Comparison of the rapid shallow breathing index (RSBI) calculated under direct and indirect form on the postoperative period of cardiac surgery*

Comparação do índice de respiração rápida e superficial (IRRS) calculado de forma direta e indireta no pós-operatório de cirurgia cardíaca*

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Abstract

Objectives: To compare and to analyze whether the values of rapid shallow breathing index (RSBI) determined by a ventilator display and a digital ventilometer were correlated. **Methods:** Twenty-two adult patients (17 males and 5 females) in the postoperative period of cardiac surgery and in mechanical ventilation were studied. Prior to the data collection, each patient was evaluated, received physical therapy, in order to promote bronchial hygiene and pulmonary reexpansion, and was positioned in elevated dorsal recumbent at 45°. After these procedures, minute ventilation (MV) and respiratory rate (RR) obtained from mechanical ventilator display and digital ventilometer were recorded. The RSBI was calculated by the ratio of RR and tidal volume (VT). Paired t-test was used to compare related variables. The intra-class correlation coefficients (ICCs) were used to measure the reproducibility of the scores. **Results:** A significant difference was found between the RSBI obtained from the ventilator and by the digital ventilometer (p=0.011). A high agreement for the RSBI (ICC=0.86), for the RR (ICC=0.80) for the VT (ICC=0.79) and a moderate agreement for the MV (ICC=0.74) were observed. The p-value was <0.05 for all variables. **Conclusions:** There were a significant agreement between the RSBI obtained from the ventilator display and the digital ventilometer.
Article registered on the Australian New Zealand Clinical Trials Registry (ANZCTR) under the number ACTRN12610000756022.

Key words: ventilator weaning; mechanical ventilation; rapid shallow breathing index; cardiac surgery; tidal volume.

Resumo

Objetivos: Comparar e analisar a correlação entre o índice de respiração rápida e superficial (IRRS) determinado com os valores fornecidos pelo software do ventilador mecânico Raphael® e pelo ventilômetro digital. **Métodos:** Participaram do estudo 22 indivíduos adultos (17 homens e 5 mulheres), intubados, no pós-operatório de cirurgia cardíaca. Antes da coleta de dados, cada indivíduo foi avaliado, recebeu atendimento fisioterapêutico a fim de promover higiene brônquica e reexpansão pulmonar e foi posicionado em decúbito dorsal elevado em 45°, e depois foram registrados os valores de volume minuto (VM) e frequência respiratória (FR) obtidos pelo ventilador e pelo ventilômetro. O IRRS foi calculado pela relação FR/volume corrente (VC). Aplicou-se o teste t-pareado para comparação das variáveis relacionadas. Utilizou-se o coeficiente de correlação intraclasse (CCI) para mensuração da replicabilidade dos escores. **Resultados:** Observou-se diferença significativa entre o IRRS obtido pelo ventilador mecânico e o obtido pelo ventilômetro (p-valor=0,011) e concordância moderada para VM (CCI=0,74), alta concordância para FR (CCI=0,80), VC (CCI=0,79) e IRRS (CCI=0,86). Para todas as variáveis, o p-valor foi menor que 0,05. **Conclusões:** Houve concordância estatisticamente significativa entre o IRRS calculado pelos valores registrados no ventilador mecânico e pela ventilometria
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Palavras-chave: desmame ventilatório; ventilação mecânica; índice de respiração rápida e superficial; índice de Tobin; cirurgia cardíaca.

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Introduction :::.

Approximately one third of patients admitted at Intensive Care Units (ICUs) need intubation as well as the institution of mechanical positive-pressure ventilation. During the postoperative of cardiac surgery, from 94 to 97% of the cases, the withdrawal of the ventilatory prosthesis occurs in a short period of time[1,2]. Once started the progressive weaning of the vasoactive drugs, being the patient hemodynamically stable, the ventilatory support may be gradually withdrawn[3].

However, in some cases, removing patients from the mechanical ventilation can be more difficult than their maintenance. The weaning process can have a duration that reaches up 40% of the total time of the ventilatory support, which increases the risk of infectious complications, mainly nosocomial pneumonia[4]. Not only the perception of the moment to starting the interruption of the ventilatory support but also choosing the most appropriate way to perform it can be guided by scientific basis, which has the potential to improve clinical outcomes[5].

According to Trouillet et al.[6], most of the cardiac surgery patients can reassume a spontaneous ventilation as soon as they recover from the anesthesia. However, about 2.6 to 22.7% of patients require prolonged mechanical ventilation, which can lead to a 40% of mortality and increase the length of hospital stay that may exceed three weeks of hospitalization.

