



# Predicting the Ventilatory Support Necessity for Acute Exacerbation of Chronic Obstructive Pulmonary Disease Patients Using Rapid Shallow Breathing Index

Mohamed Megahed<sup>1,\*</sup>, Tamer Habib<sup>1</sup>, Eman Dwidar<sup>1</sup>, Islam Ahmed<sup>2</sup>

<sup>1</sup>Critical Care Department, Faculty of Medicine, Alexandria University, Alexandria, Egypt

<sup>2</sup>Clinical Pharmacy Specialist, Faculty of Pharmacy, Alexandria University, Alexandria, Egypt

## Email address:

[dr.muhammed.megahed@gmail.com](mailto:dr.muhammed.megahed@gmail.com) (M. Megahed)

\*Corresponding author

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**Abstract:** Acute exacerbation of chronic obstructive pulmonary disease (COPD) is a common cause of intensive care unit (ICU) admission due to respiratory failure which often necessitates mechanical ventilation (MV). This study evaluated the rapid shallow breathing index (RSBI) as a predictor of ventilatory support necessity in patients admitted with acute exacerbation of COPD. This study was conducted on 100 acute COPD exacerbation patients who admitted to the critical care department at Alexandria main university hospital. All enrolled patients (n=80) were subjected on admission to RSBI measurement on admission and every 30 minutes for the first 2 hours. The RSBI cutoff value that discriminated best between the need for noninvasive and invasive MV using the Receiver Operating Characteristic (ROC) was > 241 breath/minute/Liter, it showed a sensitivity of 88.33% and a specificity of 100%. RSBI may be a good predictor of ventilatory support necessity in acute exacerbation of COPD.

**Keywords:** Critical, Pulmonology, Rapid Shallow Breathing Index, Ventilation

## 1. Introduction

Chronic Obstructive Pulmonary Disease (COPD) is a common disease characterized by persistent airflow limitation that is usually progressive and associated with an enhanced chronic inflammatory response in the airways and the lung to noxious particles or gases. Exacerbations and comorbidities contribute to the overall severity in individual patients. [1] COPD is a leading cause of mortality and results in an economic and social burden that is substantial and increasing [2-4]. The characteristic symptoms of COPD are chronic and progressive dyspnea, cough and sputum production. [5, 6]

Acute COPD exacerbation is an acute event characterized by worsening of the patient's respiratory symptoms that is beyond normal day-to-day variations and leads to a change in his regular COPD medications. Management of acute exacerbation of COPD beside treating the cause includes

Supplemental oxygen, bronchodilators, corticosteroids, antibiotics and ventilatory support if needed. [7-9]

The Rapid shallow breathing index (RSBI) is defined as the ratio of respiratory frequency to tidal volume (f/VT). It is widely used in predicting the weaning of mechanical ventilation. [10, 11] The aim of this study was to evaluate the role of RSBI as a predictor of ventilatory support necessity in acute COPD exacerbation patients admitted to ICU.

## 2. Methods

After ethical approval for this clinical trial from the local committee of ethics in the faculty of medicine of Alexandria university and the department of critical care, Informed consent was taken from the next of kin. This prospective study was conducted on 100 adult COPD patients admitted to the critical care department with acute exacerbation between the 1<sup>st</sup> of February 2016 and 2<sup>nd</sup> September of 2016.

All enrolled patients were adults of both genders. Any patients with respiratory arrest or hemodynamic instability were excluded. Also, any uncooperative patient was excluded. No pregnant females were enrolled in this study. All enrolled patients on admission were subjected to complete history taking, complete physical examination and routine laboratory investigations. During the first 2 hours of ICU admission the following parameters were monitored every 30 minutes: Vital signs, Glasgow coma score (GCS), arterial blood gases (ABG) and Rapid shallow breathing index (RSBI), a ratio determined by the respiratory rate divided by spontaneous tidal volume in liters. Acute Physiology and Chronic Health Evaluation (APACHE II) score was calculated for all patients. Then, according to mechanical ventilation (MV), patients were classified into 2 groups of requiring non-invasive MV (NIMV) and requiring invasive MV (IMV).

