

Predicting the failure of noninvasive ventilation in hypoxemic patients by updated HACOR score

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ABSTRACT

Background: Acute hypoxemic respiratory failure is a major cause of morbidity and mortality requiring ventilatory support. Non-invasive ventilation (NIV) is an alternative to invasive ventilation, and the HACOR score is widely used to predict NIV failure. The updated HACOR score incorporates additional baseline variables such as ARDS, septic shock, immunosuppression, organ failure, and the SOFA score, but evidence on its predictive utility remains limited.

Methods: This prospective observational study included adult ICU patients who were started on NIV for hypoxemic respiratory failure. Baseline data included age, sex, indication for NIV, comorbidities, SOFA score, and the presence of COVID-19, septic shock, and ARDS. Non-invasive ventilation failure prediction was assessed using original and updated HACOR scores at baseline, 1–2 hours, 12 hours, and 24 hours. Diagnostic performance was compared using the area under the curve (AUC).

Results: A total of 63 patients were included. The AUCs for original vs updated HACOR scores were 0.522 vs 0.404 at baseline, 0.899 vs 0.404 at 1–2 hours, 0.862 vs 0.957 at 12 hours, and 0.485 vs 0.500 at 24 hours. The difference in AUCs was statistically significant at 1–2 hours and 12 hours ($p = 0.0001$), but not at baseline or 24 hours.

Conclusion: The updated HACOR score, which incorporates six baseline variables and the five original scale items demonstrated improved predictive performance for NIV failure compared to the original HACOR score at certain timeframes. This suggests that the performance of both scores varies over time in predicting NIV failure.

Keywords: Acute hypoxemic respiratory failure, Non-invasive ventilation (NIV), updated HACOR score, NIV failure

INTRODUCTION

Acute hypoxemic respiratory failure is well established as one of the leading causes for intensive care and is invariably associated with high rates of mortality.¹ Hypoxemia is a condition in which arterial oxygen tension (PaO_2) is less than normal (normal $\text{PaO}_2 = 80\text{--}100$ mmHg).² Acute respiratory distress

syndrome (ARDS) is characterised by low blood oxygen levels and fluid accumulation in both lungs, caused by increased permeability of the alveolocapillary barrier and has been implicated as a common causative factor for respiratory failure in critically ill patients.³ In mild ARDS, avoiding invasive mechanical ventilation if avoided will be advantageous. Non-invasive ventilation (NIV) has emerged as an alternative to invasive ventilation thereby preventing inevitable complications of intubation such as hypotension, hypoxemia, airway trauma, bradycardia, aspiration and cardiac arrest.⁴ Non-invasive ventilation is employed as a first line treatment in 15.5% of ARDS cases⁵ and can improve

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PaO₂/FiO₂ levels and minimize breathing effort.⁶ As a result, NIV lowers the risk of intubation and mortality.⁷ Non-invasive ventilation is a critical respiratory support technique that delivers ventilatory assistance without the requirement for invasive procedures such as endotracheal intubation. It has become an essential tool in managing acute as well as chronic respiratory failure, offering many advantages, including reducing infection risk, improving patient comfort, and shortening hospital stays.⁸

Non-invasive ventilation has significantly evolved over the past few decades, transforming respiratory care in acute as well as chronic settings. Traditionally, patients with respiratory failure required invasive mechanical ventilation, and the development of noninvasive positive-pressure ventilation (NIPPV) provided an alternative to invasive mechanical ventilation, allowing patients to receive ventilatory support via a mask or nasal interface.⁹ Continuous Positive Airway Pressure (CPAP), which maintains a constant airway pressure to prevent alveolar collapse, and Bilevel Positive Airway Pressure (BiPAP), which provides different pressure levels for inhalation, exhalation and improving ventilation efficiency,⁹ are the two primary types of NIV.

Non-invasive ventilation has proven to be instrumental in managing COPD exacerbations, acute respiratory failure due to pneumonia or ARDS, cardiogenic pulmonary edema, respiratory collapse in neuromuscular disorders and also as post-extubation support to prevent reintubation.⁸ However, studies indicate that 11.7% of patients initiated on NIV require intubation, with those experiencing NIV failure showing higher mortality rates (25.2% vs. 8.9%).¹⁰

Predictive scoring systems are important in NIV management, helping clinicians assess the likelihood of NIV failure and make timely decisions regarding advancing to invasive mechanical ventilation. These scoring models are particularly valuable in hypoxemic respiratory failure, where delayed intubation can lead to increased morbidity and mortality.¹¹ The HACOR score was developed to predict NIV failure in patients with hypoxemic respiratory failure and considers heart rate, acidosis, consciousness, oxygenation, and

respiratory rate. The presence of ARDS, septic shock, immunosuppression, or organ failure, and the SOFA score prior to administration of NIV, could also contribute to NIV failure. Hence, this baseline data could contribute to an increase in the predictive ability of the HACOR score for NIV failure among the patients with hypoxemic respiratory failure; these parameters were integrated into the scoring system, and the HACOR score was updated by Duan et al.¹⁰ with a maximum achievable score of 25 points. Threshold scores greater than five at one hour of NIV indicated an 81.8% diagnostic accuracy.¹²

Since the data on the predictive power of the updated HACOR score is limited, our study aimed to predict NIV failure among the patients having hypoxemic respiratory failure by using the updated HACOR score.

