RESPIRATORY CARE Paper in Press. Published on November 26, 2013 as DOI: 10.4187/respcare.02652

The modified integrative weaning index as a predictor of extubation failure

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We declare that there are no conflicts of interest.

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ABSTRACT

Introduction: The extubation period is one of the most challenging aspects for intensive care teams. Timely recognition of the return to spontaneous ventilation is essential for reducing costs, morbidity, and mortality. Several weaning predictors are being studied in an attempt to evaluate the outcome of removing ventilatory support. The purpose of this study was to analyze the predictive performance of the modified integrative weaning index (IWI) in the extubation process.

Methods: A prospective study was performed in an intensive care unit (ICU) in a public hospital in Porto Alegre, Brazil, with 59 adult medical-surgical beds. The final population of the study comprised 153 patients on mechanical ventilation (MV) for over 48 hours who were extubated during the period from February to November 2011. Demographic data and clinical parameters were collected in addition to extubation predictors, including static compliance of the respiratory system (Cst,rs), respiratory frequency to tidal volume ratio (f/V_T), tracheal airway occlusion pressure (P0.1), and modified IWI.

Results: Extubation failure was observed in 23 (15%) of the patients. Patients with greater positive fluid balance, lower hemoglobin levels and lower levels of bicarbonate presented a higher rate of reintubation. The three modified IWI values (the first and 30th minute of the spontaneous breathing trial and the difference between both), as well as the other ventilatory parameters and extubation predictors, displayed poor extubation outcome discrimination accuracy. All indexes presented small areas under the receiver operating characteristic (ROC) curve, and no accurate cutoff point was identified.

Conclusion: We concluded that modified IWI, similar to other extubation predictors, does not accurately predict extubation failure.

Key words: Mechanical ventilation, weaning, predictive indexes of extubation.

INTRODUCTION

Although mechanical ventilation (MV) is an essential therapy for patients with respiratory failure, it is an invasive procedure and is associated with a number of complications (1,2). Approximately 90% of critically ill patients require MV (3). Most of these patients require some form of weaning to remove the invasive ventilatory support, and this process occupies over 40% of the required MV time (3,4).

The extubation period continues to be one of the most challenging aspects for intensive care teams (5). Timely recognition of the return to spontaneous ventilation is essential for reducing costs, morbidity, and mortality (6). Both delays in removing invasive ventilatory support and excessively early removal are correlated with complications that vary according to the severity of the underlying disease.

Several weaning predictors are being studied in an attempt to evaluate the outcome of removing ventilatory support (1,7-13). However, none of them have yet presented good results in discriminating the outcome of extubation, even those most used in clinical practices, such as vital capacity (VC), tidal volume (V_T), maximal inspiratory pressure (MIP), tracheal airway occlusion pressure (P0.1) and respiratory frequency to tidal volume ratio (f/V_T) (4,8,11,14-18).

Recently, a new index was created, the integrative weaning index (IWI). This index evaluates respiratory mechanics, oxygenation and respiratory pattern in an integrated manner. It demonstrated surprising accuracy for weaning failure and it was superior to all other predictors. The authors suggest that this index could also be used to predict extubation outcome (14).

Our objectives were to analyze the predictive performance of the modified IWI in the extubation process and to compare the parameter to other used predictors. Furthermore, our goal was to evaluate the accuracy of modified IWI at two different points in time: the first and 30th minute of a spontaneous breathing trial (SBT).

METHODS

This prospective study was conducted in an intensive care unit (ICU) of a public hospital in Porto Alegre, Brazil. The study ICU has 59 medical-surgical beds for adults. Patients requiring mechanical ventilation (MV) for over 48 hours and who were extubated during the period from February to November 2011 were included in the study.

The study was approved by the Institutional Ethics Committee (11-060). Because the laboratory tests and data collected in this study are part of the routine clinical practice at the hospital, the informed consent requirement was waived.