#### Statistical Analysis

Data were analyzed using SPSS software package version 24.0 (SPSS, Chicago, IL, USA). Quantitative data were expressed using range, mean, standard deviation and median while Qualitative data were expressed in frequency and percent. Qualitative data were analyzed using Chi-square test also exact tests such as Fisher exact was applied to compare the two groups. Normally distributed quantitative data were analyzed using student t-test while quantitative data that were not normally distributed was analyzed using Mann Whitney test for comparing the two groups. In addition, ROC was used to determine sensitivity of different variables in

predicting mechanical ventilation requirement.  $p$  value equal or less than 0.05 was considered significant.

### 3. Results

Regarding demographic data, there was no difference in sex of both studied groups. NIMV group showed 15 females (25%) and 45 males (75%), while IMV group showed 13 females (32.5%) and 27 males (67.5%). The age of NIMV group ranged from 41–72 years with a mean of  $52.30 \pm 7.88$  years, and 45–87 years with a mean of  $61.93 \pm 9.59$  years in IMV group, showing a significant difference between the 2 groups ( $p=0.004$ ).

Regarding the symptoms of acute COPD exacerbation, there was no significant difference between the 2 groups. 46 patients (76.66%) of NIMV group suffered from the 4 cardinal symptoms and only 14 patients (23.3%) didn't experience the increase in the purulence of their sputum, but in IMV group, 32 patients (80%) suffered from the 4 cardinal symptoms but only 8 patients (20%) didn't experience any increase in the purulence of their sputum. There was no significant difference between the two groups as regards symptoms of exacerbation of COPD. Regarding the precipitating factors of acute exacerbation, most patients in both groups were presented with chest infection and there were no any significant differences between them. The mean APACHE II score showed a statistically significant difference between the 2 groups in favor of IMV group. ( $p<0.001$ ) (Table 1).

Table 1. Demographic data of The two studied groups.

	NIMV (n = 60)	IMV (n = 40)	test	p value
Age				
Min. – Max.	41–72	45–87		
Mean $\pm$ SD.	$52.30 \pm 7.88$	$61.93 \pm 9.59$	$t = 1.417$	0.004*
Median	54	60		
Sex				
Male	45 (75%)	27 (67.5%)	$\chi^2=0.082$	pFE = 0.5
Female	15 (25%)	13 (32.5%)		
APACHE II score				
Min. – Max.	7.0 – 20.0	18.0 – 39.0		
Mean $\pm$ SD.	$11.68 \pm 2.47$	$25.03 \pm 4.35$	$t = 1.583$	<0.001*
Median	11.0	25.0		

t,  $p$  values of Student t-test for comparing between the 2 groups.

FE: Fisher Exact for Chi square test for comparing between the two groups

\*: Statistically significant at  $p \leq 0.05$

Regarding the measured vital signs in the 5 stages (on admission and every 30 minutes for the first 2 hours), heart rate on admission and respiratory rate in each stage were significantly higher in IMV group. When comparing respiratory rate values at 30, 60, 90 and 120 minutes with respiratory rate on admission, they showed a statistically significant difference in both groups ( $p=0.001$ ) and when comparing the repeated measures of heart rate with admission, only values at 90 and 120 minutes showed a statistically significant difference in NIMV group ( $p<0.05$ ), and values at 60, 90 and 120 minutes showed a statistically significant difference in IMV group ( $p<0.05$ ). GCS

assessment in the 5 stages showed that, it was significantly higher in NIMV group ( $p=0.001$ ). When comparing GCS at 30, 60, 90 and 120 minutes with GCS on admission, it showed a statistically significant difference in both groups ( $p=0.001$ ).

