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Research Article

Cardiac Ultrasound Assessment during Ventilator-Withdrawal Process: A Comparative Cohort Study

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Abstract

Introduction: Weaning of invasive ventilation is a major determinant of the outcome of critical patients. Screening of patients at risk of failure is a fundamental step in the weaning process. We aimed to study the cardiac changes and to detect the candidates for the weaning-acute pulmonary oedema (APO) during the weaning process using the Doppler-transthoracic echocardiography (TTE) device.

Methods: Prospective study including patients ventilated for at least 48H and ready for ventilator-withdrawal. Left ventricular ejection fraction (LVEF), cardiac output (CO), maximum velocity of E and A mitral waves and the tissue mitral annular wave E', deceleration time of E wave (DTE), difference between the pulmonary A and mitral A duration (Ap-Am), propagation velocity of mitral flow (Vp) and E/Vp were measured and compared between: pressure support ventilation (PSV: n = 53) versus T-Tube test (n = 37) in patients that succeeded and failed their ventilator-withdrawal process.

Results: T-tube test increased CO (in all patients) and decreased DTE, increased: E/E', d (Ap-Am) and E/Vp in failure group. E/A > 2, DTE < 150 ms, E/E' > 8, d (Am-Ap) > 10 ms and E/Vp > 2.5 were significantly related to the ventilator-withdrawal-induced APO with OR = 18.52, 95% CI [4.08 - 52], p = 0.01 and PPV at 92%.

Conclusion: Doppler-TTE detects the functional and hemodynamic cardiac changes induced by spontaneous breathing tests and helps to identify patients at high risk of ventilator-withdrawal-induced APO.

Keywords: *Echocardiography; Doppler; Ventilator-Withdrawal; Acute Pulmonary Oedema*

Abbreviations

MV: Mechanical Ventilation; ICU: Intensive Care Unit; LV: Left Ventricle; RV: Right Ventricle; APO: Acute Pulmonary Oedema; PCWP: Pulmonary Capillary Wedge Pressure; TTE: Trans Thoracic Echocardiography; PSV: Pressure Support Ventilation; FiO_2: Inhaled Oxygen Fraction; SpO_2: Pulsed Saturation; PEEP: Positive End Expiratory Pressure; HR: Heart Rate; SBP: Systolic Blood Pressure; LVEF: Left Ventricular Ejection Fraction; SV: Stroke Volume; CO: Cardiac Output; E/A: Ratio Between Early (E) and Late (A) Diastolic Velocity Peak); DTE: Deceleration Time of the Wave E; E/E': Early Diastolic Velocity Peak (E) Divided by the Maximum Velocity of Mitral Annulus at the Onset of Diastole (E'); MF: Mitral Flow; Vp: Velocity of Propagation of the Mitral Flow; duration (Ap-Am): Difference Between Duration of the A Wave of the Pulmonary Venous Flow and the A Wave of the Mitral Flow; CI: Collapsibility Index; IVC: Inferior Vena Cava; TAPSE: Tricuspid Annular Plane Systolic Excursion; SPAP: Systolic Pulmonary Arterial Pressure; IQR: Interquartile Range; OR: Odds Ratio; 95%CI: Confidence Interval at 0.05% of Error

Background

Ventilator-withdrawal is a decisive step for intensive care unit (ICU) patient's outcome. Appropriate conduct of the weaning procedure is mandatory and it requires, primary, the assessment of the patient's breathing capacity. The purpose of this behaviour is to prevent the ventilator-withdrawal failure. Ventilator-withdrawal involves changes in the interaction between patient and ventilator. These changes add to the increase of respiratory work a stimulation of sympathetic tone and thus an increase of cardiac work and myocardial oxygen consumption [1]. This may result in a myocardial ischemia in coronary patients. Similarly, increase in oxygen demand of respiratory muscles can lead to a redistribution of blood flow to the respiratory muscles at the expense of other organs which are therefore at risk of hypo perfusion [2-5]. On the other hand, this increase in adrenergic tone contributes to an increase in venous return and afterload of the left ventricle (LV), and predispose to APO [4,5]. In these patients, ventilator-withdrawal- induced APO can be detected early and avoided by the diuretics use. Doppler- Trans thoracic Echocardiography (TTE) allows a direct examination of all cardiac structures and hemodynamic changes during ventilator-withdrawal the process.

