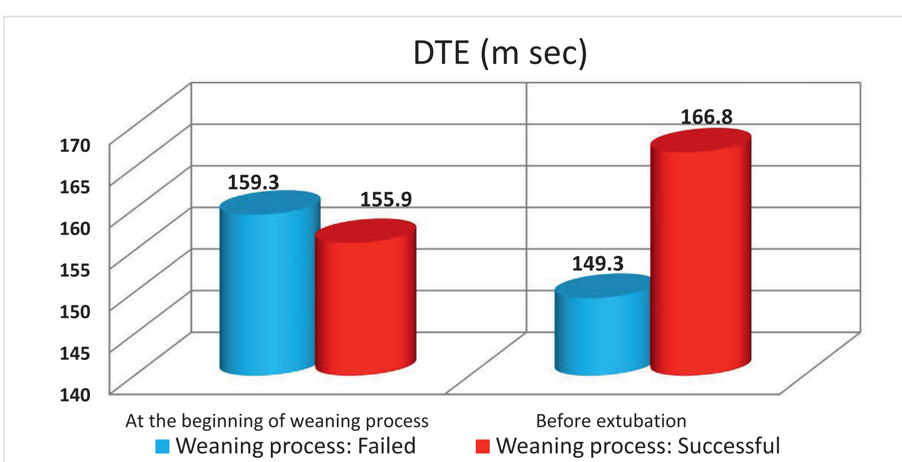

Fig. 4. Comparisons of DTE according to weaning process outcome.

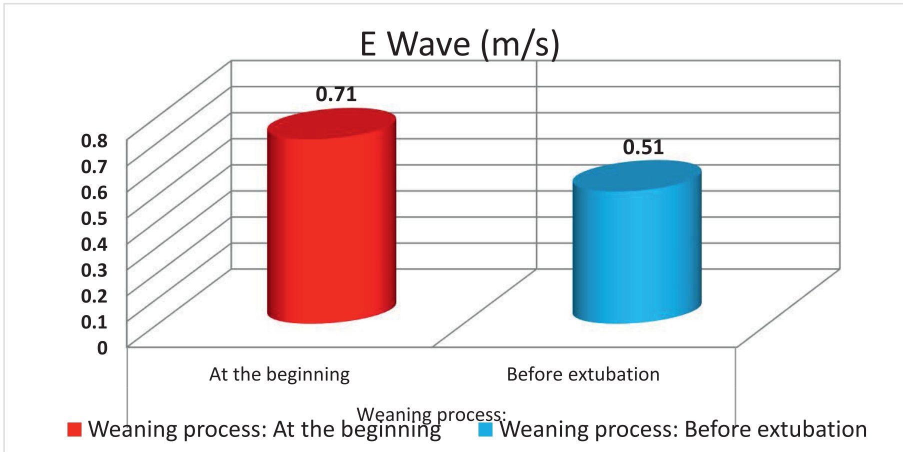

Fig. 5. Comparisons of E wave according to time weaning process.

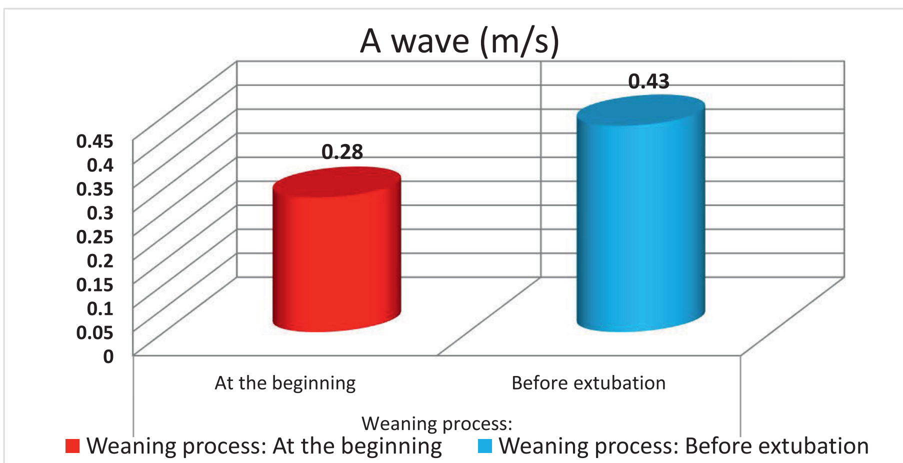

Fig. 6. Comparisons of A wave according to time weaning process.

