Effect of Continuous Positive Airway Pressure on the Rapid Shallow Breathing Index in Patients Following Cardiac Surgery*

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Objectives: To compare the rapid shallow breathing index (RSBI) under different ventilatory support settings prior to extubation trials.

Design: Prospective study.

Setting: Cardiac surgery unit at a university hospital.

Patients: A total of 33 coronary artery bypass grafting patients ready for extubation.

Interventions: Enrolled patients received a continuous positive airway pressure (CPAP) trial of 5 cm H2O and fraction of inspired oxygen (FiO2) of 40% (condition 1), a CPAP trial of 5 cmH2O and FiO2 of 21% (condition 2), and a 1-min spontaneously breathing room air trial without ventilatory support (condition 3). These trials were applied in random order.

Measurements and main results: Average values of respiratory frequency and tidal volume were measured under the three experimental conditions in all patients immediately prior to extubation. The RSBI s were determined for each patient under each condition; the average RSBI s under conditions 1, 2, and 3 were compared for significance. The average RSBI s (± SD) were significantly smaller under condition 1 (34 ± 13) and condition 2 (36 ± 14) compared to condition 3 (71 ± 24). There was no significant difference in RSBI between conditions 1 and 2.

Conclusions: The administration of 5 cm H2O of CPAP can influence the determination of the RSBI. In contrast, changes in FiO2 have no effect on RSBI determination. We speculate that using the RSBI during CPAP may mislead the clinician into premature discontinuation of mechanical ventilation. Consequently, different threshold values for the RSBI should be derived for different ventilatory support levels.

Key words: continuous positive airway pressure; coronary artery bypass grafting; mechanical ventilation; rapid shallow breathing index

Abbreviations: bpm = breaths per minute; CABG = coronary artery bypass grafting; CPAP = continuous positive airway pressure; FiO2 = fraction of inspired oxygen; RSBI = rapid shallow breathing index

It is well known that intubation and mechanical ventilation are associated with several major complications despite their life-saving potential.1–4 As such, discontinuation of mechanical ventilation and extubation should be achieved as soon as the patient is able to sustain spontaneous breathing with effective gas exchange and clear his/her secretions. Identifying the most appropriate time for discontinuation of mechanical support as well as accurately predicting the outcome of extubation has been a constant objective of physicians in the ICU.5–8 However, a controversy still remains as to whether this process is an “art” or a “science.”9 Numerous prediction parameters of weaning outcome have been developed with different degrees of sensitivity and specificity.10,11 Vital capacity,12 maximal inspiratory pressure,12,13 and minute ventilation14 have long been employed as predictors of weaning outcome. Yang and Tobin15 demonstrated that a new integrative index, the rapid shallow breathing index (RSBI), is more accurate and powerful in predicting weaning outcome than most of the traditional indexes. In that study,15 the RSBI was determined immediately after discontinuation of ventilatory support while the patients were still intubated, although without ventilatory support, and when patients breathed room air spontaneously.

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Manuscript received October 23, 2000; revision accepted June 20, 2001.
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for 1 min. During this trial, the minute volume and respiratory frequency were measured; thus, the RSBI was determined as the respiratory frequency/tidal volume ratio.

Since then, virtually all studies aimed at predicting weaning outcome have evaluated the use of the RSBI. However, a significant number of these studies have used the threshold value for the RSBI, 105 breaths/min (bpm)/L, originally derived in the study by Yang and Tobin, even though their experimental designs were not comparable to that of Yang and Tobin. In these studies, the tidal volumes and/or the respiratory rates were determined during either spontaneous breath ventilation, and/or during high fraction of inspired oxygen (Fio2) concentration (40%), and/or in the presence of positive airway pressure. In the current study, we hypothesized that the choice of ventilatory support settings can influence the RSBI.

**Materials and Methods**

This study was approved by the institutional review board, and written consent was obtained prior to initiation of study.

**Patient Population**

Thirty-three hemodynamically and clinically stable patients receiving mechanical ventilation in the cardiac surgery unit following coronary artery bypass grafting (CABG), and judged ready to undergo an extubation trial by their primary physician were included in the study.

**Study Protocol**

All patients were receiving mechanical ventilation (PB-7200ae; Puritan-Bennett, Mallinckrodt; St. Louis, MO). Prior to extubation attempts, each patient underwent three experimental conditions. During condition 1, patients received continuous positive airway pressure (CPAP) of 5 cm H2O with an Fio2 of 40%. During condition 2, patients received CPAP of 5 cm H2O with an Fio2 of 21%. During condition 3, patients were disconnected from ventilatory support for exactly 1 min, during which they spontaneously breathed room air. No pressure support or flow-by were applied during conditions 1 or 2. These three experimental conditions were applied sequentially and in random order. Conditions 1 and 2 were maintained for 15 min before collection of data, which was done over a 1-min interval.

All patients were monitored with continuous ECG, BP, and pulse oximetry during the whole study. The trial was interrupted any time the arterial saturation dropped > 5% and/or the heart rate increased/decreased > 20 to 25% of baseline levels, and/or patient manifested clinical respiratory distress as reflected by diaphoresis, chest discomfort and pain, or shortness of breath.

**Data Collection and Measurements**

A computerized pulmonary mechanics monitoring system (CO2SMO Plus! Novametrix Medical Systems; Wallingford, CT), incorporating an adult flow sensor placed between the endotracheal tube and the Y-piece of the breathing circuit, was used to measure tidal volume and the respiratory frequency during each experimental condition. The RSBI was derived for each patient by dividing the average respiratory rate by the average tidal volume. Average values for RSBI in each experimental condition were then determined and compared.

