Original article

Comparison of five weaning indices in predicting successful weaning from mechanical ventilation

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Abstract

Introduction: Mechanical ventilation is a life-supporting modality used in patients with respiratory failure. Most patients are extubated early but weaning can be prolonged in some. **Aim:** Comparison of accuracy of prediction of success of a spontaneous breathing trial (SBT) using CORE, CROP, RSBI, RSBI rate and minute ventilation recovery. **Methods:** This is a prospective observational study. 62 adult patients admitted to Multidisciplinary Intensive Care Unit during April 2012 - January 2013 were studied. All patients, orotracheally intubated and mechanically ventilated for at least 24 hours and ready for weaning were enrolled. The patients underwent SBT using pressure support ventilation (5 – 8 cm H_2O), PEEP of 5 - 8 cm H_2O, and 40% oxygen. The weaning indices were measured at 30 min and correlated with weaning success. **Results:** The mean (± SD) age was 49.7 (± 18.3) years. There were 46 male and 16 female patients. The threshold values were as follows: CORE index: ≥ 6, CROP index: ≥ 13, RSBI < 105 b/min/L, RSBI rate ≤ 20%. The sensitivity (%), specificity (%) and AUC of ROC curve were as follows: CORE (96, 66, 0.74), CROP (95, 33, 0.61), RSBI (89, 46, 0.2), RSBI rate (85, 28, 0.52) and minute ventilation recovery (higher than baseline minute ventilation at 25 min of rest on initial ventilator settings after 30 min of SBT) (n = 26) (92.3, 100, 0.93). **Conclusion:** CORE and RSBI are moderately accurate while CROP and RSBI rate are inaccurate. Minute ventilation recovery predicted weaning failure accurately.

Keywords: Mechanical ventilation, prediction, weaning indices.

Introduction

Mechanical ventilation (MV) is a life-supporting modality that is used in a significant proportion of patients in ICUs. Most of such patients are extubated quite readily. However, the first attempt at weaning from mechanical ventilation may fail in as many as 20% of mechanically ventilated patients. Weaning may account for more than 40% of the total duration of MV.[1,2] Prolonged MV is associated with a host of complications (*e.g.*, infection, particularly nosocomial pneumonia, gastrointestinal (GI) bleeding and deep venous thrombosis). On the other hand, premature extubation followed by reintubation is associated with increased morbidity and mortality.[3]

Discontinuation of mechanical ventilation, spontaneous breathing trial and extubation is carried out under the attending clinician's evaluation, arterial blood gas analysis and observation of the patient's clinical condition. Several predictors of successful weaning of ventilator support have been validated. Of these, CORE index, RSBI rate and minute ventilation recovery time are relatively new compared to the others. A multitude of factors influence weaning time and hence integrated indices are likely to be more predictive than single criterion. This prospective observational study was conducted

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to compare five weaning indices in predicting successful weaning from mechanical ventilation.

Methods

This study enrolled 62 adult patients admitted to Multidisciplinary Intensive Care Unit of Medical College University Hospital from April 2012 to January 2013. The patients were >18 years of age, orotracheally intubated and mechanically ventilated for at least 24 hours, the underlying illness which required ventilation showed improvement and they were ready for a spontaneous breathing trial.

The patients were considered ready to undergo a spontaneous breathing trial if they met the following criteria: Oxygen saturation of ≥ 90%, partial pressure of oxygen in arterial blood (PaO_2) ≥ 60 mm Hg, inspired oxygen fraction (FIO_2) < 0.5, PaO_2/FIO_2 ratio > 200, positive end-expiratory pressure of 5 – 8 cm H_2O, respiratory rate of ≤ 30 breaths/min, minute ventilation < 15 L/min, Glasgow coma scale of > 8, normal heart rate and blood pressure with no arrhythmia, no or minimal dosage of vasopressors and no sedation, normothermic and a haemoglobin concentration of ≥ 8 g/dL. Tracheostomised patients, patients with unstable haemodynamics, with neurological problems such as intracerebral haemorrhage or comatose patients, those requiring prolonged mechanical ventilation (> 10 days) and those extubated and put on noninvasive ventilation (NIV) were excluded from the study.

The following data were recorded:

Demographic data: Age, gender, severity of illness score (APACHE II) and whether they were primarily surgical or medical patients.