Aim: To predict non-invasive ventilation failure in patients with hypoxemic respiratory failure by using an updated HACOR score.

OBJECTIVES

Primary objective: To determine the predictive power of the original HACOR score for predicting NIV failure in patients with hypoxemic respiratory failure.

Secondary objective: To compare the predictive power of the updated HACOR score with the original HACOR score for predicting NIV failure in patients with hypoxemic respiratory failure.

METHODS

This was a prospective observational study conducted from July 2023 to December 2024. The study was approved by the Institutional Ethics Committee (institution?). Patients aged >18 years who were admitted to the ICU for NIV due to hypoxemic respiratory failure were included in the study. The sample size was calculated using a study by Metwaly et al. that reported that the updated HACOR score at a cutoff point >4.80 had 91% specificity. Considering similar results and assuming a 50% prevalence, at a 95% confidence level and 10% maximum error, the

sample size was estimated to be 63. Informed consent was obtained and the study was conducted in accordance with Good Clinical Practice guidelines and ethical principles as mentioned in the Declaration of Helsinki.

Exclusion criteria included patients with hypercapnic respiratory failure, those who underwent NIV after extubation, those who required emergency intubation, and those who received NIV due to acute exacerbation of chronic obstructive pulmonary disease (COPD). Figure 1 depicts the screening and selection process for the study.

Data collection was done using a convenience sampling method. Baseline data included age, sex, reason for NIV, underlying diseases, severity of disease (assessed by SOFA score), and the presence of COVID-19 infection, septic shock or ARDS. Vital statistics such as heart rate, respiratory rate, blood pressure and level of consciousness (using GCS) were measured. Arterial blood gas analysis and estimation of urine output were also done. The data of all the patients were recorded four times from baseline to 24 hours of NIV, i.e., at the baseline, after 1–2 hours, after 12 hours and after 24 hours of NIV in the case record form. The failure of NIV was considered when there was a need for intubation and invasive ventilation to the patient. Using the modified HACOR score, the goals were to predict NIV failure in patients with hypoxemic respiratory failure, as well as to compare the old HACOR score with the updated score to determine its predictive ability. Study tools used are depicted below.¹⁰

STATISTICAL ANALYSIS

Data collected were entered into an Excel sheet and analysed using GraphPad prism v.8.0.2. Descriptive statistics were used to summarize patient characteristics and outcomes. The predictive power of the original and updated HACOR scores for predicting the risk of NIV failure was calculated using sensitivity, specificity, positive predictive value and negative predictive value using a 2 × 2 table. Frequency was used to quantify both nominal and ordinal variables.

Continuous variables were evaluated using the mean and standard deviation. The chi-square or Fisher exact test was used to investigate the association between two categorical variables, while the student t test was used to assess the relationship between two continuous variables.

The area under the receiver operating characteristic (ROC) curve (C-statistic) was obtained and used to compare the risk scores.

RESULTS

Sixty-three patients who were referred to the intensive care unit for NIV due to respiratory failure were included in this prospective observational study. Descriptive statistics of the study population has been summarized in Table 1. The mean age of the patients was 53.8 ± 15 years with the oldest being 80 years old and youngest being 24 years old; 39 were male and 24 were female. Twelve patients had diagnoses of bronchopneumonia, 8 had pulmonary edema, 8 had community acquired pneumonia, 7 had lobar pneumonia, 6 had pleural effusion, and 5 had ARDS. There were 17 patients diagnosed with other conditions. Overall, 36.5% of patients ($n = 23$) had septic shock and 42.9% ($n = 27$) had ARDS. The majority of patients had SOFA scores of 6 (34.9%) and 7 (31.7%) followed by 9 (14.3%). Only 5 patients had SOFA scores of 5. The median SOFA score of these (which?) patients was 7.

Non-invasive ventilation failure was present in 10 patients (15.9%) at baseline, 12 patients (19%) at 1–2 hours, 16 patients (31.4%) at 12 hours and 1 patient (2.9%) at 24 hours. Table 3 shows the comparison of baseline parameters, parameters at 1–2 hours, 12 hours and 24 hours in patients with NIV success and failure. Heart rate, GCS and respiratory rate are significant when compared with NIV success and failure at baseline. Heart rate, pH, GCS, $\text{FiO}_2/\text{PaO}_2$, respiratory rate, HACORO and HACORU were found to be highly significant when compared with the NIV success and failure at 1–2 hours. At 12 hours, all the parameters except GCS were highly significant whereas none of the parameters had a significant

