Evaluation of the minute ventilation recovery time as a predictor of weaning in mechanically ventilated COPD patients in respiratory failure

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Abstract  Background: There is still difficulty in discontinuing mechanical ventilation (MV) in chronic obstructive pulmonary disease (COPD) patients with respiratory failure and more than 50% of the time is spent for weaning. A large spectrum of weaning indices is used. In this study we evaluated minute ventilation recovery time (MVRT) that may be a new practical measure of the ability to predict weaning outcome.

Methods: The study was conducted on 50 mechanically ventilated Acute exacerbation of COPD patients admitted to the Zagazig University Hospitals intensive care units (ICUs) with a mean age of 61.8 ± 7.6 years. They were divided into 2 groups; group I: successful weaning, included 42 patients and group II: failed weaning, included 8 patients. Minute ventilation (V̇E) was recorded 30 min just after the institution of mechanical ventilation, then every 2 h for 24 h. Minute ventilation just before the spontaneous breathing trial (SBT) was recorded, and is compared to the previous recordings of minute ventilation, if this value (pre successful weaning V̇E) was about 110% of one of the recorded V̇E values, it is now considered as the baseline V̇E of the patients and the time passed from institution of M.V till such reading is considered as the MVRT of the patient.

Results: Among 42 successfully weaned mechanically ventilated COPD patients, when compared between different weaning parameters, MVRT was significantly better as a predictor of weaning outcome.

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Introduction

The outcome of discontinuation of mechanical ventilation (MV) in COPD patients with respiratory failure is difficult to predict and more than 50% of the time the patient is receiving mechanical ventilation is spent in the process of weaning [1,9]. Various predictors have been suggested to assess patients' ability to breathe spontaneously such as minute ventilation ($V_{TE}$) < 10 L/min, negative inspiratory force 20 cm H$_2$O to 30 cm H$_2$O, inspiratory pressure/maximal inspiratory pressure ratio, and the rapid shallow breathing index (ratio of respiratory rate to tidal volume in liters, RSBI or $F_{VT}$ ratio) [1,2].

Moreover, the rapid, shallow breathing pattern of patients during trials of spontaneous breathing would confirm that it is very unlikely the patient will be weaned successfully. Whether difficult to wean is a marker of an unresolved disease process and/or failure to accurately estimate respiratory reserve in certain patients remains unknown [3,10].

Studies have focused on respiratory mechanics during the spontaneous breathing trial (SBT), but little attention has been given to the physiologic assessment after imposed work of the SBT or after the institution of ventilatory support and reversal of the sedating effect, that may provide insight into the respiratory reserve required to sustain spontaneous breathing and predict weaning outcome [4,11].

The assessment of respiratory physiologic parameters ($V_{TE}$), tidal volume ($V_{T}$) and respiratory rate (R.R) following the institution of ventilatory support may provide distinguishing characteristics between patients who are successfully weaned and those who are difficult to wean [4,8].

MVRT is defined as the time required for minute ventilation ($V_{TE}$) to return to the baseline. Baseline ($V'_{TE}$) has been defined as the patient’s total ($V_{TE}$) breathing on a resting ventilator setting within the 24 h preceding the final SBT.

A prospective study evaluating this respiratory parameter, minute ventilation ($V_{TE}$) and its recovery time to the baseline, minute ventilation recovery time (MVRT), in COPD patients with respiratory failure undergoing ventilatory support has recently shown to potentially predict weaning outcome [4,5].

MVRT is considered a promising index for the clinical assessment of respiratory reserve and thus potentiality very useful as a weaning parameter. This is normally registered when a person has a ventilator supporting his breathing due to a sickness or injury. Minute volume is calculated by taking the tidal volume and multiplying it by the respiratory rate per minute [4,5].

The initial study demonstrated that a longer MVRT was independently associated with extubation failure, with a greater predictive accuracy than other traditional respiratory variables. So the aim of the present study is to evaluate the MVRT as a predictor of weaning just after the institution of MV rather than before weaning.

Patients and methods

The study was carried out at the Intensive Care Units of Chest and Anesthesiology Departments, Zagazig University Hospitals in the period from March 2010 to January 2011.