Regarding the routine laboratory investigations, there were no any significant differences between the 2 groups in terms of hematocrit, white blood count, electrolytes, serum creatinine, blood urea nitrogen, C reactive protein or D-dimer. There was only a statistically significant difference between the 2 groups regarding platelets count in favor of NIMV group ( $p<0.05$ ). Regarding admission ABG, the mean

pH was  $7.28 \pm 0.02$  in NIMV, while it was  $7.16 \pm 0.09$  in IMV (Figure 1). Findings of ABG in NIMV patients were considerably better than IMV group. There was only a significant difference between the two groups regarding pH

and arterial carbon dioxide tension ( $\text{PaCO}_2$ ) ( $p < 0.05$ ). When comparing pH and  $\text{PaCO}_2$  values at 30, 60, 90 and 120 minutes with pH and  $\text{PaCO}_2$  on admission, they showed a statistically significant difference in both groups ( $p < 0.05$ ).

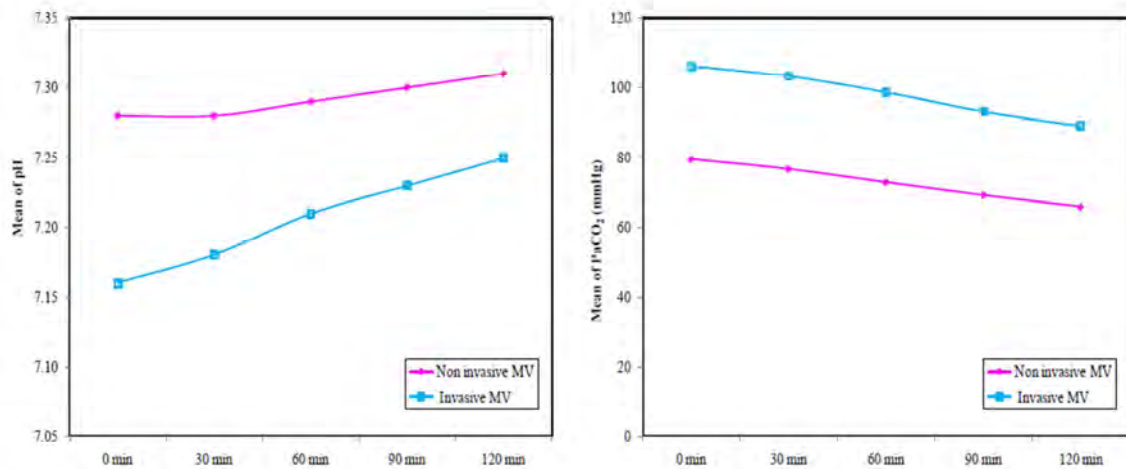


Figure 1. Main Arterial Blood Gases parameters between the 2 studied groups.

Regarding tidal volume and minute volume measured in the 5 stages, results showed a statistically significant difference between the 2 groups, it was worse in IMV group ( $p < 0.05$ ) (Table 2).

Table 2. Comparison between the two studied groups according to tidal volume.

Tidal Volume (liter)	0 min	30 min	60 min	90 min	120 min
<i>NIMV (n=60)</i>					
Min. – Max.	0.12 – 0.24	0.12 – 0.24	0.12 – 0.26	0.13 – 0.26	0.15 – 0.27
Mean $\pm$ SD.	0.17 $\pm$ 0.03	0.18 $\pm$ 0.03	0.19 $\pm$ 0.03	0.20 $\pm$ 0.03	0.21 $\pm$ 0.03
Median	0.16	0.17	0.19	0.20	0.22
<i>p<sub>i</sub> value</i>		<0.001*	<0.001*	<0.001*	<0.001*
<i>IMV (n=40)</i>					
Min. – Max.	0.08 – 0.20	0.09 – 0.22	0.09 – 0.22	0.10 – 0.24	0.10 – 0.26
Mean $\pm$ SD.	0.15 $\pm$ 0.03	0.13 $\pm$ 0.04	0.14 $\pm$ 0.04	0.15 $\pm$ 0.04	0.16 $\pm$ 0.05
Median	0.12	0.12	0.13	0.14	0.15
<i>p<sub>i</sub> value</i>		<0.001*	<0.001*	<0.001*	<0.001*
<i>t</i>	6.531	6.179	6.419	6.157	5.721
<i>p value</i>	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*

*t*, *p* values for Student t-test for comparison between the 2 groups.

