DOI: https://doi.org/10.53350/pjmhs20221612884

ORIGINAL ARTICLE

The Association of Weaning Outcome with Left Ventricular Diastolic Dysfunction in Critically Ill Patients

BUSHRA ZAFAR[1], FAKHIR RAZA HAIDRI[2], NAZIA ARAIN[1], HAFIZ WAHAJ FATMI[3], RAMESH KUMAR[1], SUPRINKA RAHEJRA[4]
[1]FCPS (Medicine), Fellow, Critical Care Medicine, SIUT
[2]FCPS (Medicine), MCPS (Pulmonology), Associate Professor (Critical Care Medicine), SIUT
[3]FCPS (Cardiology), Fellow, Critical Care Medicine, SIUT
[4]MBBS, Resident Medical Officer, Critical Care Medicine, SIUT
Corresponding author: Bushra Zafar, Email: dr.bushranoman@gmail.com, Cell: 03343872672

ABSTRACT

Objectives: The aim of this study is to investigate the correlation between left ventricular diastolic dysfunction and successful weaning from mechanical ventilation in patients who are critically ill.

Methods: An observational study was conducted at the ICU of the Sindh Institute of Urology and Transplantation (SIUT) in Karachi from April 2022 to December 2022. Essential baseline features including age, gender, duration of hospital stay, and ICU admission were documented using a predetermined proforma. Throughout the spontaneous breathing trial (SBT), hemodynamic evaluation was performed and recorded. Furthermore, respiratory and echocardiography parameters during the SBT trial as well as weaning results were documented.

Results: The research involved 103 participants, with the majority being male. Among the 40 individuals who had diastolic dysfunction, there was a noteworthy occurrence of weaning failure in 29 patients (72.5%) which was found to have statistical significance (p=0.004). Additionally, a significant correlation between LV diastolic dysfunction and in-hospital mortality (p=0.003) was discovered. In addition, an extended duration of mechanical ventilation exceeding five days significantly corresponded with LV diastolic dysfunction (p=0.007).

Conclusion: The results of our study provide additional proof to reinforce the importance of left ventricular diastolic dysfunction in predicting weaning failure from mechanical ventilation. This discovery can help medical professionals understand better how monitoring a patient's cardiac function during weaning is crucial, particularly with critically ill individuals. By recognizing the significance of LV diastolic dysfunction in this context, doctors and nurses can take proactive measures to monitor and treat any potential issues.

Keywords: Weaning outcome, Left ventricular diastolic dysfunction, critically ill patients

INTRODUCTION

The patient must be weaned from mechanical ventilation as soon as possible [1]. Failure to wean is a challenge for intensive care physicians, twenty to thirty percent of weaning attempts are unsuccessful [2]. Failure to wean is correlated with prolonged ICU admission and mortality, making its prognosis crucial [3].

Many diagnostic indicators and algorithms, including clinical, respiratory, and laboratory variables, have been presented in the past to predict weaning success from mechanical ventilation.[4] Yet, effective weaning continues to be a challenge for intensive care physicians.

Several factors play a role in weaning outcomes including hemodynamic alterations, cardiac dysfunction, and diaphragmatic dysfunction.[5] Cardiac dysfunction is more common in extubation failure, and weaning-induced pulmonary edema has been documented in 60% of extubation failures. [5-7] Negative intrathoracic pressures and sympathetic overstimulation determine an unfavorable left ventricle loading condition and increase left ventricular (LV) afterload, thereby impairing left ventricular (LV) compliance and causing LV diastolic dysfunction (LVDD) following cessation of positive-pressure ventilation [7]. With an increase in venous return, these occurrences may increase LV filling pressures and cause pulmonary edema. [8, 9]

Earlier research suggested that LVDD may be a significant disadvantage of weaning[10]; however, previous studies have produced inconsistent results. Patients with known heart disease, who are potentially at high risk for weaning failure due to pulmonary venous congestion, comprised the study population[11, 12] pre-extubation LV systolic dysfunction, not diastolic dysfunction, predicts weaning failure, contrary to what other research indicates.[13]

Nonetheless, the role of LVDD in the ICU context is less clear. Optimizing mechanical ventilation is one of the most challenging tasks in critically ill patients with LVDD.