Ventilator settings: The existing ventilator settings such as PEEP, FiO_2, dynamic compliance, mean airway pressure, intrinsic PEEP, exhaled tidal volume, respiratory rate, minute ventilation, peak inspiratory pressure and pressure support.

Arterial blood gas values: pH, PaO_2 and $PaCO_2$ from the blood gas report of that morning was recorded along with SpO_2. Adequacy of oxygenation was assessed using PaO_2/FiO_2 ratio.

Haemodynamic variables: Heart rate, systolic blood pressure, diastolic blood pressure and central venous pressure (if available).

All intubated patients on mechanical ventilation and ready for weaning were clinically evaluated by the ICU intensivist. Prior to weaning from mechanical ventilation, the patient was ventilated on either control mode or SIMV volume/pressure mode of ventilation.

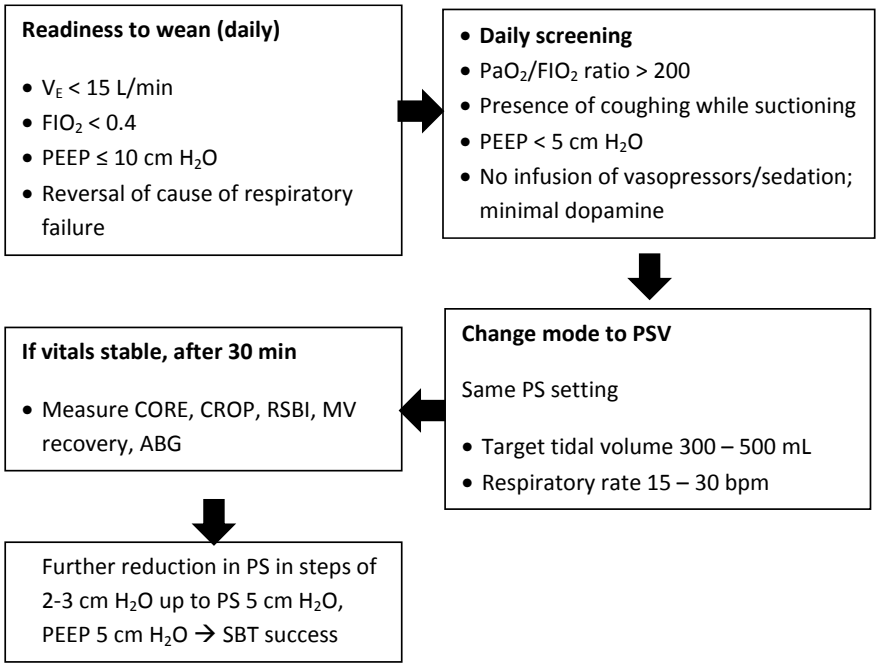

Figure 1: Flow chart for weaning process

Prior to weaning, the patient's mode of ventilation was changed over to pressure support ventilation with a set positive end expiratory pressure (PEEP) of 5 – 10 cm H_2O, pressure support level required to deliver a normal tidal volume and fractional of inspired oxygen (FiO_2) not exceeding 40%. The following algorithm illustrates steps of weaning the patient from a ventilator and also notifying the parameters which determine the weaning success/failure *(Figure 1)*.

Step 1: The patients were assessed for readiness to undergo a SBT trial based on acid base status, blood pressure, respiratory rate, minute ventilation of the patient, signs of reversal of cause of respiratory failure, positive end expiratory pressure ≤10 cm H_2O and fractional inspired oxygen ≤40%.

Step 2: Patients were put on SBT trial on PSV mode after they met the inclusion criteria. The patients were carefully monitored and the values of various indices mentioned above were collected at five, 15 and 30 minutes. Low doses of inotropes (*e.g.*, dopamine ≤ 5 μg/kg/min) were considered acceptable. If the patients tolerated the weaning procedure, an arterial blood gas was done to determine the PaO_2 (arterial oxygen tension). If any signs of respiratory distress were present, the patient was put back to the previous higher ventilatory support.

Step 3: After 30 min, the following parameters were measured: CORE, CROP, RSBI, RSBI rate and minute ventilation recovery. Blood pressure, respiratory rate and oxygen saturation by pulse oximetry were monitored.

The CROP index was calculated as follows: CROP = $[C_{dyn} \times P_{Imax}] \times PaO_2/PAO_2)]/f]$ where C_{dyn} was the dynamic compliance (ml/cm H_2O), P_{Imax}, the maximum inspiratory pressure (cm H_2O), PAO_2, alveolar partial pressure of oxygen (mm Hg), PaO_2, partial pressure of arterial oxygen (mm Hg) and f the respiratory rate (breaths/min).