Purpose of the Study

Our purposes were to analyze changes in cardiac function using Doppler -TTE during the 2-stage's weaning trial [pressure support ventilation (PSV) and T-tube] in the two subgroups of patients: success vs. failure in order to identify ventilator-withdrawal induced APO.

Methods

Study design

Descriptive and analytical prospective cohort study over a period of six months (February-July 2017) in the medical ICU of la Rabta center. The study was approved by the local ethics committee of la Rabta center. Since the protocol of the study was part of the routine daily practice of our unit, informed consent was not required. Patients or their legal parents were informed by participation in the study.

Patients were included, all patients older than 18 years, that required MV for at least 48 hours and considered ready for weaning.

We defined a patient ready for weaning when all these criteria were met: 1. resolution of the acute disease requiring MV, 2. Adequate oxygenation: pulsed saturation (SpO_2) > 95% under an inhaled oxygen fraction (FiO_2) < 40% and a positive end-expiratory pressure (PEEP) ≤ 8 cmH_2O, 3. Adequate cough and absence of bronchial congestion, 4. Adequate respiratory function (respiratory rate ≤ 35 cycles/min, exhaled minute volume > 5 ml/kg and absence of significant acidosis or alkalosis), 5. Stable hemodynamic status (heart rate (HR) ≤ 120/min, systolic blood pressure (SBP) greater than 90 mm Hg and less than 160 mm Hg) under low doses of vasopressors not exceeding 10 μg/kg/min, 6. Stable neurological state (Glasgow score > 13 in the absence of any sedation), 7. Nutritional and hydro-electrolytic status considered satisfactory. Poor echogenicity was the only exclusion criteria.

Study protocol

The Doppler-TTE was performed in the 2-stages of weaning: first stage; after 30 minutes of the PSV modality and second stage; after 30 minutes of the T-tube trial if the first test (PSV) was successful. The patient was placed in a semi-sitting position (45°) as recommended [6]. The PSV modality was performed with inspiratory help pressure at less than 16 cmH_2O and maximum PEEP at 8 cmH_2O. The T-tube trial was performed with oxygen flow < 6 L/min. The left ventricular ejection fraction (LVEF), cardiac output (CO), maximum velocity of the mitral waves E and A and the tissue mitral annular wave E', deceleration time of mitral E wave (DTE), difference between the pulmonary A and mitral A times [(Ap-Am) time], the Flow propagation velocity of mitral flow (Vp) and its derived ratio E/Vp were measured and compared between weaning success (n = 31) vs. failure (n = 22) and between weaning times: PSV-PEEP (n = 53) vs T-Tube test (n = 37). The right cavities and the inferior vena cava (IVC) were also examined. The Doppler-TTE examination was performed by two independent operators (AT and YT) following a training on the device and using a transthoracic ultrasound device (Hitachi Aloka - ARIETTA V60), equipped with the tissue Doppler imaging program and a phased array transducer C251 Convex 5-1 Mhz. Echocardiographic images were recorded together with the electrocardiogram. Doppler-TTE results did not influence the decision whether to progress or not.

Definitions

The ventilator-withdrawal failure was defined as the requirement to reconnect the patient to ventilator prior to completion of the T-tube test or the need for re-intubation within 48 hours of extubation. Ventilator-withdrawal failure should include at least one of the following: cyanosis, rapid decrease in $SpO_2 < 90\%$ or SpO_2 drop > 5% or appearance of respiratory distress signs, agitation and anxiety or impairment of neurological status, tachycardia > 150 beats/min or arrhythmia, SBP > 180 mm Hg or increase ≥ 20% or less than 90 mm Hg. Once the failure has been retained; blood gas, electrocardiogram, chest X-ray, troponine and pro BNP dosages were performed in order to identify the cause of failure.

A mitral flow type III or restrictive profile was evoked when E/A (ratio between early (E) and late (A) diastolic velocity peak) > 2 and DTE (deceleration time of the wave E) < 150 ms or pseudo normal profile II (1 < E/A < 2) with combined indices indicating a diastolic overload. These combined indices included: E/E' (Early diastolic velocity peak (E) divided by the maximum velocity of mitral annulus at the onset of diastole (E')) > 8, E/Vp_{MF} (Early diastolic velocity peak (E) divided by the velocity of propagation of the mitral flow) > 2.5 and d (Ap-Am) [difference between duration of the A wave of the pulmonary venous flow and the A wave of the mitral flow] > 10 [7,8]. In patients with atrial fibrillation (fusion of E and A waves): only E/E' ratio and E/Vp_{MF} were used to assess the left ventricle filling pressure.