*p<sub>i</sub>*: Stands for (adjusted Bonferroni) *p*-value for ANOVA with repeated measures for comparison between 0 min with each other period

\*: Statistically significant at  $p \leq 0.05$

Table 3. Comparison between 2 studied groups according to rapid shallow breathing index.

RSBI (Breath/minute/Liter)	0 min	30 min	60 min	90 min	120 min
<i>NIMV (n=60)</i>					
Min. – Max.	130.0 – 241.0	115.0 – 233.0	106.0 – 291.0	92.0 – 170.0	88.0 – 151.0
Mean $\pm$ SD.	189.42 $\pm$ 29.83	168.86 $\pm$ 27.90	144.25 $\pm$ 28.83	125.06 $\pm$ 17.16	115.16 $\pm$ 13.39
Median	187.50	166.0	141.50	124.0	109.0
<i>p<sub>i</sub> value</i>		<0.001*	<0.001*	<0.001*	<0.001*
<i>IMV (n=40)</i>					
Min. – Max.	157.0 – 687.0	138.0 – 555.0	130.0 – 500.0	125.0 – 450.0	107.0 – 346.0
Mean $\pm$ SD.	356.63 $\pm$ 118.49	303.47 $\pm$ 106.49	258.30 $\pm$ 96.86	228.93 $\pm$ 85.40	146.79 $\pm$ 58.46
Median	342.50	303.0	244.50	210.0	116.0
<i>p<sub>i</sub> value</i>		<0.001*	<0.001*	<0.001*	<0.001*
<i>t</i>	7.587*	6.785*	6.284*	6.583*	6.875*
<i>p value</i>	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*

*t*, *p* values for Student t-test for comparison between the 2 groups.

*p<sub>i</sub>*: Stands for (adjusted Bonferroni) *p*-value for ANOVA with repeated measures for comparison between 0 min with each other period.

\*: Statistically significant at  $p \leq 0.05$

RSBI: rapid shallow breathing index

Regarding the main study concept, RSBI measured in the 5 stages showed a statistically significant difference between the 2 groups ( $p < 0.001$ ). RSBI was higher in group B and when comparing RSBI values at 30, 60, 90 and 120 minutes with RSBI on admission, they showed a statistically significant difference in both groups ( $p < 0.001$ ) (Table 3). The RSBI cutoff value that discriminated best between the need for NIMV and the need for IMV was  $> 241$  breath/minute/Liter that showed a sensitivity of 88.33% and a specificity of 100% for determining the need for IMV with 100% positive predictive value (PPV) and 90.9% negative predictive value (NPV) (Figure 2).

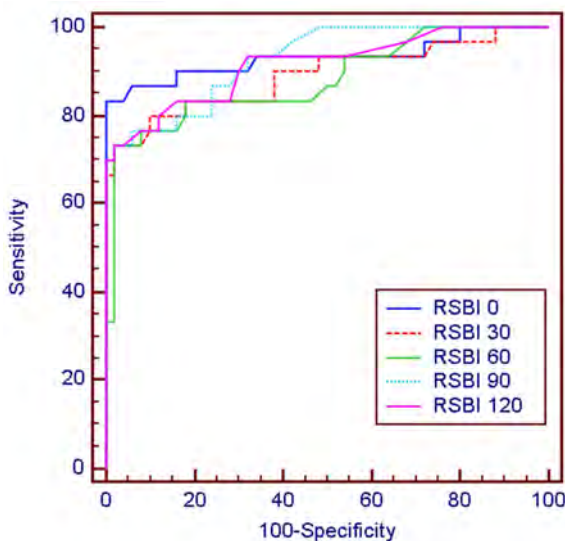


Figure 2. ROC curve for Rapid Shallow Breathing Index.

## 4. Discussion

Evidence justifying the role of RSBI in mechanically ventilated patients is yet to be fully demonstrated, although RSBI has been tested in many situations such as weaning of mechanically ventilated patients, post cardiac surgery patients and acute respiratory failure. In addition, it was compared with many predictive indices. To determine the indications of mechanical ventilation, different criteria have been stated most of them necessitate ABG analysis for definite indication of mechanical ventilation requirement. [11] Very few studies has been carried out to eliminate invasive interventions for determining ventilatory needs including Crawford's study [12] in which different parameters have been studied such as: RSBI, pH, Lactate, minute volume, Carbon Dioxide production, End-Tidal  $\text{CO}_2$  and APACHE II score.

