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The Modified Integrative Weaning Index as a Predictor of Extubation Failure

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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 were 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 ICU in a public hospital in Porto Alegre, Brazil, with 59 adult medical-surgical beds. The final population of the study comprised 153 patients receiving mechanical ventilation for over 48 h 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, ratio of breathing frequency to tidal volume, tracheal airway-occlusion pressure 0.1 s after the start of inspiratory flow, and modified IWI. RESULTS: Extubation failure was observed in 23 of the subjects (15%). Subjects with greater positive fluid balance, lower hemoglobin levels, and lower levels of bicarbonate presented a higher rate of reintubation. The 3 modified IWI values (the first and 30th minute of the spontaneous breathing trial and the difference between them), 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 curve, and no accurate cutoff point was identified. CONCLUSIONS: 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.* [Respir Care 2014;59(7):1–•. © 2014 Daedalus Enterprises]

Introduction

Although mechanical ventilation 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 mechanical ventilation.[3] Most of these patients require some form of weaning to remove the invasive ventilatory support, and this process occupies > 40% of the required mechanical ventilation 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] Delays in both removing invasive ventilatory support and exces-

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The authors have disclosed no conflicts of interest.

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sively early removal are correlated with complications that vary according to the severity of the underlying disease.

Several weaning predictors were 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, tidal volume (V_T), maximal inspiratory pressure, tracheal airway-occlusion pressure 0.1 s after the start of inspiratory flow ($P_{0.1}$), and ratio of breathing frequency (f) to V_T (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 in this study were to analyze the predictive performance of the modified IWI in the extubation process and to compare the IWI to other predictors being used. Furthermore, our goal was to evaluate the accuracy of the modified IWI at 2 different points in time: the first and 30th minute of a spontaneous breathing trial (SBT).

QUICK LOOK

Current knowledge

Daily spontaneous breathing trials are the standard of care for determining the appropriate timing of ventilator discontinuation. A number of other parameters have been used in an attempt to improve the accuracy of predicting weaning outcomes, but with little success.

What this paper contributes to our knowledge

The integrative weaning index (IWI) combines respiratory mechanics, oxygenation, and respiratory pattern into a single value to predict weaning success. The IWI did not accurately predict weaning failure.

Methods

This prospective study was conducted in the ICU of a public hospital in Porto Alegre, Brazil. The study ICU has 59 medical-surgical beds for adults. Patients requiring mechanical ventilation for over 48 h 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. 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 for the study were receiving mechanical ventilation, which was performed using a Servo*i*, Servos (Siemens-Elema AB, Solna, Sweden) or Evita XL (Dräger, Lübeck, Germany) ventilator. Readiness for weaning 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 > 65 mm Hg with no or minimal dose of vasoactive drugs), adequate mental status with no continuous sedative infusion, $P_{aO_2} > 60$ mm Hg or $S_{pO_2} > 90\%$, $F_{IO_2} < 40\%$, and PEEP ≤ 8 cm H_2O. The SBT was performed through a T-tube as a routine procedure in the unit, and the duration was 30 min.

The compliance of the respiratory system (C_{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 s was used to conclude the measurement. C_{RS} was calculated by dividing the V_T by the difference between the inspiratory plateau pressure and PEEP.

To measure $P_{0.1}$, pressure support was reduced to 7 cm H_2O, and the $P_{0.1}$ value was obtained from the average of 3 consecutive measures at 15-s intervals.

The f/V_T was calculated for the first and 30th min of the SBT, while the patient was disconnected from the ventilator, using an analog ventilometer (RM121 Respirometer, Ohmeda Japan, Tokyo, Japan). The f/V_T was obtained by dividing the f by the V_T.[15]

P_{aO_2} was obtained through blood gas collection performed before the SBT, and the parameter was used to determine the P_{aO_2}/F_{IO_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 C_{RS} and oxygen saturation measured from an arterial blood sample (S_{aO_2}) divided by f/V_T ($IWI = C_{RS} \times S_{aO_2}/[f/V_T]$). The threshold used to best discriminate the success or failure of weaning was > 25 mL/cm H_2O. In our study, we modified some aspects of the IWI, calling it the "modified IWI." We used S_{pO_2} to replace the S_{aO_2} measure. 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 2 points in time: at the first and 30th min of the SBT. For the latter measurement, we used the same value of C_{RS} obtained immediately before the SBT, and the values of S_{pO_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 mechanical ventilation or proceed to extubation was made by the attending team and was based on signs of intolerance to SBT, such as tachypnea, tachycardia, hemodynamic instability, breathing effort, and change