Statistical analyses

Quantitative variables were expressed as mean and standard deviation (SD) for Gaussian distribution variables or median and interquartile distributions (Interquartile 25 - 75), and compared using the Student's t-test or the Mann-Whitney U test as appropriate. Categorical variables were expressed in percentages and compared using the Chi^2 test or Fisher's exact test where appropriate. Quantitative measurements obtained at two times: PSV and T-tube test were compared using the non-parametric Wilcoxon test for paired samples.

The association measures between the ultrasound parameters and ventilator-withdrawal induced-APO were analyzed by logistic regression and expressed as odds ratio (OR) with 95% confidence intervals (CI). These indices included: LVEF < 50%, E/A > 2, DTE < 150 ms, E/E ' > 8, duration (Ap-Am) > 10 ms, Vp MF < 45 cm/s and E/Vp MF > 2.5. The accuracy of Doppler indices to predict ventilator-withdrawal was assessed by the receiver operating characteristics (ROC) curve.

The analyzes were performed using Statistical Package for the Social Sciences (SPSS) version 20 and the level of significance was fixed at p = 0.05.

Results

During the study period, 55 patients were considered ready for weaning. Two of them were excluded and 53 patients were studied. 16 among 53 failed the PSV test and 6 among 37 (who succeeded PSV) failed the T-tube trial. Overall, 22 failures were identified, of which the weaning-APO was in cause in 14 cases (63%). No re-intubation in extubated patients was noted (Figure 1).

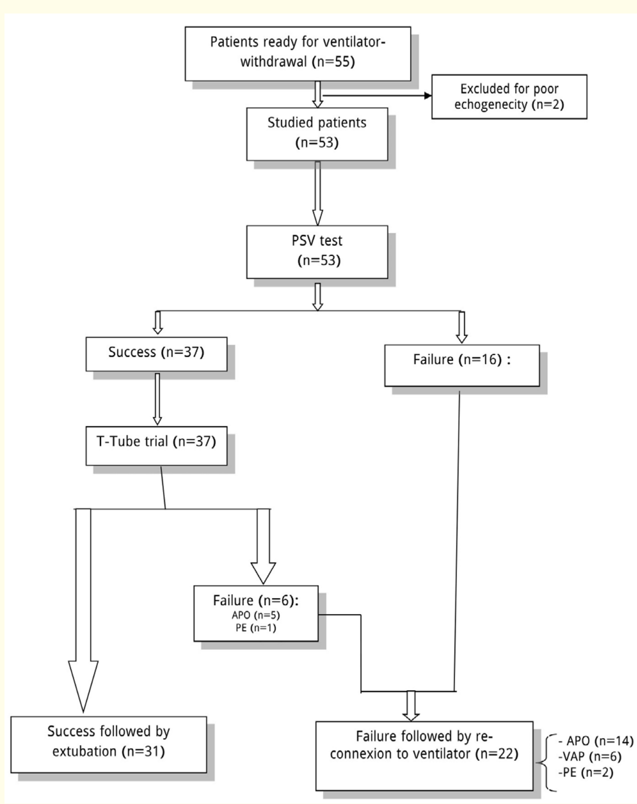

Figure 1: *Study flowchart.*

PSV: Pressure Support Ventilation; PAO: Acute Pulmonary Oedema; VAP: Ventilator Acquired Pneumonia; PE : Pulmonary Embolism.

The distribution of our population was predominantly male with a mean age at 52 years and severity scores were comparable between success and failure groups. Half of our patients were smokers, the most common underlying disease in all patients was COPD (49%) and mitral valve disease was more frequent in the failure group. ICU admission reason's was motivated by a respiratory cause in 61% of cases. The most common indication for ventilation was respiratory distress in 70%. Four patients had previously received diuretics within 48 hours of PSV. During PSV test, HR and SBP were higher in the patients of failure group. The ventilator-withdrawal failure increased length of stay, ventilator days and mortality.

