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CLINICAL RESEARCH

Comparison of different methods of obtaining the rapid shallow breathing index

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Abstract
Objective: To compare the Rapid Shallow Breathing Index (RSBI) obtained by the ventilometer and from mechanical ventilation parameters.
Methods: Randomized crossover trial, including 33 intubated patients, on mechanical ventilation for at least 24 hours, undergoing spontaneous breathing test. Patients were submitted to the measurement of RSBI by four methods: disconnected from the ventilator through the ventilometer; in Pressure Support Ventilation (PSV) mode at a pressure of 7 cm H_2O; in Continuous Positive Airway Pressure (CPAP) mode at a pressure of 5 cmH_2O with flow trigger; in CPAP mode at a pressure of 5 cmH_2O with pressure trigger.
Results: No significant difference was detected between the RSBI obtained by the ventilometer and in the CPAP mode with flow and pressure triggers, however, in the PSV mode, the values were lower than in the other measurements ($p < 0.001$). By selecting patients from the sample with higher RSBI ($\geq$ 80 cycles.min^{-1}.L^{-1}), the value of the index obtained by the ventilometer was higher than that obtained in the three options of ventilation methods.
Conclusion: The RSBI obtained in the CPAP mode at a pressure of 5 cmH_2O, in both triggers types, did not differ from that measured by the ventilometer; it is, therefore, an alternative when obtaining it from mechanical ventilation parameters is necessary. However, in the presence of borderline values, the RSBI measured by ventilometer is recommended, as in this method the values are significantly higher than in the three ventilation modalities investigated.

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Introduction

On average, 40% patients admitted to Intensive Care Units (ICUs) are on Mechanical Ventilation (MV),[1] of which up to 25% may have difficulty in weaning.[2] Once the health condition that led to respiratory insufficiency was reversed, patient should be released from MV as it imposes a series of risks.[3] On the other hand, premature extubation is susceptible to secondary complications, which, as well as its delay, also results in increased morbidity and mortality in the ICUs.[4,5]

To identify patients who are candidates for extubation, it is recommended to perform a Spontaneous Breathing Trial (SBT). It is usually done in Pressure Support Ventilation (PSV) mode, with pressure between 5 and 7 cmH_2O, or with the patient breathing spontaneously with an oxygen source connected to the endotracheal tube, lasting from 30 minutes to 2 hours.[1,3] It is considered successful weaning when the patient is successful in the SBT, and successful extubation when there is no reintubation in the first 48 hours after removal of the endotracheal tube.[3]

Even after successful SBT, up to 30% patients have failed extubation.[2] Several scores have already been proposed in an attempt to identify who will be successful at weaning and extubation,[3,6,7] and among these the Rapid Shallow Breathing Index (RSBI) is the most studied and used in ICUs because it is practical, noninvasive and easily obtained.[7] Described by Yang and Tobin,[8] it consists of obtaining the values of Respiratory Rate (RR) and Tidal Volume (TV) with the ventilometer connected to the artificial airway with the patient in spontaneous breathing for one minute. RSBI is calculated by the ratio of RR to TV (RR/TV) expressed in $cycles.min^{-1}.L^{-1}$, and values less than 105 $cycles.min^{-1}.L^{-1}$ predict success in weaning with a sensitivity of 97%, specificity of 64%, positive predictive value of 78% and negative predictive value of 95%.

Originally, ventilometer is the recommended instrument to measure the variables used in the calculation of the RSBI;[8] however, in clinical practice, many professionals obtain these values directly from the ventilator display.[4,6] Two studies – one conducted in the Federal District[4] and the other in the city of São Paulo[9] – evidenced, respectively, that 95%[4] and 85%[9] of physical therapists collect data for the calculation of RSBI based on MV parameters, citing the non-availability of the device as a justification. However, using the measurements obtained by the ventilator can compromise the accuracy of the RSBI, since non-calibrated ventilators and the addition of positive pressure can affect the accuracy of the measurement.[4,6,9]

Some studies have indicated that calculating the RSBI using data from the ventilator can interfere with the value reached.[5,10–13] Obtaining it in PSV mode, even with low pressure levels, generates lower RSBI values than from spontaneous breathing with the use of the ventilometer.[5,11,13–16] When comparing the RSBI obtained by the ventilometer with the one from Continuous Positive Airway Pressure (CPAP) mode, the data are conflicting. There are studies reporting lower values in the CPAP mode[10,15,17,18] and others that show an increase[19] or absence of difference.[11] The main consequence of using ventilatory support during the assessment would be the early extubation of patients unable to sustain spontaneous breathing.[14]

Base flow, provided by some ventilators when using flow trigger, can influence the variables measured by the ventilator for the calculation of RSBI.[10,20] The reduction in RSBI has been described[20] when obtained in MV with flow trigger compared to the pressure trigger, justifying that this effect is due to the base flow present in this type of trigger. This issue, however, needs to be further investigated.