Due to its non-invasive nature and ease of administration, Ultrasonography is an ideal screening tool that can be conveniently performed at the bedside. Previously, it was not possible to check LVDD before initiating the weaning trial because portable ultrasound devices were not available. [14] However, with recent advancements in medical technology, tissue Doppler echocardiography has made it feasible to determine left ventricular function prior to giving a spontaneous breathing trial. Doppler echocardiography has emerged as one of the most effective clinical techniques for diagnosing LVDD. This technique utilizes Doppler indices of left ventricular filling and pulmonary venous flow not only for diagnostic purposes but also for establishing prognosis and assessing the effectiveness of therapeutic therapies.[15] The objective of this study was to investigate the correlation between diastolic dysfunction of the left ventricle and weaning outcome in critically ill patients who require mechanical ventilation. By exploring this relationship, healthcare professionals may gain new insights into how best to approach patients on ventilators with diastolic dysfunction issues.

MATERIALS AND METHODS

A prospective observational design was utilized in this study. Non-probability consecutive sampling was used to select participants. The study was conducted in the ICU of Sindh Institute of Urology and Transplantation (SIUT) in Karachi, and it was aimed to be conducted from April 2022 until the sample size was completed.

In terms of sample selection, inclusion criteria were as follows: participants of either gender, age >18 years, all mechanically ventilated patients for >48 hours, and patients who fulfilled predetermined criteria for undergoing a spontaneous breathing trial (SBT). Exclusion criteria included individuals with known neuromuscular disease, pregnancy, those with naso-facial, esophageal, or other gastrointestinal abnormalities, ineligibility of echocardiographic study (poor echo window, irregular rhythm, HR >120 beats/min, non-sinus rhythm), and those who underwent a tracheostomy before or during weaning. Exclusion criteria applied in the study did not include patients with severe mitral regurgitation, mitral stenosis, or a prosthetic mitral valve since the validity of E/e' for assessing LVFP in such individuals had not been established.

After approval from the ethical review board attendants of all patients meeting the inclusion criteria will be approached for written and informed consent (attached appendix 1).

All enrolled patients who are on mechanical ventilation > 48 hrs, who have an improvement in breathing status on low-level pressure support ventilation will undergo transthoracic echocardiography. During this period, the patient will be observed for signs of respiratory distress.

Echocardiography was performed by a cardiologist. We used Toshiba xario 200 ultrasound machines with inbuilt cardiac calculation software. A phased array cardiac probe will be used to perform examinations with a frequency of 3-7 MHz. A thorough examination of the heart using different views such as parasternal long-axis view (PLAX), parasternal short axis view (PSAX), Cardiac 4 or 5 chamber views, and subxiphoid view was conducted. To record transmitral flow velocities including peak early diastolic E and peak late diastolic A, the pulsed-wave Doppler technique was used. The mitral valve tips from the apical 4-chamber view were used to place the sample volume. Tissue Doppler imaging (TDI) was also utilized in the apical 4-chamber view to obtain peak early diastolic mitral annular (e') velocity. All of these measurements were taken at the end of expiration. Finally, based on these measurements, E/A ratio and the transmitral inflow E wave to mitral annular e' (E/e') were computed.

Once the ethical review board granted approval, medical attendants approached all patients who met the requirements for inclusion. These patients were then asked to provide written and informed consent. The study enrolled patients who had been on mechanical ventilation for more than 48 hours and showed signs of improved breathing with low-level pressure support ventilation. Following this, transthoracic echocardiography was conducted on these patients to assess their heart function. Throughout the observation period, diligent monitoring of any respiratory distress exhibited by the patients was carried out as well.

Echocardiography was performed by a cardiologist using Toshiba xario 200 ultrasound machines with inbuilt cardiac calculation software. A phased array cardiac probe was used to perform examinations with a frequency of 3-7 MHz. During the medical examination, the standard echocardiography was carried out utilizing various views such as parasternal long-axis view (PLAX), parasternal short axis view (PSAX), Cardiac 4 or 5 chamber views, and subxiphoid view. Pulsed-wave Doppler method was utilized to record the transmitral flow velocities including peak early diastolic E and peak late diastolic A. The sample volume was placed at the mitral valve tips from the apical 4-chamber view. Tissue Doppler imaging (TDI) was used to obtain peak early diastolic mitral annular (e') velocity in the apical 4-chamber view. All of these measurements were taken at the end of an expiratory period. The E/A ratio along with transmitral inflow E wave to mitral annular e' (E/e') value were calculated to further evaluate cardiovascular function and overall heart health status.