The CORE index was calculated as follows: CORE = $[C_{dyn} \times [P_{Imax}/P_{0.1}] \times [PaO_2/PAO_2]/f]$ where C_{dyn} was the dynamic compliance (ml/cm H_2O), P_{Imax} was the maximum inspiratory pressure (cm H_2O), $P_{0.1}$ the airway occlusion pressure at 100 ms (cm H_2O), alveolar partial pressure of oxygen (PAO_2) and the respiratory rate (f) (breaths/min).

The rapid shallow breathing index $[RSBI = f/V_T]$, also a weaning parameter was obtained by dividing the patient's respiratory rate by the tidal volume (L).

RSBI rate was measured additionally in this study. It was calculated by obtaining the difference between the initial RSBI and the final RSBI and then dividing the result by the initial RSBI. The resulting number was then multiplied by 100. The mathematical formula was as follows: **RSBI rate** = $[(RSBI_2 - RSBI_1)/RSBI_1] \times 100$.

Minute ventilation recovery (V.ER) was recorded. Minute ventilation was measured at baseline (V_1) and ventilator support was reduced to a lower pressure support level. After 30 min of this change in ventilator support, minute ventilation was again recorded (V_2) following which the patient was returned to the previous ventilator setting. Generally, the minute ventilation is expected to increase to a higher value with reduced support and reduce with increased support. The difference in minute ventilation before and after change in ventilator support was noted ($V_2 - V_1$). The ability of the patient to return back to his baseline minute ventilation (V_1) was noted. The patient was observed for a maximum of 25 min.

Step 4: During the weaning process the ventilatory parameters were tapered gradually, by to 2 to 3 cm H_2O at a time (PEEP, pressure support) to an minimum level of 5/5 cm H_2O which was considered as the weaning criteria. SBT was given once or twice daily either in the morning or evening but the patient's respiration was supported using the previous higher ventilatory mode during the night.

If the patient was comfortable and the measured parameters were within physiological limits, PSV was continued at that level, initially for 30 minutes and then gradually progressed to at least two hours in a day, once a day, either in the morning or evening. The respiratory rate, tidal volume, minute volume, RSBI, heart rate, oxygen saturation, FIO_2 and blood pressure were recorded at baseline, 5 min,

30 min and at 2 hours. Pressure support and PEEP were gradually tapered down to around 5 cm H_2O each, which was considered adequate for weaning the patient off from the ventilator. Any signs of respiratory distress were noted and if present, the patient was reverted to the previous higher level of ventilator support.

Step 5: If the patient failed the SBT trial, the patient was put back to the higher mode and was given a rest. SBT trial was attempted later after further clinical improvement. Weaning failure was defined as the appearance of symptoms and signs of respiratory distress such as tachypnoea (spontaneous respiratory rate of > 35 breaths/min), excessive diaphoresis, flaring of alaenasi, intercostal muscle in-drawing, suprasternal retraction, accessory respiratory muscle activity, SaO_2<90%; PaO_2<80 mm Hg on FiO_2> 0.5, hypercapnia ($PaCO_2$> 45 mm Hg or >20% from pre extubation), pH < 7.33 and haemodynamic instability (increase by >30% in systolic pressure above baseline, systolic pressure >180 mm Hg, heart rate exceeding 30% above baseline or 140 breaths/min).

If the patient failed the SBT trial, he/she was put back on the higher mode, monitored and supported as necessary. This was considered as failure of SBT for that weaning attempt. If the patient became stable, another attempt at weaning was made, either in the morning or evening (the next scheduled weaning time) and all the measurements were repeated. This process continued till the patient was weaned off ventilator.

The number of days on mechanical ventilation and the days required for weaning starting from day 1 of SBT, any need to change to controlled mode of ventilation (synchronised intermittent mandatory ventilation, pressure controlled ventilation or assist control ventilation), the reason for the increase in ventilator support along with the time lag between the last SBT to the increase in ventilator support were recorded. At the end of the study, the accuracy of these five weaning indices in predicting success of weaning from mechanical ventilation were compared.

Statistical analysis was done with statistical package SPSS version 16.0 for windows. The predictive performances of the weaning parameters were examined using receiver operating characteristic (ROC) curves. Standard formulae were used to calculate the sensitivity, specificity, positive predictive value and negative predictive value of each index.