All clinical characteristics displayed in table 1.

	All patients (n = 53)	**Successful weaning group (n = 31)**	**Weaning failure group (n = 22)**	**p**
Age, years (mean ± SD)	52 ± 12	50 ± 15	55 ± 18	0.32
Sex ratio (M/F)	30/23 (1.3)	16/15 (1.06)	14/8 (1.75)	0.41
SAPS II (mean ± SD)	23±10	22 ± 9	26 ± 12	0.16
SOFA (mean±SD)	5.4±2	4.7 ± 1	5.5 ± 2	0.39
Tobacco, n (%)	29 (55%)	14 (45%)	15 (68%)	0.16
Obesity (BMI > 30), n (%)	24 (45%)	11 (35%)	13 (59%)	0.07
Co morbidities, n (%):				
• Diabetes	10(19%)	5 (16%)	5 (22%)	0.5
• Hypertension,	16 (30%)	9 (29%)	7 (32%)	1
• Mitral Valve disease	6 (11%)	1 (3.2%)	5 (22.7%)	0.05
• Ischemic heart disease,	4 (7.5%)	1 (3.2%)	3 (13%)	0.29
• COPD	26 (49%)	14 (45%)	12 (54%)	0.77
• Chronic Renal failure	2 (3.8%)	1 (3.2%)	1 (4.5%)	1
Reason for admission, n (%):				
• Respiratory cause	33 (62%)	19 (61%)	14 (63%)	0.8
• Neurological cause	10 (18%)	6 (19%)	4 (18%)	1
• Metabolic cause	5 (10%)	3 (9.6%)	2 (9%)	1
• Shock	3 (6%)	1 (3.2%)	2 (9%)	0.09
• Toxic cause	2 (4%)	2 (6.4%)	0	-
Previous use of diuretics, n (%)	4 (7.5%)	2 (6.4%)	2 (9%)	0.45
Use of catecholamine, n (%):				
• Norepinephrine	3 (6%)	1 (3.2%)	2 (9%)	0.09
• Dobutamine	1 (2%)	0	1 (4.5%)	-
• Epinephrine	2 (4%)	0	2 (9%)	-
Reasons for ventilation, n (%):				
• Respiratory cause	37 (70%)	19 (62%)	18 (81%)	0.13
• Neurological cause	16 (30%)	12 (38%)	4 (19%)	0.13
Max SBP, mmHg (mean ± SD)	144 ± 16	135 ± 21	152 ± 18	0.07
Min SBP, mmHg (mean ± SD)	83.4 ± 19	80 ± 17	88 ± 22	0.65
Max HR, beat/mn (mean ± SD)	113 ± 24	101 ± 19	126 ± 21	0.03
Min HR, beat/mn (mean ± SD)	67 ± 11	66 ± 23	68 ± 14	0.98
Length of stay, days (mean ± SD)	13.5 ± 6	10.29 ± 4.82	17 ± 7.4	0.015
Ventilator days (mean ± SD)	6.5 ± 2	4.8 ± 2.06	10.9 ± 2.21	0.008
Mortality, n (%)	10 (19%)	2 (6.4%)	8 (36%)	0.011

Table 1: *Baseline Patient's characteristics.*

SD: Standard Deviation; SAPS: Simplified Acute Physiology Score; SOFA: Sequential Organ Failure Assessment Score; BMI: Body Mass Index; COPD: Chronic Obstructive Pulmonary Disease; SBP: Systolic Blood Pressure; HR: Heart Rate.

The most common failure sign was polypnea (95%). Four patients presented neurological distress signs (anxiety/agitation or even confusion). For the ventilator-withdrawal causes, APO was diagnosed in 14 patients (63%) in front of isolated electrical anomalies (n = 4) with ST-segment shift (n = 2) and epicardial ischemia (n = 2), isolated troponin elevation (n = 5), troponin elevation with electrical anomalies (n = 4) and elevation of pro-BNP (n = 1). No case of myocardial infarction was detected. For 2 patients, pulmonary embolism was diagnosed by chest- CT scan. Six cases of VAP were diagnosed in front of several arguments (fever, abundance and change of bronchial secretions, increasing of inflammatory parameters and appearance of new radiological opacities). A diaphragmatic insufficiency was considered as a participating factor of weaning failure in some cases but its identification was not easy; since we do not practice diaphragmatic electromyogram or diaphragmatic ultrasound.