All patients screened to the study were on MV performed using a Servo*i*, Servo*s* (Siemens-Elema, AB, Sweden) or Evita XL (Dräger, Lübeck, Germany) ventilator. Weaning readiness from mechanical ventilation was tested when the attending team judged that the patient was ready to begin the weaning process and was based on the following criteria: improvement of the underlying condition that led to acute respiratory failure, afebrile, cardiovascular stability (mean arterial pressure greater than 65 mmHg with no or minimal dose of vasoactive drugs), adequate mental status with no continuous sedative infusion, partial pressure of arterial oxygen (PaO_2) greater than 60 mmHg or saturation of peripheral oxygen (SpO_2) greater than 90%, fraction of inspired oxygen (FiO_2) less than 40% and positive end-expiratory pressure (PEEP) less than or equal to 8 cmH_2O. The SBT was performed through a T-tube as a routine procedure in the unit, and the duration was 30 minutes.

The static compliance of the respiratory system (Cst,rs) was measured using volume control ventilation. When the pressure-time curve was without inspiratory efforts from the patient, an inspiratory pause of 1.0 second was used to conclude the measurement. Cst,rs was calculated by dividing the tidal volume (V_T) by the difference between the inspiratory plateau pressure and PEEP.

To measure P0.1, pressure support was reduced to 7 cmH_2O, and the P0.1 value was obtained from the average of three consecutive measures at 15-second intervals.

The f/V_T was calculated for the first and 30th minute of SBT, while patient was disconnected from the ventilator, using an analog ventilometer (Ohmeda Respirometer, RM

121, Japan). The f/V_T was obtained by dividing the respiratory rate (RR) by the tidal volume (V_T) (15).

PaO_2 was obtained through gas blood collection performed before the SBT, and the parameter was used to determine the PaO_2/FiO_2 ratio.

The IWI was created to evaluate respiratory mechanics, oxygenation and respiratory pattern in an integrated manner. It is calculated as the product of Cst,rs and SaO_2 divided by f/V_T (IWI = Cst,rs x SaO_2 / [f/V_T]). The threshold used to best discriminate the success or failure of weaning was > 25 ml/cmH_2O. In our study, we modified the IWI in some aspects, calling it modified IWI. We used SpO_2 to replace the SaO_2 obtained by sampling arterial blood. This substitution is justified by the good correlation between both (19) parameters and because it is easier to obtain the former. In addition, measurement was performed at two points in time: at the first and 30th minute of the SBT. For the latter measurement, we used the same value of Cst,rs obtained immediately before the SBT and the values of SpO_2 and f/V_T at its end.

The respiratory variables were measured by previously trained respiratory physiotherapists. The decision to return the patient to MV or proceed to extubation was made by the attending team and based on the signs of intolerance to SBT, such as tachypnea, tachycardia, hemodynamic instability, breathing effort and change in mental status. Patients were reintubated according to attending team based on the following criteria: decrease in oxygen saturation to less than 88%, despite use of high FiO_2; worsening of arterial pH or $PaCO_2$; respiratory muscle fatigue; hemodynamic instability; copious secretions that the patient could not remove adequately; and decreased mental status. It is important to highlight that these criteria are those used in the unit but they were not explicitly checked before reintubation.

Extubation failure was defined as reintubation within less than 48 hours. We did not evaluate weaning failure, but to compare it to other studies, weaning failure was defined by the inability to tolerate SBT.

In addition to the ventilatory parameters and predictive indexes, demographic and clinical data were collected. The Simplified Acute Physiologic Score (SAPS) III was calculated upon admission to the ICU. All patients were followed to determine ICU and hospital mortality.

The data are presented as the mean ± SD. Continuous numerical variables were analyzed by use of the Student t test. ROC curves were constructed to evaluate the discriminatory power of the predictors used. Linear regression analysis was used to evaluate the relationship between SaO_2 and SpO_2. All the data collected were analyzed using the commercially available statistical program SPSS 15.0 (SPSS, Chicago, IL). A $p < 0.05$ value was considered statistically significant.

RESULTS

We screened 358 patients requiring mechanical ventilation for over 48 hours who were extubated. Two hundred and five of these patients were excluded because they were extubated without performing a SBT (n=77), suffered accidental extubations (n=6) or were on MV with equipment that did not have the devices needed to perform the proposed measurements (n = 122). The final population consisted of 153 patients.

The demographic characteristics and clinical parameters of the patients are described in Table 1. The most common cause of initiating MV was pneumonia, which was present in 68 (44.4%) patients.

