ECHOCARDIOGRAPHIC INSIGHTS OF WEANING FAILURE: PREDICTION & PERSPECTIVES

Naumovski F[1]

[1]University Clinic for Traumatology, Orthopedics, Anesthesiology, Reanimation, Intensive Care and Emergency Department – Skopje, Department for Anesthesia, Reanimation and Intensive Care - Skopje

Abstract

It has been reported that around 20-30% of mechanically ventilated patients will develop weaning failure. Since the causes of weaning failure could be diverse, a structured ABCDE approach was developed in order to deal successfully with such patients. Cardiac dysfunction as a reason for weaning failure will be discussed in this article, as well as the role of point of care echocardiography in detection and treatment guidance. Regarding the process of switching patients from positive pressure ventilation to spontaneous breathing, few cardiopulmonary interactions occur with potential of failing especially in patients with cardiac and pulmonary comorbidities. It is well known that in every patient with cardiac dysfunction the level of SvO2 is expected to be lower than 50%. Systolic disfunction is less frequent cause of weaning failure and could be diagnosed by simple measurement of MAPSE or LV FAC. On the contrary, diastolic dysfunction is the leading cause for weaning failure from cardiac origin precipitated by the elevating of preload and afterload by the spontaneous respiration. Diastolic disfunction could be easily assessed by measuring the E/A ratio using transmitral PW Doppler and measuring e' using septal tissue doppler. Calculation of E/e' ratio produces a value of Left Atrial Pressure (LAP) which could be converted in Pulmonary Capillary Wedge Pressure (PCWP) by using the equitation of Nageh. Measuring a high E wave, low e' wave and a higher E/e' ratio were strongly associated to a diastolic disfunction in a patient that was difficult to wean. Performing echocardiography before and during a spontaneous breathing trial should be a mainstay for ruling out the weaning failure risk because of cardiac dysfunction. Higher values for E/e' showing high left ventricular filling pressures in patients who are difficult to wean suggest that diastolic dysfunction lies in the essence of weaning failure.

Key Words: *Diastolic disfunction , Point of Care Echocardiography, Weaning Failure.*

Introduction

Weaning failure has been defined as an experiencing spontaneous breathing trial failure or a need of reintubation within 48 hours of an extubation a previously mechanically ventilated patient (1). Regardless the cause weaning failure has been associated with significant morbidity and mortality related to long lasting positive pressure mechanical ventilation (2). Weaning failure etiology could be diverse and in most of the cases multifactorial including different pathophysiological pathways that disable the patient to be weaned off successfully.

Since termination of positive pressure ventilation and transition to spontaneous breathing initiates complex physiologic cardio-pulmonary interactions while reaching homeostasis, this could be a source of multiple cardiac disturbances in patients with already known or not yet established diagnosis of underlying cardiac disease. Termination of mechanical ventilation leads to a greater right ventricular preload while negative intrathoracic pressures at the end of inspiration generate greater left ventricular afterload. Both, elevated preload and afterload with the increased sympathetic activity and work of breathing lead to significantly greater myocardial oxygen consumption due to the need of increased contractility as a response to the myocardial stretch. Increased preload and afterload in combination with increased work of breathing could lead to marked elevation of pulmonary artery occlusion pressure clinically manifesting as a Weaning Induced Pulmonary Oedema (WiPO). All physiological happenings which are demanded by the switch of positive pressure ventilation to spontaneous breathing are compared to an exercise stress test for the cardiovascular system by Pinsky MR. et al. (3). Despite many pathophysiological events that could be involved in the development of weaning failure, so far, the central role plays the elevation of the preload and the afterload initiated by the negative intrathoracic pressure which could have deleterious effects over the previously diseased heart which myocardium is not ready to meet the body needs.