Hemodynamic and Doppler-TTE modification during the T-tube test

The transition to T-trial trial increased significantly HR, SBP and CO in both successful and failure groups. The CO increase was related, mainly, to tachycardia induced by T-tube test since the SV did not change between the 2 stages of weaning.

For the weaning success group: E/A, DTE, E/E', Duration (Ap-Am), Vp MF and E/Vp MF did not change during the T-tube test compared to PSV mode.

For the failure group: E/A tends to increase without reaching statistical significance, DTE decreased considerably and E/E', d (Ap-Am) and E/Vp increased significantly. No changes in the IVC- collapsibility index and SPAP were observed (Table 2).

	PSV (n = 53)	T-Tube (n = 37)	p
HR (beat/mn), mean ± SD			
• Success	101 ± 19	108 ± 26	0.05
• Failure	126 ± 21	134 ± 23	0.02
SBP (mm Hg), mean ± SD			
• Success	135 ± 21	146 ± 10	0.014
• Failure	152 ± 18	166 ± 21	0.029
LVEF (%), mean ± SD			
• Success	62 ± 7	64 ± 5	0.12
• Failure	49 ± 10	48 ± 13	0.33
SV (ml), mean ± SD			
• Success	74 ± 24	75 ± 17	0.78
• Failure	69 ± 28	68 ± 21	0.8
CO (l/mn), mean ± SD			
• Success	6.5 ± 2.9	6.9 ± 1.8	0.009
• Failure	6.8 ± 2.5	7.1 ± 2	0.01
E/A, mean ± SD			
• Success	1.40 ± 0.57	1.42 ± 0.46	0.14
• Failure	1.61 ± 0.72	1.64 ± 0.7	0.08
DTE (ms), mean ± SD			
• Success	199 ± 73	198 ± 66	0.5
• Failure	154 ± 57	133 ± 53	$< 10^{-3}$
E/E', mean ± SD			
• Success	7.07 ± 3.5	6.8 ± 4	0.65
• Failure	9.44 ± 4.8	12.8 ± 4.5	0.007
d (Ap-Am) (ms), mean [IQR 25 - 75]			
• Success	2.25 [-12 - 17]	6.7 [-14 - 9]	0.22
• Failure	27 [17 - 38]	48 [19 - 66]	0.001
Vp MF (cm/s), mean ± SD			
• Success	55 ± 16	54 ± 9	0.9
• Failure	46 ± 13	43 ± 15	0.18
E/Vp MF, mean ± SD			
• Success	1.2 ± 0.5	1.4 ± 0.8	0.17
• Failure	2.8 ± 0.6	3.2 ± 0.5	0.025
IVC-CI (%), mean ± SD			
• Success	17 ± 13	16 ± 8	0.82
• Failure	14 ± 11	13 ± 6	0.16
SPAP, mean ± SD			
• Success	35 ± 10	34 ± 2	0.33
• Failure	43 ± 7	45 ± 5	0.12

Table 2: *Hemodynamic and Doppler echocardiographic assessment during the 2-weaning stages: PSV versus T-tube for the 2 groups (success and failure)*

PSV: Pressure Support Ventilation; HR: Heart Rate; SBP: Systolic Blood Pressure; LVEF: Left Ventricular Ejection Fraction; SV: Stroke Volume; CO: Cardiac Output; E/A: Ratio Between Early (E) and Late (A) Diastolic Velocity Peak; DTE: Deceleration Time of the Wave E; E/E': Early Diastolic Velocity Peak (E) Divided by the Maximum Velocity of Mitral Annulus at the Onset of Diastole (E'); d (Ap-Am): Difference Between Duration of the A Wave of the Pulmonary Venous Flow and the A Wave of the Mitral Flow E; Vp MF: Velocity of Propagation of the Mitral Flow; E/Vp_{MF}*: Early Diastolic Velocity Peak (E) Divided by the Velocity of Propagation of the Mitral Flow; MF: Mitral Flow; IVC-CI: Inferior Vena Cava- Collapsibility Index; SPAP: Systolic Pulmonary Arterial Pressure.*

Doppler-TTE indices and ventilator-withdrawal-induced-APO

For the univariate analysis, E/A > 2, DTE < 150 ms, E/E' > 8, duration (Am-Ap) > 10 ms, E/Vp > 2.5 were significantly associated with weaning APO but not in multivariate analysis. The coexistence of these indices was significantly related to the occurrence of APO (overall OR = 18.52, 95% CI [4.08 - 52], p = 0.01) (Table 3). In the same way, the ROC curve analysis showed a good positive predictive value (PPV) at 92% for all these Doppler parameters to predict weaning induced APO (Figure 2).