The decision of interrupting the mechanical ventilation is usually based on the patient's clinical presentation and on the clinical experience of the medical team. The mortality rate due extubation failure is 50%, which indicates the potential gravity of this type of event[7,8].

Studies carried out over the last years have become weaning from the mechanical ventilation safer, based upon scientific evidence and, therefore, reducing the empiricism that was applied to this technique. It has been observed that the conduction of the weaning process has become increasingly more scientific rather than and act of art[9-15].

The success of the withdrawal of the positive pressure, in many cases, only occur with the appropriate use of indexes that can objectively evaluate, as early as possible and with a lower chance of error, the indicated moment for this withdrawal[14-16]. Thus, the predictive indexes of weaning should be used in order to reduce the chances of failure resulting from this process[17].

There are more than 50 indexes described in the literature, and only some of them can objectively assist the clinical decisions related to the probability of success or failure of the withdrawal from mechanical ventilation. However, according to III Brazilian Consensus of Mechanical Ventilation, the rapid shallow breathing index (RSBI), or Tobin index, seems to be the most accurate[3].

The RSBI is calculated by dividing the respiratory rate (RR) for tidal volume (TV). The units are breaths per liter per minute, and the reference value is 104. Values above 104 are largely correlated with failure of weaning from mechanical ventilation, and values below 104 indicate the possibility of success[17].

The logic behind this index is in the fact that the better compliance and the greater inspiratory effort, associated with an adequate gas exchange and a lower RR, the greater is the probability of sustaining the spontaneous ventilation without the ventilatory prosthesis. The main advantages of these measures are that they can be obtained at the bedside with portable devices (ventilometer), is easily reproducible, can be performed in a short period of time, is non-invasive and without the need for any laboratory data. This index can be useful to reduce the failure of the premature weaning and to eliminate the delay in the weaning of patients potentially able to be dispensing from the ventilatory support[18].

The calculation of RSBI can be performed using the values provided by the ventilator display, but is not yet an established routine in ICUs due to the fact that the pressure for ventilatory support, even small, still offers aid to the inspiration of the patient, saving some work. Thus, this measure is not a pragmatic expression of the reality and may even be overestimated[19].

The possibility of calculating pressure of ventilatory support in zero can be harmful to the patient by determining increased respiratory effort, leading to the occurrence of inspiration through an artificial system (orotracheal tube coupled with the mechanical ventilator circuit) only pressurized with positive end-expiratory pressure (PEEP). The minimum pressure of support that may compensate the resistance of the circuit should be adjusted up to 8 cmH_2O[3]. The difficulty of obtaining RSBI can occur in situations in which the ventilometer is not available at the ICU, either for logistic reasons or due to its high cost, and the weaning needs to be evaluated and progressed[20].

Thus, the objective of the present study was to compare and to evaluate the agreement between the RSBI calculated with the values provided by the software of the mechanical ventilator Raphael® and that calculated through values obtained by the digital ventilometer.

Methods :::.

The present study has been approved by the Ethics in Research Committee of the University of Medical Sciences of Universidade Estadual de Campinas (Unicamp), Campinas, SP,

Brazil, protocol nº: 526/2008. All participants (and/or relatives) signed the informed consent term in the preoperative.

Study design

This was a prospective, open and descriptive study, using a convenience sample.

Location and study period

The study was carried out at the ICU of the Hospital das Clinicas (HC) of Unicamp. The data were collected between August and December 2008.

Subjects

The study population was constituted by a convenience sample, out of which were part 22 adult patients (age ≥18 years) interned in ICU-HC-Unicamp, at the immediate postoperative period of elective cardiac surgery and under invasive mechanical ventilation.

The inclusion criteria were: patients intubated with orotracheal tube with diameter between 7.5 and 9.0 mm; those who did not show tense or bloated abdomen; those who were undergoing mechanical ventilation for less than 24 hours of the trademark Hamilton Medical Raphael (software version-1)[21], spontaneous mode, using the amount of ventilatory support pressure of 10 cm of water, PEEP equal to 5 cm of water and fraction of inspired oxygen (FiO_2) lower or equal to 0.4; with the oxygenation index greater than 200, without sedation and with the score on the Glasgow coma scale at 11-T; those who were hemodynamically stable without vasoactive drugs or only with dopamine ≤5 mg / kg / min or dobutamine ≤10 mg / kg / min; the non febrile ones and with normal electrolytes. Extubation was previously decided by the ICU care team.