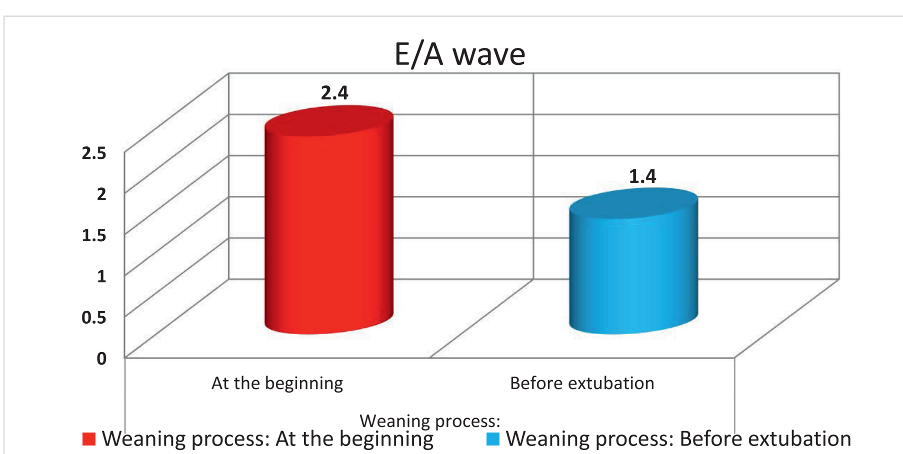

Fig. 7. Comparisons of E/A wave according to time weaning process.

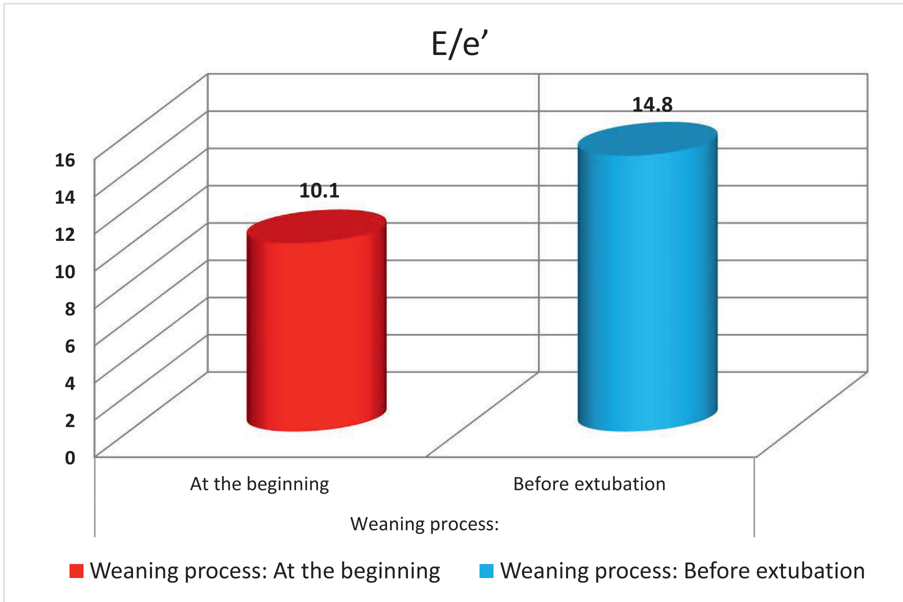

Fig. 8. Comparisons of E/e’ wave according to time weaning process.