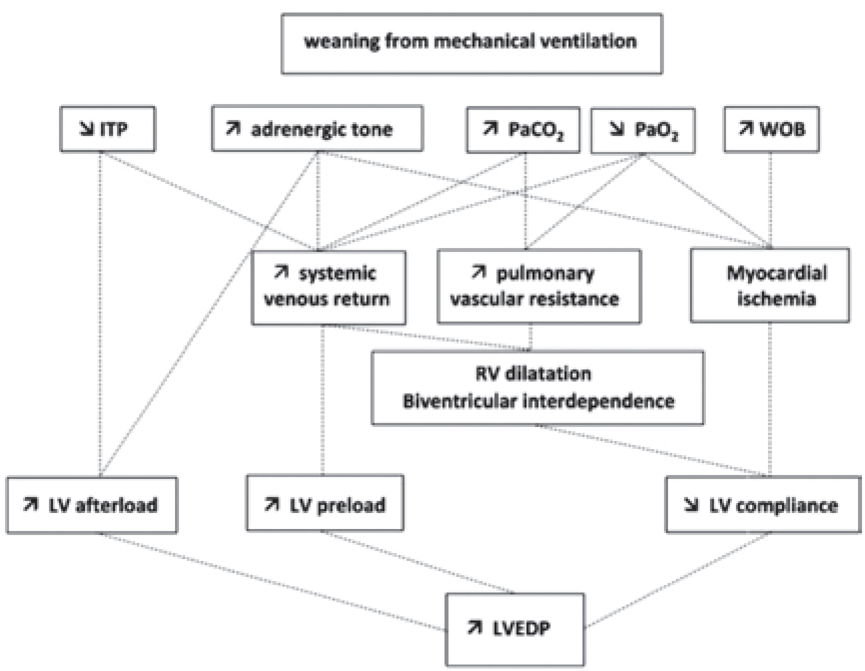

Figure 1. Pathophysiology of weaning failure.

Regarding the cause of weaning failure, many studies highlight the importance of cardiac competence and existing cardiac diseases as a main reason why some patients are difficult to wean, and others are not. Therefore, according to Boles JM et al. cardiovascular dysfunction is a leading cause for weaning failure (1), while in 42% of all patients that failed to be weaned properly, heart failure was found to be the underlying cause (4). Evidence for WiPO was found in 59% of the patients in the study of Liu J. et al. where cardiac comorbidities and COPD were identified as an independent risk factor (5). Despite comorbidities, Liu J et al. has identified that the presence of negative passive leg raising test was associated to development of WiPO (8) which means that positive hydration balance in critically ill patients contributes to developing weaning failure.

Establishing a WiPO diagnosis demands right heart catheterization, in order Pulmonary Artery Occlusion Pressure to be assessed and measured, and values above 18mmHg are considered as a cut off value in terms of confirming the diagnosis (6). Nowadays, WiPO has been diagnosed non-invasively using transthoracic echocardiography, cardiac biomarkers and measuring extravascular lung water. Therefore, critical care echocardiography and lung ultrasound are the mainstay in diagnosing the cause and mechanism of weaning failure. According to Teboul JL., assessment of LV diastolic function is far more important than LV systolic function when talking about the cardiac origin of weaning failure (7) appointing the importance of preserved left ventricular compliance as a key to successful transition from positive pressure ventilation to a spontaneous breathing. Assessment of LV diastolic function could be easily done in 4 chamber view of the heart with measuring the transmitral Pulse Wave Doppler velocity, where we can distinguish two waves: E (early diastole) and A (atrial kick). The first, E wave is important when assessing diastolic function in combination with E' or e' which are measured using Tissue Doppler, measuring these variables at the level of the mitral ring at lateral and septal position respectively.

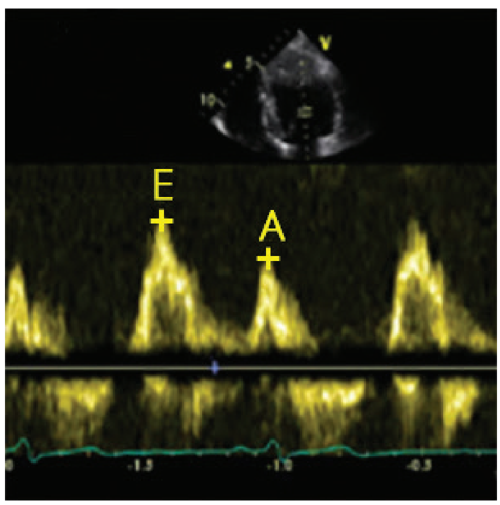

Figure 2. Assessment of transmitral flow and measuring E (early diastole) & A (atrial kick).