Considering the difficulty – due to the lack of resources in many services – in obtaining the RSBI by a ventilometer,[4,9] and also the ease that currently exists with the incorporation of its calculation and presentation in the display of the most modern ventilators,[6] it justifies the investigation of which ventilation parameter could offer indices with values closer to those generated by means of the ventilometer, and also the possible interference of the base flow in these results. The goal of the study was to compare the RSBI obtained through the ventilometer with that obtained from MV parameters in PSV mode and in CPAP mode with flow and pressure triggers.

Methods

The study was approved by the Research Ethics Committee of the Federal University of Espírito Santo – UFES (opinion 1.472.040) and registered on the Brazilian Clinical Trial Registry (ReBEC) with protocol n RBR-96cwz48. Family members or guardians of patients received information regarding the study and their rights, allowing their participation by signing the Informed Consent Form (ICF). The CONSORT (Consolidated Standards of Reporting Trials) guidelines were followed when reporting this study.

A randomized prospective crossover study was conducted in the ICU of a university hospital in Vitória, state of Espírito Santo. All patients who were admitted to the ICU, between August 2018 and March 2019, were evaluated for possible participation in the study. Participants were selected according to the following inclusion criteria: both sexes; aged 18 years and older; hospitalized in the ICU; intubated and on MV for at least 24 hours; ventilated with Puritan-Bennett 840 or Dixtal 3012 plus ventilators; undergoing SBT; hemodynamically stable, without continuous administration of vasopressors or central nervous system depressants; and with a PaO_2/FiO_2 relation above 200 mmHg. Tracheostomized patients, reintubated in the last seven days or whose family member or guardian refused to sign the informed consent form were excluded.

The following clinical and demographic data were collected from patients: age, sex, race, the Simplified Acute Physiology Score 3 (SAPS 3) prognostic index, reason for admission to the ICU, reason for intubation and time from intubation to SBT, ventilatory and monitoring parameters. All decisions about SBT and extubation were made by the ICU care team according to the sector routine, without interference from researchers.

Patients were included in the study when submitted to SBT, which was performed in PSV mode, with PSV less than or equal to 7 cmH_2O, PEEP less than or equal to 8 cmH_2O, and fraction of inspired O_2 (FiO_2) less than or equal to 40%.[3] Ventilation data for the calculation of the RSBI was collected during the SBT (between 15 and 120 minutes SBT) and prior to extubation, as long as the patient did not show any of the

following signs of intolerance: RR greater than 35 rpm; Saturation of Peripheral Oxygen (SpO_2) less than 90%; heart rate greater than 140 bpm; systolic blood pressure greater than 180 mmHg or less than 90 mmHg; and signs and symptoms of agitation, sweating, or altered level of consciousness.[3]

All patients were submitted to the four methods of obtaining the RSBI, and their data were later compared. For data collection, they were kept in the supine position with 45° head elevation. RSBI was calculated from the variables TV and RR, verified both through an analog ventilometer (Wright) and through the ventilator display, with the patient submitted to three ventilation modalities: PSV of 7 cmH_20 with pressure trigger (2 cmH_2O); CPAP of 5 cmH_2O with pressure trigger (2 cmH_2O) (CPAP/P); and CPAP of 5 cmH_2O with flow trigger (2 LPM) (CPAP/F).

Changes in ventilation modes were carried out by physical therapists in the sector, and data were recorded by researchers. The sequence for obtaining the index was first in the PSV mode, since it was already the ventilation mode in which they were undergoing the SBT, and the order of obtaining in the other modalities was randomized, by the researchers, by drawing opaque and sealed envelopes containing the different options of sequences. It was not possible to blind the evaluators given the difficulty of preventing the evaluator from knowing the ventilation modality of the patient at the time of data collection.

For the collection of ventilator data, a period of two minutes was waited after each change in ventilation mode, for stabilization purposes, and then the minute volume and RR values were recorded for four consecutive times, with a minimum interval of three breaths between them. To calculate the RSBI, the minute volume value was divided by the RR to obtain the TV, followed by the division of the RR by TV, in liters. RSBI values of the four measures were calculated, excluding the most discrepant and averaging the others.