LV volumes using the bi-plane Simpson method when image quality was suitable, or visually estimated when poor image quality did not allow sufficient identification of the endocardium. LVEF<50% was used to identify systolic dysfunction. The 2016 European Society of Cardiology guidelines (LVEF50% with plasma BNP concentration >35 pg/mL and (E/e’ ratio 13 or e’ 9) and (E/e’ ratio 13 or e’ 9) were used to define isolated diastolic dysfunction (with preserved LVEF). However, since there isn't a single, widely agreed-upon definition, we also evaluated the following definitions as a sensitivity analysis: LVEF 50% and (E/e’>8 or e’/a’ ratio 1), LVEF 50%, E/e’ >8 and plasma BNP concentration >200 pg/mL. Using S′ waves and e’ waves, respectively, the dynamics of LV contractility and relaxation during weaning trials were evaluated. Digital copies of the echocardiography images were kept. Over a minimum of three cardiac cycles, all measurements were averaged (five to ten in case of non-sinus rhythm).

Inclusion criteria: were those allowing early weaning in patient receiving mechanical ventilation for less than 24 h.

Exclusion criteria; pregnancy, known allergy to furosemide or sulfonamides, cerebral edema, mythenia gravis, acute inflammatory poly radiculo neuropathy, decision to withdraw life support and

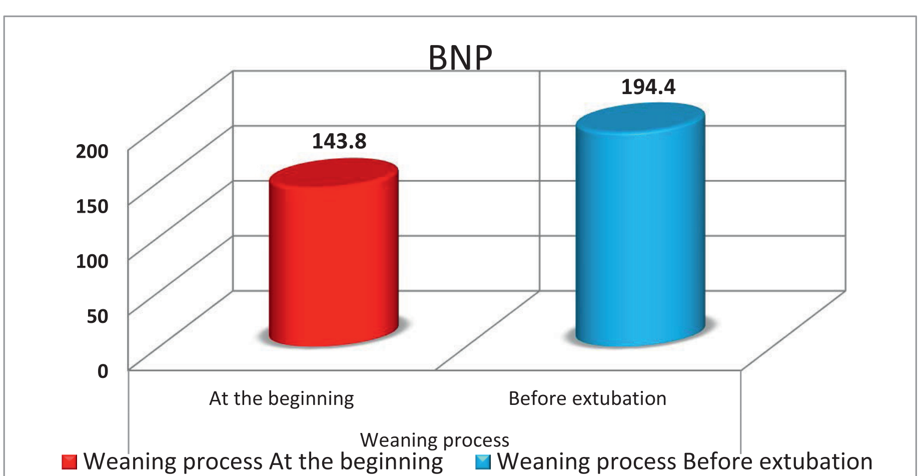

Fig. 9. Comparisons of BNP according to time weaning process.

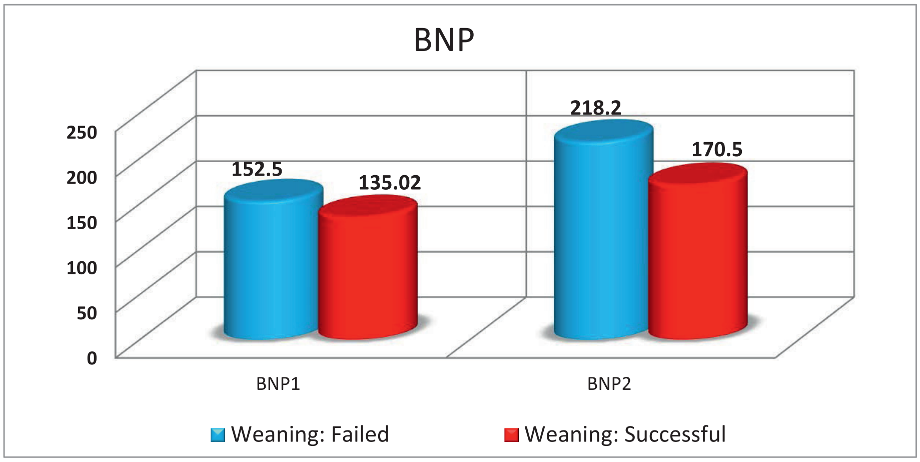

Fig. 10. Comparisons of plasma BNP according to weaning process outcome.

prolonged cardiac arrest with poor neurological prognosis.

