Predictors of spontaneous breathing outcome in mechanically ventilated chronic obstructive pulmonary disease patients

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Background Morbidity and mortality due to chronic obstructive pulmonary disease (COPD) represents a worldwide pandemic, with exacerbations necessitating mechanical ventilation representing important aspects of disease management. Attempts to search for better weaning indices (WIs) is a continuous process. This study seeks for best index predicting weaning outcome in COPD patients.

Patients and methods 2One hundred and fifty COPD patients (110 men, 40 women) receiving mechanical ventilation were included in this study. Weaning process as early as possible was considered. Patients who were receiving mechanical ventilation of more than 24 h underwent daily screen of subjective and objective indices for weaning readiness. Measurements done on admission and through weaning process included: acute physiology and chronic health evaluation II score, simplified acute physiology score II, CORE (compliance, oxygenation, respiration, and effort) index, rapid shallow breathing index (RSBI), WI, integrative weaning index (IWI), compliance, rate, oxygenation, and pressure (CROP) index and $P_{0.1}$/negative inspiratory force index.

Results There is a highly significant difference between weaning success and failure groups regarding the CORE index, RSBI, WI, IWI, CROP index, and $P_{0.1}$/negative inspiratory force. CORE index had the highest area under the curve (0.929) which was significantly higher than other indices included in the study.

Conclusion RSBI, WI, IWI, and CROP index displayed moderate accuracy in predicting spontaneous breathing trial success in COPD patients. CORE index showed better diagnostic performance in predicting successful weaning and had the highest accuracy.
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Keywords: chronic obstructive pulmonary disease, compliance, oxygenation, respiration and effort index, weaning from mechanical ventilation, weaning predictors

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Introduction

Chronic obstructive pulmonary disease (COPD) represents a major cause of morbidity and mortality worldwide that induces a high socioeconomic burden [1,2]. The prevalence and burden of COPD are projected to extend over the approaching decades because of aging of the world's population and continued exposure to COPD risk factors [3].

COPD exacerbations represent an acute worsening of respiratory symptoms that demand an additional therapy [4]. COPD exacerbations had deleterious effect on the health status, rates of hospitalization, and readmission and it can induce respiratory failure [5,6]. Mechanical ventilation here aims to provide adequate oxygenation and ventilation, reduce the work of breathing, and improve patient comfort until the condition that forced the need for this technique has been alleviated [7].

Once mechanical ventilation is initiated, planning for weaning should stars. Timing is crucial as early or late extubation is associated with increased morbidity and mortality [8]. Traditionally, the decision to start weaning process was taken by the attending physician after improvement of patient's clinical condition, arterial blood gas parameters, and largely depends on clinical experience [9]. This method is not reproducible and ignores vital aspects in assessing readiness for weaning such as muscle fatigue [10].

Several predictors of successful weaning have been studied, mostly displaying good sensitivity but low specificity [11]. One of the most accurate and most studied indices is rapid shallow breathing index (RSBI), which was first suggested by Yang and colleagues. RSBI displayed a positive predictive value (PPV) of 0.78 and a negative predictive value (NPV) of 0.95 [12].

Compliance, rate, oxygenation, and pressure (CROP) index represents an integrative index first described by Yang and Tobin [12] (compliance, respiratory rate, oxygenation, and pressure). Delisle *et al.* [13] proposed the CORE index (an integrative index of compliance, oxygenation, respiration, and patient effort) which was developed by adding airway occlusion pressure ($P_{0.1}$) to the CROP index, suggesting that would improve

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spontaneous breathing trial (SBT) outcome prediction. In 2009, a new integrative weaning index (IWI) reported that had a PPV of 0.99 and an NPV of 0.86 [14]. Weaning index (WI) is described by Huaringa *et al*. [15] as a simple integrated parameter that displayed a PPV of 0.95 and an NPV of 0.94. WI= (RSBI×elastance index×ventilatory demand index).

As described research to reach for the ideal predictor is a continuous process. This study aimed to compare the accuracy of various predictors in predicting SBT outcome in mechanically ventilated COPD patients.

