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# Weaning Approach with Weaning Index for Postoperative Patients with Mechanical Ventilator Support in the ICU

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**Background:** The weaning index is a useful tool for avoiding the detrimental consequences of weaning failure, rapidly identifying patients who are potentially ready for spontaneous breathing, and accelerating the process of liberation from mechanical ventilation. This study examined the use of the weaning index as a weaning and extubation predictor in postoperative patients on mechanical ventilatory support in an intensive care unit (ICU).

**Methods:** Mechanical ventilation was discontinued in patients through pressure support ventilation (PSV), and a T-piece was applied to 169 patients. The success or failure of the weaning process was evaluated according to the preoperative conditions of the patient and their weaning indices, such as the rapid shallow breathing index (RSBI), vital capacity, inspiratory pressure. The duration of mechanical ventilation and the length of stay in the ICU and the hospital were recorded.

**Results:** Weaning from mechanical ventilatory support and extubation was performed successfully in 94.6% of patients. Sixty minutes after applying the T-piece, the $PaO_2/FiO_2$ ratio (P/F ratio) was significantly higher and the RSBI was significantly lower in the weaning success group than in the weaning failure group. The ASA class and the percentage of emergency procedures were significantly lower ($p < 0.05$) in the weaning success group.

**Conclusions:** Not only the weaning index as RSBI but also P/F ratio, ASA class and emergency status need to be considered for successful weaning and extubation in postoperative ICU patients on mechanical ventilator support. **(Korean J Anesthesiol 2007; 53: S 47～51)**

**Key Words:** mechanical ventilation, postoperative patients, rapid shallow breathing index, weaning and extubation predictor, weaning index.

## INTRODUCTION

Critical care physicians must carefully weigh the benefits of rapid liberation from mechanical ventilation against the risks of premature trials of spontaneous breathing and extubation.[1,2] This is especially true for postoperative patients that may fail to wean due to an impaired respiratory center or, more frequently, as a result of neuromuscular abnormalities, such as respiratory muscle fatigue, impaired lung mechanics, impaired gas exchange capability, and airway abnormalities.[3-6]

The use of a weaning index is important to avoid the detrimental consequences of a failed weaning attempt, rapidly identify patients who are potentially ready for spontaneous breathing, and, therefore, accelerate the process of liberation from mechanical ventilation, which is usually preceded and ended with extubation.[7-10] Vital capacity (VC), inspiratory pressure, and minute ventilation have been traditionally employed as a predictor of weaning outcome.[11-13] The rapid shallow breathing index (RSBI), a integrative index which is determined by the respiratory frequency to tidal volume ratio, is a more accurate predictor of weaning outcome than traditional methods.[14,15]

We performed this study to investigate the use of a weaning index of respiratory parameters to predict the weaning and extubation in the postoperative patients on mechanical ventilatory support in the intensive care unit (ICU). Our

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hypothesis was that the assessment of both the weaning index and the physiologic parameters of a patient who has been liberated from mechanical ventilatory support might provide distinguishing characteristics between patients who successfully will wean and extubate and those who fail, so that these differences could serve as a predictor of weaning and extubation success.

## MATERIALS AND METHODS

The written informed consents were obtained from the patients and their relatives at the preoperative visit. All patients who required mechanical ventilation after their surgical procedure for more than 12 hours and who were admitted with orotracheal intubation to one of two medical-surgical ICUs from October 2002 to March 2003 were eligible for inclusion in our study. Thirty, 36, 91 and 12 patients were undergone head and neck, thoracic, abdominal and spine or extremity surgery, respectively. Patients who were undergone neurosurgery or heart surgery were excluded from the study.

All patients were ventilated by the Purittan-Benett 7200$^{TM}$ (Nellcor, Carlsbad, CA, USA) and had a 7-8 mm diameter endotracheal tube. Almost all of the patients received analgesics and /or sedatives without neuromuscular blocking agents within 12 hours of weaning from mechanical ventilation. Once the patients recovered, the patients were planned for the weaning process (Fig. 1).