Patients

The study was conducted on 50 mechanically ventilated AE-COPD patients with acute on top of chronic respiratory failure (ACRF) admitted to both department ICUs. They were 26 males and 24 females, their age ranged from 53 to 78 years with a mean age of 61.8 ± 7.6 years, they were divided into 2 groups as follows:

Group I: Successful weaning

This group included 42 patients (84%) who succeeded the first spontaneous breathing trial of weaning and did not need reinstitution of mechanical ventilation and extubation was done through 24 h later. They were 20 male patients (47.62%) and 22 female patients (52.38%).

Group II: Failed weaning

This group included 8 (16%) patients who did not succeed the first spontaneous breathing trail of weaning and did not need reinstitution of mechanical ventilation and extubation was done during 24 h later. They were 8 male patients (44.44%) and 4 female patients (22.22%).

Conclusion

The minute ventilation recovery time is a good, reliable predictor of weaning success ($P = 0.002$). MVRT had high sensitivity and specificity of 76% and 85%, respectively at a cutoff value of 11.7 h. MVRT had a strong correlation with weaning outcome in comparison to other weaning parameters used in the study.

So the aim of the present study is to evaluate the MVRT as a predictor of weaning just after the institution of MV rather than before weaning.
MVRT as a predictor of weaning outcome in mechanically ventilated COPD patients

All patients were sedated by using intravenous Midazolam (15 mg) at a dose of 0.2 mg/kg administered slowly during intubation as it is available in both ICUs. Midazolam is a rapidly acting sedative, has short duration of action up to less than 2 h when given intravenously.

All patients were mechanically ventilated by either Puritan Bennett 7200, Servo I or Inspiron LS ventilators on the following parameters.

All patients were put on Synchronized intermittent mandatory ventilation (SIMV) mode plus pressure support ventilation (PSV) (15–22 cm H2O) according to the protocol used in both ICUs.

- Oxygen concentration: started by FIO2 100% then adjusted by arterial blood gases to keep PaO2 ≥ 60 mmHg and SaO2 ≥ 90% with FIO2 < 60%.
- Tidal volume (Vt): 6–8 ml/kg.
- Respiratory rate: 12–14 breaths/min.
- Trigger sensitivity: −0.5 to −1 cm H2O.
- Inspiratory flow rate: 50 to 80 L/min.
- Positive end expiratory pressure (PEEP): 0–10 cm H2O.

The aim of these parameters was to keep the patient’s PaCO2 just above 60 mmHg and to reach the predicted basal PaCO2, which is calculated according to the equation: Basal PaCO2 = 2 × HCO3 – 8 [2].

All patients were mechanically ventilated for at least 48 h, during this period they were subjected to the following:

1. Full medical history is taken from the patient’s relatives.
2. Chest X-ray (CXR).
3. Electrocardiography (ECG).
5. Random blood sugar (RBS).
6. Liver and kidney function tests.
7. Serum D-Dimer is done for suspected pulmonary thromboembolism cases.
8. Assessment of other comorbidities.
9. Daily monitoring for:
   - Neurological assessment by Glasgow Coma Scale (GCS) with the best score of 15 and the worst score of 3 (without sedation).
   - Oxygen saturation using a MASIMO Signal Extraction Pulse Oximeter.
   - Arterial blood gases analysis (ABGs) using a Chiron Diagnostic Rapid Lab 860.
   - Electrolyte measurement; serum Na+, K+.
   - Hemoglobin level.
   - Blood pressure, pulse.
   - Random blood sugar and every 6 h blood sugar analysis for diabetic patients. Maximum inspiratory pressure (PIMAX) during and just before weaning is recorded.
   - Respiratory rate and exhaled tidal volume to get the rapid shallow breathing index (RSBI).
   - Airway occlusion pressure (P0.1) and [compliance, respiratory rate, oxygenation and pressure system] (CROP) index were recorded during and just before weaning.

Method of calculation of the MVRT: Minute ventilation is recorded once the patient began to regain his consciousness as evidenced by: [4]

A- Assessment of the patient’s conscious level, spontaneous movement, eye opening etc.

At this point this was considered the zero time from which we start to record the minute ventilation of the patient from the ventilator screen every two hours till 24 h.

Minute ventilation just before successful SBT was recorded, and was compared to the previous recordings of minute ventilation, if this value (preweaning V E) was about 110% of one of the recorded V E values, it is now considered as the baseline V E of the patients and the time of such reading is considered as the MVRT of the patient.