Patients and methods

Patients

This study was performed on 150 critically ill patients diagnosed with COPD during the period between January 2015 and December 2016.

Inclusion criteria

Patients with COPD are eligible for enrollment if they are admitted to the respiratory ICU and requiring invasive mechanical ventilation (diagnosis confirmed on the basis of medical history, physical examination, chest radiography, and previous pulmonary function tests if available). Indications of mechanical ventilation included: needed noninvasive ventilation failure, respiratory or cardiac arrest, severe hemodynamic instability, and/or diminished consciousness.

Exclusion criteria

The exclusion criteria are noninvasive ventilation without subsequent invasive ventilation, previous tracheostomy, neurological and neuromuscular diseases hindering the respiratory drive, patients who had suffered unplanned extubation (UE) before or during the weaning process and patients with postarrest encephalopathy.

The included patients underwent careful history taking, full clinical examination, chest radiography, routine laboratory investigations (whenever needed), arterial blood gases on a daily basis and also before and after start of SBT. Severity assessment was done on the day of ICU admission by acute physiology and chronic health evaluation (APACHE) II score [16] and simplified acute physiology score II [17].

Procedures

Initiation of mechanical ventilation

The included patients were intubated using endotracheal tubes of size 7.0–8.0 mm. Ventilation was performed with the Puritan-Bennett 840 ventilator (Puritan-Bennett corporation Pleasanton CA, USA made in Ireland.). The patients were adjusted on synchronized intermittent mandatory ventilation, volume-controlled mode. Setting parameters: initial settings coped with ventilatory strategies in obstructive lung disease mentioned in the literature. Machine rate: started with 8–10 breath/min. FiO_2: started with high fraction of inspired oxygen concentration (0.7–1.0) to ensure adequate tissue oxygenation. After an initial blood gas value is obtained, a fraction of the inspired oxygen concentration was titrated to reach SaO_2 (88–92%). Positive end expiratory pressure (PEEP): PEEP setting started at 5 cm H_2O, and a watch kept at plateau pressure or peak inspiratory pressure and hemodynamics. Extrinsic PEEP which is equal to 80% of auto-PEEP was added in case of auto-PEEP development. *I-E* ratio: started with *I-E* ratio of 1 : 3. Flow rate: adjusted from 60 to 100 l/min and flow wave form adjusted to square form, with a monitoring peak inspiratory pressure of less than or equal to 40–45 cmH_2O and plateau pressure of less than 30 cmH_2O. Trigger: from 1 to 2 l/min for flow [18,19]. Monitored parameter: included peak airway pressure, plateau pressure, exhaled tidal volume, minute ventilation (MV), and graphic display (including pressure, flow, and volume scalars). Vital signs were monitored continuously including heart rate, respiratory rate (RR), and oxygen saturation (SpO_2).

Weaning procedure

The patients who were receiving mechanical ventilation for more than 24 h underwent daily screening for subjective and objective indices for the assessment of readiness to wean. Weaning was conducted according to the statement of the ERS, ATS, European Society of Intensive Care Medicine, Society of Critical Care Medicine, and Societé de Réanimation de Langue Francaise [20]: improvement of disease acute phase which necessitated mechanical ventilation (assessed by APACHE II scoring); absence of excessive tracheobronchial secretion (8 h before the weaning process there was no need for bronchial toilet more than twice); stable neurological status; no hemodynamic instability; PaO_2 more than 60 mmHg or SaO_2 more than or equal to 90% or more with FiO_2 less than or equal to 0.4; spontaneous RR less than 35/min; and spontaneous respiratory volume (V_T) more than 5 ml/kg of ideal body weight [20]. Respiratory parameters were determined from the digital display of the mechanical ventilator.