Extubation failure was observed in 23 (15%) patients. The success and failure groups did not present any significant differences regarding SAPS III, age, cause for beginning MV, time of MV before extubation, use of non-invasive ventilation (NIV) after extubation or vasoactive drugs. Patients with greater positive fluid balance, lower hemoglobin levels and lower levels of bicarbonate presented a higher rate of reintubation. Extubation failure was correlated with higher mortality in the ICU and in hospital (Table 1).

The three modified IWI results (first and 30th minute of the SBT and the difference between them) were not associated with extubation failure (Table 2). Furthermore, all patients with modified IWI ≤ 25 ml/cmH_2O presented successful extubation. The other predictors, such as f/V_T, were also not associated with extubation outcome (Table 2). The areas under the ROC curves of modified IWI are shown in Figure 1.

SaO_2 and SpO_2 showed an excellent correlation ($r^2 = 0.91$; $p < 0.001$).

DISCUSSION

We determined that modified IWI is not accurate for discriminating extubation outcome. To the best of our knowledge, this is the first study to evaluate the index for this purpose.

None of the three modified IWI results displayed any association with extubation failure. A recent study demonstrated excellent accuracy of the index in evaluating weaning failure (14). In that study, the authors also suggested that this index could be used to predict extubation failure. The suggestion was based on an analysis of 10 patients who presented such an outcome. Some differences between that study and ours might explain the results obtained. First, we must consider the difference between weaning failure and extubation failure. In the study by Nemer et al., the main outcome analyzed was weaning failure, with a secondary analysis of the patients who presented extubation failure (14). In our study, the index was tested exclusively to predict extubation outcome. Historically, weaning predictors have shown greater accuracy in discriminating weaning outcome as compared with extubation outcome (1,4,6,8,15-18). Although the IWI is promising, it possibly presents the same pattern. Second, we did not use a fixed FiO_2. Finally, the increased size of the sample used to evaluate extubation may have contributed to differing results.

It should be highlighted that the use of modified IWI at the end of the SBT and the difference between the final and initial modified IWI also did not present an association with extubation failure. Our hypothesis was that these variables may be more accurate than the initial modified IWI, as already shown for other indexes (20).

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In our opinion, seeking predictive indexes associated with extubation failure is more important than with weaning failure. Tanios et al. (21) already demonstrated that the use of predictive indexes when deciding to perform a SBT delays extubation. In addition, the test proved very secure (22). Thus, in clinical practice, the value of a predictive index that suggests that the patient is ready to undergo the SBT is uncertain. However, deciding the right time to perform extubation is very important. Premature extubation, with a higher risk of reintubation, is associated with a greater need for tracheostomy, longer length of stay in the ICU and in hospital and greater mortality (11,23). At the other extreme, late extubation increases the risk of pneumonia, length of time in the ICU and hospital mortality (1,2). In our study, the patients who required reintubation presented ICU mortality rates that were approximately 5 times higher than those who were successfully extubated. In this context, a predictive index for extubation outcome would be invaluable. Unfortunately, modified IWI did not prove very accurate for the latter purpose.

A few clinical parameters appear to be associated with extubation failure. In our study, a greater positive fluid balance, lower hemoglobin levels and lower levels of bicarbonate increased the chances of reintubation. Some authors (24,25) had already demonstrated this association with a positive fluid balance and anemia. The relationship between bicarbonate and this outcome is a new finding. These clinical parameters should be tested in future studies and most likely be evaluated in the weaning process.

The poor accuracy of weaning predictors to evaluate extubation is nothing new. One of the possible explanations is that besides the clinical parameters cited previously, the quality of coughing and the amount of respiratory secretions are most likely associated with the development of extubation failure. None of these variables are taken into account in the predictive indexes. The bad performance of modified IWI in predicting the extubation outcome in our study most likely has the same explanations. An index that does not include these variables probably will not present a good performance. Thus, the results were not surprising.