Exclusion criteria [4]

Patients were excluded from the study if they had concomitant diseases, such as renal failure, cancer, cerebrovascular stroke, cardiogenic pulmonary edema, acute myocardial infarction, diabetic ketoacidosis and cardiac arrest and death.

Statistical methods

Results are expressed as mean ± SD, normally distributed variables were compared by Student’s t test. Categorical data were assessed using the Χ2 or Fisher two tailed exact tests. P < 0.05 was considered statistically significant. The independent effects of these variables on extubation outcome were explored using multiple logistic regression analysis. The ability of certain respiratory parameters to discriminate between successful and failed extubation was assessed using the receiver operating characteristic (ROC) Fig. 1 curve analysis. Statistical analysis was performed using the commercially available software (SPSS for Windows (version 16.0)).

Results

Fifty mechanically ventilated patients with acute on top of chronic respiratory failure (ACRF) were included in this study. They were 24 males and 26 females with age range from 53 to 78 years with a mean of 61.8 ± 7.6 years. They were divided into 2 groups; group 1: successful weaning patients (42 patients), their mean age was 60 ± 6.5 years and group 2; failed weaning patients (8 patients) their mean age was 78 years with a mean of 61.8 ± 7.6 years.

Figure 1 ROC curve showing the large area under the ROC curve for the MVRT.
age was 70.5 ± 7.3 years with no significant difference ($P = 0.641$). Also, no significant difference was found regarding sex distribution ($P = 0.793$) and smoking pattern ($P = 0.428$) in both groups (Table 1).

In this study comparison between different weaning parameters in both groups demonstrated that, MVRT was significantly shorter in the successful weaning group (group 1) 15.5 ± 1.7 vs. 10.3 ± 1.7 in the failed weaning group ($P = 0.002$), while the other weaning parameters did not differ significantly between both groups at the time of SBT (Table 2).

Minute ventilation recovery time (MVRT) had a higher sensitivity and specificity of 76% and 85% respectively at a cut-off value of 11.7 h, than other weaning parameters in the first 12 h of mechanical ventilation (Table 3).

While there was very weak non-significant correlation between MVRT and first CO$_2$ and first pH ($P = 0.55, 0.176$ respectively, Table 4).

Table 5 shows that the MVRT has the highest correlation with successful weaning outcome ($r = 42, P < 0.05$) in comparison to other weaning parameters.

Table 6 shows the multivariate logistic regression analysis which indicated that the MVRT is the most predicting independent variable for outcome with the highest score (8.09) and significance ($P = 0.004$).

Discussion

A large spectrum of weaning predictors has been studied with either simple weaning indices, simple measures of load and capacity e.g. (negative inspiratory force, maximum inspiratory pressure $P_{\text{Imax}}$, tidal volume ($V_T$), and breathing frequency ($f$) or integrative weaning indices requiring special equipment e.g. minute ventilation ($V_E$), the ratio of breathing frequency to tidal volume ($f$/$V_T$), $P_{\text{0.1}}$, and compliance, rate, oxygenation, and pressure system (CROP) index [5,8].

However, a study by Conti and colleagues [7] showed that vital capacity, $V_{1}$, $P_{0.1}$, $V_{1}E$, respiratory frequency (RR), maximum inspiratory pressure ($P_{\text{Imax}}$), (RSBI) and ($f$/$V_T$) are poor predictors of weaning outcome in an ICU population. Whether difficult to wean is a marker of an unresolved disease process and/or failure to accurately estimate the respiratory reserve in certain patients remains unknown.

Studies have focused on respiratory mechanics during the spontaneous breathing trial (SBT), but little attention has been given to the physiologic assessment after the institution of ventilatory support and reversal of the sedating effect. This may provide insights into the respiratory reserve required to sustain spontaneous breathing and predict weaning outcome [5,11].

