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RESEARCH ARTICLE
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PREDICTING NIV FAILURE IN COPD PATIENTS USING THE SERIAL HACOR SCORE

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Abstract

Background:
Non-Invasive Ventilation (NIV) is a key therapeutic approach for managing acute respiratory failure in patients with Chronic Obstructive Pulmonary Disease (COPD). However, NIV failure remains a significant clinical challenge, often leading to increased morbidity and mortality. The HACOR score comprising Heart rate, Acidosis, Consciousness level, Oxygenation, and Respiratory rate has emerged as a potential tool to predict NIV failure. This study aimed to evaluate the predictive utility of the HACOR score in COPD patients undergoing NIV in the Intensive Care Unit (ICU) of Gulab Devi Hospital.

Objective:
To evaluate the effectiveness of the HACOR score in predicting NIV failure in COPD patients admitted to the Intensive Care Unit of Gulab Devi Chest Hospital.

Methodology:
This was a prospective observational study conducted over six months involving COPD patients admitted with acute respiratory failure who required NIV. HACOR scores were calculated at three time intervals: before initiating NIV, at 1-hour post-initiation, and at 24 hours. Statistical analysis included logistic regression, receiver operating characteristic (ROC) curve analysis, and chi-square testing to examine the association between HACOR scores and NIV outcomes.

Results:
A total of 109 patients were included. The mean HACOR score was 10.2 (SD±4.5) after 1 hour 7.8 (SD 3.2) and after 24 hours of NIV 6.5 (SD 2.8). Chi-square analysis showed a significant correlation between higher HACOR scores and NIV failure at all-time points ($p < 0.05$). ROC curve analysis demonstrated good predictive accuracy with AUC values of 0.82 (before NIV),0.78 (1 h post-NIV)

and 0.75 (24 h post-NIV). HACOR cut-off values predicting failure were ≥9 before NIV (PPP 0.78; NPP 0.85), ≥7 after 1 hour (PPP 0.75; NPP 0.82), and ≥ 6 after 24 hours (PPP 0.72; NPP 0.80.
Conclusion:
The HACOR score is a reliable and practical tool for early prediction of NIV failure in COPD patients. Its implementation can aid in risk stratification, allowing timely clinical decisions to optimize NIV use and improve patient outcomes.

Keywords: COPD, HACOR score, Non-Invasive Ventilation, NIV failure, Acute respiratory failure, Risk stratification, ICU, Predictive score, AECOPD, Respiratory monitoring.

Introduction:
Chronic Obstructive Pulmonary Disease (COPD) is a progressive and debilitating respiratory condition that poses a significant global health burden. It is characterized by persistent respiratory symptoms and airflow limitation, typically resulting from prolonged exposure to harmful particles or gases, most notably tobacco smoke. The disease involves structural changes in the lungs, including small airway fibrosis, parenchymal destruction, and chronic inflammation, which ultimately lead to emphysema and decreased pulmonary function. According to the World Health Organization, COPD accounts for over three million deaths annually, making it the third leading cause of mortality worldwide. The growing burden of COPD, particularly in aging populations, underscores the urgent need for effective management strategies and early interventions to mitigate disease progression and reduce mortality[1, 2].
Clinically, COPD presents with a spectrum of symptoms such as chronic cough, sputum production, wheezing, and progressive dyspnea. These symptoms tend to worsen during exacerbations, which are defined as acute episodes of symptom worsening beyond normal day-to-day variations and are often triggered by infections or environmental pollutants[3, 4]. Exacerbations significantly accelerate disease progression, diminish quality of life, and increase the risk of hospitalization and mortality[5, 6].
Non-Invasive Ventilation (NIV) has become a cornerstone in the management of acute exacerbations of COPD (AECOPD), particularly in patients with acute hypercapnic respiratory failure. NIV delivers positive pressure ventilation through a facial or nasal interface, avoiding the complications associated with invasive mechanical ventilation such as ventilator-associated pneumonia, barotrauma, and prolonged intubation. Clinical trials and guidelines strongly support the use of NIV in appropriate COPD patients, citing benefits such as improved gas exchange, reduced intubation rates, decreased length of hospital stay, and lower mortality. However, despite its effectiveness, NIV is not universally successful, and its failure necessitating intubation is associated with significantly worse outcomes[7, 8].
Identifying early predictors of NIV failure is crucial for timely escalation of care and to avoid delays in initiating invasive mechanical ventilation. Parameters such as the degree of acidosis, level of consciousness, severity of hypoxemia, and presence of comorbidities have been investigated as potential indicators. Studies have shown that low pH, high $PaCO_2$ levels, and poor clinical response within the first hour of NIV are associated with treatment failure. Therefore, continuous monitoring and early risk stratification play a vital role in improving patient outcomes[9].
The HACOR score a clinical scoring system based on Heart rate, Acidosis (pH), Consciousness level, Oxygenation (PaO_2/FiO_2), and Respiratory rate was developed to predict NIV failure in patients with acute respiratory failure. Each component is assigned a weighted score, with higher total scores indicating increased likelihood of NIV failure. A HACOR score greater than 5 within the first hour of NIV initiation has been associated with a significantly higher risk of treatment failure, thereby providing clinicians with a valuable, objective tool to guide management decisions. Although validated in various populations, including patients with hypoxemic respiratory failure, limited data exist regarding the predictive performance of the HACOR score specifically in COPD patients experiencing hypercapnic respiratory failure[10]. To enhance NIV success, strategies such as early initiation, optimal ventilator settings, continuous monitoring, and multidisciplinary team involvement

