Echocardiographic evaluation during weaning from mechanical ventilation

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INTRODUCTION: Echocardiographic, electrocardiographic and other cardiorespiratory variables can change during weaning from mechanical ventilation.

OBJECTIVES: To analyze changes in cardiac function, using Doppler echocardiogram, in critical patients during weaning from mechanical ventilation, using two different weaning methods: pressure support ventilation and T-tube; and comparing patient subgroups: success vs. failure in weaning.

METHODS: Randomized crossover clinical trial including patients under mechanical ventilation for more than 48 h and considered ready for weaning. Cardiorespiratory variables, oxygenation, electrocardiogram and Doppler echocardiogram findings were analyzed at baseline and after 30 min in pressure support ventilation and T-tube. Pressure support ventilation vs. T-tube and weaning success vs. failure were compared using ANOVA and Student’s t-test. The level of significance was p<0.05.

RESULTS: Twenty-four adult patients were evaluated. Seven patients failed at the first weaning attempt. No echocardiographic or electrocardiographic differences were observed between pressure support ventilation and T-tube. Weaning failure patients presented increases in left atrium, intraventricular septum thickness, posterior wall thickness and diameter of left ventricle and shorter isovolumetric relaxation time. Successfully weaned patients had higher levels of oxygenation.

CONCLUSION: No differences were observed between Doppler echocardiographic variables and electrocardiographic and other cardiorespiratory variables during pressure support ventilation and T-tube. However cardiac structures were smaller, isovolumetric relaxation time was larger, and oxygenation level was greater in successfully weaned patients.

KEYWORDS: Echocardiography; Doppler echocardiogram; Cardiorespiratory variables; Ventilator weaning; Artificial ventilation.

Schifelbain LM, Vieira SRR, Brauner JS, Pacheco DM, Naujorks AA. Echocardiographic evaluation during weaning from mechanical ventilation. Clinics. 2011;66(1):107-111.

Received for publication on October 14, 2010; First review completed on October 14, 2010; Accepted for publication on October 19, 2010

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INTRODUCTION

Weaning from mechanical ventilation (MV) involves changes in the interaction between patient and ventilator. During weaning, the support provided by the ventilator is reduced, while the patient progressively takes over the work of breathing. Changes associated with transition from MV to spontaneous ventilation overload the cardiorespiratory system with increases in: venous return, left ventricle (LV) afterload, O2 consumption and catecholamine secretion.

The return of spontaneous breathing can increase myocardial O2 demand and the product of heart rate x arterial blood pressure by as much as 35%, which can lead to myocardial ischemia. However, this increase was not associated with weaning failure. A study of 15 patients with chronic obstructive pulmonary disease who failed during weaning from MV demonstrated that, during the first 10 min of spontaneous breathing, there was an increase in cardiac index (CI), heart rate (HR), central venous pressure (CVP) and arterial blood pressure (BP). An increase in pulmonary capillary wedge pressure (PCWP) from 8 to 25 mmHg was associated with evidence of acute respiratory failure due to increased preload. After 1 week of treatment with diuretics, these patients were weaned...
There is evidence that 6–10% of patients using a multiparameter monitor (Philips; In patients on MV, saturation (rpm), and SaO, = mL), minute volume (Ve = L/min), 11 inspiratory pressure at an inspiratory level of 10 cmH2O, patients breathing was aided by equipment with graduated oxygen at 5 L/min. The other method was PSV in which 30 min. patients were submitted to the other method for the first method of weaning for 30 min. After a rest period of 30 min, the assessment was performed immediately and the patient placed back on MV with the same parameters used at the beginning of the weaning protocol.

Clinical assessment included data on identification, diagnosis, Acute Physiologic and Chronic Health Evaluation (APACHE) II score for the first 24 h after admission, level of consciousness, preexisting heart disease, use of sedative drugs and opioids, type of mechanical ventilator used, ventilation mode, MV parameters and arterial blood gas analysis. Patients were also monitored non-invasively: BP, HR, f and SaO2 using a multiparameter monitor (Philips; USA). Ventilation mechanics were monitored using a VENTRAK 1500 (Novametrix Medical Systems, Wallingford, CT, USA) connected to a PC Pentium 100 using software provided by Novametrix for data storage and later analysis. The following parameters were analyzed: f (rpm), tidal volume (Vt = mL), minute volume (Ve = L/min), rapid–shallow breathing index (RSBI or f/Vt) and airway occlusion pressure (P0.1).