The exclusion criteria were: patients aged <18 years; tracheostomized patients, those who were hemodynamically unstable and/or using vasoactive drugs in higher doses than those given above. Patient who refused (or their relatives) to sign the informed consent form previously, those who used the a different ventilator than the Hamilton Medical Raphael (software - version 1) and those who stayed longer than 24 hours on mechanical ventilation were also excluded.

Equipment

The following equipment was used: mechanical ventilator *Hamilton Medical Raphael (software - version 1)* e digital ventilometer (AINCA, Model 00-295), being all ventilators used in the study were previously tested on the analyzer for mechanical ventilator (Vent Aid®- model Michigan 49504), which was calibrated.

Methods

Patients admitted to the ward of Cardiology, HC-Unicamp, candidates for elective cardiac surgery were informed about the study and the procedures that they would be exposed in the immediate postoperative period, and under their agreement (and/or their family), after any possible doubt was answered, they signed the informed consent form.

Before starting the data collection in the immediate postoperative period, all patients underwent physical therapy evaluation at the ICU, including assessment of the neurological, cardiorespiratory and electrolyte states. They received physical therapy treatment that included respiratory physical therapy through bronchial hygiene: bilateral vibrocompression and aspiration of the orotracheal tube in order to promote bronchial hygiene and proper maintenance of gas exchange.

For data collection, the patients were positioned in elevated dorsal recumbent at 45°, staying in this position until the stabilization of blood pressure as well as the heart rate. It was administered, before performing ventilometry, during one minute, a fraction of inspired oxygen of 1.0, in order to preserve an adequate blood oxigenation (observed in a non invasive way by pulse oximeter attached to the multiparameter monitor of the ICU). The oxygen saturation should remain above 95%. After this time, the values of minute ventilation (MV), compliance, pulmonary resistance and spontaneous RR of patients, as measured by the ventilator, were recorded. Then the patients were temporarily disconnected from the ventilatory prosthesis, and, during such procedure, it was offered oxygen with 10 L/min through the macronebulization circuit, in perpendicular way, distant 2 cm from the output of the ventilometer just allowing entrance of oxygen during the patient's inspiration, with intention of promoting adequate blood oxygenation during the measurement of direct ventilometry. The digital ventilometer was attached to the orotracheal tube, recording the volume of air expired during 60 seconds and, in the same way as before, the patient's RR was verified during that period, seeking the subsequent calculation of the ratio of RR/TV (RSBI). The TV, used for the RSBI calculation, was obtained by dividing the MV by RR in both methods.

Annotation of the parameters provided by the ventilator was done firstly due to the fact that the patient was already connected to the mechanical ventilation and, after this measure; the patient was disconnected from the ventilator and connected the ventilometer.
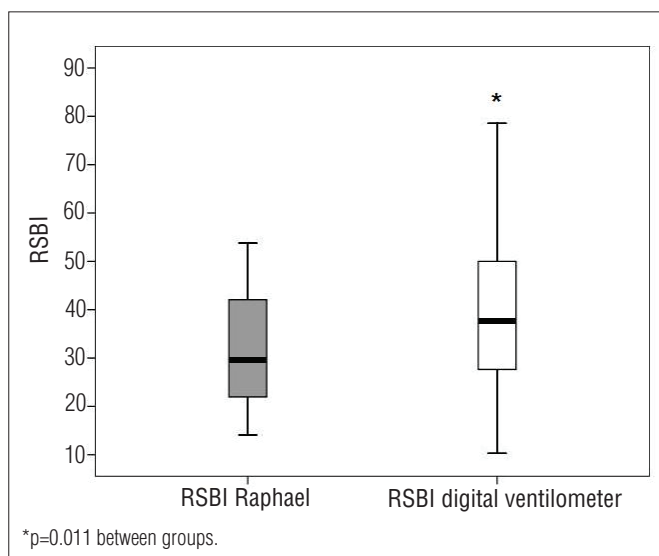
Statistical analysis

The SPSS statistical program, version 13.0 was used for the descriptive analysis of the numeric and categorical variables of groups. The paired *t*-test was applied for correlation of the studied variables. Values of p<0.05 were considered as statistically significant. The agreement between the tests was verify through the Interclass Correlation Coefficient (ICC) to measure the replicability of the scores. To verify the ICC degree, the following scores were adopted: ICC <0.40 - low agreement; ICC 0.40 to 0.75 - moderate agreement and ICC> 0.75 - high agreement[22].

Table 1. Demographic, anthropometric and clinical data of patients (n=22).