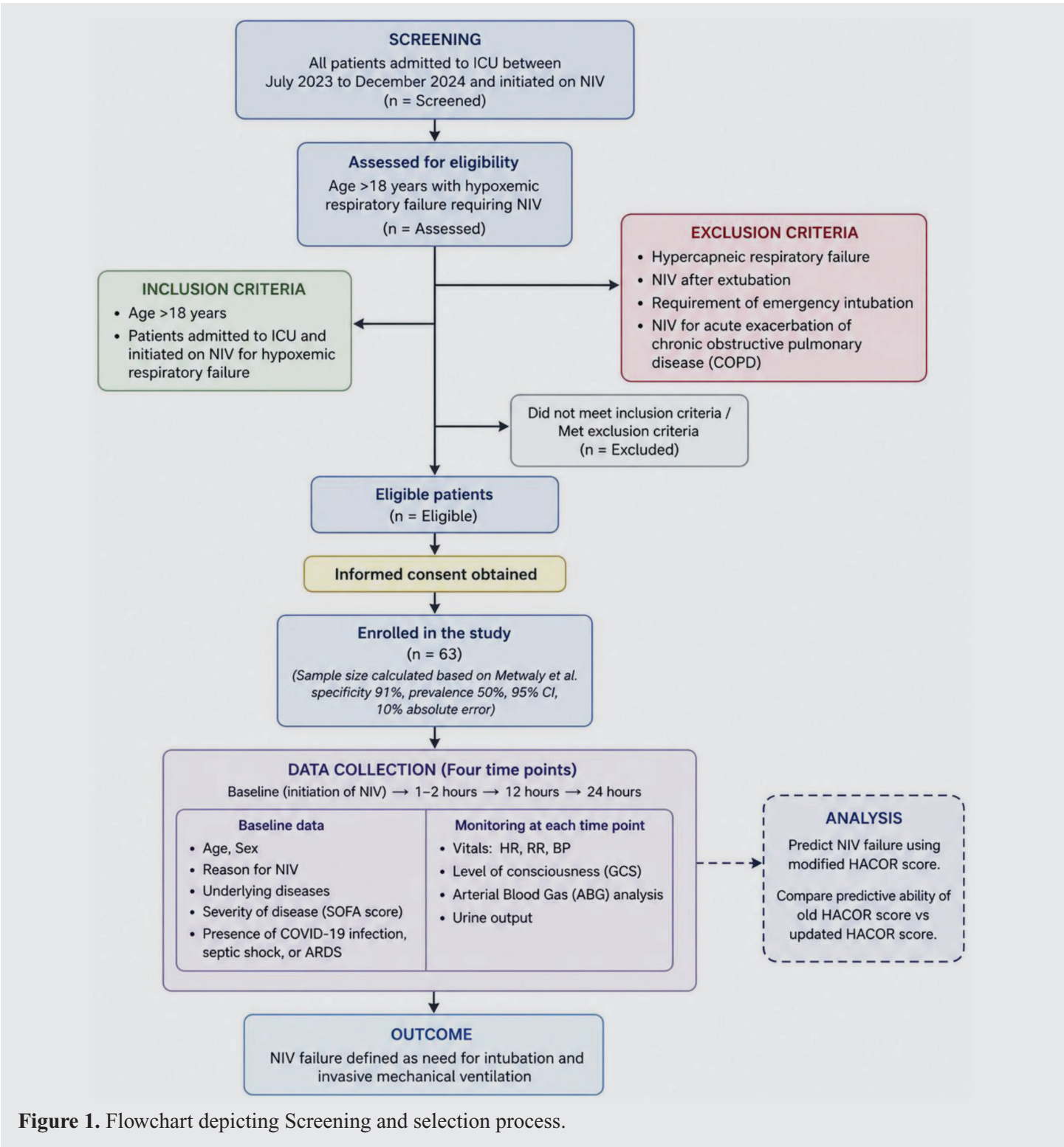


Figure 1. Flowchart depicting Screening and selection process.

Table 1. Demographic Data of Study Population

	N (n = 63)	%	Mean	SD
Mean age, years			53.8	15
Males	39	61.9		
Females	24	38.1		
Diagnosis:				
Bronchopneumonia	12	19.1		
Pulmonary Edema	8	12.7		
Community acquired pneumonia	8	12.7		
Lobar pneumonia	7	11.1		
Pleural Effusion	6	9.5		
ARDS	5	7.9		
Others	17	27		
Septic shock present	23	26.5		
ARDS present	27	42.9		
SOFA Score:				
5	5	7.9		
6	22	34.9		
7	20	31.7		
8	7	11.1		
9	9	14.3		
NIV Failure:				
At Baseline (n = 63)	10	15.9		
At 1–2 hours (n = 63)	12	19		
At 12 hours (n = 51)	16	31.4		
At 24 hours (n = 35)	1	2.9		

difference between NIV success and failure groups at 24 hours. Table 2 summarizes the HR, pH, GCS, FiO₂/PaO₂, RR, HACORO and HACORU at baseline, 1–2 hours, 12 hours, and 24 hours.

Figure 2 (A) depicts the ROC curve for the original and updated HACOR scores. The area under the curve for the original HACOR score is 0.522. The P value was 0.829 and not significant; the 95% CI was between 0.308 and 0.736 respectively. At a score of 5.5, sensitivity and specificity were 40% and 66% respectively. The area under the curve for

the updated HACOR score was 0.404. The P value was 0.337 and not significant; 95% CI was between 0.214 and 0.594 respectively. At a score of 15.25, sensitivity and specificity was found to be 20% and 83% respectively.

Figure 2 (B) shows the ROC curve for the original and updated HACOR scores at 1–2 hours. The area under the curve for original HACOR score was 0.889. The P value was 0.0001 and was highly significant; the 95% CI was between 0.794 and 0.983 respectively. At a score of 6.5, the sensitivity and specificity were 83% and 83% respectively. The area under the curve for updated HACOR score was 0.404. The P value was 0.0001 and highly significant; 95% CI was between 0.877 and 0.997 respectively. At a score of 15.5, sensitivity and specificity were 91% and 86% respectively.