Cardiac performance was assessed using 12-lead ECG and echocardiogram using a Caris ultrasound machine (Esaote Spa, Genova, Italy) with pulse, continuous and color Doppler, and a 2.5–3.5 MHz transducer, coupled to a 17-inch Sony Cpd-e200 monitor. The following data were analyzed: Mode M; bidimensional mode; spectral and tissue Doppler and myocardial performance index (Tei index). Ejection fraction was determined using the Teicholz method as it offers greater accuracy than the Cubo method, has less interobserver variation and is less dependent on an optimal echocardiographic window to obtain measurements. The Simpson method,11 color Doppler echocardiography was used to assess LV systolic and diastolic function and structural abnormalities. Echocardiogram was always performed by the same cardiologist. Echocardiogram and ECG were done at baseline and in the 30th minute of each method after resting for 30 min between methods.

Statistical analysis

Measurements obtained during PSV and T-tube were compared. Patients were classified into two groups based on weaning success or failure. Analyses were performed with the aid of Statistical Package for the Social Sciences (SPSS) 12.0, and results were presented as mean ± standard deviation or median (interquartile 25–75). Comparisons were made using Student's t-test for paired and unpaired samples and analysis of variance (ANOVA) for repeated measures. The level of significance was set at p<0.05.

The weaning protocol was interrupted if the patient exhibited: oxygen arterial saturation (SaO2) <98%, oxygen arterial pressure (PaO2) <60–55 mmHg, respiratory rate (f) >35–38 rpm or increased by 50%, HR >140 bpm or increased by 20%, systolic blood pressure >180 mmHg or <90 mmHg or increased/reduced by 20% and agitation, diaphoresis or a reduced level of consciousness. This was considered failure of the weaning trial.

Clinical status, respiratory mechanics and arterial blood gas analyses, electrocardiograms (ECG) and echocardiograms were performed during the trial period (at baseline and at the 30th minute of each ventilation mode). If the patient showed signs of decompensation before the predetermined time, the assessment was performed immediately and the patient placed back on MV with the same parameters used at the beginning of the weaning protocol.

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RESULTS

During the period between December 2005 and August 2007, 24 patients were assessed. Thirteen (58%) patients were male, and the mean age was 53 ± 20 years. Mean APACHE score was 18 ± 14. Median time on MV was 13 (8–21) days and length of stay in the ICU was 22 (13–35) days. Eight patients (33%) had neurological diseases, and the remaining patients had been admitted for sepsis, general postoperative care, neoplasms and respiratory infections. Ten patients (41.7%) had a history of hypertension and/or thoracic pain, with no history of myocardial infarction or previous left ventricular failure. Eleven patients were tracheostomized. Seven patients failed during the weaning trial. Two of them died and five were weaned later. Of the successfully weaned patients, only one was reintubated after 5 days, and one died because of a lymphoma. The individual characteristics of the patients assessed are described in Table 1.

At baseline, all patients were on MV settings, with PSV at 15–20 cmH2O, PEEP at 5 cmH2O and a FiO2 of 0.4. With respect to the variables analyzed at baseline and at the end of 30 min using Doppler echocardiogram, the size of the left atrium (LA), the interventricular septum, the posterior wall and LV diastolic diameter (LVD) were all significantly smaller among patients who were successfully weaned from MV at the first attempt. Isovolumetric relaxation time (IVRT) was significantly shorter among patients whose weaning failed. The Tei index values were slightly higher among patients who failed, but without statistical significance (Table 2).

The mean Doppler echocardiography results during the two weaning modes (PSV, T-tube) were very similar, and no differences were observed when comparing the outcome (success vs. failure in Table 3). Results observed during PSV and T-tube were similar to values observed at baseline.