Echocardiographic indices	Univariate analysis Results	Multi variate analysis Results
LVFE < 50%	OR = 2.24 95% CI [0.96 - 4.36] p = 0.09	OR = 1.48 95% CI [0.55 - 2.79] p = 0.9
E/A > 2	OR = 1.86 95% CI [1.05 - 3.28] p = 0.04	OR = 1.04 95% CI [0.66 - 3.03] p = 0.25
DTE < 150 ms	OR = 2.46 95% CI [1 - 6.08] p = 0.042	OR = 2.16 95% CI [0.56 - 4.42] p = 0.71
E/E' > 8	OR = 7.95 95% CI [2.72 - 23.29] $p < 10^{-3}$	OR = 3.88 95% CI [0.72 - 11.20] p = 0.20
Duration (Am-Ap) > 10 ms	OR = 4.50 95% CI [1.53 - 13.20] p = 0.008	OR = 2.53 95% CI [0.63 - 9.44] p = 0.32
Vp MF < 45 cm/s	OR = 2.11 95% CI [0.85 - 4.23] p = 0.064	OR = 1.69 95% CI [0.66 - 3.80] p = 0.65
E/Vp > 2.5	OR = 1.45 95% CI [1.03 - 2.04] p = 0.045	OR = 0.89 95% CI [0.38 - 2.14] p = 0.88
	Overall OR = 18.52, Overall OR [4.08 -52], p = 0.01	