Figure 2 (C) shows the ROC curve for the original and updated HACOR scores at 12 hours. The area under the curve for original HACOR score is 0.862. The P value was 0.0001 and highly significant; 95% CI was between 0.759 and 0.964 respectively. At a score of 5.5, sensitivity and specificity were 87% and 60% respectively. The area under the curve for the updated HACOR score is 0.957. The P value was found to be 0.0001 and was highly significant; the 95% CI was between 0.888 and 1 respectively. At a score of 15.5, the sensitivity and specificity were 91% and 86% respectively.

Figure 2 (D) shows the ROC curve for the original and updated HACOR scores at 24 hours. The area under the curve for original HACOR score is 0.485. The P value was 0.961 and was not significant; the 95% CI was between 0.298 and 0.672 respectively. The area under the curve for updated HACOR score is 0.5. The P value was 1.000 and was not significant; the 95% CI is between 0.305 and 0.695 respectively. At 24 hours, when 5 was used as the cutoff point for original HACOR score, the sensitivity and specificity were 91.6% and 62% respectively.

At 1–2 hours, when 5 is used as the cut-off point for the original HACOR score, the sensitivity and specificity were 91.6% and 62%. The positive predictive value and negative predictive value were 36%

Table 2. HR, pH, GCS, FiO₂/PaO₂, RR, HACORO and HACOR U at Baseline, 1–2 hours, 12 hours and 24 hours

Parameters	At Baseline (n = 63) Mean ± SD	At 1–2 hours (n = 63) Mean ± SD	At 12 hours (n = 51) Mean ± SD	At 24 hours (n = 35) Mean ± SD
HR (Beats/Min)	120 ± 7	120 ± 9	118 ± 9	112 ± 8
pH	7.3 ± 0.03	7.3 ± 0.04	7.31 ± 0.39	7.34 ± 0.04
GCS	14.9 ± 0.1	14.9 ± 0.3	14.9 ± 0.1	15 ± 0
FiO ₂ /PaO ₂ mmHg	179 ± 22	180 ± 20	188.5 ± 36	253 ± 267
RR	27 ± 3	28 ± 4	28 ± 5	25 ± 4
HACORO	5 ± 1.6	5.4 ± 2.2	5.1 ± 2.9	3.8 ± 2.8
HACORU	11.8 ± 3.1	12.2 ± 3.9	11.4 ± 4.3	8.7 ± 2.9

HR, Heart Rate (beats per minute); GCS, Glasgow Coma Scale; FiO₂/PaO₂, fractional inspired oxygen to partial pressure of arterial oxygen ratio; RR, respiratory rate; HACORO, original HACOR score; HACORU, updated HACOR score.