**Statistical Analysis**

The average values for RSBI under each of the experimental conditions were compared using analysis of variance for repeated measures, the Scheffe test for post hoc analysis, and the Student’s t test. Statistical significance was considered at the 5% level (p < 0.05).

**Results**

Patient characteristics are presented in Table 1. Throughout the three experimental trials of the study, there was no significant deterioration in the heart rate, BP, and/or oxygen saturation that necessitated aborting any of the experimental trials. The average RSBI was significantly smaller during condition 1 (34 ± 13) and condition 2 (36 ± 14) compared to condition 3 (71 ± 23). There was no significant difference in RSBI between conditions 1 and 2. The use of 5 cm H2O of CPAP had a profound decrease (49%) on RSBI (condition 2 vs condition 3). In contrast, changes in Fio2 had no significant change on RSBI determination (condition 1 vs condition 2). The changes in RSBI between conditions 1, 2, and 3 were due to changes in both the tidal volume and respiratory rate (Fig 1, 2). All patients were successfully extubated at the end of the study.

**Discussion**

The present study demonstrates that the RSBI can be influenced by the ventilatory support settings. The RSBI decreased by 49% during a CPAP trial on

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<th>Table 1—Demographic Data*</th>
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<td>Aortic valve replacement</td>
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<td>Mitral valve replacement</td>
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*Data are presented as mean ± SD unless otherwise indicated.
room air as compared to 1 min of spontaneously breathing room air without ventilatory support. Thus, using the threshold value of 105 bpm/L for the RSBI during CPAP may mislead health-care professionals into premature discontinuation of mechanical ventilation. Since CPAP administration resulted in significant reduction of the RSBI, patients might be extubated based on an acceptable RSBI (ie, < 105 bpm/L as established by Yang and Tobin), when in fact the RSBI could be much higher when CPAP is eliminated and the RSBI determined during 1 min of spontaneously breathing room air without ventilatory support.

Previous studies have reported benefits for the use of CPAP during weaning COPD patients from mechanical ventilation. The use of CPAP in COPD patients resulted in a decrease of work of breathing and dyspnea, and in the pressure-time product for the inspiratory muscles and the diaphragm, mainly by lowering the inspiratory threshold represented by the intrinsic positive end-expiratory pressure. In patients with open-heart surgery, it has been shown that the presence of positive end-expiratory pressure can result in increasing of end-expiratory lung volume, in fewer atelectatic and fewer unperfused lung units, and improving arterial-alveolar oxygen gradients.

Other studies have indicated that positive end-expiratory pressure does not provide a significant and sustainable clinical advantage. However, most of these studies were assessing the long-term effect of discontinuation of positive airway pressure. In the current study, the effect of discontinuation or elimination of CPAP was immediately assessed within 1 min of the intervention. The current data indicate that in CABG patients, the elimination of CPAP resulted in a true change in breathing pattern as reflected by a decrease of tidal volume and a subsequent increase in respiratory rate. In normal subjects, as well as patients with lung diseases, similar changes in the breathing pattern following elimination of positive airway pressure have been reported.

In contrast to other studies, the current study did not show any significant changes in the breathing pattern due to the step changes in the Fio2. This could be due to the fact that the patient population in the current study did not have an active lung disease and mechanical ventilation was used postoperatively although 50% of the patients had a previous smoking history.

In the current study, the patient population received mechanical ventilation for postoperative management following open-heart surgeries. This is in contrast to most of the studies that have used the RSBI to predict weaning outcome from mechanical ventilation in patients with a broad spectrum of respiratory diseases. However, since the aim of the current study was to look at the RSBI under different ventilatory support settings, it was believed that a homogeneous group of patients with no active lung disease would best serve the purpose of the study. This does not eliminate the need to confirm the current findings in patients receiving mechanical ventilation primarily due to active respiratory diseases.

Our data clearly show that the use of CPAP resulted in a significant decrease in the RSBI (ie, 49%). However, this study was not designed and intended to establish a new cutoff value for the RSBI. All patients were weanable, had no underlying chronic respiratory diseases, and were successfully extubated. When the RSBI was determined during condition 3 (ie, patient spontaneously breathing room for 1 min without ventilatory support), all patients had a RSBI < 105 bpm/L that clearly indicates their readiness to be extubated and their ability to adequately sustain spontaneous breathing. As such, no individual patient was brought from the...
not-able-to-wean range (ie, RSBI > 105 bpm/L) to the able-to-wean range (ie, RSBI < 105 bpm/L) with the use of CPAP. However, this does not eliminate the possibility that if a patient's RSBI was in the not-able-to-wean range, then the use of CPAP could bring the patient RSBI into the able-to-wean range.

In our study, the methodology of using a 1-min equilibration period during condition in comparison to 15-min equilibration periods in conditions 1 and 2 might have affected the determination of the RSBI. However, during condition 3, we intended to use the same experimental conditions exactly as previously described by Yang and Tobin. Furthermore, previous studies have reported that the duration of spontaneous breathing room air without ventilatory support might not have an effect on the RSBI. Petriani et al reported that there was no statistically significant difference between RSBIs determined from data collections of 5 min compared with those of 10 min and 15 min with a coefficient of variation as low as 3%. Another study by Krieger et al reported no changes in the RSBI over a period up to 2 h.

In conclusion, the current study indicates that the choices of ventilator support settings may have an effect on the determination of the RSBI. Caution should be taken when determining the RSBI under different levels of ventilatory support. The predictive values reported by Yang and Tobin should only be adopted if the determination of the index is performed under similar experimental conditions to the ones applied by Yang and Tobin, in which the patients were disconnected from ventilator support and were spontaneously breathing room air for 1 min.

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