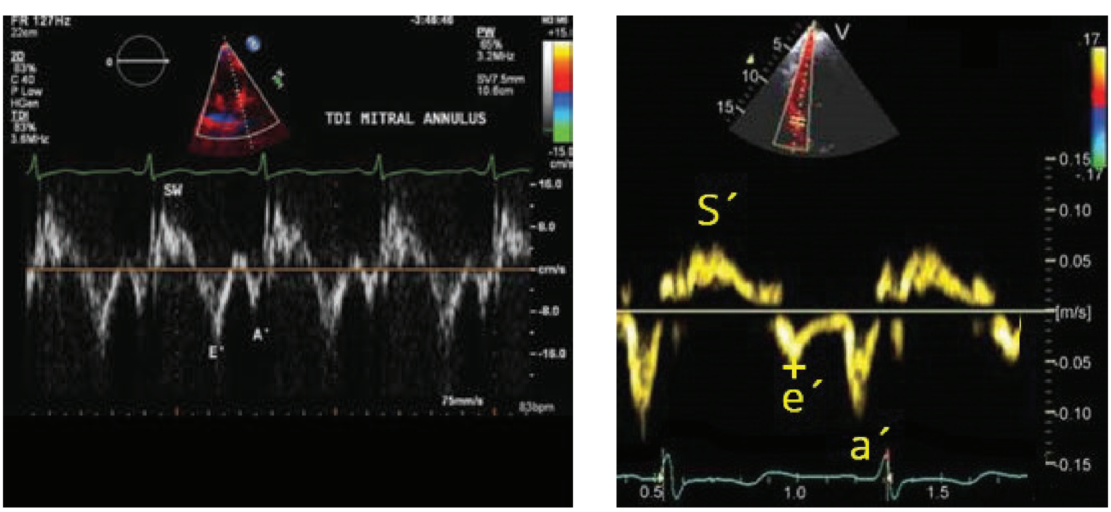

Figure 3 and 4. Tissue Doppler trace of lateral E' and septal e'.

According to the literature, measuring the E/E' and E/e' indexes is useful in assessment of LV filling pressures. E/E' is considered as normal when the values measured are below 8 which is confirming PAOP lesser than 18mmHg (8). Therefore, higher values for E/E' and E/e' indexes suggest higher LV filling pressures and LV diastolic dysfunction. Patients exhibiting a higher E/E' before the beginning of the weaning, or with incremental trend during the spontaneous breathing trial, will develop weaning failure (9,10). In the metanalysis of Almeida CA it was confirmed that higher baseline levels of E/E' before weaning starts, as well as developing higher E/E' indexes during the weaning process, were strongly associated with weaning failure (11). Since values of E/E' and E/e' represent the left ventricular filling pressures in terms of interpretation of the results of the above mentioned metanalysis increased left ventricular filling pressures suggest existing a non-compliant ventricle which stiffness could be a limitation for successful weaning. Increasing the velocity of E' during weaning process has shown association with successful weaning, while the lack of improvement of E' was associated with weaning failure (12). Hence, serial transthoracic echocardiographic exams should be performed in order to follow trending of the E' as a surrogate of left ventricular relaxation capability in terms of cardiac performance during weaning. Measurement of E' and E/E' in a time framework obviously could assess patient's readiness for weaning, as well as to predict development of its failure. De-novo wall motion abnormalities, as well as increasing of the already existing or de-novo developed mitral regurgitation, were found in patients where cardiac ischemia was present, and were identified as the underlying cause for weaning failure (13). Serial echocardiographic assessment of cardiac function was recommended in terms of screening and early diagnosis of weaning failure. The baseline examination should be done prior the start of the spontaneous breathing test, and the second examination should be performed in 15-30 minutes after starting the spontaneous breathing test (14) having in mind that cardiac failure as a reason for weaning failure will be met early on or immediately after starting spontaneous breathing test. One study has compared the modes of weaning and the frequency of weaning failure where particular modes were used, and they concluded that PSV+PEEP was superior mode of weaning versus PSV+ZEEP and T-peace in terms of weaning failure incidence. PSV+ZEEP is a better mode than T-peace, while T-peace was found to be the most associated ventilation mode with weaning failure by cardiac origin (4).