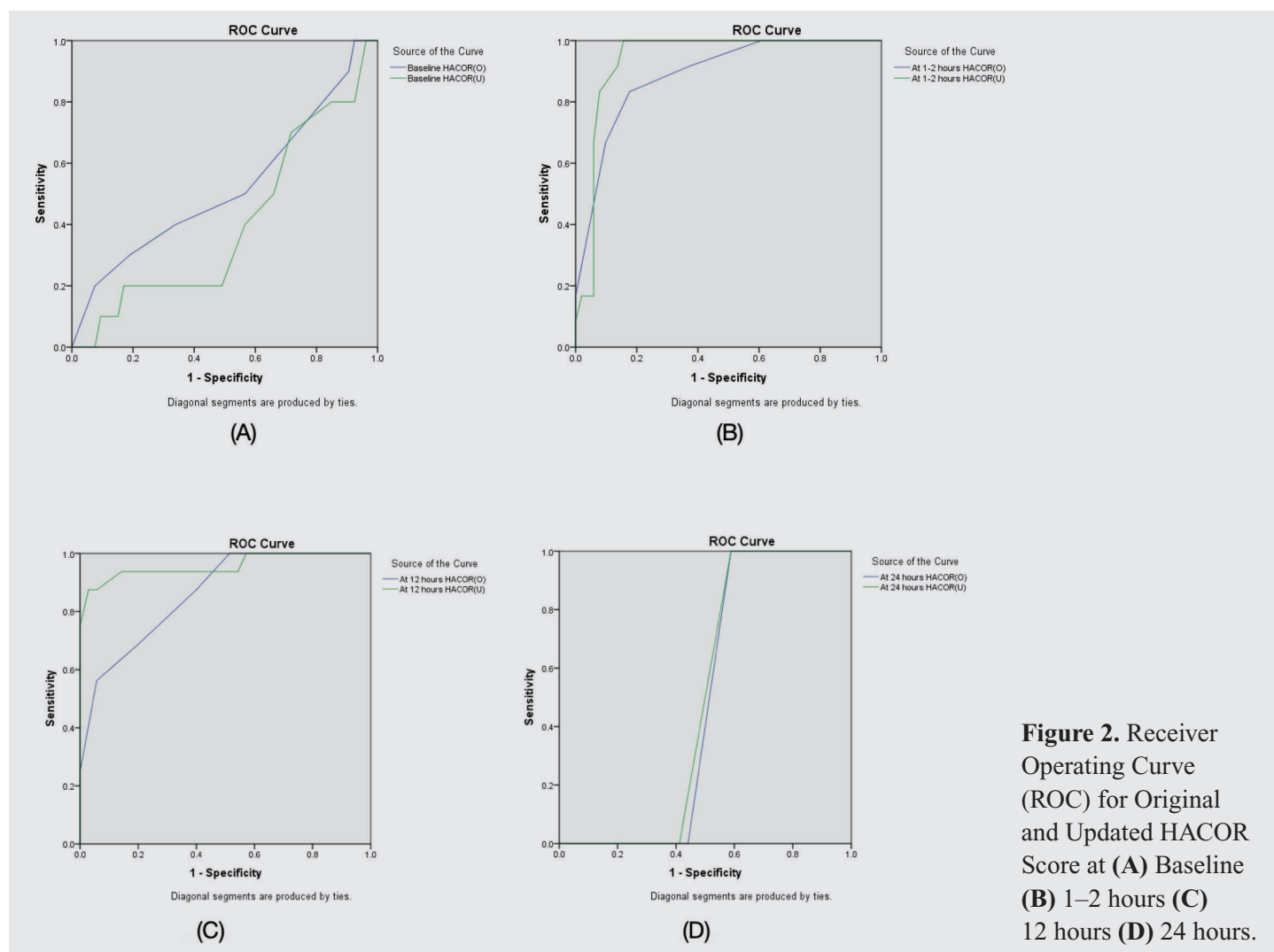


Figure 2. Receiver Operating Curve (ROC) for Original and Updated HACOR Score at (A) Baseline (B) 1–2 hours (C) 12 hours (D) 24 hours.

Table 3. Comparison of HR, pH, GCS, FiO₂/PaO₂, RR, HACORO and HACOR U at Baseline, 1–2 hours, 12 hours, 24 hours and 24 hours Between NIV Success and NIV Failure Groups

Parameters	At Baseline (n = 63)			At 1-2 hours (n = 63)			At 12 hours (n = 51)			At 24 hours (n = 35)		
	NIV Success (n = 53)	NIV Failure (n = 53)	P Value	NIV Success (n = 53)	NIV Failure (n = 53)	P Value	NIV Success (n = 53)	NIV Failure (n = 53)	P Value	NIV Success (n = 53)	NIV Failure (n = 53)	P Value
HR (Beats/Min)	119 ± 6	125 ± 9	0.022	118 ± 9	128 ± 5	0.001	115 ± 8	125 ± 6	0.0001	112 ± 8	124 ± 0	0.159
pH	7.31 ± 0.03	7.29 ± 0.03	0.429	7.32 ± 0.03	7.27 ± 0.03	0.0001	7.33 ± 0.03	7.28 ± 0.02	0.0001	7.34 ± 0.03	7.35 ± 0	0.811
GCS	15 ± 0	15 ± 0	0.02	15 ± 0	14.6 ± 0.5	0.0001	15 ± 0	15 ± 0	0.504	15 ± 0	15 ± 0	0.999
FiO ₂ /PaO ₂ mmHg	178 ± 21	181 ± 27	0.742	184 ± 20	165 ± 26	0.003	199 ± 37	167 ± 14	0.002	254 ± 271	196 ± 0	0.833
RR	27 ± 2	29 ± 4	0.037	27 ± 4	32 ± 3	0.0001	26 ± 4	32 ± 4	0.0001	25 ± 4	24 ± 0	0.791
HACORO	5 ± 1.6	5.3 ± 1.8	0.588	4.8 ± 2	7.8 ± 1.4	0.0001	4 ± 2.8	7.4 ± 1.4	0.0001	3.8 ± 2.8	4 ± 0	0.943
HACORU	12 ± 3	11 ± 3	0.347	11 ± 3	17 ± 1	0.0001	9.3 ± 3.1	15.8 ± 2.3	0.0001	8.7 ± 2.9	9.5 ± 0	0.794

HR, Heart Rate (beats per minute); GCS, Glasgow Coma Scale; FiO₂/PaO₂, fractional inspired oxygen to partial pressure of arterial oxygen ratio; RR, respiratory rate; HACORO, original HACOR score; HACORU, updated HACOR score.

and 96%. At 12 hours, when 5 was used as the cut-off point for the original HACOR score, the sensitivity and specificity were 87% and 60%. The positive predictive value and negative predictive value were 50% and 91%. At 1–2 hours, when 15.5 was used as the cutoff point for the updated HACOR score, the sensitivity and specificity were 91.6% and 86%. The positive predictive value and negative predictive value were 61% and 97%. At 12 hours, when 15.5 was used as the cutoff point for the updated HACOR score, the sensitivity and specificity were 62% and 100%. The positive predictive value and negative predictive value were 100% and 85%.

DISCUSSION

The current study determines the predictive ability of the updated HACOR score and compares it to the original HACOR score for predicting NIV failure in patients with hypoxemic respiratory failure. The original HACOR score assessed heart rate, acidosis, consciousness, oxygenation, and respiratory rate. Although the predictive power of the original HACOR study has been shown to be effective in some studies,^{11–13} there was a limitation in that it did not consider the baseline data. Duan et al. modified the HACOR score after determining that the presence of ARDS, septic shock, immunosuppression, and organ failure could contribute to NIV failure. This study adds to the relatively limited literature on the predictive ability of the updated HACOR score.