2.1. Statistical analysis of data

Data were analyzed using Statistical Program for Social Science (SPSS) version 24. Quantitative data were expressed as mean ± SD (for normally distributed data) and median (IQR) (for abnormally distributed data). Qualitative data were expressed as frequency and percentage.

Probability (*P* value)

- *P* value < 0.05 was considered significant.
- *P* value < 0.001 was considered highly significant.
- *P* value > 0.05 was considered insignificant.

Ethics and patient consent

All procedures will follow Al-Azhar University Ethical committee regulations, and patient consent will be taken from all patients.

3. Results

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Table 1. Comparisons of demographic data according to weaning process outcome.

		Weaning process				Stat. test	P value
		Failed ($N = 50$)		Successful ($N = 50$)			
Age (years)	Mean	67.8		67.1		MW = 1166	0.562 NS
	±SD	7.8		12.5			
Sex	Male	30	60%	35	70%	$X^2 = 1.09$	0.295 NS
	Female	20	40%	15	30%		
DM	No	31	62%	27	54%	$X^2 = 0.65$	0.418 NS
	Yes	19	38%	23	46%		
HTN	No	26	52%	24	48%	$X^2 = 0.16$	0.689 NS
	Yes	24	48%	26	52%		
COPD history	No	37	74%	35	70%	$X^2 = 0.19$	0.656 NS
	Yes	13	26%	15	30%		
MV duration (days)	Mean	6.8		6.6		MW = 1179.5	0.624 NS
	±SD	2.7		2.9			

MW: Mann Whitney U tests. X^2: Chi-square test. NS: p value > 0.05 is considered non-significant.
This table shows no statistical significant difference (p value > 0.05) between patients with failed weaning process and patients with successful weaning process as regard demographic data (age, sex, DM, HTN, COPD history and MV duration).

Table 2. Comparisons of TTE according to time weaning process.

		Weaning process		MW	P value
		At the beginning (N = 100)	Before extubation (N = 100)		
E Wave (m/s)	Mean	0.71	0.51	3091.5	<0.001 HS
	±SD	0.08	0.24		
A wave (m/s)	Mean	0.28	0.43	1779.5	<0.001 HS
	±SD	0.05	0.14		
E/A wave	Mean	2.4	1.4	2450.5	<0.001 HS
	±SD	0.7	1.0		
E/E'	Mean	10.1	14.8	937	<0.001 HS
	±SD	1.5	3.0		

MW: Mann Whitney U tests. HS: p value < 0.001 is considered highly significant.

This table shows:

Highly statistical significant (p value < 0.001) decreased E wave before extubation (0.51 ± 0.24) when compared with the beginning of weaning process (0.71 ± 0.08).

Highly statistical significant (p value < 0.001) increased A wave before extubation (0.43 ± 0.14) when compared with the beginning of weaning process (0.28 ± 0.05).

Highly statistical significant (p value < 0.001) decreased E/A wave before extubation (1.4 ± 1.0) when compared with the beginning of weaning process (2.4 ± 0.7).

Highly statistical significant (p value < 0.001) increased E/e' before extubation (14.8 ± 3) when compared with the beginning of weaning process (10.1 ± 1.5).

Table 3. Comparisons of BNP according to time weaning process.

		Weaning process		MW	P value
		At the beginning (N = 100)	Before extubation (N = 100)		
BNP	Mean	143.8	194.4	2485	<0.001 HS
	±SD	22.6	53.3		

MW: Mann Whitney U test. HS: p value < 0.001 is considered highly significant.

This table shows highly statistical significant (p value < 0.001) increased plasma BNP before extubation (194.4 ± 53.3) when compared with the beginning of weaning process (143.8 ± 22.6).

Table 4. Multivariate logistic regression analysis for factors predictive of weaning process outcome in studied patients.