Preparation to spontaneous breathing trial

Usually SBT was conducted early in the morning. Patient ensured to be awake, cooperative, and not receiving sedative infusions. Communication with the patient and explanation of the procedure was done. The baseline parameters were recorded. The duration of the SBT lasted usually 30–120 min [21]. Modes of SBT: participants who fulfilled the criteria for weaning readiness were randomized in a ratio of 1 : 1 to start SBT using either proportional assist ventilation (PAV +) or pressure support ventilation (PSV). PAV+: correct ideal body weight, endotracheal tube size, and maximum airway pressure (40 cmH_2O) were ensured to be entered correctly. Initial gain of 60% support is proposed in our protocol. Initial PEEP was 5 cmH_2O and FiO_2 was less than or equal to 40%. The assist was reduced by 10–20% every 1–2 h (provided no respiratory distress). If no respiratory distress at 10–20% assists, extubation was considered [22]. PSV: SBT started with a low level of PEEP (5 cmH_2O) and a low level of pressure support (8 cmH_2O). If no signs of distress at 120 min, extubation was considered. If the patient is unable to tolerate or distressed, the patient is fully rested until the next day when the process begins again.

Variables monitored during spontaneous breathing trial

Dyspnea, fatigue, anxiety, and distress were subjectively assessed. The vital signs were monitored and recorded including RR, heart rate, and blood pressure. Ventilatory data were recorded including spontaneous tidal volume, RR, MV, peak pressure, and f/V_T. Also static compliance (sing inspiratory pause button of the ventilator) and dynamic compliance (using The Respiratory Mechanics Software Option for the Puritan-Bennett 840 ventilator) were measured. Values were displayed on the ventilator and we used the average of three breaths. Negative inspiratory force (NIF) (measured using RM software option three times and the most negative result was taken), $P_{0.1}$ (measured five times over a period of 60–90 s), and the average of these measurements was taken [23].

Weaning predictors assessment

Numerous weaning predictors were evaluated for the assessment of patient readiness for weaning with comparison between sensitivity, specificity, PPV, NPV, and area under the curve (AUC) for each including: CORE index=$[C_{dyn}\times(P_{Imax}/P_{0.1})\times(PaO_2/PAO_2)]/f$ (C_{dyn} is the dynamic compliance, P_{Imax} is the maximal inspiratory pressure, PAO_2 is the oxygen tension in alveolar air, and *f* is the RR). CORE index was calculated manually. A cutoff value of more than 8 was used to predict the success of SBT [13]. RSBI cutoff value of less than or equal to 105 breath/ml/min was used to predict the success of SBT [12,24]. WI=[RSBI×(peak pressure/NIF)×(MV×10)]. WI was calculated manually. A cutoff value of less than or equal to 100 was used to predict the success of SBT [15]. IWI=$[C_{st,rs}\times SaO_2/RSBI]$ ($C_{st,rs}$ is the static compliance). IWI was calculated manually. A cutoff value of more than or equal to 25 ml/cmH_2O was used to predict the success of SBT [14]. CROP index=$[C_{dyn}\times P_{Imax}\times(PaO_2/PAO_2)]/f$. CROP was calculated manually. A cutoff value of more than or equal to 13 ml/breath/min used to predict success of SBT [12,13]. $P_{0.1}$/NIF cutoff value less than or equal to 0.15 was used to predict the success of SBT [24].

Outcome of spontaneous breathing trials

Signs of SBT failure, which were used as criteria for ending the trial, include: an fR of more than 35/min, heart rate of more than 140/min (or >20% change from the initial value), systolic blood pressure of more than 180 mmHg or less than 90 mmHg, PaO_2 of less than or equal to 60 mmHg or SaO_2 less than 90% on FiO_2 less than or equal to 0.4, pH less than or equal to 7.32, or a reduction in pH of more than or equal to 0.07, $PaCO_2$ more than 50 mmHg or an increase in $PaCO_2$ of more than 8 mmHg, worsening of respiratory distress, and deterioration of the neurological status [20]. The weaning outcome is deemed successful when the unassisted spontaneous breathing is maintained for 48 h with no signs of respiratory distress, with a pH more than of 7.35 and PaO_2 of more than 60 mmHg in a patient receiving an FiO_2 less than or equal to 0.5 through a mask [20]. Weaning outcome is deemed a failure when the patient needed noninvasive ventilation, reintubation, or death occurred within 48 h of extubation [25].

Ethical consideration

The study was approved by the Institutional Ethics Committee Faculty of Medicine. Also, written informed consent was given by surrogate decision makers.