For the measurement by means of the ventilometer, patients were disconnected from the ventilator and placed on spontaneous breathing with the ventilometer connected to the endotracheal tube; if necessary (to keep SpO_2 above 92%), oxygen could be offered through a macronebulization circuit, with an oxygen flow of a maximum of 5 $L.min^{-1}$. Before the measurement, a period of 30 seconds to 1 minute was waited for the breathing pattern to stabilize. Data collection could be interrupted if the patient had any of the signs of intolerance described for the SBT, which was properly attended by the ICU care team.

Statistical analysis

The sample size was calculated based on previous data,[13] considering a minimum detectable difference of 19.15, standard deviation of 20.71, alpha error of 5% and power of 90%, suggesting a total of 30 individuals. Data were analyzed using the statistical software SPSS version 20.0 (Armonk, New York, USA). The normal distribution of continuous variables was checked using the Shapiro-Wilk test. For comparison of continuous variables, the ANOVA for repeated measures or the Friedman non-parametric test was applied, depending on the normal distribution or not of the data, respectively. Continuous variables are presented as mean and standard deviation (parametric data) or median and 25–75% Interquartile (IQ) range (non-parametric data). The RSBI was also compared within the subgroup of patients who presented the index with values greater than or equal to 80 $cycles.min^{-1}.L^{-1}$. A bilateral *p*-value less than 0.05 was adopted as a level of statistical significance for all tests.

Table 1 Clinical and demographic characteristics of patients (n = 33).

Characteristics	Values
Age (years)	62.3 ± 15.7
Color [n (%)]	
Brown	17 (52)
White	13 (39)
Black	3 (9)
Sex [n (%)]	
Female	18 (55)
Male	15 (45)
SAPS 3	59.1 ± 14.4
Reasons for admission to the ICU [n (%)]	
Abdominal surgery	6 (18)
Acute myocardial infarction	6 (18)
Cardiac insufficiency	4 (12)
Sepsis	4 (12)
Cardiorespiratory arrest	4 (12)
Acute respiratory insufficiency	2 (6)
Others	7 (22)
Reasons for intubation [n (%)]	
Secondary to surgery	14 (43)
Acute respiratory insufficiency	12 (36)
Lowering the level of consciousness	2 (6)
Others	5 (15)

ICU, Intensive Care Unit; SAPS 3, Simplified Acute Physiology Score 3.
Values expressed as mean ± standard deviation or absolute value and percentage.

Results

Participants were 33 patients, with a mean age of 62.3 ± 15.7 years, mean SAPS 3 of 59.1 ± 14.4 and average time elapsed from intubation to SBT of 4.7 ± 4.0 days. The other clinical and demographic characteristics are listed in Table 1. There were no adverse events related to the study protocol.

Table 2 lists the parameters of MV and hemodynamic and oxygenation monitoring of patients before the beginning of data collection.

RSBI was lower when obtained in the PSV mode than that obtained in the CPAP/P, CPAP/F modes and by the ventilometer ($p < 0.001$), with no difference between these (Table 3). By selecting from the sample, the patients who presented RSBI by the ventilometer greater than or equal to 80 $cycles.min^{-1}.L^{-1}$ (which could be considered of greater risk for extubation, given the proximity to the cutoff values for this index), it was noted that, in these people (n = 6), the RSBI measured by the ventilometer was higher than those observed through the PSV, CPAP/F and CPAP/P modes ($p = 0.003$), with no significant difference between them (Table 3).

Table 2 Ventilation and monitoring parameters before data collection (n = 33).

Variables	Values
PaO_2/FiO_2 relation	354.5 ± 126.4
SBT time (min)	71.1 ± 63.9
FiO_2	0.31 ± 0.05
SpO_2 (%)	96.5 ± 2.1
PSV (cmH_2O)	7.1 ± 0.4
PEEP (cmH_2O)	5.4 ± 0.5
RR (rpm)	19.1 ± 6.1
TV (mL)	492.6 ± 165
Initial SBP (mmHg)	131.7 ± 24.2
Initial DBP (mmHg)	69.2 ± 11.1
Initial HR (bpm)	92.5 ± 17.8
Type of ventilator [n (%)]	
Puritan-Bennett 840	22 (66.6)
Dixtal 3012 plus	11 (33.4)
Intubation time to SBT (days)	4.7 ± 4.0

DBP, Diastolic Blood Pressure; FiO_2, Fraction of Inspired Oxygen; HR, Heart Rate; PaO_2, Pressure of Arterial Oxygen; PEEP, Positive End-Expiratory Pressure; PSV, Pressure Support Ventilation; RR, Respiratory Rate; SBP, Systolic Blood Pressure; SBT, Spontaneous Breathing Test; SpO_2, Peripheral Oxygen Saturation; TV, Tidal Volume.
Values expressed as mean ± standard deviation or absolute value and percentage.

