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Assessment of the Rapid Shallow Breathing Index as a Predictor of Weaning of Patients with Prolonged Mechanical Ventilation

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ABSTRACT

Background: *About 8% of patients experience prolonged mechanical ventilation after cardiac surgery. Development of criteria for successful liberation of a patient from mechanical ventilation and extubation may be highly dependent on the clinical situation. Different criteria were used for ventilator weaning. We designed a clinical trial to determine the usefulness of rapid shallow breathing index (RSBI) as a predictor for successful weaning from mechanical ventilation.*

Materials and Methods: *In a prospective observational study, 52 patients who had prolonged mechanical ventilation (> 72 h) after open cardiac surgery were studied. Patients had 60 – min spontaneous breathing trials and satisfied at least 5 weaning predictors and fulfilled the criteria for discontinuing mechanical ventilation. Traditional weaning criteria and RSBI were determined. According to the outcome assessment of weaning, patients were divided into failure or success groups.*

Results: *The mean RSBI values were significantly different between the failure (103.5±21.9 breath/min/L) and success groups (80.4±15.3 breath/min/L, p=0.0001). There was no significant difference regarding the values of other prediction criteria between the two groups. Using RSBI <105 (breath/min/L) as the threshold value for predicting successful weaning, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy were 92.5%, 70%, 92.5%, 70% and 88% respectively.*

Conclusion: *Although a small number of patients require prolonged ventilatory support after open cardiothoracic surgeries, growing experience in critical care settings and mechanical ventilation cause favorable outcomes. Ventilator weaning is more likely to be successful if RSBI is less than 105 (breath/min/L). This index is a more valuable and accurate predictor of weaning than other weaning predictors.* ***(Tanaffos 2007; 6(3): 30-35)***

Key Words: *Outcome assessment, Ventilator weaning, Cardiac surgery, Rapid shallow breathing index.*

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INTRODUCTION

The most common reason for undergoing mechanical ventilation during and after anesthesia is impaired respiratory drive (1). Weaning from mechanical ventilation is the transition from mechanical ventilation (MV) to spontaneous breathing by the patient (2,3). Discontinuation of ventilatory support in a patient whose only reason for mechanical ventilation is residual anesthesia is generally straightforward. A different approach is often required for a patient who has had prolonged ventilatory support for chronic respiratory or cardiovascular disease (4). A controversy still remains as to wether weaning is an art or a science(5).

About a quarter of cardiac surgery patients are extubated in the operative room or after 4 h in the intensive care unit (ICU). About 8% of patients experience prolonged mechanical ventilation (defined as >72 h following ICU arrival)(6). Acute lung injury, sometimes progressing to acute respiratory distress syndrome (ARDS), can occur in up to 12% of postoperative cardiac patients (7). Development of criteria for the successful liberation of a patient from mechanical ventilation and extubation may be highly dependent on the clinical situation. The rapid shallow breathing index (RSBI) [respiratory frequency (breath/min) divided by tidal volume in liters] has been shown to be predictive of weaning success (8). It was introduced by Yang and Tobin (9) and has been reported as an extremely useful and easily measured variable for weaning from mechanical ventilation(10,11). However, some articles have questioned the accuracy of this index (12,13). The difficulty in using parameters to determine the ability of a patient to breathe spontaneously without ventilatory support may be due to the fact that the study population differs and therefore the parameters determined based on one group of patients may not apply to others, such as the elderly or those with pulmonary disease (14). Spontaneous breathing trials (SBT) have been proposed recently as the most efficient method of weaning patients from Mehanical Ventilation(MV)(15).

The purpose of this study was to investigate the efficacy and effects of RSBI in predicting weaning success in patients under prolonged mechanical ventilation after open cardiac surgery.

MATERIALS AND METHODS

During an 18-month period, 52 patients, who had prolonged mechanical ventilation (>72 h following ICU arrival) after open cardiac surgery, were enrolled in this prospective observational study at the Shahid Rajaei Cardiovascular Medical Center. The patients had 60 – min spontaneous breathing trials and satisfied at least 5 weaning predictors as follows:

1. Tidal volume during spontaneous breathing (VT)>325-408ml (4-6 ml/kg), 2. PaO_2 (on FiO_2<0.5) > 60 mmHg, 3. Arterial pH >7.3, 4. A-a gradient (FiO_2=1.0) <350 mmHg, 5.PaO2/FiO2 >200(1), and also fulfilled other criteria of discontinuing mechanical ventilation such as: hemodynamic stability, body temperature<38^oC, adequate hemoglobin, adequate mentation and acceptable electrolytes.