This study presents some limitations. The exclusion of patients may have added a bias to the results obtained. In addition, because the number of patients was small, we cannot exclude with certainty that the negative results are not due to a beta error. Furthermore, we used the 30 minutes SBT. Perhaps the 2-hour SBT could better discriminate extubation outcome and provide different results (26). The accuracy of the measurement of the static compliance of the respiratory system when patients are not paralyzed is not clear. We tried to minimize this limitation by avoiding respiratory cycles with inspiratory efforts of the patient, after assessing the digital display. The measure of P0.1 was performed with 7 cmH_2O pressure support. As we use the heat and moisture exchange filter, this may have influenced this parameter (27-29). Besides, P0.1 on Servo-i was recorded without occlusion maneuver. Although there are criteria for reintubation in the unit, the decision to reintubate was made by the attending physician. This may have added another bias to the results obtained. Finally, the study was conducted at a single center, making it difficult to generalize the results.

We concluded that modified IWI, as well as other weaning predictors, do not accurately predict extubation failure. The indexes derived from modified IWI (at the 30th minute of SBT and the difference between first and 30th minute) presented similar results. Thus, we do not yet have a good predictive index for discriminating extubation outcome. Future studies should fill this gap.

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RESPIRATORY CARE Paper in Press. Published on November 26, 2013 as DOI: 10.4187/respcare.02652

Figure 1. Receiver operating characteristic curve of modified IWI

RESPIRATORY CARE Paper in Press. Published on November 26, 2013 as DOI: 10.4187/respcare.02652

Table 1. Demographic characteristics and clinical parameters

Variable	**Extubation success (n = 130)**	**Extubation failure (n = 23)**	**p**
Age, years	56.3 ± 17.8	62.1 ± 14.1	0.14
Gender, male n (%)	69 (53.1)	12 (52.2)	1.00
SAPS III	59.8 ± 15.9	70.6 ± 19.1	0.09
COPD, n (%)	14 (10.8)	3 (13.0)	0.72
Cause of acute respiratory failure			0.49
COPD acute exacerbation	6 (4.6)	1 (4.3)	
Pneumonia	56 (43.1)	12 (52.2)	
Cardiac failure	12 (9.2)	3 (13.0)	
Neurological	10 (7.7)	2 (8.7)	
Postoperative	17 (13.1)	2 (8.7)	
Cardiac arrest	9 (6.9)	3 (13.0)	
Miscellaneous	20 (15.4)	-	
Days on MV	7.6 ± 4.7	8.0 ± 4.9	0.68
Hb (g/dL)	9.2 ± 2.0	8.1 ± 1.4	0.013
Lactate (mmol/L)	1.3 ± 0.6	1.4 ± 0.9	0.36
Fluid balance during 24 h before extubation, ml	106.4 ± 1503.0	803.2 ± 1363.4	0.04
pH	7.43 ± 0.1	7.44 ± 0.1	0.78
$PaCO_2$ (mmHg)	39.3 ± 6.9	34.9 ± 6.0	0.005
PaO_2 (mmHg)	111.3 ± 37.1	107.1 ± 34.9	0.62
HCO_3 (mmol/L)	26.7 ± 5.0	23.9 ± 5.1	0.017
PaO_2/FiO_2	356.4 ± 118.8	345.5 ± 122.1	0.69
ICU mortality, n (%)	11 (8.5)	10 (43.5)	< 0.001
Hospital mortality, n (%)	38 (29.2)	14 (60.9)	0.012

SAPS, Simplified Acute Physiology Score; COPD, chronic obstructive pulmonary disease; MV, mechanical ventilation; Hb, hemoglobin

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Table 2. Ventilatory parameters at MV and SBT

Variable	Extubation success (n = 130)	Extubation failure (n = 23)	p
PSV (cmH2O)	11.9 ± 2.0	11.7 ± 1.6	0.60
PEEP (cmH2O)	5.8 ± 0.9	5.7 ± 0.7	0.53
FiO_2	0.32 ± 0.05	0.33 ± 0.04	0.36
SpO_2	98.8 ± 1.5	98.6 ± 2.1	0.54
Cst (mL/cmH2O)	39.4 ± 15.5	38.5 ± 11.0	0.80
P0.1 (cmH2O)	1.5 ± 1.1	1.7 ± 1.3	0.52
Minute volume (L)	9.2 ± 3.3	9.9 ± 3.1	0.36
Tidal volume (mL)	427.5 ± 187.0	437.2 ± 137.3	0.81
Respiratory rate (breaths/min)	22.5 ± 5.9	23.1 ± 4.7	0.64
f/V_T (breaths/min/L)			
First minute of SBT	63.0 ± 35.9	60.0 ± 27.2	0.71
30th minute of SBT	58.3 ± 29.9	64.7 ± 27.7	0.35
Difference between first and 30th minute of SBT	-4.6 ± 27.9	4.7 ± 20.9	0.13
Modified IWI (mL/cmH_2O)			
First minute of SBT	93.9 ± 105.3	80.1 ± 56.5	0.54
30th minute of SBT	96.3 ± 98.9	70.7 ± 49.7	0.23
Difference between first and 30th minute of SBT	2.5 ± 58.3	-9.3 ± 25.3	0.34