Mechanical ventilation was discontinued under the direction of critical care physicians. We started the weaning process with the pressure support ventilation (PSV) mode, followed by the application of the T-piece and extubation. A patient was enrolled in the study only when he/she fulfilled all of the criteria that indicated his/her readiness for the T-piece, which are as follows: no postoperative surgical complications, an improvement of the underlying cause of acute respiratory failure, an awake and collaborative mental state (Ramsay sedation score of 2), adequate gas exchange, as indicated by the $PaO_2/FiO_2$ ratio (P/F ratio) with at least 200 mmHg at a maximal $FiO_2$ level of 0.40, maximal positive end expiratory pressure (PEEP) of 5 $cmH_2O$, maximal inspiratory peak pressure (IPS) of 12 $cmH_2O$, maximal ratio of the respiratory frequency to tidal volume of 105 breaths/min/L, a stable hemodynamic without the need for vasoconstrictors, a core temperature 36-38$^{o}$C, a hemoglobin level greater than 10 g/dl, and no relevant electrolyte disorders. If the patient met one or more of the following T-piece failure criteria, then the trial was terminated: a respiratory rate greater than 34 breaths /min, a heart rate greater than 139 beats/min, a systolic arterial pressure greater than 180 mmHg or less than 90 mmHg, a $SpO_2$ level less than 90%, or signs of agitation, anxiety, or diaphoresis.[16] When a trial was terminated, due to T-piece failure, the patient resumed mechanical ventilation with the same settings prior to the T-piece, and any further attempt to wean was at the discretion of the attending physician. Those who successfully completed the 60-minute trial period were immediately extubated. And, the patients were closely monitored at least 24 hours after extubation.

Prior to being weaned from mechanical ventilator, as

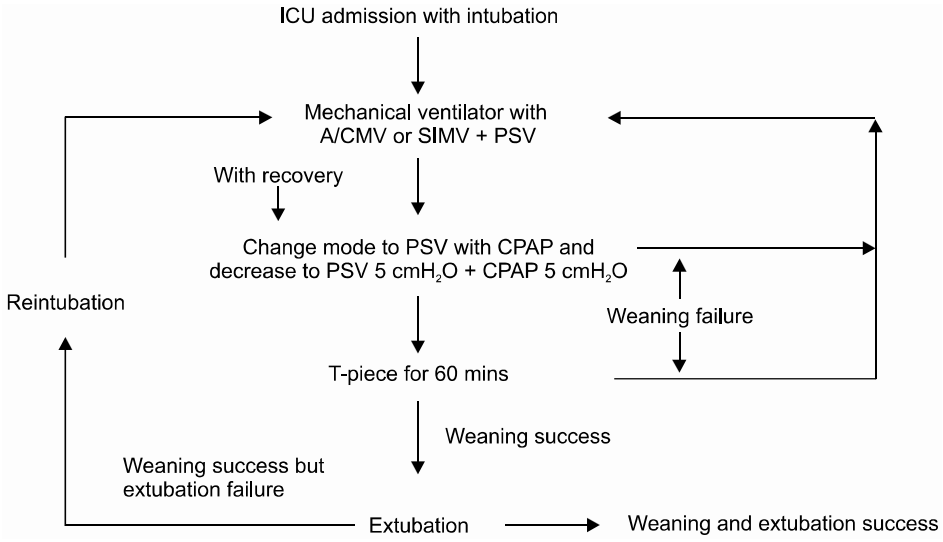


**Fig. 1.** The diagram of weaning process. The flow chart shows that the weaning process starts with PSV + CPAP and preceeds with the application of T-piece and extubation. A/CMV: assisted/controlled mechanical ventilation, SIMV: synchronized intermittent mandatory ventilation, PSV: pressure support ventilation, CPAP: continuous positive airway pressure.

determined by the critical care physician, the following variables were measured in each patient: the spontaneous minute volume and the vital capacity, which were both measured with the Wright's spirometer, the respiratory rate during unassisted breathing through the endotracheal tube, and the maximum negative inspiratory force, which was measured as the best of three voluntary forced inspiratory maneuvers against an occluded airway through a differential pressure transducer. The respiratory parameters were measured twice: once at the PSV mode and again 60 minutes after the T-piece was applied. These respiratory parameters were the respiratory rate, tidal volume, minute ventilation, RSBI, maximal inspiratory force ($P_{imax}$), and the vital capacity (VC). The P/F ratio and the $PaCO_2$ were measured three times, once at the PSV mode, 60 minutes after the T-piece was applied, and 30 minutes after the extubation was performed. The duration of the ventilator support and of the length of stay (LOS) while in the ICU and in the hospital were measured starting from the intubation time in the operation room to the discharge from the ICU and hospital in the patients who undergone weaning and extubation.

Data were expressed as mean ± SD or as the number of patients. Continuous, normally distributed variables were compared, using the Student's t-test; for the variables that are not normally distributed, the Wilcoxon rank-sum test was used. Categorical data were assessed using the Fisher two-tailed exact test. Linear regression was used to determine the relationship between continuous variables, and the independent effects of these variables on extubation outcome were explored using multiple logistic regression analysis. All significant variables were included as independent variables in the regression model, as well as the age, height, ideal body weight, and APACHE II score. The ability of certain respiratory parameters to discriminate between successful and failed extubations was assessed, using the receiver operating characteristics (ROC) curve analysis. Sensitivity, specificity, positive predictive values, and negative predictive values were not reported in order to avoid dependence on a threshold value. Statistical analysis was performed, using a commercially available analysis software (SPSS 12.0) version. P values less than 0.05 were considered statistically significant.