Statistical analysis

Statistical package for the Social Sciences) software program, version 21 (IBM Inc., Armonk, New York, USA) and Medcalc (MedCalc Statistical Software version 18.2.1 (MedCalc Software bvba, Ostend, Belgium, http://www.medcalc.org, 2018), were used for data recording and processing. Nonparametric tests were used in the current study. Receiver operating characteristic (ROC) curve was used to evaluate the predictive performance of each WIs. The area under the ROC curves for each index was calculated by the nonparametric method of Delong *et al.* [26]. *P* value: considered significant if *P* less than 0.05.

Results

During the study period, 234 patients were intubated and fulfilled the inclusion criteria, 84 (35.9%) patients did not start weaning because of death in 69 (29.5%) patients and UE in 15 (6.4%) patients. The remaining 150 (64.1%) patients met the criteria of weaning and started the weaning process from mechanical ventilation by either PAV+ or PSV mode.

Demographic data and patient characteristics are shown in Table 1. Male patients were 110 (73.3%), while women were 40 (26.7%). The mean age was 61.56±7.28 years. As regards smoking history, 56.7% of patients were current smokers.

Table 1 Demographic data and patient characteristics (150 mechanically ventilated chronic obstructive pulmonary disease patients)

Parameters	Mechanically ventilated COPD patients (*N*=150)
Sex	
Male	110 (73.3)
Female	40 (26.7)
Age (years)	
Mean±SD	61.56±7.28
Median (range)	62 (45–80)
BMI (kg/m^2)	25.32±4.99
Smoking status	
Current smoker	85 (56.7)
Nonsmoker	40 (26.7)
Exsmoker	25 (16.7)
Exacerbations	
Last year (No.)	1.85±1.07
Hospitalizations	
Last year (No.)	0.41±0.58
APACHE II at admission	24.93±5.03
APACHE II at randomization	15.9±3.88

Data are presented as mean±SD, median (range), or *n* (%). APACHE, acute physiology and chronic health evaluation; COPD, chronic obstructive pulmonary disease.

APACHE II score measured on the first day of ICU admission was 24.93±5.03. The mean APACHE II score at randomization was 15.9±3.88. The mean simplified acute physiology score II in total patients was 38.9±10.09 with a mean expected mortality of about 38%.

Regarding SBT outcome, 105 of 150 (70%) patients tolerated the breathing trial and underwent successful extubation, while 45 (30%) patients failed first SBT (Table 2).

Mean values for different WIs used to predict weaning success between the success group and the failure group are shown in Table 3. The success group shows highly

Table 2 Outcome of spontaneous breathing trial and occurrence of complications (150 mechanically ventilated chronic obstructive pulmonary disease patients)

Weaning outcomes	Mechanically ventilated COPD patients (*N*=150)
Success	105 (70)
Failure	45 (30)
Failed trial	31 (20.7)
Weaning by NIV	8 (5.3)
Reintubation or death within 48 h	6 (4.0)
Complications	
HAP	19 (12.7)
Venous thromboembolism	3 (2)
Pneumothorax	2 (1.3)
Major arrhythmia	10 (6.7)

Data are presented as *n* (%). COPD, chronic obstructive pulmonary disease; HAP, Hospital acquired pneumonia; NIV, noninvasive ventilation.

Table 3 Comparison between different weaning indices as regards weaning success or failure

Parameters	Spontaneous breathing outcome		*P* value
	Success group (*N*=105)	Failure group (*N*=45)	
RSBI (≤105)	71.74±19.6	119.78±36.51	<0.001*
Median (range)	69 (30–125)	118 (54–202)	
CORE index (>8)	13.31±7.27	2.77±1.36	<0.001*
Median (range)	10.93 (2.1–41)	2.46 (1–5.85)	
WI (≤100)	66.1±28.71	159.54±76.54	<0.001*
Median (range)	62.68 (11–157.5)	153.33 (26–364)	
IWI (> 25)	66.9±29.77	30.85±15.5	<0.001*
Median (range)	61.47 (24.8–209)	25.9 (8.9–82.3)	
CROP index (≥13)	17.19±7.0	6.69±3.25	<0.001*
Median (range)	15.55 (4.7–47)	5.58 (2.5–16.4)	
$P_{0.1}$/NIF (≤0.15)	0.07±0.05	0.16±0.1	<0.001*
Median (range)	0.06 (0.01–0.4)	0.15 (0.04–0.64)	