The positive likelihood ratio (PLR) calculated using the following formula: [sensitivity/(1 – specificity)]. It indicates the probability of a positive index resulting in successful weaning from MV, divided by the probability of the same index resulting in weaning failure. The PLR expresses how many times it is more likely to obtain a positive result for a given index in patients who have been weaned from MV compared with those who have not. The negative likelihood ratio (NLR) is calculated as follows: [(1 – sensitivity)/specificity]. It indicates the probability of a negative index resulting in successful weaning from MV divided by the probability of the same index resulting in weaning failure. In other words, the NLR expresses how many times it is more likely to obtain a negative result for a given index in patients who have not been weaned from MV compared with those who have.

An LR between 0.5 - 2.0 indicates that a parameter is mildly associated with the post-test probability of weaning success or failure.Values of LR between 2.0 - 5.0 and 0.3 - 0.5 are weakly but significantly associated with changes in the probability of weaning success or failure, respectively. Values of LR between 5.0 - 10.0 and 0.1 - 0.3 are more significantly associated with changes in the probability of weaning success or failure, respectively. Values of LR above 10 and below 0.1 are strongly associated with changes in the probability of weaning success or failure, respectively.

The analysis of the ROC curve allows the ability of an index to discriminate between two groups of patients (those who have been weaned and those who have not) to be evaluated, with the advantage of not depending on the cut-off value selected .A test can be classified as follows: AUC<0.50; uninformative, AUC between 0.50 - 0.69; inaccurate, AUC between 0.70 - 0.89; moderately accurate, AUC between 0.90 - 0.99; highly accurate and AUC of 1.00; perfect.

Results

62 patients who were admitted to the Multidisciplinary Intensive Care Unit for mechanical ventilation and had regained ability to tolerate low levels of pressure support alone (< 10 cm H_2O), in the course of their weaning from full ventilator support were enrolled in the study.

The study was designed to be observational in nature. The mode of ventilation and the decision to wean a patient off ventilator was made at the discretion of the intensivist. Weaning criteria and their accuracy were measured once the patients could be ventilated using pressure support alone.

Demographic data: The mean (± SD) age of the patients was 49.7 (± 18.3) years. There were 46 male patients and 16 female patients. Most of them were medically ill and were admitted for various reasons including pneumonia, sepsis, COPD, stroke, myocardial infarction and snake bite.

Weaning indices: The following weaning indices were evaluated: CORE, CROP, RSBI, RSBI rate and minute ventilation recovery. *Table 1* shows the sensitivity, specificity, positive and negative predictive values of the five weaning indices. *Table 2* shows the positive likelihood ratio, negative likelihood ratio, area under the ROC curve (AUC) and the significance of all the five weaning indices.

Table 1: Sensitivity, specificity, positive and negative predictive values of five weaning indices

Index	Threshold value	Sensitivity	Specificity	Positive predictive value	Negative predictive value
CORE	> 6	96	66	92	80
CROP	> 13	95	33	84	80
RSBI	> 105 b/ min/L	90	47	86	55
RSBI rate	> 20%	85	23	80	40
Minute ventilation recovery at 25 min of recovery after SBT	≤ Baseline	92.3	100	100	92.85

Table 2: Positive likelihood ratio, negative likelihood ratio, area under the ROC curve and usefulness for predicting success of weaning from mechanical ventilation of five weaning indices

Index		Positive likelihood ratio	Negative likelihood ratio	AUC	Usefulness for prediction of success of weaning
CORE	> 6	2.8	0.06	0.741	Moderately accurate
CROP	> 13	1.41	0.07	0.62	Inaccurate
RSBI	> 105 b/ min/L	1.69	0.2	0.72	Moderately accurate
RSBI rate	> 20%	1.1	0.6	0.52	Inaccurate
Minute ventilation recovery at 25 min of recovery after SBT	≤ Baseline	∞	0.0077	0.93	Highly accurate

CORE index: The ROC curve for CORE index showed an AUC of 0.741 showing that the CORE index was moderately accurate for prediction of weaning success *(Figure 2)*.