Table 1. Demographic Characteristics and Clinical Parameters

Variables	Extubation Success (n = 130)	Extubation Failure (n = 23)	P
Age (y)	56.3 ± 17.8	62.1 ± 14.1	.14
Male sex	69 (53.1)	12 (52.2)	> .99
SAPS III	59.8 ± 15.9	70.6 ± 19.1	.09
COPD	14 (10.8)	3 (13.0)	.72
Cause of acute respiratory failure			.49
COPD 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)	-	
Duration of MV (d)	7.6 ± 4.7	8.0 ± 4.9	.68
Hb (g/dL)	9.2 ± 2.0	8.1 ± 1.4	.013
Lactate (mmol/L)	1.3 ± 0.6	1.4 ± 0.9	.36
Fluid balance during 24 h before extubation (mL)	106.4 ± 1,503.0	803.2 ± 1,363.4	.04
pH	7.43 ± 0.1	7.44 ± 0.1	.78
P_{aCO_2} (mm Hg)	39.3 ± 6.9	34.9 ± 6.0	.005
P_{aO_2} (mm Hg)	111.3 ± 37.1	107.1 ± 34.9	.62
HCO_3 (mmol/L)	26.7 ± 5.0	23.9 ± 5.1	.02
P_{aO_2}/F_{IO_2}	356.4 ± 118.8	345.5 ± 122.1	.69
ICU mortality	11 (8.5)	10 (43.5)	< .001
Hospital mortality	38 (29.2)	14 (60.9)	.01

Data are mean ± SD or n (%) unless otherwise stated.
SAPS III = Simplified Acute Physiology Score III
MV = mechanical ventilation
Hb = hemoglobin

in mental status. Patients were reintubated according to the attending team based on the following criteria: decrease in oxygen saturation to < 88%, despite use of high F_{IO_2}; worsening of arterial pH or P_{aCO_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 < 48 h. 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 Physiology Score III was calculated upon admission to the ICU. All patients were followed up to determine ICU and hospital mortality.

The data are presented as the mean ± SD. Continuous numerical variables were analyzed by use of the Student's t test. Receiver operating characteristic curves were constructed to evaluate the discriminatory power of the predictors used. Linear regression analysis was used to evaluate the relationship between S_{aO_2} and S_{pO_2}. All the data collected were analyzed using a commercially available statistical program (SPSS version 15.0, SPSS, Chicago, Illinois). $P < .05$ was considered to be statistically significant.

Results

We screened 358 patients requiring mechanical ventilation for > 48 h who had been extubated. Two hundred five of these patients were excluded because they had been extubated without performing an SBT (n = 77), had experienced accidental extubations (n = 6), or were receiving mechanical ventilation 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 mechanical ventilation was pneumonia, which was present in 68 patients (44.4%).

Extubation failure was observed in 23 patients (15%). The success and failure groups did not present any signif-

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Table 2. Ventilatory Parameters at Mechanical Ventilation and Spontaneous Breathing Trial

Variables	Extubation Success (n = 130)	Extubation Failure (n = 23)	P
PSV (cm H_2O)	11.9 ± 2.0	11.7 ± 1.6	.60
PEEP (cm H_2O)	5.8 ± 0.9	5.7 ± 0.7	.53
F_{IO_2}	0.32 ± 0.05	0.33 ± 0.04	.36
S_{pO_2}	98.8 ± 1.5	98.6 ± 2.1	.54
C_{RS} (mL/cm H_2O)	39.4 ± 15.5	38.5 ± 11.0	.80
$P_{0.1}$ (cm H_2O)	1.5 ± 1.1	1.7 ± 1.3	.52
Minute volume (L)	9.2 ± 3.3	9.9 ± 3.1	.36
V_T (mL)	427.5 ± 187.0	437.2 ± 137.3	.81
Breathing frequency (breaths/min)	22.5 ± 5.9	23.1 ± 4.7	.64
f/V_T (breaths/min/L)			
First min of SBT	63.0 ± 35.9	60.0 ± 27.2	.71
30th min of SBT	58.3 ± 29.9	64.7 ± 27.7	.35
Difference between first and 30th min of SBT	–4.6 ± 27.9	4.7 ± 20.9	.13
Modified IWI (mL/cm H_2O)			
First min of SBT	93.9 ± 105.3	80.1 ± 56.5	.54
30th min of SBT	96.3 ± 98.9	70.7 ± 49.7	.23
Difference between first and 30th min of SBT	2.5 ± 58.3	–9.3 ± 25.3	.34