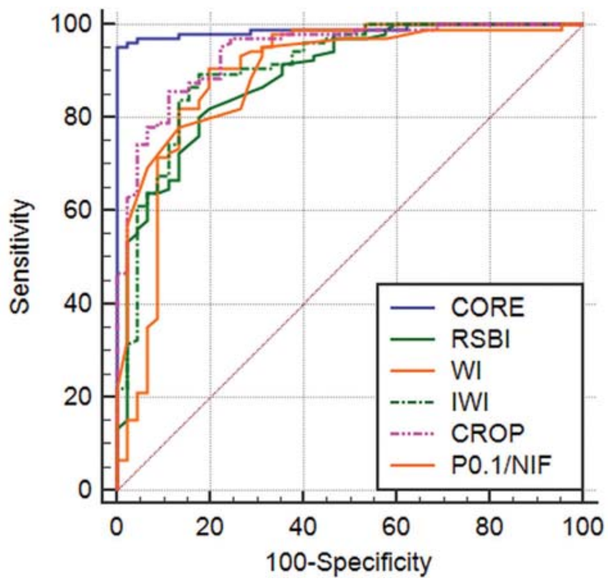
Data are presented as mean±SD. CORE, compliance, oxygenation, respiration, and effort; CROP, compliance, rate, oxygenation, and pressure; IWI, integrative weaning index; $P_{0.1}$/NIF, airway occlusion pressure/negative inspiratory force; RSBI, rapid shallow breathing index with cutoff predicting a weaning success of less than or equal to 105; WI, weaning index. *Statistically significant.

Table 4 Diagnostic test performance of each index used to predict weaning success

Parameters	Sensitivity	Specificity	PPV	NPV	Accuracy	AUC
RSBI ≤105	*94.29*	*53.33*	*82.5*	*80.0*	*82.00*	*0.738*
RSBI ≤87	*80.00*	*82.22*	*91.3*	*63.8*	*80.67*	*0.888*
CORE >8	*85.71*	***100.00***	***100.0***	*75.0*	***90.00***	***0.929***
CORE >5.85	*95.24*	*100.00*	*100.0*	*90.0*	*96.67*	*0.989*
WI ≤100	*90.48*	*77.78*	*90.5*	*77.8*	*86.75*	*0.852*
IWI ≥25	***99.05***	*62.22*	*86.0*	***96.6***	*88.00*	***0.892***
CROP ≥13	*71.43*	*95.56*	*97.4*	*58.9*	*78.67*	*0.835*
$P_{0.1}$/NIF ≤0.15	*97.14*	*42.22*	*79.7*	*86.4*	*80.67*	*0.687*

AUC, area under the curve; CORE, compliance, oxygenation, respiration, and effort; CROP, compliance, rate, oxygenation, and pressure; IWI, integrative weaning index; NPV, negative predictive value; PPV, positive predictive value; $P_{0.1}$/NIF, airway occlusion pressure/negative inspiratory force; RSBI, rapid shallow breathing index; WI, weaning index. CORE index had the highest specificity, positive predictive value, accuracy and area under the curve (highlighted in bold and italic) while IWI showed the highest sensitivity and negative predictive value.

Figure 1



Receiver operator characteristic curve for indices to predict successful extubation: RSBI, rapid shallow breathing index; CORE, compliance, oxygenation, respiration, and effort; WI, weaning index; IWI, integrative weaning index; CROP, compliance, rate, oxygenation, and pressure; $P_{0.1}$/NIF, airway occlusion pressure/negative inspiratory force.

significant higher values for CORE index, integrated WI, and CROP index than the failure group, while the failure group shows highly significant higher values for RSBI, WI, and $P_{0.1}$/NIF than the success group.