When comparing the TV measured in the different methods, in the PSV mode, the values were higher than those obtained by the ventilometer, CPAP/P and CPAP/F modes ($p = 0.002$), with no difference between them. The RR identified by the ventilometer was similar to that in mode CPAP/F, but higher than in CPAP/P and PSV ($p = 0.004$). The RR observed in CPAP/F was not different from that obtained in CPAP/P, however it was higher than in PSV.

Discussion

The correct time to interrupt MV is still a challenge in ICUs; a test capable of predicting the success of extubation is of great value.[7] Ways of obtaining the RSBI that require less investment and provide greater practicality have been investigated.[14–20]

In the present study, it was found that obtaining the RSBI from MV parameters, particularly in the PSV mode, produces values significantly lower than those calculated from the ventilometer. In addition, the RR and TV values were also more discrepant in the PSV mode than in the other methods. The CPAP mode, regardless of the type of trigger, seems to be a more adequate alternative, since in this mode the values did not differ from those measured by the ventilometer.

The evidence that, in PSV, RSBI values are lower than those of the ventilometer has been already described in previous studies, with PSV values of 10 cmH_2O[11,14] and 7 cmH_2O,[5] and even with minimum values of 5 cmH_2O.[13,15,16,21] In fact, the PSV around 5 to 7 cmH_2O is able to compensate for the resistance imposed by the endotracheal tube and the ventilator circuit, which does not occur in the measurement performed with the ventilometer because the resistance imposed by the tube remains.[22] Thus, the use of PSV in obtaining RSBI reduces its value and can provide a false indication that the patient is able to be released from ventilation support.[14]

Despite this evidence, PSV is the most commonly used ventilation mode for obtaining RSBI by the ventilator.[4,9] A study conducted in the city of São Paulo (SP)[9] showed that 91% physical therapists used it, with PSV values ranging from 6 to 12 cmH_2O. This is probably because it is the ventilation mode in which the patient is already during the SBT. In addition, there is currently the measurement of the RSBI incorporated in the algorithms of many ventilators and shown on the display as one of the ventilation parameters,[6] which further favors the achievement of this index in ventilation modes and in the pressure levels at which patients are being ventilated.

When comparing the RSBI obtained by the ventilometer with the one in the CPAP mode, the results of the present study are similar to those described by a group of authors.[11] When comparing the index in three different modalities (PSV of 10 cmH_2O, CPAP of 5 cmH_2O, and spontaneous ventilation), they detected no differences between the RSBI values obtained with the ventilometer and in the CPAP mode but identified significantly lower values in the PSV mode.

Other authors[19] tested five strategies for obtaining RSBI (ventilometer; CPAP of 5 cmH_2O with FiO_2 of 21% and 40%; and CPAP of 0 cmH_2O, with FiO_2 of 21% and 40%) and observed higher values of RSBI in the four CPAP options compared to the ventilometer ($p < 0.05$). This result was contrary to that evidenced in other studies,[10,17,18] which reported

Table 3 Comparison of RSBI, tidal volume and respiratory rate in the four methods.

Parameter	Ventilometer	PSV	CPAP/F	CPAP/P	*p*-value
TV (mL)	430 (350–500)	500 (430–580)[a]	450 (350–570)	430 (370–540)	0.002[d]
RR (rpm)	21.2 ± 6.3[b,c]	18.5 ± 5.4	20.3 ± 4.9[b]	19.2 ± 5.2	0.004[e]
RSBI (cycles.min^{-1}.L^{-1})	46.3 (30.3–65.8)	33 (26.4–44.7)[a]	46.3 (29.7–61.9)	37.6 (28.3–60.7)	< 0.001[d]
RSBI ≥ 80 (cycles.min^{-1}.L^{-1})	90.6 ± 10.8[a]	65.5 ± 19.8	68.5 ± 12.8	73.6 ± 9.6	0.003[e]