**Table 1.** Perioperative Patient Characteristics

| | Success group (n = 159) | Failure group (n = 10) |
|---|---|---|
| Age (yr) | 62.5 ± 16.8 | 66.2 ± 9.3 |
| Height (cm) | 163.5 ± 8.6 | 158.2 ± 6.1 |
| Weight (kg) | 62.3 ± 10.6 | 59.6 ± 5.8 |
| ASA class (I/II/III) | 5/97/57 | 0/2/8* |
| Operation time (hr) | 5.1 ± 2.8 | 4.5 ± 2.9 |
| I/O (ml) | 2,476 ± 1,582 | 2,108 ± 1,262 |
| P/F ratio | 406.9 ± 113.2 | 299.7 ± 104.3* |
| APACHE II score | 10.1 ± 4.3 | 12.2 ± 3.5 |
| Emergency op. (%) | 19 (13.2) | 5 (50.2)† |

All data are presented as mean ± SD or as number of patients (%). ASA: American Society of Anesthesiologists, I/O: input/output, P/F ratio: $PaO_2/FiO_2$ at the preoperative state, APACHE II score at ICU admission: acute physiology and chronic health evaluation II score at ICU admission, Emergency op.: Emergency operation. *: $P < 0.05$ compared to the success group by the Wilcoxon rank-sum test, †: $P < 0.05$ compared to the success group by the $\chi^2$ test.

## RESULTS

One hundred sixty nine patients were included in the study. Successful weaning from mechanical ventilator support and extubation was performed in 159 patients (94.6%). Weaning and extubation failure were developed in 10 patients (5.4%) due to hypercarbic or hypoxemic respiratory failure.

There was no significant difference in age, weight, height, duration of operation, total fluid intake and output throughout

**Table 2.** Respiratory Parameters in the Weaning Success and Failure Patients

| Respiratory parameter | Mode of ventilation | Success group (n = 159) | Failure group (n = 10) |
|---|---|---|---|
| P/F ratio | PSV | 415.5 ± 100.4 | 333.5 ± 93.5 |
| | T60 | 374.5 ± 110.8 | 278.4 ± 104.7* |
| | 30 min after ext | 306.8 ± 93.8 | 227.3 ± 60.8 |
| $Paco_2$ (mmHg) | PSV | 37.2 ± 5.9 | 37.4 ± 5.5 |
| | T60 | 37.1 ± 5.8 | 40.5 ± 5.8 |
| | 30 min after ext | 38.1 ± 5.2 | 40.3 ± 8.3 |
| RSBI (breath/ml) | PSV | 34.1 ± 15.0 | 43.3 ± 16.3 |
| | T60 | 42.8 ± 26.1 | 72.2 ± 46.4* |
| $P_{imax}$ ($cmH_2O$) | PSV | 36.6 ± 7.7 | 37.5 ± 2.8 |
| | T60 | 36.8 ± 7.1 | 32.5 ± 3.5 |
| VC (ml/kg) | PSV | 19.5 ± 5.8 | 16.5 ± 4.7 |
| | T60 | 18.5 ± 6.1 | 15.1 ± 3.5 |

Data are presented as mean ± SD or as the number of patients (%). 30 min after ext: 30 minutes after extubation, T60: 60 minutes after the T-piece is applied, P/F ratio: $Pao_2/Fio_2$ ratio, RSBI: rapid shallow breathing index, $P_{imax}$: maximal inspiratory pressure, VC: vital capacity. *: $P < 0.05$ compared to the success group by the Wilcoxon rank-sum test.

**Table 3.** Area under the ROC Curve for the Prediction of the Extubation Outcome

| Variables | Area |
|---|---|
| P/F ratio at pre-op | 0.68 |
| P/F ratio at 60 min of T-piece | 0.57 |
| P/F ratio at 30 min after extubation | 0.90 |
| $P_{imax}$ at PSV | 0.65 |
| $P_{imax}$ at 60 min of T-piece | 0.82 |
| RSBI at PSV | 0.77 |
| RSBI at 60 min of T-piece | 0.90 |

P/F ratio at pre-op: $Pao_2/Fio_2$ ratio at the preoperative status, P/F ratio at 60 min of T-piece: $Pao_2/Fio_2$ ratio 60 minutes after the T-piece was applied, P/F ratio at 30 min after ext: $Pao_2/Fio_2$ ratio 30 minutes after the extubation, $P_{imax}$ at PSV: maximal inspiratory pressure of the pressure support ventilation, $P_{imax}$ at 60 min of T-tube applied: maximal inspiratory pressure 60 minutes after the T-piece was applied, RSBI at PSV: rapid shallow breathing index at the continuous airway pressure mode, RSBI at 60 min of T-tube: rapid shallow breathing index 60 minutes after the T-piece was applied.

the operation, diagnostic category, and severity of illness based on APACHE II scores upon ICU admission, between two groups. The P/F ratio at the preoperative state was significantly higher (406.9 ± 113.2) ($P < 0.05$), and the ASA class and the percent of the emergency operation were significantly lower (13.2%) ($P < 0.05$) in the weaning success group (Table 1).