Diagnostic performance tests of each index used to predict weaning success are summarized in Table 4. CORE index with a cutoff value of more than 8 had the highest specificity (100%), PPV (100%), and the highest accuracy (90%), while, its sensitivity and NPV were 85.7 and 75.0%, respectively. It also had an excellent AUC (highly accurate AUC=0.929) among all studied indices as shown in Fig. 1. The threshold value of the CORE index that improves its sensitivity, NPV, and AUC (95.2, 90.0, and 0.989, respectively) was more than 5.85.

Table 5 Comparison of the areas under the receiver operator characteristic curves for the studied weaning indices (*P* value)

Index	CORE	RSBI	WI	IWI	CROP
RSBI	0.000*	–	–	–	–
WI	0.007*	0.889	–	–	–
IWI	0.002*	0.357	0.687	–	–
CROP	0.008*	0.031*	0.095	0.167	–
P0.1/NIF	0.000*	0.662	0.767	0.944	0.225

CORE, compliance, oxygenation, respiration, and effort; CROP, compliance, rate, oxygenation, and pressure; IWI, integrative weaning index; $P_{0.1}$/NIF, airway occlusion pressure/negative inspiratory force; RSBI, rapid shallow breathing index; WI, weaning index. *Statistically significant.

IWI with a cutoff value of more than or equal to 25 had the highest sensitivity (99.05%) and NPV (96.6%), while its specificity and PPV were 62.2 and 86.0%, respectively. It also had excellent AUC (moderately accurate AUC=0.892) as shown in Fig. 1.

RSBI with a cutoff value of less than or equal to 105 showed high sensitivity (94.2%) and NPV (82.5%), while its specificity and PPV were 53.3 and 80.0%, respectively. It also had a moderately accurate AUC of 0.738.

The threshold value of RSBI that improves its specificity and PPV and AUC (82.22%, 91.3%, and 0.888, respectively) was less than or equal to 88. The area under the ROC curves for each index was classified according to the guidelines proposed by Swets [27].

Comparison of ROC curves for the studied WIs is demonstrated (Table 5). AUC for the CORE index was significantly higher than the AUC for other WIs (RSBI, WI, IWI, CROP index, and $P_{0.1}$/NIF).

Discussion

Among the 234 patients admitted to respiratory ICU, who met inclusion criteria and intubated during this study, 150 patients started the weaning process. These results are consistent with Funk *et al.* [28] who reported that the weaning process was not started in 33% of patients because of death or UE. In our results 35.9% did not start weaning because of death or UE. They also reported that 0.2% extubated accidentally which is much less than our result. However, Boles *et al.* [20] stated that UE incidence ranges from 0.3 to 16% and Lee *et al.* [29] reported an incidence of 6.7% of UE.

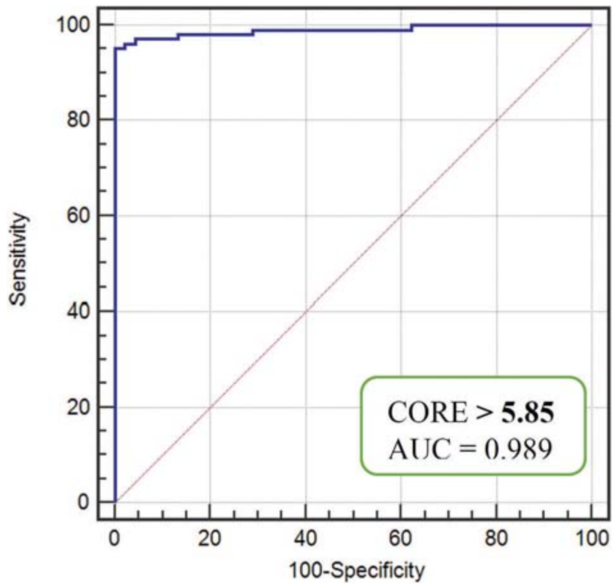
Clinical judgment alone was inaccurate regarding the prediction of successful weaning (67% NPV and 50% PPV). SBT showed a PPV of 85%; however, 15% of the patients who experience successful SBT suffer from extubation failure within 48 h after extubation [30]. WIs introduced to improve weaning outcome prediction include those which evaluate one single function and other integrated indices such as the CORE index, WI, IWI, and CROP index.