		B	SE	p value	Odds	95% CL	
Age		- 0.006	0.019	0.765	0.99	0.95	1.03
Sex		- 0.44	0.42	0.296	0.64	0.28	1.47
DM		- 0.32	0.4	0.418	0.71	0.32	1.59
HTN		0.16	0.4	0.689	1.17	0.53	2.5
COPD history		- 0.19	0.44	0.656	0.82	0.34	1.96
MV duration		- 0.029	0.071	0.684	0.97	0.84	1.11
At start of weaning	Arterial pH	- 0.7	3.2	0.831	0.49	0.001	311.8
	PAO_2/FIO_2	0.003	0.006	0.655	1.0	0.99	1.01
	PCO_2	- 0.027	0.02	0.187	0.97	0.93	1.01
	RR	0.07	0.056	0.208	1.07	0.96	1.19
	O_2 sat.	0.0	0.06	1.0	1.0	0.87	1.14
	HR	- 0.008	0.017	0.620	0.99	0.96	1.02
	Mean BP	- 0.083	0.04	0.038	0.92	0.85	0.99
	E wave	1.15	2.4	0.632	3.1	0.02	349
	A wave	5.3	4.3	0.216	219.4	0.04	115511
	E/A	- 0.035	0.29	0.906	0.9	0.54	1.71
	E/e'	- 0.03	0.13	0.784	0.96	0.74	1.25
	LEVF	0.043	0.029	0.140	1.04	0.98	1.1
	DTE	- 0.008	0.01	0.413	0.99	0.97	1.01
Before extubation	Arterial pH	- 1.15	3.7	0.762	0.31	0.0	539.7
	PAO_2/FIO_2	0.01	0.006	0.120	1.01	0.99	1.02
	PCO_2	- 0.21	0.023	0.367	0.97	0.93	1.02
	RR	- 0.001	0.041	0.984	0.99	0.92	1.08
	O_2 sat.	0.015	0.71	0.831	1.01	0.88	1.16
	HR	- 0.017	0.012	0.159	0.98	0.96	1.0
	Mean BP	−0.06	0.029	0.037	0.94	0.89	0.99
	E wave	2.8	0.89	0.002	16.4	2.8	95.8
	A wave	- 3.2	1.5	0.03	0.04	0.002	0.72
	E/A	0.59	0.2	0.004	1.8	1.2	2.7
	E/e'	- 0.3	0.07	<0.001	0.73	0.63	0.85
	LEVF	0.036	0.028	0.204	1.03	0.98	1.09
	DTE	0.045	0.012	<0.001	1.04	1.02	1.07
Hb		0.077	0.11	0.516	1.08	0.85	1.36
Creat		0.058	0.31	0.851	1.06	0.57	1.94

(*continued on next page*)

Table 4. (continued)

B: Regression coefficient, SE: Standard error, CL: Confidence interval.

Using multivariate logistic regression analysis, this table demonstrates that the following factors were predictive for weaning process outcome:

Mean BP at the start of weaning (B = − 0.083, SE = 0.04, P = 0.038, odds = 0.92 & 95% CL = 0.85−0.99).

Mean BP before extubation (B = − 0.06, SE = 0.029, P = 0.037, odds = 0.94 & 95% CL = 0.89−0.99).

E wave before extubation (B = 2.8, SE = 0.89, P = 0.002, odds = 16.4 & 95% CL = 2.8−95.8).

A wave before extubation (B = −3.2, SE = 1.5, P = 0.03, odds = 0.04 & 95% CL = 0.002−0.72).

E/A wave before extubation (B = 0.59, SE = 0.2, P = 0.004, odds = 1.8 & 95% CL = 1.2−2.7).

E/E′ before extubation (B = − 0.3, SE = 0.07, P < 0.001, odds = 0.73 & 95% CL = 0.63−0.85).

Table 5. Comparisons of plasma BNP according to weaning process outcome.

		Weaning process		MW	P value
		Failed (N = 50)	Successful (N = 50)		
BNP1 (at the beginning)	Mean	152.5	135.02	672	<0.001 HS
	±SD	21.9	19.7		
BNP2 (Before extubation)	Mean	218.2	170.5	636	<0.001 HS
	±SD	47.7	48.1		

This table shows:

*Highly statistical significant (p value < 0.001) increased plasma BNP1 in patients with failed weaning (152.5 ± 21.9) when compared with plasma BNP1 in patients with successful weaning (135.02 ± 19.7).