Table 3: *Ultrasonographic indices and ventilator-withdrawal-induced-APO.*

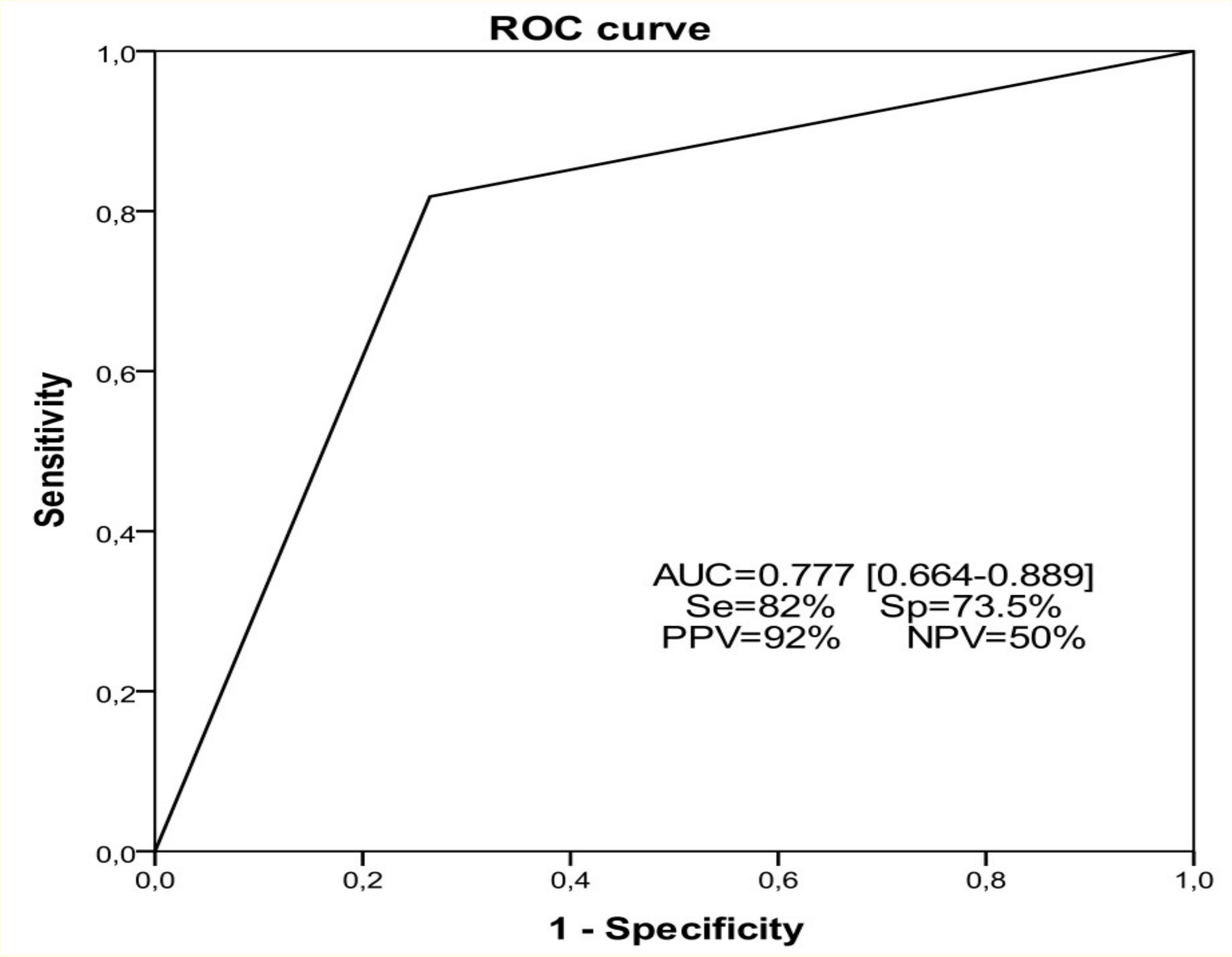

Figure 2: *Accuracy with ROC curves of Doppler parameters to predict weaning induced pulmonary oedema.*
ROC: Receiver Operating Characteristics; AUC: Area Under the Curve; Se: Sensitivity; Sp: Specificity; PPV: Positive Predictive Value; NPV: Negative Predictive Value.

Discussion

T-tube trial increased SBP, HR and CO (both in the success and failure groups) and decreased DTE, increased E/E ‘, duration (Ap-Am) and E/Vp MF in the failure group. These following indices: E/A > 2, DTE < 150 ms, E/E’ > 8, duration (Am-Ap) > 10 ms, E/Vp > 2.5 were associated, in univariate analysis, to the ventilator withdrawal- APO but not in logistic regression. It was their simultaneous coexistence that was significantly related to the APO with a good PPV at 92%.

In most ventilated patients, weaning from ventilator is envisaged once the respiratory impairment cause was resolved. However, 20% to 30% of patients are considered difficult to wean from ventilator withdrawal [9]. Our incidence was more considerable at 41.5% (22/53) and it can be explained by the severity at admission (mean SOFA score = 5) and the considerable rate of co morbidities. The medical ICU physicians often try to use a two-step screening approach before extubation: combine the weaning criteria and then switch to Spontaneous Breathing trial by T-tube test.

Doppler Echocardiographic assessment is an integral part of the routine evaluation of ICU patients with dyspnea or heart failure [8] and even more interest during weaning process. Before the switch to T-tube trial, echocardiography allows the detection of a pre-existing diastolic or systolic cardiac dysfunction, which predisposed to the occurrence of a cardiogenic APO [4,10-12]. Systolic dysfunction is usually assessed by LVEF using the Simpson method. When switching from PSV mode to T-tube test, a significant increase in heart rate and cardiac output, reflecting that spontaneous breathing work was comparable to a real stress test [13]. Our results are concordant with these data.

Diastolic dysfunction or preserved ejection fraction heart failure is associated with a ventricular relaxation disorder compromising left ventricular filling [14]. It can be assessed by Doppler ultrasound with studying mitral blood flow analysis, tissue Doppler of the mitral annulus, pulmonary venous flow analysis and transmitral flow velocity [15]. Increase of E/A and/or increase in E/E’ were correlated with elevation of pulmonary-capillary wedge pressure (PCWP) measured using a pulmonary artery catheter (PAC) [16].