We observed a highly significant difference in comparing the weaning predictors (RSBI, CORE index, WI, IWI, CROP index, and $P_{0.1}$/NIF) between patients who succeeded or failed first SBT. Ebrahimabadi *et al.* [31] and El-Shahat *et al.* [32] reported similar results regarding IWI; Mabrouk *et al.* [33] regarding RSBI and CORE; and Savi *et al.* [10] regarding RSBI and CROP index.

In the present study, CORE index cutoff value of more than 8 presented the highest probability of weaning success when the test was positive (1.00) and the highest accuracy (90%) among the studied indices. The area under the ROC curves for CORE was significantly higher than the area of RSBI (0.929 and 0.738, respectively), and the other studied indices (WI, IWI, CROP index, and $P_{0.1}$/NIF). These results are concordant with Delisle *et al.* [13] who stated that the CORE index was the most accurate predictor for SBT success, with an AUC of 1.00 which was higher than other indices in their study including the CROP index (AUC=0.91), $P_{0.1}$ index (AUC=0.81), and RSBI (AUC=0.77). They also declared that the CORE index with a cutoff point of more than 8 predicting successful weaning had the highest PPV of 0.96 and the highest NPV of 1.0 [13].

CORE index with our proposed cutoff value more than 5.85 (Fig. 2) presented the highest PPV (1.00) and NPV (0.10). The AUC for the CORE index with a cutoff value of more than 5.85 was the highest (0.989). According to the results of this study, a CORE index of more than 5.85–8 is the best index to discriminate the success or failure of weaning among COPD patients in respiratory ICU. We suggest that the ICU physicians should not perform any trial of extubation when the CORE is less than 5.85 and to extubate any patient with minimal hesitation when the CORE more than 8.

Figure 2



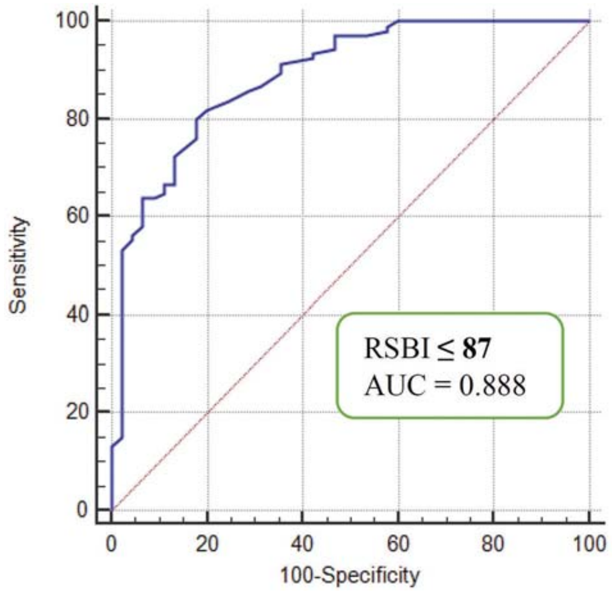
Receiver operator characteristic curve for indices to predict successful extubation. CORE index, compliance, oxygenation, respiration, and effort.

Assessment of diagnostic test performance of RSBI used to predict weaning success when a cutoff value is≤105: the revealed sensitivity is 0.94 and specificity is 0.53 with an AUC of 0.738. This agrees with previous studies as that of Nemer *et al.* [14] who revealed a sensitivity of 0.81, specificity of 0.73 with an AUC of 0.85. Also Yang and Tobin [12] who first proposed RSBI as a predictor for weaning success stated a sensitivity of 0.9), specificity of 0.64 with an AUC of 0.89. The use of the RSBI as an index to predict successful weaning has been widely studied in the intensive care setting [14]. The performance of the RSBI has been shown to range from moderate to good (AUC, 0.72–0.89) [34,35], which agrees with our results where the RSBI was moderately accurate in predicting weaning success.

The RSBI with a cutoff value of less than or equal to 87 presented a higher probability of weaning success when the test was positive (0.91) with a higher area under the ROC curves (0.888) (Fig. 3). Sensitivity and specificity for the aforementioned cutoff value (≤87) were 0.80 and 0.82, respectively.