LV diastolic dysfunction was evaluated in accordance with specific criteria. Patients displaying the following characteristics on Echocardiography were identified as having LVDD[20]: a Septal e′ reading of less than 7 cm/s or a lateral e′ reading of less than 10 cm/s; and an Average E/e′ reading greater than 14. Weaning failure, on the other hand, was defined as an unsuccessful spontaneous breathing trial (SBT) or the need for reintubation within 48 hours following extubation.[20] A patient was deemed to have had a successful SBT if they exhibited no indications of respiratory distress (including O2 saturation below 95%, respiratory rate over 35/min, heart rate over 150/min, systolic blood pressure over 180 mm Hg or below 90 mm Hg), no worsening of consciousness level, and/or no onset or exacerbation of discomfort.[19]

The SBT procedure persisted for a duration ranging from 30 to 60 minutes, after which patients who did not exhibit any indications of respiratory discomfort were deemed eligible for extubation. If the SBT proved to be unsuccessful, patients were reverted back to control mode and subjected to another attempt the following day. Ultimately, the decision regarding extubation or continuation of mechanical ventilation was at the discretion of the physician in charge.

"Weaning success was defined as the group of individuals who passed the initial spontaneous breathing trial (SBT) without any need for reintubation within 48 hours.[17] The SBT is considered a weaning test that determines a patient's ability to be safely extubated.

In cases where critically ill adults need to be liberated from mechanical ventilation, the Official American College of Chest Physicians/American Thoracic Society Clinical Practice Guideline has offered a recommendation. Instead of using a T-piece for SBT (spontaneous breathing trial), the guideline suggests the use of inspiratory pressure with low-level pressure support. The recommended range for this pressure support is approximately 5-8 cmH2O. This approach is believed to be more effective in helping patients recover their natural breathing rhythm and avoid complications during the weaning process. The use of this technique can also potentially reduce the risk of reintubation, which can lead to further complications and extended hospital stays. Therefore, it is important for healthcare providers to consider this guideline when deciding on the appropriate method for liberating mechanically ventilated patients who are critically ill.[18]

Baseline characteristics such as age, gender, duration of hospital, and ICU stay were collected in a predefined proforma. Hemodynamic assessment was done throughout the SBT trial and recorded during SBT every 30 minutes intervals. Respiratory and echocardiography parameters during the SBT trial were recorded.

All the data was entered and analyzed in SPSS version 26.0. Quantitative variables (like age, body mass index, APACHE score, SOFA score, CPOT score, fluid balance, Ultrafiltration volume, number of SBT attempts, laboratory parameters, and echocardiography parameters) were reported as mean (SD) or median (IQR) depending upon normality. The frequencies and percentages of qualitative variables such as gender, comorbidities, patient category, reason for intubation, Glasgow Coma Scale (GCS) score, patient outcome, Spontaneous Breathing Trial (SBT) outcome, Weaning outcome, and Confusion Assessment Method for Intensive Care Unit (CAM-ICU) were reported. Categorical variables were analyzed using the Chi-square/Fisher exact test to establish any associations between them. Similarly, quantitative variables between groups were compared using the Mann-Whitney test. The Chi-square test was conducted to assess the association between Left Ventricular Diastolic Dysfunction (LVDD) and weaning failure. Furthermore, multivariable logistic regression was employed to determine the correlation between weaning success and failure.

RESULTS

The study consisted of 103 patients, out of which 63 (61.17%) were males. The average age of the patients was 42.98 ± 6.42 years. 31 patients were overweight (30.10%), 20 (19.42%) patients were obese. 29 (28.16%) patients had diabetes mellitus, and 54 (52.43%) patients had hypertension (Table 2).

Table 1: Patient Characteristics (n = 103)

Variable	Mean ± SD
Age in years	42.98 ± 6.42
Severity Score	
- APACHE II SCORE	10.39 ± 7.43
- SOFA SCORE	10.39 ± 7.65
HEMODYNAMICS (0 MINUTES)	
- SBP (mmHg)	121.67 ± 18.89
- DBP (mmHg)	75.87 ± 15.00
- MAP	89.15 ± 13.33
- HR (beats/min)	98.35 ± 13.82
- RR (per min)	21.83 ± 5.30
HEMODYNAMICS (30 MINUTES)	
- SBP (mmHg)	123.76 ± 19.28
- DBP (mmHg)	89.33 ± 95.28
- MAP	89.46 ± 13.13