*Highly statistical significant (p value < 0.001) increased plasma BNP2 in patients with failed weaning (218.23 ± 47.7) when compared with plasma BNP2 in patients with successful weaning (170.5 ± 48.1).

Table 6. Multivariate logistic regression analysis for factors predictive of weaning process outcome in studied patients.

		B	SE	p-value	Odds	95% CL	
Age		- 0.006	0.019	0.765	0.99	0.95	1.03
Sex		- 0.44	0.42	0.296	0.64	0.28	1.47
DM		- 0.32	0.4	0.418	0.71	0.32	1.59
HTN		0.16	0.4	0.689	1.17	0.53	2.5
COPD history		- 0.19	0.44	0.656	0.82	0.34	1.96
MV duration		- 0.029	0.071	0.684	0.97	0.84	1.11
At start of weaning	Arterial pH	- 0.7	3.2	0.831	0.49	0.001	311.8
	PAO2/FIO2	0.003	0.006	0.655	1.0	0.99	1.01
	PCO2	- 0.027	0.02	0.187	0.97	0.93	1.01
	RR	0.07	0.056	0.208	1.07	0.96	1.19
	O2 sat.	0.0	0.06	1.0	1.0	0.87	1.14
	HR	- 0.008	0.017	0.620	0.99	0.96	1.02
	Mean BP	- 0.083	0.04	0.038	0.92	0.85	0.99
	E wave	1.15	2.4	0.632	3.1	0.02	349
	A wave	5.3	4.3	0.216	219.4	0.04	115511
	E/A	- 0.035	0.29	0.906	0.9	0.54	1.71
	E/E′	- 0.03	0.13	0.784	0.96	0.74	1.25
	LEVF	0.043	0.029	0.140	1.04	0.98	1.1
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	PAO2/FIO2	0.01	0.006	0.120	1.01	0.99	1.02
	PCO2	- 0.21	0.023	0.367	0.97	0.93	1.02
	RR	- 0.001	0.041	0.984	0.99	0.92	1.08
	O2 sat.	0.015	0.71	0.831	1.01	0.88	1.16
	HR	- 0.017	0.012	0.159	0.98	0.96	1.0
	Mean BP	−0.06	0.029	0.037	0.94	0.89	0.99
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	A wave	- 3.2	1.5	0.03	0.04	0.002	0.72
	E/A	0.59	0.2	0.004	1.8	1.2	2.7
	E/E′	- 0.3	0.07	<0.001	0.73	0.63	0.85
	LEVF	0.036	0.028	0.204	1.03	0.98	1.09
	DTE	0.045	0.012	<0.001	1.04	1.02	1.07
Hb	0.077	0.11	0.516	1.08	0.85	1.36	
Creat	0.058	0.31	0.851	1.06	0.57	1.94	
BNP1	- 0.039	0.011	<0.001	0.96	0.94	0.98	
BNP2	- 0.019	0.004	<0.001	0.98	0.97	0.99	

Using multivariate logistic regression analysis, this table demonstrates that the following factors were predictive for weaning process outcome:
Mean BP at the start of weaning (B = − 0.083, SE = 0.04, $P = 0.038$, odds = 0.92 & 95% CL = 0.85–0.99).
Mean BP before extubation (B = − 0.06, SE = 0.029, $P = 0.037$, odds = 0.94 & 95% CL = 0.89–0.99).
E wave before extubation (B = 2.8, SE = 0.89, $P = 0.002$, odds = 16.4 & 95% CL = 2.8–95.8).
A wave before extubation (B = −3.2, SE = 1.5, $P = 0.03$, odds = 0.04 & 95% CL = 0.002–0.72).
E/A wave before extubation (B = 0.59, SE = 0.2, $P = 0.004$, odds = 1.8 & 95% CL = 1.2–2.7).
E/E′ before extubation (B = − 0.3, SE = 0.07, $P < 0.001$, odds = 0.73 & 95% CL = 0.63–0.85).
BNP1 (B = − 0.039, SE = 0.011, $P < 0.001$, odds = 0.96 & 95% CL = 0.94–0.98).
BNP2 (B = − 0.019, SE = 0.004, $P < 0.001$, odds = 0.98 & 95% CL = 0.97–0.99).