During T-tube trial, changes concerned DTE, E/E’, d (Ap-Am) and E/Vp in failure group. No differences were observed in E/A ratio. For Caille V., *et al.* [17], increase in E/E’ was not significant, however, increase in E/A and shortening of DTE were significant. With PSV test, E/A was not a discriminating Doppler index between subgroups based on initial LVEF [17]. In contrast, DTE was significantly reduced in patients with impaired systolic function compared to other subgroups with less impaired EF [17]. For Ait-Oufella., *et al.* [18], E/A rose from 0.91 to 1.17, (p = 0.01), after ventilator disconnection, and DTE decreased from 185 ms to 160 ms, p = 0.02. For Schifelbain., *et al.* [19], isovolumetric relaxation time (IVRT) was longer in patients successfully weaning.

No results from relevant clinical studies on the combined indices [duration (Ap-Am), Vp MF and E/Vp] to have comparative overviews. These new doppler indices are presumed to be difficult to interpret. They appear to be influenced by strong and rapid preload variations, such as those observed in haemodialysis patients [20], congestive heart failure [21] and animal models [22].

In addition, tissue Doppler velocities recorded at the mitral annulus may be influenced by the presence of a segmental contraction anomaly affecting LV basal segments, particularly in its lateral wall. CI of IVC was similar before and after T-tube test, suggesting more that this parameter represents a dynamic preload index rather than a water hyperinflation. Concerning the RV function, there was no difference in either TAPSE or SPAP between the two groups at baseline and before/after T-tube. This likely reflects the absence of pulmonary hypertension induced by T-tube test. A sudden rise in SPAP and appearance of a paradoxal septum were very helpful for the diagnosis of PE as a cause of failure. The guidelines of the 2016 American Society of Echocardiography and the European Association of Cardiovascular Imaging identified several parameters to be considered in evaluating diastolic function and updating cut offs [8]. The proposed cut offs are variable depending on the underlying cardiac condition (sinus tachycardia, restrictive cardiomyopathy, mitral stenosis...) [8]. The cut offs used in our study adhered to a focus on the evaluation of filling pressures grouping predictive Doppler index studies in resuscitation patients [7]. Thus, by analyzing the association of the following predefined indices: LVEF < 50%, E/A > 2, DTE < 150 ms, E/E ‘ > 10, duration (Am-Ap) > 10 ms, E/Vp > 2.5, their coexistence was found to be significantly related to the weaning cardiogenic APO (OR = 18.52, 95%CI [4.08 - 52], p = 0.01) with a good PPV. No index, taken only, was an independent factor related to ventilator withdrawal-APO. An observational study of Papanikolaou., *et al.* [14] retained weaning failure in 56% of patients: 23 patients in the T-tube and 5 required re-intubation within 48h. Pre-T-tube test values of E/E' lateral > 7.8 and E/Vp > 1.51 were predictive of weaning failure with an area under the curve, sensitivity and specificity that were at 0.86, 79% and 100% for E/E' lateral > 7.8 and 0.74, 75% and 73% for E/Vp > 1.51. Lateral E/E' was the only factor independently associated with weaning failure with OR = 5.62, 95% CI (1.17-26.96), p = 0.03 [14].

Strength and weakness

Our study was non-selective, including all ventilated patients ready for weaning regardless of their cardiac or respiratory co-morbidities. To the best of our knowledge, data about ultrasound evaluating filling pressure focus on the results of pulsed Doppler mitral flow and those associated with tissue doppler of the mitral annulus. The indices combining the results of the pulsed Doppler of the mitral flow and those of pulmonary venous flow (Ap-Am duration) and the measurement of the rate of propagation of the mitral flow (E/Vp MF) are exceptionally reported in clinical studies.

Nevertheless, our study is limited by its mono-centric design and the sample size of recruited patients. Second, a number of our patients had previously received inotropes (3 patients) and others diuretics (4 patients). This could generate a selection bias. For the first group, inotropes could influence the LVEF and CO measurements. For the second, diuretics could relieve LV overload during T-tube test, especially for patients with impaired LVEF. Also, we have no information about the evolution of the 14 patients with pulmonary oedema: it will be interesting to know the evolution of the Doppler mitral flow after treatment but we estimated that wasn't the purpose of the study. Further studies are needed to evaluate the impact of this screening strategy on the weaning process and patient outcome.

Conclusion

Our study further strengthens the importance of ultrasound hemodynamic exploration in the management of weaning process. It reproduces all cardiac changes during spontaneous breathing test and helps to identify patients at high risk of weaning induced pulmonary oedema.

Declaration

The authors declare that they have no competing interests.

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