Data are mean ± SD.
PSV = pressure support ventilation
C_{RS} = compliance of the respiratory system
$P_{0.1}$ = airway-occlusion pressure 0.1 s after the start of inspiratory flow
V_T = tidal volume
f/V_T = ratio of breathing frequency to tidal volume
SBT = spontaneous breathing trial
IWI = integrative weaning index

icant differences regarding Simplified Acute Physiology Score III, age, cause for beginning mechanical ventilation, time of mechanical ventilation before extubation, use of noninvasive ventilation after extubation or use of 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 the hospital (Table 1).

The 3 modified IWI results (first and 30th min of the SBT and the difference between them) were not associated with extubation failure (Table 2). Furthermore, all patients with a modified IWI of ≤ 25 mL/cm H_2O underwent extubation successfully. The other predictors, such as f/V_T, were also not associated with extubation outcome (Table 2). The areas under the receiver operating characteristic curves of the modified IWI are shown in Figure 1.

S_{aO_2} and S_{pO_2} showed an excellent correlation ($r^2 = 0.91$, $P < .001$).

Discussion

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

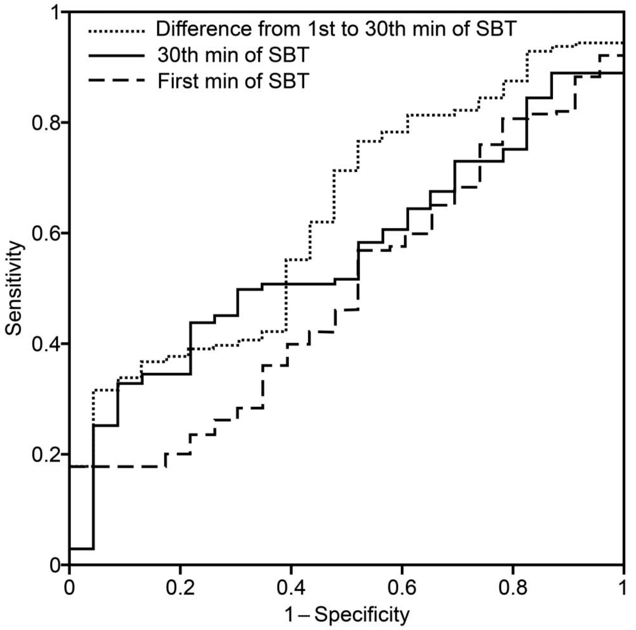

Fig. 1. Receiver operating characteristic curve of modified integrative weaning index. SBT = spontaneous breathing trial.

None of the 3 modified IWI results displayed any association with extubation failure. A recent study[14] demonstrated excellent accuracy of the IWI in evaluating weaning failure. In that study,[14] 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 with 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[14] the main outcome analyzed was weaning failure, with a secondary analysis of the patients who presented with extubation failure. In our study, the IWI was tested exclusively to predict extubation outcome. Historically, weaning predictors have shown greater accuracy in discriminating weaning outcome 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 F_{IO_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 the modified IWI at the end of the SBT, and the difference between the final and initial modified IWI values 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]

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 an SBT delays extubation. In addition, the test proved to be 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 on 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, a longer stay in the ICU and the hospital, and higher mortality.[11,23] At the other extreme, late extubation increases the risk of pneumonia, the length of time in the ICU, and hospital mortality.[1,2] In our study, the patients who required reintubation had ICU mortality rates that were ~5 times higher than those who were successfully extubated. In this context, a predictive index for extubation outcome would be invaluable. Unfortunately, the 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 should 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 the modified IWI in predicting extubation outcome in our study most likely has the same explanations. An index that does not include these variables probably will not perform well. Thus, the results were not surprising.

This study has 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 min SBT. Perhaps the 2-h SBT could better discriminate extubation outcome and provide different results.[26] The accuracy of the measurement of the C_{RS} 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 measurement of $P_{0.1}$ was performed with 7 cm H_2O pressure support. As we use the heat and moisture exchange filter this may have influenced this parameter.[27-29] Besides, the $P_{0.1}$ on the Servo*i* ventilator was recorded without an 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 the modified IWI as well as other weaning predictors do not accurately predict extubation failure. The indexes derived from the modified IWI (at the 30th minute of SBT and the difference between the first and 30th minute) showed 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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