Modified Rapid Shallow Breathing Index Adjusted With Anthropometric Parameters Increases Predictive Power for Extubation Failure Compared With the Unmodified Index in Postcardiac Surgery Patients

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Objective: **The aim of this study was to determine the best predictors of successful extubation after cardiac surgery, by modifying the rapid shallow breathing index (RSBI) based on patients' anthropometric parameters.**

Design: **Single-center prospective observational study.**

Setting: **Two general intensive care units at a single research institute.**

Participants: **Patients who had undergone uncomplicated cardiac surgery.**

Interventions: **None.**

Measurements and Main Results: **The following parameters were investigated in conjunction with modification of the RSBI: Actual body weight (ABW), predicted body weight, ideal body weight, body mass index (BMI), and body surface area. Using the first set of patient data, RSBI threshold and modified RSBI for extubation failure were determined (threshold value; RSBI: 77 breaths/min (bpm)/L, RSBI adjusted with ABW: 5.0 bpm × kg/mL, RSBI adjusted with BMI: 2.0 bpm × BMI/mL). These threshold values for RSBI and RSBI adjusted with ABW or BMI were validated using the second set of patient data. Sensitivity values for RSBI, RSBI modified with ABW, and RSBI modified with BMI were 91%, 100%, and 100%, respectively. The corresponding specificity values were 89%, 92%, and 93%, and the corresponding receiver operator characteristic values were 0.951, 0.977, and 0.980, respectively.**

Conclusions: **Modified RSBI adjusted based on ABW or BMI has greater predictive power than conventional RSBI.**

KEY WORDS: rapid shallow breathing index, cardiac surgery, anthropometric parameters, postoperative care

MOST CARDIAC SURGERY PATIENTS are able to resume spontaneous ventilation as soon as they recover from anesthesia. In some patients, however, discontinuation of ventilation and extubation can be more difficult than maintaining it. The discontinuation process can account for up to 40% of the total time spent on ventilator support; long durations of ventilator support increase the risk of infection and associated complications that arise mainly from nosocomial pneumonia.[1] Up to 23% of cardiac surgery patients require prolonged mechanical ventilation, leading to a longer hospital stay, and this is associated with a 40% mortality rate. On the other hand, premature extubation also increases the risk of prolonged ventilator support and results in a high mortality risk. Therefore, it is important to identify the earliest and safest time for discontinuation of ventilation and extubation,[2] and it is also important to predict precisely which patients can tolerate spontaneous breathing without ventilator support. Because decisions for extubation based solely on the expert's clinical judgment are not always accurate,[3] several predictors of extubation failure are used to aid in decision-making.[4–6]

Recent review articles suggested 3 criteria (inadequate cough, excessive secretions, and poor mental status) as useful predictors of extubation failure after the discontinuation of ventilation.[7] However, these guidelines have a significant false negative rate; therefore, some cardiac surgery patients develop respiratory distress after extubation, even in the absence of the above symptoms.

The rapid shallow breathing index (RSBI) is considered to be the most accurate predictive index for successful patient extubation. Patients on ventilators who are unable to tolerate independent breathing generally breathe with high frequency and low tidal volume (TV). Therefore, RSBI is calculated by dividing the respiratory rate (RR) by TV. A gradual improvement in RSBI denotes greater inspiratory effort (high TV) and is associated with improved gas exchange and a low RR. This index can be used to predict the incidence of failure of premature extubation and reduces delays in the weaning of patients potentially suitable for discontinuation from ventilator support. The predictive value of the RSBI has been estimated to be 0.85, which means that this index fails in a considerable number of patients.[8]

However, this useful predictive value also has a significant false positive rate. Therefore, clinicians should improve accuracy of predictive value for extubation. The authors hypothesized that the predictive capacity of the RSBI may be improved by customizing the test for each patient in terms of anthropometric parameters. The goal of the authors was to optimize the RSBI as a predictor for extubation failure among patients after cardiac surgery, by testing the effect of anthropometric parameters on its predictive accuracy.

METHODS

The study was approved by the relevant ethics committee, and informed consent was waived because it was an observational study. Consecutive patients who had undergone uncomplicated cardiac surgery were enrolled in the study.

Exclusion criteria included age <18 years, ventilation for >24 hours in the intensive care unit (ICU) before the application of a spontaneous breathing trial (SBT), and the presence of neurologic or neuromuscular disorders. The study was conducted from April 2011 to June 2011 in 2 general ICUs with a combined total of 33 beds, at a hospital-based research institute that performs approximately 3,500 cardiothoracic surgeries per year.

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1053-0770/2601-0001$36.00/0
http://dx.doi.org/10.1053/j.jvca.2014.06.022

Patients were ventilated mechanically using MAQUET ventilators (GmbH & Co. KG, Rastatt, Germany) in synchronized intermittent mandatory ventilation mode. Patients were weaned from the ventilators if stable hemodynamics were maintained with minimal catecholamine levels. The standard catecholamine infusion limits were epinephrine < 0.05 μg/kg/min, norepinephrine < 0.05 μg/kg/min, dopamine < 5 μg/kg/min, and dobutamine < 5 μg/kg/min. When patients tolerated the ventilator support of pressure support (PS) < 10 cmH_2O, and positive end-expiratory pressure < 10 cmH_2O, an SBT was performed for 30 minutes under 5 cmH_2O of PS and 5 cmH_2O of continuous positive airway pressure (CPAP). The authors terminated the SBT and excluded patients from the study if they exhibited either agitation and anxiety, depressed mental status, diaphoresis, cyanosis, effort respiratory pattern, inadequacy of gas exchange, hemodynamic instability, or subjective discomfort.[9]

Patients exhibiting any of these exclusion criteria were switched back to the previous ventilator support level. When the patient tolerated SBT, the TV and RR were recorded after 30 min of SBT.