PSV, pressure support ventilation; PEEP, positive end-expiratory pressure; FiO_2, fraction of inspired oxygen; Cst, static compliance; P0.1, tracheal airway occlusion pressure; f/V_T, respiratory frequency to tidal volume ratio; SBT, spontaneous breathing trial; IWI, integrative weaning index

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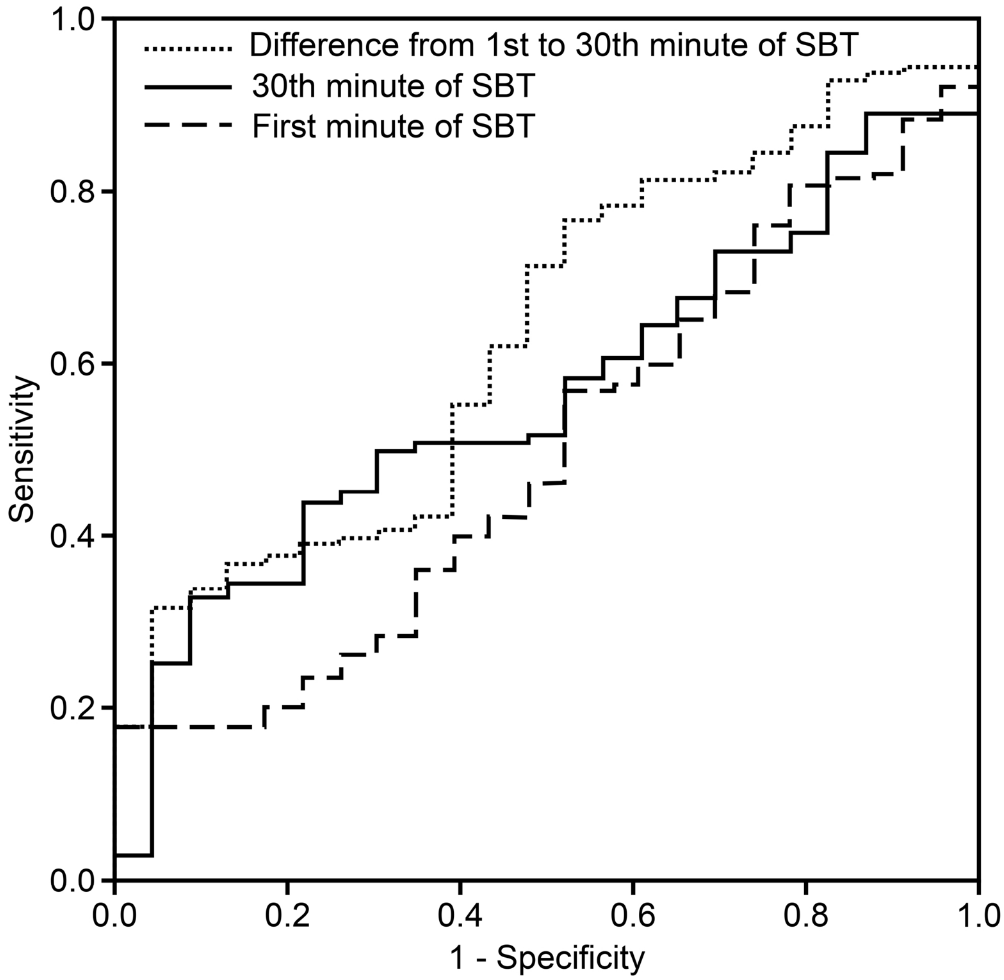

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