Variables	Mean ± SD/ N
Gender (F/M)	5/17
Weight (kg)	75.59±17.21
Height (cm)	167±9.29
Type of Surgery	
CABG	16
Valve Replacement	2
CABG + Valve Replacement	1
CABG + Geometric reconstr. left ventricle	3
Extra-corporeal circulation pump (min.)	79.86±25.34
Vasoactive drugs	18
Number of tracheal tube	
7.5	1
8	8
8.5	11
9	2

CABG=Coronary artery bypass surgery; SD=standard deviation.

*p=0.011 between groups.

Figure 1. Distribution of values of RSBI (rapid shallow breathing index), obtained with the ventilator and the ventilometer.

Results

Of the 22 studied subjects, 17 were male and five were females. All underwent elective cardiac surgery. Five were smokers, nine ex-smokers and eight reported no smoking. Demographic variables and anthropometric characteristics of the individuals, the types of cardiac surgery that each one was submitted, the time of extracorporeal circulation, the use of vasoactive drugs and the size of the tracheal tube used are shown in the Table 1 (data represented as absolute values, or as mean±standard deviation, as appropriate).

Table 2 shows the mean, the standard deviation, ICC, the confidence interval and p value of the following variables: MV, RR, TV and RSBI, as measured by the ventilator display and through the digital ventilometer. There were observed statistically significant differences between the values involved.

Observing the behavior of the sample, with respect to RR measured through the two instruments, there is a trend to maintain the corresponding values on most measures, confirming the correlation established by the test, with ICC of 0.8.

Regarding the TV, the ICC value of 0.79 expresses that the values were corresponding, and, in eight subjects, the TV showed to be similar when measured by the two modes of measurement. In five individuals, the measure of the digital spirometer was higher than that registered by the mechanical ventilator display and, in seven individuals, the measure recorded by the mechanical ventilator display was higher than that one recorded by the digital ventilometer.

Analyzing the MV values, in which the ICC was 0.74, it can be noticed that, in five individuals, MV showed similar values in the two measures. However, in 13 individuals, the measure by the ventilometer was higher, and, in only two individuals, the MV was higher measured by the mechanical ventilator display.

Table 2. Values of ventilatory variables in the two tests (n=22).

Variables	Ventilator Mean ± SD	Ventilometer Mean ± SD	ICC	CI	p-value
MV (L/min)	8.75±2.5	10.22±3.64	0.741	0.376; 0.892	0.002
RR (bpm)	16.45±45	19.40±5.39	0.803	0.525; 0.918	0.000
TV (L/min)	0.547±0.13	0.539±0.16	0.79	0.495; 0.913	0.000
RSBI (bpm)	33±16.1	39.7±16.7	0.866	0.678; 0.944	0.000

ICC=intraclasses correlation coefficient; CI=confidence interval; MV=minute volume; RR=respiratory rate; TV=tidal volume; RSBI (rapid shallow breathing index).

Discussion :::.

According to Toufen Júnior et al.[23], the technological evolution of mechanical ventilators does not involve directly benefit on the care offered to critical patient, because there still are a lack of comparative clinical trials that show significant differences when these instruments are acquired. This fact justified the design of this study which investigated the association of values calculated through the machine and compared them with the calculation made by the ventilometer.

In the literature review by Meade et al.[24] as well as in the original study on the RSBI and on the measures that compose it[25-27], it was argued that this index is more accurate and predictive of success or failure in weaning, and the design of the original study used direct measurements through a spirometer for measurements of MV and RR.

It is noteworthy that in the present sample, based on the results obtained by both methods of measurement (mechanical ventilator and ventilometer), all patients had a favorable rate for extubation, that is, with values below 104. Furthermore, no patient in this study had failed in the weaning process. It is also important to highlight that the patients belonged to a population of individuals in the immediate postoperative period of cardiac surgery, unlike other population types, as individuals on mechanical ventilation for more than 24 hours.

Mont'Alverne et al.[20] demonstrated that 100% of physical therapists from private hospitals of the city of Fortaleza use RSBI as predictive index of weaning and, at public hospitals at the same city, 76% use RSBI as a predictive index. In the same study, the authors reported that over 70% of physical therapists, both at private and public hospitals, get the data of RR through direct observation of chest expansion, and for the MV, they use the direct respirometry. This reinforces the hypothesis that it is necessary to create a faster and more practical way to obtain these values for predicting weaning (by the mechanical ventilator, for example), since most of professionals use this resource dayly on their activities inside the national ICUs.