- HR (beats/min)	100.46 ± 14.85
- RR (per min)	24.39 ± 6.04
HEMODYNAMICS (60 MINUTES)	
- SBP (mmHg)	126.78 ± 21.22
- DBP (mmHg)	80.48 ± 14.45
- MAP	92.83 ± 16.77
- HR (beats/min)	103.38 ± 19.40
- RR (per min)	6.87 ± 8.14
Lab Parameters	
- Troponin (pg/ml)	120.65 ± 179.11
- CK-MB	30.11 ± 24.02
- Hb (gm/l)	9.18 ± 1.30
- Albumin (gm/l)	3.13 ± 0.71
ECHO parameters (during SBT)	
- LVEF (%)	54.43 ± 8.87
- E wave (cm/s)	87.97 ± 19.48
- A wave (cm/s)	76.38 ± 16.06
- Septal e' wave (cm/s)	8.72 ± 2.42
- E/e' ratio	10.96 ± 4.58
- E/A ratio	1.21 ± 0.43
- TAPSE (mm)	18.18 ± 2.74
- PASP mmHg	4.87 ± 6.35
- IVC DIAMETER (mm)	15.77 ± 2.18

The study found that 45 (43.69%) patients experienced weaning failure. Additionally, 25 (24.27%) patients died during the course of the study (Table 2).

Table 2: Sociodemographic, clinical parameters and outcomes of patients

Parameters	N (%)
Gender	
Female	40 (38.83%)
Male	63 (61.17%)
BMI Categories	
Underweight	7 (6.80%)
Normal weight	45 (43.69%)
Overweight	31 (30.10%)
Obese	20 (19.42%)
Diabetes Mellitus Type	29 (28.16%)
Hypertension	54 (52.43%)
COPD	4 (3.88%)
Ischemic Heart Disease	2 (1.94%)
Chronic Kidney Injury	27 (26.21%)
ESRD	18 (17.48%)
Neuromuscular Dysfunction	2 (1.94%)
Severe Pneumonia	34 (33.01%)
Metabolic Acidosis	60 (58.25%)
Septic Shock	31 (30.10%)
Postoperative	20 (19.42%)
Congestive Heart Failure	2 (1.94%)
Major Surgery	2 (1.94%)
Category Of The Patient	
Medical	65 (63.11%)
Surgical	38 (36.89%)
Weaning Outcome	
Fail	45 (43.69%)
Success	58 (56.31%)
Patient Outcome	
Death	25 (24.27%)
Discharged	78 (75.73%)

Out of the total of 40 patients with diastolic dysfunction, weaning failure occurred in 29 (72.5%) and this correlation was statistically significant (p=0.004) (Table 3).

Table 3: Association between LV diastolic dysfunction and weaning outcome

	LV diastolic dysfunction			p-value
	Yes	No	Total	
Weaning				
Failed	29 (72.50%)	16 (25.40%)	45 (43.69%)	0.004
Successful	11 (27.50%)	47 (74.60%)	58 (56.31%)	
Total	40 (38.83%)	63 (61.17%)		

A noteworthy correlation was discovered between LV diastolic dysfunction and in-hospital mortality (p=0.003). The incidence of death was found to be higher among patients with LV diastolic dysfunction, with 16 (40.00%) patients dying as compared to 9 (14.29%) patients without this dysfunction. Overweight individuals had a greater probability of experiencing diastolic dysfunction in comparison to those with a BMI < 25 kg/m2 (p=0.004) (Table 4). A duration of MV that exceeded five days was also significantly associated with LV diastolic dysfunction (p=0.007) (Table 4).

Table 4: Association of LV diastolic dysfunction with sociodemographic and clinical parameters

Parameters	LV diastolic Function		P-value
	Yes	No	
Gender			
Male	20 (50.00%)	43 (68.25%)	0.063
Female	20 (50.00%)	20 (31.75%)	
BMI Category			
Underweight	2 (5.00%)	7 (11.11%)	0.004
Normal weight	11 (27.50%)	36 (57.14%)	
Overweight	20 (50.00%)	13 (20.63%)	
Obese	7 (17.50%)	7 (11.11%)	
Age			
Age<25	4 (10.00%)	13 (20.63%)	0.156
Age>25	36 (90.00%)	50 (79.37%)	
Category patient			
Medical	29 (72.50%)	36 (57.14%)	0.115
Surgical	11 (27.50%)	27 (42.86%)	
Length of stay			
LOS < 5	7 (17.50%)	11 (17.46%)	0.995
LOS > 5	33 (82.50%)	52 (82.54%)	
Duration of mechanical ventilation			
less than 5	18 (45.00%)	45 (71.43%)	0.007
Greater than 5	22 (55.00%)	18 (28.57%)	
Patient Outcome			
Death	16 (40.00%)	9 (14.29%)	0.003
Discharged	24 (60.00%)	54 (85.71%)	