In all patients, morphine sulfate 0.5µg/kg IV was used to provide adequate analgesia.

The patients who required reintubation due to laryngeal edema, those who had extubated themselves, required tracheostomy or short-term mechanical ventilation (less than 48 h) were excluded from the study.

One type of ventilator (Drager, Evita 2 Dura) was used in all patients. Primary and daily setting of ventilators and the decision to extubate the patient were made by the ICU physicians. During the weaning process, the arterial blood gases (ABG) values were checked and the patients were separated from mechanical ventilation by gradually decreasing the respiratory rate and pressure support (PS) in SIMV (synchronized intermittent mandatory

ventilation) and PSV (pressure support ventilation) modes. Then spontaneous breathing was induced while the patient was attached to the ventilator, with a low level of PS (5-10 cm H_2O). After one hour of spontaneous breathing, respiratory frequency, tidal volume and minute volume were recorded from the ventilator scales and measurements. RSBI was then measured while the patient was connected to the ventilator which had been set to the spontaneous mode. Throughout the weaning trial, the FiO_2 setting was kept constant while vital signs, pulse oximetry, oxygen saturation (SPO_2) and hemodynamic status were monitored. After a 2-hour SBT, the decision for reinstitution of mechanical ventilation (trial failure) was made by the ICU physicians.

In order to assess the outcome of weaning from mechanical ventilation, patients were divided into two groups of failure and success. Standard formulas were used to calculate the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy of the rapid-shallow-breathing index (16). A true-positive result was defined as an RSBI < 105 in a patient who was successfully weaned, while a true-negative result occurred when the RSBI > 105 (breath/min/L) and the patient required reinstitution of ventilatory support within 48 h of weaning or extubation. Data analysis was also made by independent sample t-test ($p<0.05$ was considered significant).

RESULTS

Two patients were excluded from the study due to auto-extubation and need for re-intubation. The characteristics of the patients are listed in Table 1. According to this table, mean ejection fraction was significantly lower in the failure group compared to the success group (p=0.03). Pump time and aortic cross clamp time were also longer in this group, but these differences were not statistically significant. There was no significant difference regarding the daily morphine injections between the two groups of patients. Table 2 shows RSBI and weaning parameters in all patients. Ten patients had an RSBI greater than 105 (breath/min/L), within 1 h of starting their spontaneous breathing trials. In this group three patients were successfully weaned from the ventilator. Of the 40 patients who had an RSBI less than 105 (breath/min/L), 3 patients failed weaning. Ten (20 %) patients had failed weaning and 40 (80%) patients were successfully weaned from mechanical ventilation. The average RSBI values were significantly different among the failure (103.5±21.9 breath/min/L) and success groups (80.4±15.3 breath/min/L), p= 0.0001. There was no significant difference regarding the values of other prediction criteria between the two groups. (Table 2, and Figure 1).

Table 1. Patient characteristics*

	Successfully weaned	Failed Weaning	P value
Patients (No)	40	10	
Age (yr)	67 ± 3	69±2	0.085
Ejection Fraction (%)	40.0±5.9	33.0±7.8	0.03
Pump Time (min)	97.3±19.4	113.9±23.2	0.25
Cross Clamp Time (min)	59.9±11.6	72.0±13.8	0.07
Morphine injection (mg/day)	8.2±0.3	7.9±2.2	0.094

*Data expressed as mean ±SD.

Table 2. Parameters for weaning from mechanical ventilation and RSBI*

	Successfully weaned	Failed Weaning	P value
Tidal Volume (ml)	414.6 ± 65.9	417.0±66.0	0.919
PaO_2/PAO_2	154.7±12.7	152.3±	0.664
PaO_2/FiO_2	200.9±29.6	192.6±23.3	0.412
$PaCO_2$ (mmHg)	36.7±4.5	38.0±4.1	0.443
PaO_2 (mmHg)	100.3±14.8	96.3±11.6	0.424
PH	7.41±03	7.39±06	0.084
RSBI (breath/min/L)	80.4±15.38	103.5±21.90	0.0001

*Data are expressed as mean ±SD.