Extubation was determined by an anesthesiologist and implemented as soon as possible after the assessment.

The following clinical characteristics were determined: Age, sex, height, actual body weight (ABW) as measured on admission, predicted body weight (PBW), ideal body weight, BMI, body surface area, ejection fraction (EF), tricuspid annular plane systolic excursion, and European system for operative risk evaluation score (EuroSCORE).[10] Pre-existing complications including hypertension, chronic obstructive pulmonary disease, renal impairment, recent myocardial infarction, and type of surgical procedure were recorded.

Spontaneous minute volume of ventilation and RR were measured by a ventilator monitor with a digital output after 30 minutes on SBT. Spontaneous TV was calculated by dividing minute volume by RR, while RSBI was calculated by dividing RR by TV (in L). The predictive power of each modified RSBI was calculated by dividing RSBI by either ABW, PBW, ideal body weight, BMI, or body surface area in order to evaluate which parameters were the best predictors for extubation. For example, in the case of ABW, RSBI adjusted for ABW = RR (breaths/min)/TV (mL)/ABW (kg). (see Supplementary Information).

Extubation was defined as successful when the patient had maintained discontinuation of ventilator support for more than 48 hours after extubation.[11] Occasionally, noninvasive ventilation (NIV) was used as a prophylactic measure after extubation in patients identified to be at a high risk of reintubation by an expert anesthesiologist, but who did not develop acute respiratory failure. Patients who received prophylactic NIV were excluded from the study.

The authors analyzed extubation failure using 2 sets of patients. The first set, selected by temporal order, was used to evaluate the threshold value for extubation failure. The threshold values of each predictor were selected as those that resulted in the fewest false classifications. The second set of patients was assigned to the prospective validation analysis group that was used to assess the predictive power of the threshold value of each index. These analyses were performed after collecting data of all patients to ensure impartiality of the validation study.

Continuous variables were expressed as mean and standard deviation, and categoric variables as frequencies and percentages. Student's t test was used to compare parametric variables, and the Mann-Whitney test was used to compare nonparametric variables; p values of < 0.05 were considered significant.

The authors calculated linear regression analysis between patients' characteristics and respiratory parameters defined as useful parameters in univariate analysis. If correlation between predictive parameters was significant, it was not used in multivariate analysis. Multivariate logistic regression analysis performed with predictive parameters seemed to be useful, based on the training set. Sensitivity, specificity, receiver operator characteristic (ROC) curves, positive predictive value, negative predictive value, odds ratio, and likelihood ratio were calculated for each modification of the RSBI.

Statistical analyses were performed using Ekuseru-Toukei 2008 (Social Survey Research Information, Tokyo, Japan).

Table 1. Characteristics and Preoperative Comorbidities of Patients in the Training Set

Clinical Characteristics	Total (n = 96)	Successful Extubation (n = 84)	Extubation Failure (n = 12)	p value
Age (yr)	55.9 ± 10.2	55.3 ± 10.7	56.9 ± 4.0	0.747
Sex, female (%)	25 (25%)	22 (26%)	0 (0%)	0.062
Height (m)	1.62 ±0.08	1.61 ± 0.08	1.64 ± 0.08	0.311
Actual body weight (kg)	68.0 ± 12.2	67.3 ± 12.2	73.8 ± 12.1	<u>0.016</u>
Predicted body weight (kg)	57.9 ± 7.5	57.5 ± 7.4	60.2 ± 7.2	0.283
Ideal body weight (kg)	57.5 ± 5.6	57.2 ± 5.5	59.0 ± 5.9	0.328
Body mass index (kg/m^2)	26.0 ± 3.8	25.9 ± 3.9	27.5 ± 3.1	<u>0.025</u>
Body surface area (m^2)	1.72 ± 0.17	1.71 ± 0.71	1.80 ± 0.18	0.166
EuroSCORE	2.3 ± 2.0	2.2 ± 2.0	2.1 ± 1.2	0.374
Hypertension, n (%)	75 (78%)	64 (76%)	11 (92%)	0.454
Diabetes, n (%)	43 (45%)	34 (40%)	9 (75%)	0.032
COPD, n (%)	33 (34%)	28 (33%)	5 (42%)	0.746
Renal impairment, n (%)	6 (6%)	4 (5%)	2 (17%)	0.162
Ejection fraction (%)	55.5 ± 11.1	56.8 ± 10.7	47.8 ± 10.8	<u>0.048</u>
TAPSE (cm)	2.1 ± 0.4	2.1 ± 0.4	2.1 ± 0.5	0.684
Recent myocardial Infarction, n (%)	23 (24%)	20 (24%)	3 (25%)	1.000
CABG, n (%)	79 (82%)	67 (80%)	12 (100%)	0.117
Valve, n (%)	11 (12%)	11 (13%)	0 (0%)	0.349
Combined surgery, n (%)	6 (6%)	6 (7%)	0 (0%)	1.000

NOTE. Factors were compared between extubation failure patients and successful extubation patients. The underlined values show statistical significance as $p < 0.05$.

Abbreviations: CABG, coronary artery bypass graft; COPD, chronic obstructive pulmonary disease; TAPSE, tricuspid annular plane systolic excursion.