The P/F ratio 60 minutes after the T-piece applied was significantly higher (374.5 ± 110.8) ($P < 0.05$), and the RSBI was significantly lower (42.8 ± 26.1) ($P < 0.05$) in the weaning success group (Table 2). The area under the ROC curve for the RSBI at 60 minutes after the T-piece applied and the P/F ratio at 30 minutes after the extubation were larger (0.90), compared to the other respiratory parameters (Table 3).

Duration of ventilator support and length of stay (LOS) in both the ICU and hospital were significantly shorter in the weaning success group ($P < 0.05$). The mortality in both the ICU and hospital were significantly lower in the weaning success group ($P < 0.05$) (Table 4).

## DISCUSSION

In this study, we performed successful weaning from mechanical ventilator support and extubation in 94.6% of the patients. The RSBI at 60 minutes after the T-piece applied was significantly

**Table 4.** Length of Stay (LOS) and Mortality in the Weaning Success and Failure Patients

| | Success group (n = 159) | Failure group (n = 10) |
|---|---|---|
| Ventilator day (days) | 2.1 ± 2.9 | 15.2 ± 5.8* |
| LOS in ICU (days) | 5.0 ± 3.2 | 22.1 ± 17.2* |
| LOS in hospital (days) | 25.6 ± 13.3 | 42.6 ± 32.8* |
| ICU mortality | 0 (0) | 1 (10)* |
| In hospital mortality | 1 (1) | 2 (20)* |

All data are presented as mean ± SD or as number of patients (%). LOS: length of stay. *: $P < 0.05$ compared to the success group by the Wilcoxon rank-sum test.

lower in the patients who successfully weaned than those that failed weaning (Table 2). The other parameters, such as the VC, $P_{imax}$ measured at PSV mode and 60 minutes after the T-piece was applied, were not significantly different between the two groups. Therefore, the RSBI is regarded as the best suitable weaning index.[17] The area under the ROC curve was comparably the largest for the RSBI levels 60 minutes after the T-piece was applied and for the P/F ratio 30 minutes after the extubation (Table 3). The accuracy of the RSBI measurement may be compromised, but, unlike other methods, the advantages of RSBI measurement are the reproducibility of the results, the ease of automated measurements, and the unconscious process of taking measurements.[1,18]

We evaluated the medical history and preoperative clinical conditions of each patient in addition to their weaning index. The P/F ratio at the preoperative state was significantly higher in patients that successfully weaned than the patients who failed, and both the ASA class and the percent of emergency operations were significantly lower ($P < 0.05$), although the APACHE II score upon ICU admission after the surgical procedure was not significantly different between the two groups. The successful weaning was associated more with the preoperative conditions of the patients than their conditions at the time of ICU admission.

The gradual decrease of PSV or spontaneous ventilation is suggested as the proper weaning method.[19-22] The use of PSV resulted in a decrease of RSBI in our study without any significant difference between the weaning success and failure groups. For most surgical procedures, a gradual withdrawal of support is not necessary for successful weaning.[3] Accordingly, a majority of postoperative patients can be weaned rapidly from mechanical ventilation or after a brief trial of spontaneous breathing.

Failure to wean is usually a result of one or two processes of oxygenation or ventilatory failure. Oxygenation failure is most commonly associated with alveolar filling processes or small lung volumes. Ventilation failure implies a mechanical or neuromuscular disorder with impaired ventilation and hypercarbia, which most commonly reflects muscle fatigue. The P/F ratio at 60 minutes after the T-tube was applied was significantly higher in the patients who were successfully weaned than patients who failed ($P < 0.05$). There was no difference of the $PaCO_2$ levels measured three times throughout the weaning period between the two groups. The patients who experienced weaning failure had a poorer outcome than those with weaning success, with a longer duration of ventilator days, as well as LOS in both the ICU and hospital stays ($P < 0.05$).

In conclusion, both a weaning index, such as the RSBI, and the preoperative medical conditions of a patient, such as the P/F ratio, ASA class, and their emergency status, have to be considered to successfully wean the postoperative ICU patients from mechanical ventilator support and to extubate.

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