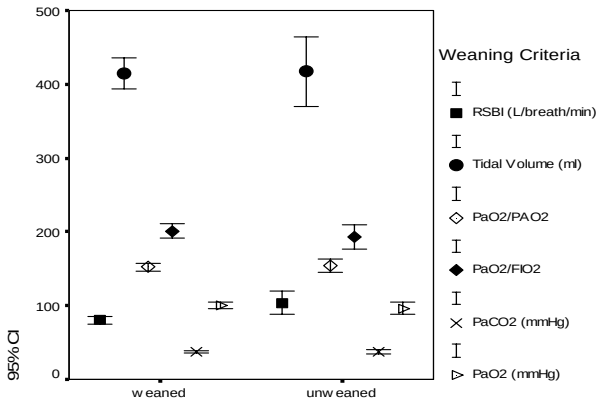

Figure 1. Weaning criteria and rapid shallow breathing index (RSBI). There was no significant difference between the two groups regarding the weaning criteria.

Using RSBI <105 (breath/min/L) as the threshold value for predicting successful weaning, the sensitivity, specificity, PPV, NPV, and diagnostic accuracy were 92.5%, 70%, 92.5%, 70% and 88% respectively.

DISCUSSION

Weaning is defined as the gradual reduction of ventilatory support and replacement with spontaneous ventilation. In some cases, this process is rapid and uneventful; however, for some patients the process may be prolonged for days or weeks. Indeed, a gradual transition is only required in less than 30% of patients receiving mechanical ventilatory support. Being able to identify the majority of patients who do not require a gradual transition would lessen the likelihood of ventilator-associated complications as well as being cost effective(17,18).

Since the traditional weaning parameters lacked the sensitivity and specificity required for predicting weaning outcomes and the fact that some of these parameters need complex instruments to measure, newer parameters were developed that have been shown to have superior predictive values. The spontaneous respiratory rate /tidal volume, (rapid shallow breathing index), is the most accurate predictor of weaning success among patients (19). These results may change when the parameters are measured in patients breathing on continuous positive airway pressure (20). We used a lower level of PS (5-10 cm H2O) in all patients to decrease breathing effort and resistance during spontaneous ventilation, and the parameters were measured in the same situation.

One reason for the inaccuracy of previously tested weaning parameters may be due to the time they were measured. The spontaneous breathing trial did not have a set time limit in the present study which might be another limitation to this study. Prospective, controlled studies have shown that approximately 75% of patients can be weaned and extubated if they successfully complete a 30-min spontaneous trial and this limit is as useful as a longer trial (e.g. 2 h)(8)

The prevalence of weaning failure in our study (20%) is similar to other recent studies that have attempted to predict weaning outcome, in which weaning failure ranged from 22 to 44% (21,22).

Some medications such as propofol and benzodiazepine infusion can cause changes in breathing patterns and RSBI that may mislead this conclusion that a patient is not ready to begin a spontaneous breathing trial (23). In our study, there was no significant difference regarding daily morphine use, between the two groups of patients.

Several events may be interfering with successful cessation of mechanical ventilation. Depressed ventilatory drive owing to respiratory alkalosis or present sedation may prevent successful tracheal extubation (24). Excessive workload on the respiratory muscles imposed by excessive hyperinflation, airway secretions, bronchospasm, increased pulmonary water retention or increased carbon dioxide production from fever(25). In the

present study we tried to consider and correct all of the above mentioned problems to achieve successful weaning from mechanical ventilation.

The sensitivity, specificity, PPV, and NPV of RSBI compared favorably to those of recent studies that used more complicated parameters to predict weaning success (21,22). As noted in previous studies, the prevalence of weaning failure can influence the performance of a weaning index. The prevalence of weaning failure in turn can be influenced by various factors that differ among institutions, including clinical judgment, criteria for selecting patients for weaning trials and also for defining respiratory failure.

Some investigators have demonstrated that total cardiopulmonary bypass (CPB) time in excess of 120 minutes was an important operative factor for extubation failure and prolonged mechanical ventilation.(26,27) CPB time has been repeatedly identified as a risk factor, and a correlation between CPB time and inflammatory cytokine release has also been demonstrated. Low cardiac output states are also important because prolonged periods of inadequate perfusion result in addition of mediator release (28,). In our study, ejection fraction (EF) was significantly lower in the failed weaning group. CPB and X-clamp time were higher, but these differences were not statistically significant.

Some studies have shown that RSBI measured upon termination of SBT is a superior predictor to RSBI measured at the start of SBT in determining the likelihood of successful liberation from mechanical ventilation in critically ill patients (29).

Although a small number of patients require prolonged ventilatory support after open cardiothoracic surgeries, growing experience in critical care settings and use of mechanical ventilation lead to favorable outcomes. Weaning is more likely to be successful if RSBI is less than 105 (breath/min/L), and this index is more valuable and more accurate for prediction than other weaning predictors.

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