If the updated HACOR score were high, the rate of NIV failure was high in patients who were deemed low risk based on the original HACOR score. Patients at high risk (as determined by the original HACOR score) had a low probability of NIV failure if their updated HACOR scores were low. The updated HACOR score showed considerable improvement in predicting NIV failure compared to the original score. Three threshold values were created to help clinical staff make decisions: low, moderate, high, and very high probability of NIV failure.

The mean age of the patients in the study was 53.8 ± 15 years. Most patients were in the age groups

40–60 years and >60 years and were male. Some studies have evaluated the correlation between age and NIV failure. In a single-center, prospective cohort study including patients ≥ 65 years with COPD, acute CPE, CAP, bronchiectasis, and kyphoscoliosis, who were on NIV for AHRF in the ICU within a 4-year period, the study concluded that the efficacy of NIV was independent of age in patients having AHRF.¹⁴

Age is important in the predictive accuracy of the HACOR and updated HACOR scores for NIV failure in hypoxemic respiratory failure. Studies indicate that older patients tend to have higher HACOR scores due to age-related physiological changes, such as reduced respiratory muscle strength, impaired gas exchange, and increased history of comorbidities. The updated HACOR score incorporates additional baseline factors, including the presence of pneumonia, cardiogenic pulmonary edema (CPE), ARDS, immunosuppression, and septic shock, which are more prevalent in older populations.¹⁵ These modifications enhance the predictive validity, with higher scores correlating with increased NIV failure rates. The updated HACOR score has demonstrated superior predictive power compared with the original version, particularly in elderly patients, by integrating these age-associated risk factors.¹⁶

The patients in the present study were diagnosed with bronchopneumonia, pulmonary edema, CAP, pleural effusion, lobar pneumonia, ARDS, and other conditions. Many had ARDS and septic shock. Non-invasive ventilation failure is linked to baseline conditions such as ARDS, septic shock, immunosuppression, and organ failure.⁷ Patients with pneumonia face an elevated risk of NIV failure due to pronounced hypoxemia, excessive airway secretions, and compromised lung compliance.¹⁷ Similarly, individuals with interstitial lung disease (ILD) often experience higher NIV failure rates, largely attributed to progressive fibrosis, diminished lung elasticity, and impaired oxygen diffusion.¹⁸ While NIV is generally effective in managing COPD exacerbations, factors such as diaphragmatic dysfunction and persistent hypercapnia can contribute to treatment failure. In addition, those suffering from septic shock or immunosuppression are more vulnerable to NIV failure due to systemic

inflammation, metabolic instability, and a weakened respiratory drive.¹⁹ Hence, Duan et al. incorporated these pre-NIV parameters in the HACOR score and updated and validated it.¹⁰

A SOFA score is also incorporated in the updated HACOR score. In the present study, the patients had median SOFA scores of 7 at the baseline. A study by Innocenti et al. showed a higher SOFA score was related to an increase in mortality rate in the whole population admitted to the high-dependence unit and in septic patients.²⁰ In another study (name?), the SOFA score was found to be higher in the NIV failure group than in the NIV success group. It was also observed that the SOFA score was the most common variable related to NIV failure. Patients who had SOFA scores >5 were at a higher risk of NIV failure (odds ratio 3.3, 95% CI 2.4–4.5).²¹ Similar findings were shown by another study (name?) conducted in patients with CAP and who were on NIV. This study found that NIV failure was correlated to SOFA scores (OR 1.33).²² Patients with elevated SOFA scores often experience systemic inflammation, metabolic derangements, and impaired respiratory mechanics, making NIV less effective.²³

Several physiological markers influence NIV success or failure. Studies have shown that a pH <7.28 is a significant predictor of NIV failure, indicating severe respiratory compromise. The study by Duan et al. also found that a PaO₂/FiO₂ ratio <150 mmHg was a strong predictor of NIV failure, reinforcing the importance of oxygenation status.¹⁰ An elevated respiratory rate (>30 breaths/min) was identified as an independent predictor of NIV failure, reflecting increased respiratory effort and impending failure.

Since the updated HACOR score expands its predictive framework by integrating additional clinical factors such as pneumonia, CPE, ARDS, immunosuppression, septic shock, and SOFA score, these refinements improve its accuracy, especially in patients with elevated SOFA scores, who exhibit a higher probability of NIV failure.^{15,19} Research indicates that the updated HACOR score demonstrates greater predictive accuracy for NIV failure than the original HACOR score, as reflected in its higher area under the curve (AUC). The incorporation of the SOFA score enhances risk

stratification, enabling clinicians to make more precise decisions regarding NIV management.¹⁵

In our study, we observed the NIV failure in the patients included in the study over 24 hours. We recorded different parameters at baseline, 1–2 hours, 12 hours and 24 hours, including heart rate, respiratory rate, pH, GCS, $\text{FiO}_2/\text{PaO}_2$ (mmHg), SOFA score and HACOR scores (updated and original). At baseline, 10 patients had NIV failure, and when the baseline parameters were compared, significant differences in the NIV failure and success group were found in heart rate, respiratory rate, and $\text{FiO}_2/\text{PaO}_2$. In the later observations all the parameters had significant differences between the two groups. The HACOR score can help clinical physicians recognize NIV failure earlier. The increased risk of death on baseline features might be the cause of the high mortality in the late failure group. When using the HACOR score to guide NIV treatment, healthcare professionals should address this issue with careful consideration.^{12,24}