The aim of the present study was to assess this respiratory physiologic parameter, minute ventilation ($V_E$) immediately following the institution of ventilatory support, it is hypothesized that its recovery time to baseline $V_E$. Minute ventilation

<table>
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<th>Cut-off</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
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<tr>
<th>Parameters</th>
<th>Pearson correlation coefficient</th>
<th>$P$-value</th>
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<tbody>
<tr>
<td>MVRT and duration of MV</td>
<td>$r = 0.42$</td>
<td>&lt;0.003</td>
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<tr>
<td>MVRT and initial PaCO$_2$</td>
<td>$r = 0.07$</td>
<td>0.55</td>
</tr>
<tr>
<td>MVRT and first pH</td>
<td>$r = 0.1$</td>
<td>0.176</td>
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</table>
Minute ventilation recovery time (MVRT) may be a practical measure of the ability to predict weaning outcome. Minute ventilation recovery time (MVRT) is defined as the time required for minute ventilation ($V_{E}$) to return to baseline following a successful spontaneous breathing trial (SBT), and is of help in the physiologic assessment after imposed work of the SBT [4,5]. A longer recovery time represents decreased respiratory reserve and inability to maintain unsupported breathing and consequently weaning difficulty or extubation failure.

In the present study, patients with comorbidity as ischemic heart diseases, chronic liver disease and renal diseases were excluded to avoid any direct or indirect effect of such morbidities on the respiratory system performance.

In this study, there was no significant difference between those who passed the first SBT (successful weaning group) and those who failed weaning regarding age, sex, and smoking history (Table 1), a finding that helps the comparison to be fair, and allowed a better evaluation of the MVRT in both groups, as this finding had abolished the impact of both age and smoking on the severity of COPD of either group.

Among the different predictors of weaning, MVRT was significantly different between the successful weaning group and the failed weaning group with a mean of 10.3 ± 1.7 h in the successful group, and 15.5 ± 1.7 h in the failed weaning group ($P = 0.002$) (Table 2).

The shorter MVRT is associated with successful weaning. This reflects the ability of the patient to regain his respiratory reserve early, also the ability of MVRT to predict weaning success better than other parameters could be explained by the nature of this parameter i.e. although other parameters as CROP, RSBI, $P_{0.1}$, and $P_{Imax}$ are reliable and integrative, they are affected by not only the respiratory system mechanics but also other factors such as chest and abdominal wall compliance e.g., CROP index, neurological drive e.g. ($P_{0.1}$) which are variable from one moment to another. Conversely, the MVRT is rather a continuous parameter that reflects the capacity of the respiratory system to maintain its ability and endurance (RR and tidal volume) effectively for certain time interval.

This finding was in agreement with Martinez et al. [5] who found that patients with $V_{E}$ returned early to baseline after SBT and reinitiation of MV were successfully extubated, otherwise other patients who did not return early to baseline minute ventilation had a poor weaning outcome.

Although the extubation outcome could not be entirely predicted by MVRT, it was found MVRT may be a strong predictor of weaning outcome, as shown by the ROC curve analysis where the area under the Receiver Operating Characteristic Curve was comparably large for MVRT ($0.87 ± 0.06$), and exceeded other parameters used in the present study. The ROC curve analysis of MVRT in the present study at different cutoff points had showed that the area under the ROC curve was comparably larger for MVRT than other predictors at a cutoff point of 11.7 h with the highest sensitivity of 76% and specificity of 85% as a predictor of weaning. This finding is in consistency with, Martinez et al. [5] where the area under the ROC curve was larger in MVRT than other respiratory parameters used in his study.

In addition, the short MVRT has had the strongest correlation with weaning outcome in comparison to other weaning parameters used in the present study ($P_{Imax}$, RSBI, $P_{0.1}$, CROP index) with $P$-value < 0.05 (Table 5). It was also shown by the multivariate logistic regression analysis that the MVRT is the independent variable that achieves the highest score (8.09) with high significance ($P = 0.004$) in predicting weaning outcome among all other weaning predictors used in this study. These findings together suggest the good predictive value of this parameter for weaning success but a large sample size or a larger scale of patients is needed for this finding to be validated and to be generalized, since the small sample size in the present study does not allow such validation.

In the present study, the MVRT had highly significant correlation with the duration of mechanical ventilation ($P = 0.003$) (Table 4), i.e., the shorter MVRT will be associated with a decreased duration of mechanical ventilation and consequently favorable outcome and successful weaning. This result is in agreement with Martinez et al. [5] who observed that the shorter MVRT was associated with early extubation. This finding reflects the power of the respiratory muscles to regain its activity and contractile function early and the ability of the patients to be independent from ventilator assistance earlier.

In conclusion; the minute ventilation recovery time is a good, reliable predictor of weaning success and it is the most independent parameter among other weaning predictors that can predict a successful spontaneous breathing trial.

References