Table 1 - Clinical characteristics of the patients assessed.

| Age | Sex | APACHE II | Time on MV | Hypertension/thoracic pain | Outcome |
|-----|-----|-----------|------------|----------------------------|---------|
| 57  | W   | 22        | 7          | Yes                        | Success |
| 35  | W   | 22        | 8          | No                         | Failure |
| 65  | W   | 22        | 31         | Yes                        | Failure |
| 90  | M   | 24        | 45         | No                         | Failure |
| 27  | W   | 11        | 66         | No                         | Success |
| 45  | M   | 6         | 4          | No                         | Failure |
| 32  | M   | 19        | 50         | Yes                        | Success |
| 64  | M   | 17        | 12         | No                         | Failure |
| 51  | M   | 23        | 28         | Yes                        | Failure |
| 66  | W   | 32        | 13         | No                         | Failure |
| 74  | W   | 17        | 11         | Yes                        | Success |
| 27  | M   | 21        | 23         | Yes                        | Failure |
| 68  | W   | 24        | 8          | No                         | Failure |
| 76  | M   | 16        | 16         | Yes                        | Success |
| 51  | M   | 16        | 7          | Yes                        | Failure |
| 21  | M   | 16        | 15         | No                         | Failure |
| 22  | M   | 19        | 21         | No                         | Failure |
| 51  | W   | 22        | 19         | No                         | Failure |
| 34  | M   | 2         | 12         | No                         | Failure |
| 45  | W   | 22        | 7          | No                         | Failure |
| 78  | M   | 34        | 11         | Yes                        | Failure |
| 72  | M   | 15        | 14         | Yes                        | Failure |
| 63  | W   | 12        | 7          | No                         | Failure |
| 68  | M   | 23        | 13         | No                         | Failure |

APACHE = Acute Physiologic and Chronic Health Evaluation; M = man; MV = mechanical ventilation; W = woman.

Table 2 - Baseline Doppler echocardiographic assessment of the patient sample (mean ± SD).

|                  | Success (n = 17) | Failure (n = 7) | p*  |
|------------------|------------------|----------------|-----|
| LA (mm)          | 3.44 ± 5.1       | 41.9 ± 2.9     | 0.001 |
| RV (mm)          | 18.3 ± 3.2       | 22.6 ± 6.3     | 0.135 |
| LVS (mm)         | 39.9 ± 4.4       | 33.4 ± 7.1     | 0.416 |
| LVD (mm)         | 50.5 ± 4.7       | 56.3 ± 5.3     | 0.016 |
| SEP (mm)         | 9.3 ± 1.5        | 11.3 ± 0.8     | 0.006 |
| PW (mm)          | 9.3 ± 1.6        | 11.3 ± 0.9     | 0.006 |
| EF (%)           | 70.2 ± 5.9       | 69.6 ± 11.7    | 0.900 |
| E (m/s)          | 0.71 ± 0.14      | 0.82 ± 0.29    | 0.352 |
| A (m/s)          | 0.76 ± 0.25      | 0.67 ± 0.3     | 0.444 |
| E/A Ra           | 1.02 ± 0.39      | 1.53 ± 0.98    | 0.221 |
| IVRT (m/s)       | 112 ± 31.4       | 84.5 ± 20.8    | 0.046 |
| DT (m/s)         | 239 ± 72         | 187 ± 43       | 0.101 |
| E' (m/s)         | 0.09 ± 0.03      | 0.13 ± 0.04    | 0.053 |
| A' (m/s)         | 0.14 ± 0.12      | 0.29 ± 0.36    | 0.329 |
| E/E' Ra          | 8.25 ± 2.95      | 7.24 ± 3.62    | 0.480 |
| Tei index        | 0.60 ± 0.18      | 0.66 ± 0.46    | 0.614 |

A = peak velocity of A wave; A' = A′ wave; DT = deceleration time; E = peak velocity of E wave; E′ = E′ wave; E/A Ra = E/A ratio; E′/E Ra = E′/E′ ratio; EF = ejection fraction; IVRT = isovolumetric relaxation time; LA = left atrium; LV = left ventricle; LVD = left ventricular diastolic diameter; LVS = left ventricular systolic diameter; Tei index = myocardial performance index; PW = posterior wall; RV = right ventricle; SEP = interventricular septum.

*Unpaired t-test.

Twelve-lead electrocardiograms did not detect any differences between baseline assessment and weaning modes assessed. No changes in ST segment were detected during continuous cardiac monitoring.

There were no statistical differences for cardiorespiratory assessment during baseline and weaning trials. However, patients whose weaning was successful showed higher PaO2 and SaO2 (133 ± 30 vs. 103 ± 33, p = 0.04; and 98 ± 1.1 vs. 96 ± 1.9, p = 0.01). We also observed a tendency to a lower f/Vt (75 ± 39 vs. 91 ± 19, p = 0.13) and to a lower P0.1 (0.46 ± 0.17 vs. 0.62 ± 0.09, p = 0.4) during T-tube in this group of patients.