Weaning failure was more strongly associated with diastolic dysfunction rather than LV systolic function (15). Therefore, weaning failure was met in patients with higher E/e' indexes, higher E wave and lower e' wave which suggest myocardial stiffness. Elevating the values for E/e' but not E/A, was associated with weaning failure (11) which means that high left ventricular filling pressures as a result of myocardial stiffness play a crucial role in unsuccessful weaning. The importance of the diastolic function in successful weaning was once again elaborated in a study where dobutamine stress test was performed in patients difficult to wean and has revealed elevating the E/E' in those patients who failed to wean but did not change in patients where weaning was successful (16). Isolated diastolic dysfunction was more frequent in patients with weaning failure in comparison to ones with systolic dysfunction. Again, greater E/e' index as well as lowering the e' were identified to be associated with weaning failure as a sign of diastolic incompetence of the left ventricle (17).

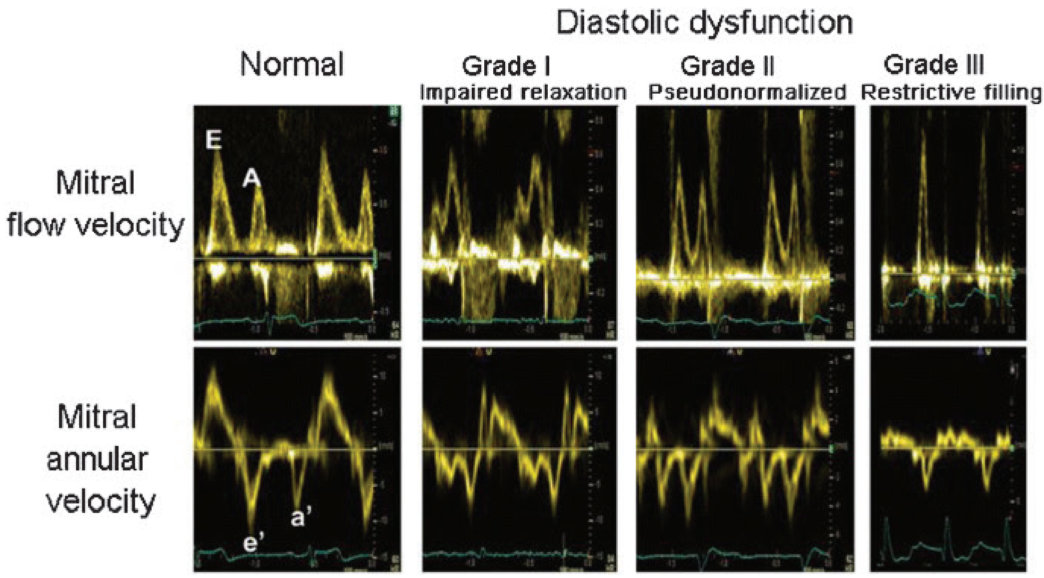

Figure 5. Doppler tracing in different stages of diastolic disfunction.

According to the all above-mentioned statements, performing a Point of Care Echocardiographic examination should be done before starting weaning due to risk detection and stratification which appoints the predictable power of estimated E/E', E/e' and E/A, but also during the spontaneous breathing trial where patients with silent diastolic disfunction will develop greater values for E/E' and E/e' due to lowering of E' and e' which will reveal myocardial stiffness and incompetence of the left ventricle to be as compliant as needed. Performing an echocardiographic examination after unsuccessful weaning will definitely help in confirming the diagnosis if there is underlying cause of cardiac origin.

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