Observations	Incidence	Characteristics	Patients (N)	Author
The E/e' ratio and SOFA score were independent predictors of mortality	84%	ICU patients with sepsis and septic shock.	60	Rolando 2015
70% had grade I, 12% grade II and 18% grade III.	58%	ICU patients at admission	86	Zapata 2014
E/e' ratio was higher in the failed group (80%) than in the successful group (35%).	48%	ICU patients during weaning from MV	68	Moschietto 2012
Reduced mitral annular e' velocity was the strongest predictor of mortality.	40.4%	ICU patients with sepsis and septic shock	206	Landesberg 2012
26% had grade I (57%failed SBT) and 74% grade II –III (80% failed SBT)	54%	ICU patients during weaning from MV	50	Papanikolaou 2011

4. Discussion

By determining when the patient can rely on himself to perform spontaneous breathing, weaning outcome predictors help to avoid the needless extension of mechanical ventilation. They also help to avoid premature weaning attempts that might cause cardiovascular, respiratory, or psychological distress.[7]

In general, weaning success cannot be predicted only by mechanical breathing parameters since they do not account for cardiac readiness and reserves. In order to help the wean team, it is vital to look for methods that can evaluate heart function.[8]

The majority of critical care units are using echocardiography more often as the most prevalent noninvasive technique for unbiased hemodynamic evaluation. Transthoracic echocardiography (TTE) should be done to determine the cardiac cause of respiratory weaning failure, according to mounting evidence.

The current research set out to assess how well TTE might be used to foretell when critically sick patients will be unable to successfully wean themselves off of artificial ventilation. One hundred adult patients of both sexes who had been hospitalized to the critical care unit at Al-Hussein University Hospital were the subjects of the current research.

The population under study was split into groups that had successful and unsuccessful weaning outcomes. The TTE measures of the two groups were contrasted. Age, gender, reason for ICU hospitalization, and the purpose and length of MV were consistent among the groups under study. However, the unsuccessful weaning group had a much higher prevalence of concurrent illnesses, such as diabetes and hypertension.

As measured by pulsed wave Doppler early (E) and late (A) diastolic wave velocities at the mitral valve and tissue Doppler early (E) and late (A′) diastolic wave at the lateral mitral valve annulus, we discovered that there is a significant increase in filling pressures with altered ventricular relaxation. On the other hand, there is no significant change in systolic function (as assessed by LVEF & plasma BNP concentration).

This is in line with the findings of Filippo, 2021,[9]who discovered that isolated diastolic dysfunction was linked to a delay in weaning and that increased filling pressures with impaired left ventricular relaxation may be a major factor in weaning trial failure. As a screening test, other methods such brain natriuretic peptides are helpful.

Routine echocardiography can help to identify early stages of diastolic dysfunction, and repeated echocardiography throughout the ICU stay could help to adjust the therapy and improve the prognosis of our patients. Siddiqui et al. study ‘s from 2012[9] studied the risk factors for prolonged postoperative MV defined DM as one of the risk factors.

Incidence of diastolic dysfunction in critically ill patients as regard previous studies:

4.1. Conclusion

Isolated diastolic dysfunction & rising BNP was associated with a prolongation of weaning. Increased filling pressures with left ventricle relaxation impairment may be a key mechanism of weaning trial failure Fig. 1–10 and Tables 1–6.

Ethics

The research procedure was authorized by the ethics review board of Al-Hussein University Hospital and the Al-Azhar University.

No donor provided any financial or moral support for this study, which might have influenced or adversely affected the study's findings.

Disclosure

The authors have no financial interest to declare in relation to the content of this article.

Authorship

All authors have a substantial contribution to the article.

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Conflicts of Interest

There are no conflicts of interest.

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