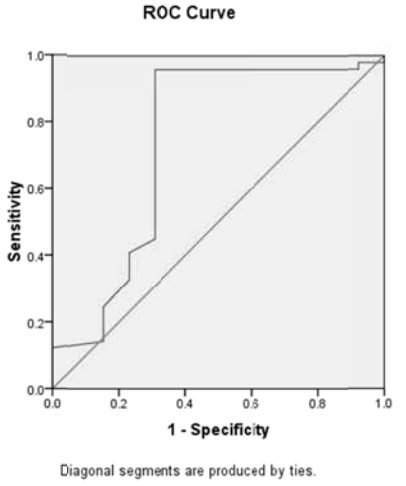

Figure 2: The ROC curve for CORE index.AUC was 0.741 showing that the CORE index was moderately accurate for prediction of weaning success.

CROP index: The ROC curve for CROP index showed an AUC was 0.62 showing that the CROP index was inaccurate for prediction of weaning success *(Figure 3)*.

Rapid shallow breathing index (RSBI): The ROC curve for RSBI showed an AUC was 0.72 showing that the RSBI index was moderately accurate for prediction of weaning success *(Figure 4)*.

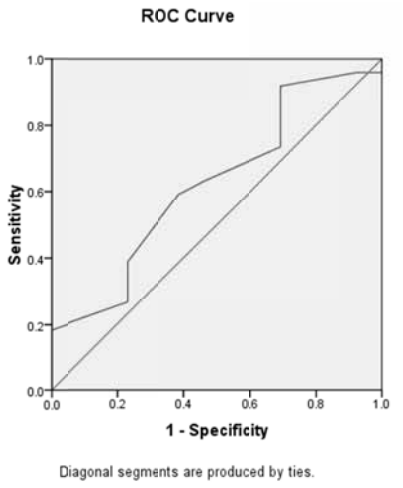

Figure 3: The ROC curve for CROP index.AUC was 0.62 showing that the CROP index was inaccurate for prediction of weaning success.

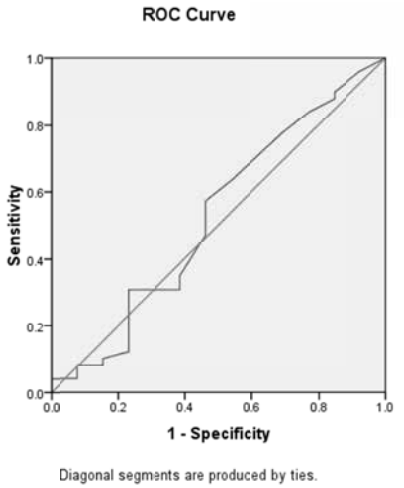

Figure 5: The ROC curve for RSBI rate. AUC was 0.52 showing that the RSBI index was inaccurate for prediction of weaning success.

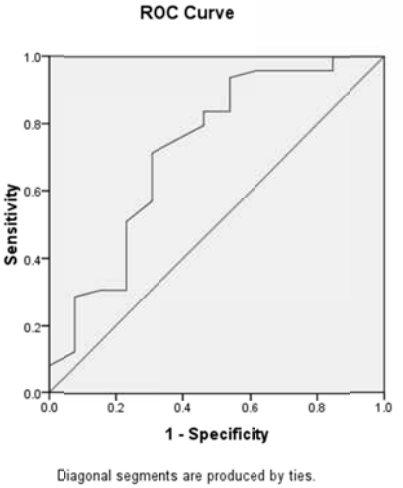

Figure 4: The ROC curve for RSBI. AUC was 0.72 showing that the RSBI index was moderately accurate for prediction of weaning success.

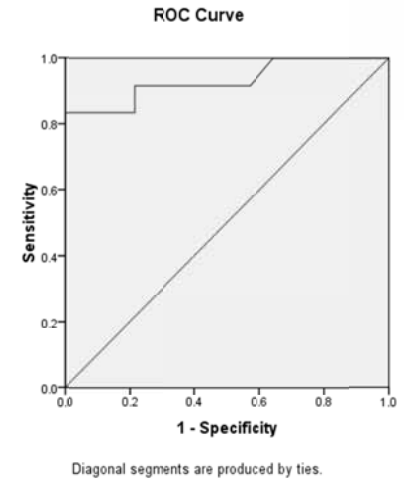

Figure 6: The ROC curve for minute ventilation recovery at 25 min after SBT (n = 26). AUC was 0.93showing that this index was highly accurate for prediction of weaning success.

RSBI rate: The ROC curve for RSBI rate with an AUC was 0.52 showed that the RSBI index was inaccurate for prediction of weaning success *(Figure 5)*.