In concordance with the current results, de Souza *et al.* [36] studied RSBIs calculated by two different methods: RSBI calculated by the traditional method

Figure 3



Receiver operator characteristic curve for indices to predict successful extubation. RSBI, rapid shallow breathing index.

[12] with that of the RSBI calculated directly from MV parameters. The cutoff point for the RSBI calculated directly from the ventilator data to predict weaning success in their study was (RSBI ≤80.1) with a sensitivity of 0.80, specificity of 0.65, and an AUC of 0.82.

As regards assessing another novel index namely the WI, the WI cutoff value of less than or equal to 100 presented a sensitivity of 0.9, specificity of 0.77, and AUC for WI was higher than the area of RSBI ratio with a cutoff of less than or equal to 105 (0.852 and 0.738, respectively). These results are concordant with Huaringa *et al.* [15], who evaluated the accuracy of an WI of less than or equal to 100 to predict the weaning outcome, and recorded a sensitivity of 0.97, specificity of 0.89, and an AUC of 0.96. Our results regarding AUC for WI (cutoff value ≤100) revealed moderate accuracy while Huaringa and colleagues stated that the AUC for WI was highly accurate; this may be attributed to the different study population, sample size, and NIF measurement technique.Regarding assessment of diagnostic test performance of IWI used to predict weaning success with a cutoff value (≥25) in this study, it revealed the highest sensitivity among the studied indices 0.99 and a specificity of 0.62 with an AUC of 0.892 indicating moderate accuracy. The IWI with a cutoff value of more than or equal to 25 presented a PPV of 0.86 and the highest NPV of 0.97.

Nemer *et al.* [14] stated that IWI presented high accuracy (97%), with an AUC of 0.96 larger than that under the curves for the f/V_T ratio (0.85), and also larger than that under the curves for the other indices. IWI presented PPV (0.99) and NPV (0.86). These results agree with ours regarding high accuracy for IWI (88%) and AUC for IWI (0.892) which was higher than other indices in our study except for CORE index which was not included in the Nemer *et al.* [14] study, as it was first proposed in 2011 by Delisle *et al.* [13].

El-Baradey *et al.* [37] concluded that IWI is a strong predictor of weaning outcome. Their results showed high sensitivity (0.97), specificity (0.78), PPV (0.92), and NPVs (0.93). Several studies have introduced this index as a desirable tool for predicting the weaning outcome reporting 0.9–0.97 sensitivity, 0.67–0.94 specificity, a PPV of 90–99%, NPV of 50–93%, and an accuracy of 87–92% [38,39].

As regards diagnostic test performance of CROP index, we found a sensitivity of 0.71, specificity of 0.96, PPV of 0.97, NPV of 0.58, and an AUC of 0.835. In agreement Li *et al.* [40] in a study to assess CROP index performance in predicting weaning outcome in COPD patients with acute exacerbation showed best value of CROP index which could predict weaning success to be more than or equal to 13.52 with a specificity of 0.92 and sensitivity of 0.87. The PPV was 0.97 and NPV was 0.58 which agree with our results.

Our results regarding assessing the diagnostic test performance of $P_{0.1}$/NIF used to predict weaning success with a cutoff value (≤0.15 cmH_2O) had a sensitivity of 0.97, specificity of 0.42, PPV of 0.8, NPV of 0.86, and an AUC of 0.687, reflecting lower accuracy than the previously mentioned WIs. Conti *et al.* [24] who proposed a similar cutoff value with a sensitivity of 0.92, specificity of 0.14, and an AUC of 0.71. The results were similar but with a marked decrease in specificity reflecting that this index was capable of predicting SBT failure in 14% of the patients.

Conclusion

The CORE index showed better diagnostic performance in predicting successful weaning and had the highest accuracy compared with RSBI, WI, IWI, and CROP index. Limitations of the study: our study is a single-center study with a small sample of selected patients; moreover, the specific clinical characteristics of the study population (COPD patients) may limit generalization of the results.

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Conflicts of interest

There are no conflcits of interest.

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