DISCUSSION

There were no differences between the Doppler echocardiography variables during the two weaning methods. The analysis of the Doppler echocardiograms demonstrated that the sizes of cardiac structures were significantly smaller in patients who were successfully weaned from MV at the first attempt, whereas IVRT was significantly shorter among patients whose weaning failed. Considering cardiorespiratory variables, PaO2 and SaO2 were significantly higher among successfully weaned patients with no other significant differences.

Several research teams have investigated prognostic indices for weaning success, including f/Vt ratio2–14 and P0.1.15 The lower the f/Vt, the greater the chance of successfully withdrawing MV.12,14,16 In our study, f/Vt was higher and P0.1 was lower among patients who could not be weaned, although without statistical difference. However, in agreement with the literature, successfully weaned patients showed better oxygenation levels.15

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 our study, there were no wave; DT = deceleration time; E = peak Caille et al. Our patients did not exhibit hypervolemia, p

The IVRT can be influenced by factors including without ratio; i.e. the lower the value of IVRT, the higher the ratio measured by tissue Doppler, demon-

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. In our study, there were no differences in cardiorespiratory variables analyzed echocardiography between the two weaning methods, suggesting equivalency between both methods of weaning in the population studied. Our results are in disagreement with recent data published in the literature. Caille et al. analyzed weaning patients and observed that echocardiogram can detect T-tube-induced changes in the central hemodynamic status, helping to identify patients at high risk of cardiac-related weaning failure. Cabello et al., monitoring weaning patients with a Swan–Ganz catheter, also observed differences in cardiovascular responses comparing T-tube with PSV. It is important to consider that, in these studies, there was a large number of patients with cardiac diseases and/or signs of cardiac failure. In our sample, patients were under MV for a long period of time, but there was no evidence of preexisting defined heart disease or LV failure.

The baseline LA diameter, intraventricular septum thickness, posterior wall thickness and LV diastolic diameter were significantly larger among patients whose weaning failed. It has been demonstrated that increased LA size could cause an increased filling pressure due to reduced LV compliance or diastolic dysfunction. There is evidence in the literature suggesting that this increase in the size of the LA measured by echocardiography could be predictive of cardiovascular outcomes even in individuals without atrial pathologies or valve disease.

We also observed in our study that the value of IVRT was significantly lower among failing weaning patients. Also, the pressure gradient represented by the deceleration time, which normally changes in line with IVRT, was lower, although not statistically significant among patients who failed. The deceleration time is characteristically prolonged when relaxation is abnormal and becomes shorter when relaxation is rapid or high ventricular filling pressures occur. The IVRT can be influenced by factors including ischemia, hypoxemia and right ventricle overload (which prolong the time) and blood volume status (indirect variation). Its absolute value is inversely related to PCWP, i.e. the lower the value of IVRT, the higher the PCWP. Our patients did not exhibit hypervolemia, which could have influenced the behavior of echocardiographic measurements. The preload, assessed in terms of the E'/E ratio measured by tissue Doppler, demonstrated variation within normal limits (below 15) without any significant difference between the two groups of patients.

Our research did not demonstrate electrocardiographic abnormalities at all assessment situations, suggesting less or no heart disease among these patients who were admitted predominantly as a result of neurological and infectious diseases, with only prior history of hypertension recorded. Research evaluation of weaning from MV has demonstrated cardiac ischemia mainly in patients with known coronary artery disease, and sometimes also in normal patients. In an earlier study carried out by our team, ST segment abnormalities suggestive of myocardial ischemia were also observed on ECG during both methods of weaning, but in this previous study, a greater number of severe cardiac patients was included.

As limitations of this study, we have to consider that the number of patients evaluated was small. In addition, no severe ischemic heart or heart failure patients were included, which may explain the absence of ischemia and cardiac dysfunction during weaning. Another limitation is that, although no patient had clinical signs of cardiac failure, fluid balance or the use of diuretic drugs before the weaning trial were not recorded.