Minute ventilation recovery: Out of the 62 patients, a total of 26 patients showed an increase in minute ventilation at the end of 30 min of SBT. In all others, it decreased. Of the 26 patients, nine had an increase in minute ventilation of < 1 L/min whereas 17 patients had an increase of ≥ 1 L/min at 30 min of SBT. When minute ventilation was checked after putting them back on the ventilator at the previous setting for 25 min, six patients returned to their original baseline level of minute ventilation and in seven patients, it reduced to below baseline level of minute ventilation. In 13 patients, minute ventilation remained higher than baseline. All the patients in whom the minute ventilation remained higher than at baseline, except one, failed to be weaned off ventilator. The ROC curve for minute ventilation recovery (n = 26) had an AUC of 0.93 showing that this index was highly accurate for prediction of weaning success *(Figure 6)*.

Discussion

Weaning from mechanical ventilation is the process of reducing ventilatory support, ultimately

resulting in a patient breathing spontaneously and being extubated. Several objective criteria have been proposed to assess whether a patient is ready to be weaned off a ventilator.[4-8]

Meade *et al* found that the sensitivity and specificity of CORE index was high compared to the other weaning indices.[9] This was because of the inclusion of $P_{0.1}$ in their index. $P_{0.1}$ is very informative and reliable in the weaning process. They found that the CORE index was the most powerful SBT predictor,with an AUC of 1.0 0 (95% CI 0.92–1.00) and had the highest sensitivity and specificity. We found the CORE index to be only moderately accurate in predicting weaning success where the sensitivity was 96% and specificity was 66%. The ROC curve for CORE index had an AUC of 0.741.

Yang and Tobin proposed the CROP index,[9] but Alvisi and colleagues showed that a CROP index at a threshold value of >16 mL/breaths/min is a good predictor of weaning outcome.[10] They found that it was somewhat cumbersome to use it in the clinical setting. In the present study, CROP index with a threshold value of 13 mL/breaths/min had a sensitivity of 95% and positive predictive value of 84% but with very poor specificity of 33% and negative predictive value of 66%. The AUC for the ROC curve was 0.62%, which again suggested that it was uninformative.

The RSBI was originally described in a prospective cohort study by Yang and Tobin who found that an RSBI >105 breaths/min/L was associated with weaning failure, while an RSBI<105 breaths/min/L predicted weaning success with a sensitivity, specificity, positive predictive value, and negative predictive value of 97, 64, 78, and 95 percent, respectively.[9] The pre-test probability of weaning success in the study population was approximately 60 percent.[10-13] We found that the sensitivity and positive predictive values to be 89 and 86%, but the positive and negative predictive values were low. RSBI rate wasdescribed initially by Segal *et al*[14] The AUC of ROC curve for RSBI rate in this study was 0.72, which suggested moderate association of the index with weaning success.

Minute ventilation recovery as an index has not been described in literature in the form that we have used. Minute ventilation recovery time has been suggested as a weaning index where in the shorter time the patient takes to return to his baseline ventilation, higherare his/her chances of successful weaning off ventilator.[16-18] This assumes that the minute volume increases when the patient is put on SBT.

In the present study, only 26 patients had an increase in minute ventilation at the end of 30 min of SBT. After this period, when they were put back on the ventilator on the previous setting, the minute ventilation either settled back to the baseline or decreased to below baseline in 12 patients but increased to above baseline in 14 patients. 13 of these 14 patients, who had a higher than baseline minute ventilation, failed weaning. The sensitivity, specificity, positive and negative predictive values were 92.3%, 100%, 100% and 92.85 % respectively. The ROC curve had an AUC of 0.93 which makes it a very accurate weaning predictor.

Among the five weaning indices that were studied, the minute ventilation recovery is the strongest and most reliable predictor. The sample size in this study was 62 but for this index, it was only 26. Minute ventilation recovery seems to be a promising weaning index but has to be validated in a larger study.

Conclusions

Of the five weaning indices studied, CORE> 6 and RSBI < 105 breaths/min/L are moderately accurate while CROP > 13 mL/breaths/min and RSBI rate < 20% are inaccurate or uninformative. Minute ventilation recovery, higher than baseline minute ventilation at 25 min of rest on initial ventilator settings after 30 min of SBT predicting weaning failure seems to be highly accurate.

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