When predicting NIV failure in patients with hypoxemic respiratory failure, the HACOR score demonstrated high sensitivity and specificity.^{11,13,22} Despite the fact that the same characteristics are used to predict NIV failure in that patient population as in the COPD population, the weights assigned to each variable change significantly. For instance, heart rate is the least important variable in hypoxemic patients, while oxygenation is the second most important variable, despite consciousness being the most important factor in both patient groups. The pathophysiological distinctions between hypoxemic and COPD patients can account for these variations.^{12,24}

In the present study, the AUC of ROC curve for the original and updated HACOR score at baseline did not show any significant difference. The sensitivity and specificity of both scores at baseline were also less and did not show significant differences. However, the AUC for the updated HACOR score was higher than that of the original HACOR score at 1–2 hours and 12 hours (0.889 vs 0.904 and 0.862 vs 0.957 respectively). Duan et al. found that using the updated HACOR score resulted in a higher AUC in the training cohort demonstrating good accuracy and superior performance compared with the original HACOR score.¹⁶

The HACOR score was established and validated with data from a respiratory ICU. Every patient was treated by respiratory specialists and had a respiratory etiology. The updated HACOR score, however, was created at nine institutions and verified in nine more. The patients were treated by various doctors, came from various intensive care units, and had various etiologies. As a result, the doctors and patients in the updated HACOR evaluation were more reflective of the general population. This is an additional explanation for why the updated HACOR score has a better predictive power compared to the original.¹⁰

Due to the significant risk of NIV failure, using NIV for patients having pneumonia, ARDS, or *de novo* acute respiratory failure remains debatable.^{13,25–27} NIV failure rates can occasionally exceed 70%.²⁸ There are no recommendations in the guidelines for utilizing NIV in these patients.²⁹ Regardless of whether it was evaluated after 1, 2, 12, or 24 hours of NIV, the updated HACOR score in the study by Duan et al. demonstrated significant predictive power for NIV failure in these patients.¹⁰ An increased chance of NIV failure is indicated by a higher updated HACOR score. Similar results were shown in the present study.

As a result, the new updated HACOR score offers clinical professionals managing NIV a crucial point of reference. Early intubation may be an option for individuals whose updated HACOR score indicates a high likelihood of NIV failure and requirement of intubation.¹⁰ High-risk patients may benefit from closer monitoring, greater personnel, and improved device supply as late NIV failure is linked to higher mortality.^{7,12} When making an intubation decision in ordinary clinical practice, doctors may partially consult the respiratory rate, pH, and $\text{PaO}_2/\text{FiO}_2$ ratio readings. It can be challenging to figure out how to integrate these variables with other risk factors to make better decisions. One physician might focus more on the $\text{PaO}_2/\text{FiO}_2$ ratio, while another might focus more on respiratory rate. The modified HACOR score's primary contribution is the weighing of each variable. It quantitatively determines each variable's weight while accounting for the main risk factors. The new HACOR score gives doctors more relevant information to help them make informed decisions, even though it may be partially explained by self-fulfilling prophecy.

LIMITATIONS

Even though the study adds valuable findings on the predictive ability of the updated HACOR score, there are several limitations. This was a single-center study, thus the findings may not be applicable to the broader population. The sample size of the study is modest, which may reduce the prediction potential of NIV failure. The decision to intubate the patients was left to the attending physician's discretion. As a result, this could have an impact on the predictive power of the HACOR score. The current study is an observational study, thus there may be some confounding factors influencing the evaluation of the HACOR score.

CONCLUSION

The modified HACOR score, which combines six baseline variables with the original five physiological indicators, has better predictive accuracy for predicting noninvasive ventilation (NIV) failure in patients with acute hypoxemic respiratory failure. This improved score system addresses the limitations of the original HACOR model by including baseline factors that influence NIV outcomes, thereby increasing its clinical relevance and stratification capacity. The revised score is a practical and evidence-based measure that can help frontline physicians identify high-risk patients early, optimize treatment options, and perhaps reduce the occurrence of delayed intubation and related morbidity. Future research should evaluate its applicability across varied demographics and healthcare settings to strengthen its relevance in respiratory care pathways.

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AUTHOR CONTRIBUTIONS

Karthik K Shetty was responsible for data curation, formal analysis, investigation, visualisation and original draft writing. Nagesh Kumar TC was responsible

for conceptualization, methodology and supervision. Aadithya Shyllesh H contributed to the investigation, validation, data curation, original manuscript draft and formal analysis. Sneha Reddy Pulkurthi was responsible for validation, manuscript writing, review and editing.

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Conflicts of interest: none

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REFERENCES

1. Ketcham SW, Sedhai YR, Miller HC, et al. Causes and characteristics of death in patients with acute hypoxemic respiratory failure and acute respiratory distress syndrome: a retrospective cohort study. *Crit Care*. 2020;24(1):391.
2. Samuel J, Franklin C. Hypoxemia and hypoxia. Common surgical diseases: an algorithmic approach to problem solving. 2008:391–4.
3. Meyer NJ, Gattinoni L, Calfee CS. Acute respiratory distress syndrome. *Lancet*. 2021;398(10300):622–37.
4. Shore K, Walker S, Palozzi L, et al. Complications of intubation in an academic medical-surgical ICU. *Intensive Care Med Exp*. 2015;3(Suppl 1):A431. doi: 10.1186/2197-425X-3-S1-A431.
5. Bellani G, Laffey JG, Pham T, et al. Noninvasive ventilation of patients with acute respiratory distress syndrome. Insights from the LUNG SAFE study. *Am J Respir Crit Care Med*. 2017;195(1):67–77.
6. L'Her E, Deye N, Lellouche F, et al. Physiologic effects of noninvasive ventilation during acute lung injury. *Am J Respir Crit Care Med*. 2005;172(9):1112–18.
7. Ferreyro BL, Angriman F, Munshi L, et al. Association of noninvasive oxygenation strategies with all-cause mortality in adults with acute hypoxemic respiratory failure: a systematic review and meta-analysis. *JAMA*. 2020;324(1):57–67.