are crucial. The use of predictive tools like the HACOR score can significantly improve clinical decision-making by identifying high-risk patients early in their treatment course[11].

Understanding the underlying mechanisms contributing to NIV failure such as poor patient-ventilator synchrony, inadequate pressure support, or disease progression is essential for improving success rates. Patient-related factors, including comorbidities, obesity, neuromuscular weakness, and psychological distress, may also hinder NIV effectiveness. Importantly, NIV failure not only increases morbidity and mortality but also prolongs hospital stays, heightens healthcare costs, and negatively impacts patient well-being[12].

By assessing HACOR scores at different time intervals prior to NIV initiation, at 1 hour, and at 24 hours the study seeks to establish cut-off values that may help clinicians intervene more promptly and effectively. Ultimately, this research contributes to the growing body of evidence supporting the integration of clinical scoring systems in the management of AECOPD, thereby improving patient outcomes and optimizing healthcare delivery[13].

Methodology

This study was designed as a comparative observational study conducted over a period of six months following the approval of the research synopsis. The research was carried out in the Medical Intensive Care Unit (ICU) at Gulab Devi Chest Hospital, a tertiary care facility specializing in pulmonary and critical care services.

The target population for this study comprised patients diagnosed with Chronic Obstructive Pulmonary Disease (COPD) who were undergoing Non-Invasive Ventilation (NIV) for acute respiratory failure. A sample size of 109 patients was determined using Yamane's formula for sample size calculation, considering a population size (N) of 150 and a 5% margin of error. The formula used was:

$$n = \frac{N}{1+Ne^2}$$

where n is the required sample size, N is the population size, and e is the margin of error. Based on this calculation, a total of 109 patients were included in the final sample.

A non-probability purposive sampling technique was employed to recruit eligible participants. Patients were selected based on predefined inclusion and exclusion criteria. Written informed consent was obtained from all participants or their legal guardians prior to enrollment in the study.

Inclusion criteria: Consisted of male and female patients aged between 18 and 70 years, with a confirmed diagnosis of COPD and meeting clinical criteria for the initiation of NIV.

Exclusion criteria: Included patients younger than 18 or older than 70 years, those who required intubation within the first hour of NIV initiation, individuals with contraindications to NIV, and patients diagnosed with non-COPD conditions necessitating NIV.

The primary variables assessed in this study included demographic parameters such as age and gender, along with clinical components of the HACOR score heart rate, pH (acidosis), level of consciousness (Glasgow Coma Scale), oxygenation (PaO_2/FiO_2 ratio), and respiratory rate.

A structured data collection tool was developed in the form of a patient proforma, which was completed upon patient enrollment. This proforma captured all relevant demographic and clinical information in a standardized format. Data collection was carried out prospectively, and only patients who met all inclusion criteria and none of the exclusion criteria were enrolled in the study.

All collected data were entered and analyzed using Statistical Package for the Social Sciences (SPSS), version 27. Descriptive statistics were applied to summarize the data. Quantitative variables such as age, heart rate, respiratory rate, and HACOR scores were presented as means with standard deviations, along with minimum and maximum values to reflect data distribution. Categorical variables were described using frequencies and percentages.

To assess the association between HACOR scores and the incidence of NIV failure, Chi-square tests were applied. Additionally, the predictive value of the HACOR score and its individual components at various time intervals (prior to NIV, 1 hour after NIV, and 24 hours post-NIV) was evaluated.

Results were presented in the form of tables, graphs, and charts for clarity and visual interpretation. The level of statistical significance was set at $p < 0.05$, and all findings were interpreted accordingly to determine the strength and validity of the HACOR score as a predictor of NIV failure in COPD patients.

Results:

The table1 shows average patient age was approximately 60 years. The majority were male (66%) and either current or former smokers (nearly 60%). More than half of patients had a COPD diagnosis exceeding 5 years, and 42% had a history of previous NIV use, indicating recurrent severe exacerbations.