A study of Gonçalves et al.[2] verified that the majority of physical therapists used the RSBI as a criterion for weaning, but 95% of respondents reported obtaining data (RR and MV), through the ventilator display, being the use of spirometer carried out by only 5% of the respondents and that of the 20 ICUs studied, only five had the ventilometer. In the study of Rodrigues et al.[28], it was verified that 91% of the consulted physical therapists obtained the ventilatory variables with the patient connected to mechanical ventilation on the ventilatory support pressure mode, with pressure levels of ventilatory support ranging from 6 to 12 cmH_2O, not taking into account that the ventilator support pressure overestimates the value of RSBI, which was confirmed in the present data.

The fact that there is no equipment available for direct measurement of the Tobin index complicates the evaluation process of weaning, and the measure obtained by the values expressed by the ventilator display is a practical alternative to obtain an approximate value of this index[2], whereas, according to this study, there is correlation between the values obtained by the two methods, being necessary a correction factor.

The studies of Santos et al.[19], Lee et al.[29] and Stroetz et al.[30] verified that RSBI obtained through the mechanical ventilator, with the patient under ventilation with ventilatory support pressure of 10 cmH_2O, overestimates the conclusion of the index, in other words, it obtains a lower index than that provided by the ventilometer.

In the study of Patel et al.[31], in which researchers obtained RSBI with patients ventilating with Continuous Positive Airway Pressure (CPAP) of 5 cmH_2O and tube T, it was observed that CPAP overestimates the index result. Still, in this study, the researchers reported that the type of measurement of RSBI, either by data from the ventilator or by ventilometry, demonstrate no significant difference in patients with 72 hours or more of mechanical ventilation.

Fiore Júnior et al.[32] demonstrated that, even with minimum levels to compensate the resistance of the orotracheal tube, the ventilatory support pressure overestimates TV and decrease the value of RSBI obtained through the ventilator, corroborating the results observed in the present sample, which also showed that the RSBI obtained by the mechanical ventilator was lower than the one obtained by the ventilometer. However, the responsible for this result was the increase of RR and not the increase of TV, when there was no positive pressure.

In the study mentioned above[32], the authors obtained the variables RR, MV, TV and RSBI in two ways: after 30 minutes in tube T and connecting the ventilometer to the expiratory branch of the ventilator, with ventilatory support pressure of 7 cmH_2O. They observed differences similar to the ones observed in the present study in relation to the RSBI. In the referred authors' sample, to maintain the MV, when this measure was performed by the ventilometer, there was an increase of the RR as a consequence to a decrease of the TV. When the measure was performed with ventilatory support pressure, there was a decrease in RR due to an increase of TV, differing from the present study because there were no significant changes in TV with positive pressure.

Most of the studies on how to obtain the RSBI aims to compare the measurements performed by instruments[12,28,30]. This study aimed not only to compare the measures that showed significant differences, but also to evaluate the agreement levels among them, in order to validate the correspondence of the values measured using a ventilometer and the mechanical ventilator.

El-Khatib[33] compared RSBI with patients in positive pressure on CPAP mode with 5 cmH$_2$O, using two values of FiO$_2$ of 0.4 and 0.21 respectively. After, the positive pressure was withdrawn, leaving the patient in ambient air. When it was compared the RSBI among the three moments, there was a decrease of the RSBI value when the patient was in CPAP mode, independent of FiO$_2$. There was a decrease of TV when the patient ventilated without positive pressure, behaving inversely to RR. This author observed a difference of 49% among the RSBI obtained with and without positive pressure. In the present study, this difference was 17%.

In summary, the present study demonstrated that there was a statistically significant agreement between the RSBI calculated from values obtained by direct ventilometry and that one obtained through the values available in the display of the mechanical ventilator Raphael®. Given the importance and the widespread use, in daily practice, of this index as a predictor for the success of weaning from mechanical ventilation, it is worth every effort to make the procedure faster, simpler and easily applied, eliminating additional costs for acquisition of new equipments, besides turning faster the decision-making with regards to the extubation, which may reduce the risks inherent in the use of prolonged mechanical ventilation.

Further studies are needed with a larger sample, so that they can establish an accurate correction factor for RSBI values with different methods and to avoid the overestimation of the index by ventilatory support pressure.

There were difficulties in knowing the patients who would effectively do the elective cardiac surgery, since it was hobbled by the responsible medical team which often needed to meet unexpected emergency cases and caused the postponement of elective surgeries. There was also difficulty in the exclusive availability of the Raphael ventilator for the research, since there were more two types of mechanical ventilators that could be used for those patients within the service routine.

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