CPAP, Continuous Positive Airway Pressure; CPAP/F, CPAP mode with flow trigger; CPAP/P, CPAP mode with pressure trigger; PSV, Pressure Support Ventilation; RR, Respiratory Rate; RSBI, Rapid Shallow Breathing Index; TV, Tidal Volume.
[a] $p < 0.05$ compared with the other methods.
[b] $p < 0.05$ compared with PSV.
[c] $p < 0.05$ compared with CPAP/P; values expressed as median (25–75% quartiles) or mean ± standard deviation.
[d] Friedman test.
[e] Repeated measures ANOVA.

lower values of RSBI obtained with CPAP of 5 cmH_2O when compared with the ventilometer. One hypothesis for such discrepancies is the different ventilators used in the studies.

Taking into account that the average RSBI found in the sample of the present study was around 40 to 50 $cycles.min^{-1}.L^{-1}$, and assuming that the interference of the chosen method could be greater in those patients whose RSBI values were closer to the cutoff value established by Yang and Tobin,[8] this study analyzed separately the RSBI values calculated in the four methods, selecting only patients with the index $\geq$ 80 $cycles.min^{-1}.L^{-1}$ (from the values obtained by the ventilometer), considered here the sample most susceptible to extubation failure. Values observed on the ventilometer were higher than those of the three ventilation methods, demonstrating that in the sample of patients with the worst indices, obtaining the RSBI from MV parameters was more inadequate.

This result corroborates other study[13] in which, when separating in the sample the patients who were successful or unsuccessful in extubation, it was also found that the RSBI value did not differ between the two methods (ventilometer versus PSV of 5 cmH_2O) in the successful group, but was smaller when obtained in PSV among patients who failed extubation; this confirms that the discrepancies are accentuated in individuals in potentially more severe condition. One explanation is that ventilation support can reduce respiratory work by compensating for altered pulmonary mechanics and the additional load imposed by the endotracheal tube among those with worse respiratory reserve.

Another aspect analyzed was the possible interference of the base flow, provided by the ventilators when the flow trigger was programmed in the values obtained from RSBI. About this, some authors[10] expected to find a higher RSBI with a CPAP of 0 cmH_2O when compared to the ventilometer, but found lower values, attributing this ventilation aid to the interference of the base flow. Subsequently, other researchers[20] found lower RSBI values in the CPAP mode of 0 cmH_2O with flow trigger compared to pressure trigger and that obtained by the ventilometer, suggesting the interference of the base flow on such values.

In the present study, similar values were verified in the RSBI obtained in CPAP modes with flow and pressure triggers and in the ventilometer. A possible explanation may be in the mechanical ventilators used, since it has already been demonstrated that the base flow values differ between the ventilators.[23] In addition, there are studies comparing the effects of pressure trigger with flow trigger in patients ventilating in CPAP which also found no differences in the values of TV, RR,[24,25] and the RSBI calculated by the ventilator.[25]

An alternative that has emerged is the use of different cutoff values when using the ventilator to obtain the index. Unlike the classic value of 105 $cycles.min^{-1}.L^{-1}$,[8] a previous study[16] reported greater accuracy in predicting the success of weaning with a cutoff value of 100 $cycles.min^{-1}.L^{-1}$ for the RSBI measured using the ventilometer, and 75 $cycles.min^{-1}.L^{-1}$ when calculated in the PSV of 5 cmH_2O. Another study[26] found a cutoff value of 88.5 $cycles.min^{-1}.L^{-1}$ for the RSBI obtained by the ventilometer, and 80.1 $cycles.min^{-1}.L^{-1}$ in the PSV of 5 cmH_2O, analyzed using the ROC curve. Such an analysis was not possible in the present study due to the sample size.

The limitations of this study are the sample size and the fact that it is a convenience sample. Added to this is the difficulty of blinding the evaluators when obtaining data in the different methods of measuring the index.

Conclusion

The RSBI measured by the ventilometer did not differ from that obtained in the CPAP mode, both with pressure and flow triggers, but it was significantly higher than in the PSV mode. Thus, in view of the need to analyze the RSBI calculated from MV parameters, it is suggested that, to obtain it, the patient should be placed on the CPAP mode, with a value of 5 cmH_2O. However, in the presence of borderline RSBI values, the use of the ventilometer is recommended, as in this mode the values are significantly higher than those verified in the three options of investigated ventilation parameters.

Conflicts of interest

The authors declare no conflicts of interest.

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