In this study using the Receiver Operating Characteristic (ROC), the RSBI on admission evaluated sensitivity ratio was 83.33% and specificity value was 100%. In the subsequent 4 stages, the evaluated sensitivity ratios were 73.33% and specificity values were 98%. Cut off points in the 5 stages were more than 241, 223, 188, 164 and 147, respectively were associated with high sensitivity and

specificity for determining the need for IMV.  $\text{RSBI} > 241$  was associated with the highest sensitivity and specificity for determining the need for IMV.  $\text{RSBI} \leq 241$ , 223, 188, 164 and 147, respectively were associated with high sensitivity and specificity for determining the need for NIMV.  $\text{RSBI} \leq 241$  was associated with the highest sensitivity and specificity for determining the need for NIMV.

In accordance with this study as regarding the predictive ability of RSBI for necessity of MV, Hassan Soleimanpour et al. [15] tested the hypothesis that RSBI could predict necessity of NIMV in COPD exacerbation. Hassan's study was conducted on 98 patients divided into 2 groups of requiring NIMV and not requiring NIMV. Logistic Regression statistical tests revealed that RSBI prior to treatment, an hour and 2 hours subsequent to treatment, in addition to possessing high diagnostic sensitivity in patients requiring NIMV, has also a significant predictive ability on admission in patients requiring NIMV. As at each measured stage, evaluated sensitivity ratios were 94.8%, 92.8%, 97.7% and specificity values were 94.8%, 92.8% and 97.7%, respectively and values for cutoff point were  $\geq 110$ , 105 and 107, respectively. Also, Crawford et al. [14] conducted a blinded observational trial. The threshold value for RSBI that discriminated best between no NIMV and the need for NIMV was determined in 61 patients. 35 patients who did not require NIMV had a mean RSBI of 105, and 26 patients with NIMV had a mean RSBI of 222. A ROC curve was constructed, a  $\text{RSBI} > 120$  showed a sensitivity of 81% and a specificity of 74%.

In this study, the mean APACHE II score in IMV group was higher than in NIMV group ( $p < 0.001$ ). The Putinati study [16] was conducted on a group of 59 patients with COPD admitted with acute respiratory failure and a high APACHE II score. High APACHE II score was predictive of failure of NIMV and the need for intubation, a result in accordance with Confalonieri et al. [17] and Lin et al. [18]. However, in the study of Lin [18], RSBI failed to be considered as good predicting factor of successful NIMV intervention in patients with acute respiratory failure. Youshida et al. [19], observed that patients in need of intubation had significantly higher APACHE II scores and lower arterial pH, as APACHE II score higher than 17 and respiratory rate above 25 breaths/minute after receiving NIMV for 1 hour were introduced as independent determinants of requiring intubation.

In this study, there was a significant difference in admission level of acidosis and hypercapnia between patients enrolled in the study and also a significant difference was noted after initiation of MV either with NIMV or IMV. In Putinati et al. study [16], they found a significant difference in admission level of acidosis and hypercapnia between patients successfully ventilated with NIMV and those who failed with NIMV. NIMV was effective in reducing  $\text{PaCO}_2$  levels and improving pH in all patients, a result in accordance with the findings of Brochard, Meduri,

Ambrosino and Wysocki. [20-23]

## 5. Conclusion

The Rapid Shallow Breathing Index cutoff value that discriminated best between the need for noninvasive and invasive MV using the Receiver Operating Characteristic (ROC) was  $> 241$  breath/minute/Liter, it showed a sensitivity of 88.33% and a specificity of 100%. RSBI may be a good predictor of ventilatory support necessity in acute exacerbation of COPD. The limitation of this study was the small sample size. Further studies are recommended to evaluate the use of serial RSBI and RSBI rate together.

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