8. Demoule A, Girou E, Richard JC, et al. Benefits and risks of success or failure of noninvasive ventilation. *Intensive Care Med.* 2006;32(11):1756–65.
9. Thille AW, Contou D, Fragnoli C, et al. Non-invasive ventilation for acute hypoxemic respiratory failure: intubation rate and risk factors. *Crit Care.* 2013;17(6):R269.
10. Duan J, Han X, Bai L, et al. Assessment of heart rate, acidosis, consciousness, oxygenation, and respiratory rate to predict noninvasive ventilation failure in hypoxemic patients. *Intensive Care Med.* 2017;43(2):192–9.
11. Stefan MS, Priya A, Pekow PS, et al. A scoring system derived from electronic health records to identify patients at high risk for noninvasive ventilation failure. *BMC Pulm Med.* 2021;21(1):52.
12. Tsushima K, Yokoyama T, Matsumura T, et al. The potential efficacy of noninvasive ventilation with administration of a neutrophil elastase inhibitor for acute respiratory distress syndrome. *J Crit Care.* 2014;29(3):420–5.
13. Bai L, Ding F, Xiong W, et al. Early assessment of the efficacy of noninvasive ventilation tested by HACOR score to avoid delayed intubation in patients with moderate to severe ARDS. *Ther Adv Respir Dis.* 2022;16:17534666221081042.
14. Tallman TA, Peacock WF, Emerman CL, et al. ADHERE Registry. Noninvasive ventilation outcomes in 2,430 acute decompensated heart failure patients: an ADHERE Registry Analysis. *Acad Emerg Med.* 2008;15(4):355–62.
15. Duan J, Chen L, Liu X, et al. An updated HACOR score for predicting the failure of noninvasive ventilation: a multicenter prospective observational study. *Crit Care.* 2022;26(1):196.
16. da Silva MPN, Lunardi AC. Comparison of the clinimetric properties of the two versions of the HACOR scale for predicting noninvasive ventilation failure in Brazilian patients. *Acute Crit Care.* 2025;40(2):322–9.
17. Abraham SV, Azeez AK, Padmanabhan A. NIV failure in respiratory failure: an analysis. *Egypt J Bronchol.* 2023;17(1):29.
18. Faverio P, De Giacomi F, Sardella L, et al. Management of acute respiratory failure in interstitial lung diseases: overview and clinical insights. *BMC Pulm Med.* 2018;18(1):70.
19. Pratyusha K, Jindal A. Non-invasive ventilation failure – predict and protect. *Indian J Crit Care Med.* 2023;27(2):149.
20. Carron M, Freo U, Zorzi M, et al. Predictors of failure of noninvasive ventilation in patients with severe community-acquired pneumonia. *J Crit Care.* 2010;25(3):540.e9–14.
21. Masip J, Páez J, Merino M, et al. Risk factors for intubation as a guide for noninvasive ventilation in patients with severe acute cardiogenic pulmonary edema. *Intensive Care Med.* 2003;29(11):1921–8.
22. Shirakabe A, Hata N, Yokoyama S, et al. Predicting the success of noninvasive positive pressure ventilation in emergency room for patients with acute heart failure. *J Cardiol.* 2011;57(1):107–14.
23. Watson A, Yadollahi S, Fahmy A, et al. Non-invasive ventilation for community-acquired pneumonia: Outcomes and predictors of failure from an ICU Cohort. *Medicina (Kaunas).* 2023;60(1):81.
24. Carrillo A, Gonzalez-Diaz G, Ferrer M, et al. Non-invasive ventilation in community-acquired pneumonia and severe acute respiratory failure. *Intensive Care Med.* 2012;38(3):458–66.
25. Beasley MB. The pathologist's approach to acute lung injury. *Arch Pathol Lab Med.* 2010;134(5):719–27.
26. Moretti M, Cilione C, Tampieri A, et al. Incidence and causes of non-invasive mechanical ventilation failure after initial success. *Thorax.* 2000;55(10):819–25.
27. Carratù P, Bonfitto P, Dragonieri S, et al. Early and late failure of noninvasive ventilation in chronic obstructive pulmonary disease with acute exacerbation. *Eur J Clin Invest.* 2005;35(6):404–9.
28. Arrivé F, Coudroy R, Thille AW. Early identification and diagnostic approach in acute respiratory distress syndrome (ARDS). *Diagnostics (Basel).* 2021;11(12):2307.
29. Matthay MA, Arabi Y, Arroliga AC, et al. A new global definition of acute respiratory distress syndrome. *Am J Respir Crit Care Med.* 2024;209(1):37–47.