Table 3 - Mean Doppler echocardiogram results for minute 30 using PSV and T-Tube: weaning success vs. failure (mean ± SD).

|           | PSV     | T-tube  | p*       |
|-----------|---------|---------|----------|
| LA (mm)   |         |         |          |
| Success   | 33 ± 3.8| 34 ± 4  |          |
| Failure   | 35 ± 3.2| 35 ± 2.6| 0.68     |
| RV (mm)   |         |         |          |
| Success   | 18 ± 3.8| 18 ± 4.1|          |
| Failure   | 20 ± 5.7| 22 ± 2.7| 0.12     |
| LVS (mm)  |         |         |          |
| Success   | 31 ± 4.4| 31 ± 4.1|          |
| Failure   | 32 ± 6.1| 31 ± 8.7| 0.32     |
| LVD (mm)  |         |         |          |
| Success   | 51 ± 3.9| 51 ± 5.2|          |
| Failure   | 54 ± 6.2| 54 ± 7.7| 0.77     |
| SEP       |         |         |          |
| Success   | 9 ± 1.9 | 9 ± 1.8 |          |
| Failure   | 11 ± 0.8| 11 ± 0.8| 0.81     |
| PW        |         |         |          |
| Success   | 9 ± 1.6 | 9 ± 2.3 |          |
| Failure   | 11 ± 0.9| 11 ± 0.8| 0.83     |
| EF (%)    |         |         |          |
| Success   | 70 ± 8.4| 69 ± 6.1|          |
| Failure   | 71 ± 10 | 73 ± 10 | 0.23     |
| E (m/s)   |         |         |          |
| Success   | 0.70 ± 0.23| 0.80 ± 0.17|          |
| Failure   | 0.82 ± 0.22| 0.81 ± 0.24| 0.16     |
| A (m/s)   |         |         |          |
| Success   | 0.77 ± 0.23| 0.76 ± 0.26|          |
| Failure   | 0.71 ± 0.23| 0.69 ± 0.22| 0.34     |
| E/A Ra    |         |         |          |
| Success   | 1.12 ± 0.47| 1.15 ± 0.46|          |
| Failure   | 1.31 ± 0.65| 1.38 ± 0.84| 0.84     |
| IVRT (m/s)|         |         |          |
| Success   | 107 ± 24| 97 ± 17 |          |
| Failure   | 84 ± 24 | 88 ± 19 | 0.21     |
| DT (m/s)  |         |         |          |
| Success   | 233 ± 64| 215 ± 61|          |
| Failure   | 192 ± 36| 198 ± 35| 0.48     |
| E' (m/s)  |         |         |          |
| Success   | 0.105 ± 0.03| 0.102 ± 0.03|          |
| Failure   | 0.108 ± 0.03| 0.096 ± 0.03| 0.23     |
| A' (m/s)  |         |         |          |
| Success   | 0.121 ± 0.03| 0.140 ± 0.08|          |
| Failure   | 0.123 ± 0.04| 0.106 ± 0.03| 0.11     |
| E/E' Ra   |         |         |          |
| Success   | 7.92 ± 4.33| 8.54 ± 3.39|          |
| Failure   | 7.83 ± 2.37| 8.62 ± 1.84| 0.86     |
| Tei index |         |         |          |
| Success   | 0.61 ± 0.19| 0.53 ± 0.13|          |
| Failure   | 0.58 ± 0.20| 0.48 ± 0.12| 0.94     |

A = peak velocity of A wave; A' = A'/ wave; DT = deceleration time; E = peak velocity of E wave; E' = E'/ wave; E/A Ra = E/A ratio; E/E' Ra = E/E' ratio; EF = ejection fraction; IVRT = isovolumetric relaxation time; LA = left atrium; LVD = left ventricle diastolic diameter; LVS = left ventricle systolic diameter; Tei index = myocardial performance index; PSV = pressure support ventilation; PW = posterior wall; SEP = interventricular septum.

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. In our study, there were a large number of patients with cardiac diseases and/or signs of cardiac failure. In our sample, patients were under MV for a long period of time, but there was no evidence of preexisting defined heart disease or LV failure.
CONCLUSION

In the present study, there were no differences in echocardiographic evaluation or in electrocardiographic and other cardiorespiratory variables comparing PSV and T-tube in this population of cardiac patients receiving MV for a long period of time. Weaning failure patients presented LA diameter, intraventricular septum thickness, posterior wall thickness and LV diameter significantly larger than weaning success patients. Further studies with a greater number of patients and including subjects with heart disease are necessary in order to clarify echocardiographic changes during weaning from MV and differences between cardiac and non-cardiac patients. It seems that echocardiogram tests could be useful in identifying failure weaning patients in a subgroup of cardiac ones.

ACKNOWLEDGMENTS

We thank the Cardiovascular Institute in Santa Maria/RS (ICARDIO) for assistance with Doppler echocardiography and ECG tests.

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