DISCUSSION

The current findings of our research demonstrate that in 72.5% of patients with LV diastolic dysfunction, weaning failure occurred, which is a significant correlation. Our results align with the findings of several studies mentioned in the references.[22-25]

A study conducted by Papanikolaou et al.[22] emphasizes the role of LV diastolic dysfunction in weaning from mechanical ventilation. This is a significant finding as it indicates that incomplete recovery of cardiac output resulting from LV diastolic dysfunction may contribute to weaning failure, which can prolong hospitalization and increase healthcare costs. Furthermore, Suárez et al. [23] also recognize the importance of diastolic dysfunction in critically ill patients and its potential to impact outcomes in patients with sepsis, heart failure, and acute respiratory distress syndrome (ARDS). The authors suggest that LV diastolic dysfunction may lead to the development of ARDS, which requires extended ventilator support and has high mortality rates. Another study by Saleh and Vieillard-Baron [24] further supports this claim by discussing the role of diastolic dysfunction in the pathogenesis of weaning failure. This demonstrates how understanding the mechanisms behind LV diastolic dysfunction can improve patient care through early identification and intervention to prevent weaning failure and other complications associated with critical illness.

In a detailed analysis conducted by Sanfilippo et al. [25], it was found that echocardiography parameters, particularly those related to the left ventricle's diastolic dysfunction, could be used to predict weaning failure. This finding highlights the crucial role of transthoracic echocardiography in evaluating cardiac function and detecting potential problems during the process of weaning from mechanical ventilation. These results are significant since they provide healthcare professionals with a valuable tool for identifying patients who may experience difficulties during weaning or require

more intensive monitoring. Therefore, regular assessments of cardiac function using echocardiography should be considered an essential part of the medical management plan for patients undergoing mechanical ventilation who are being weaned off it.

A recent research conducted by Cavefors et al. [26] sheds light on the relationship between isolated diastolic dysfunction and higher mortality rates in critically ill patients. According to the study, if left unaddressed, this condition might lead to adverse outcomes. The authors recommend that healthcare professionals should prioritize screening for diastolic dysfunction in critically ill patients and take appropriate measures to manage it effectively. By doing so, they can potentially improve the patients' chances of survival and better their overall health outcomes.

In this study, a notable correlation between LV diastolic dysfunction and mortality within the hospital setting (p=0.003) was also explored. Diastolic dysfunction pertains to the decreased ability of the left ventricle to relax during diastole, which culminates in augmented filling pressures and decreased cardiac output.

The research findings have uncovered a crucial correlation between LV diastolic dysfunction and prolonged mechanical ventilation. The study has revealed that patients experiencing diastolic dysfunction may encounter increased filling pressures and reduced cardiac output, which ultimately makes it arduous for them to breathe naturally on their own. This can be explained by the fact that diastolic dysfunction impedes the blood flow into the lungs, causing a domino effect leading to respiratory distress. Therefore, early diagnosis of LV diastolic dysfunction could help prevent prolonged mechanical ventilation in patients with heart conditions or those at risk of developing one.

Clinicians must assess the left ventricular (LV) diastolic function of patients undergoing weaning from mechanical ventilation to ensure successful outcomes. Poor LV diastolic function can hinder the process of weaning, and hence, healthcare professionals are advised to modify the weaning protocol or provide additional hemodynamic support as required. However, more research is necessary to determine the optimal management approach for patients with diastolic dysfunction undergoing mechanical ventilation weaning. Therefore, healthcare practitioners should exercise caution and individualize their treatment decisions considering unique clinical circumstances of such patients.

CONCLUSION

In conclusion, our findings provide further evidence to support the significance of LV diastolic dysfunction in weaning failure from mechanical ventilation. The current findings highlight the importance of identifying and managing diastolic dysfunction in critically ill patients to improve outcomes. These findings sheds light on the importance of regular monitoring of cardiac function in critically ill patients, particularly those undergoing weaning from mechanical ventilation.

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