Table 1: Demographic and Baseline Characteristics of Study Participants (N = 109)

Variable	Value/Distribution
Age (years)	Mean ± SD = 59.87 ± 12.95
Gender	Male: 72 (66.06%) Female: 37 (33.94%)
Smoking History	Never Smoked: 44 (40.37%) Smokers: 21 (19.27%) Former Smokers: 44 (40.37%)
Duration of COPD Diagnosis	<1 year: 16 (14.68%) 1–5 years: 39 (35.78%) 6–10 years: 31 (28.44%) >10 years: 23 (21.10%)
Previous NIV Use	Yes: 46 (42.20%) No: 63 (57.80%)

Table 2: Mean ± SD of HACOR Score Components in NIV Success vs. Failure Groups at Different Time Points

Parameter	Time Point	NIV Success (Mean ± SD)	NIV Failure (Mean ± SD)	*p*-value
Heart Rate (bpm)	At Initiation	96.34 ± 14.82	93.42 ± 16.41	0.215
	After 1 Hour	92.34 ± 15.23	93.88 ± 14.65	0.542
	After 24 Hours	94.00 ± 13.42	94.84 ± 13.71	0.712
Acidosis (pH)	At Initiation	7.28 ± 0.07	7.23 ± 0.10	**0.012**
	After 1 Hour	7.31 ± 0.09	7.25 ± 0.10	**0.021**
	After 24 Hours	7.37 ± 0.08	7.25 ± 0.09	**<0.001**
Consciousness (GCS)	At Initiation	11.20 ± 3.12	10.37 ± 3.58	0.188
	After 1 Hour	12.03 ± 3.10	10.60 ± 3.45	**0.032**
	After 24 Hours	13.93 ± 3.01	9.84 ± 3.28	**<0.001**
Oxygenation (PaO_2/FiO_2)	At Initiation	252.87 ± 5.23	116.84 ± 6.18	**<0.001**
	After 1 Hour	253.28 ± 4.88	119.87 ± 5.92	**<0.001**
	After 24 Hours	252.89 ± 5.05	117.06 ± 6.00	**<0.001**
Respiratory Rate (/min)	At Initiation	29.28 ± 5.12	30.44 ± 5.91	0.268
	After 1 Hour	27.59 ± 4.90	28.69 ± 5.21	0.332
	After 24 Hours	27.81 ± 4.23	27.80 ± 4.37	0.991
Total HACOR Score	At Initiation	9.15 ± 3.92	12.38 ± 3.71	**<0.001**
	After 1 Hour	8.03 ± 3.54	11.24 ± 3.68	**<0.001**
	After 24 Hours	6.21 ± 3.08	10.12 ± 3.81	**<0.001**

Table 2 shows the values of individual parameters of HACOR score at initiation. 1 hour and 24 hours in both success and failure groups. Patients who succeeded on NIV showed consistent clinical improvement in all components of the HACOR score across time. In contrast, those who failed NIV had persistently worse parameters. Notably, PaO_2/FiO_2 ratios in the failure group remained critically low, and consciousness levels deteriorated after 24 hours. The total HACOR score was significantly higher at all-time points in the failure group, supporting its use as a predictor of poor NIV outcome.

p-values were obtained using independent *t*-tests (or Mann–Whitney U tests where appropriate). Values in bold indicate statistically significant differences ($p < 0.05$).

Table 3: Predictive Accuracy of HACOR Score and Individual Components for NIV Failure at Different Time Points

Parameter	Best OR Range	AUC Range	PPV Range	NPV Range	Interpretation
Heart Rate (per min)	3.0–4.0	0.68–0.72	70–75%	65–70%	Moderate predictor
Acidosis (pH)	4.2–5.0	0.74–0.78	76–80%	70–75%	Strong predictor
Respiratory Rate (per min)	4.0–5.0	0.71–0.75	73–77%	68–72%	Strong predictor
Oxygenation (PO2/FiO2)	7.8–10.0	0.81–0.85	84–88%	78–82%	Best individual predictor
GCS	3.5–4.5	0.70–0.74	72–76%	67–71%	Moderate predictor
HACOR Score (Total)	9.5–12.0	0.86–0.90	88–92%	84–88%	Highest overall accuracy

Table 7.3 compares the predictive performance of the HACOR score and its individual components (heart rate, acidosis, respiratory rate, oxygenation, and consciousness) at initiation, 1 hour, and 24 hours of NIV. Oxygenation consistently showed the strongest predictive value among individual parameters, with the highest odds ratios (OR 7.8–10.0) and AUC values (0.81–0.85), as well as superior positive (84–88%) and negative predictive values (78–82%). Acidosis and respiratory rate were also strong predictors (OR ~4–5, AUC 0.73–0.78), with reasonably high predictive values (PPV ~75–78%; NPV ~70–73%). Heart rate and GCS demonstrated moderate predictive ability (OR 3–4.5, AUC 0.68–0.74), with lower PPV and NPV compared to oxygenation. The composite HACOR score outperformed all individual parameters, maintaining the highest accuracy across all time points (OR 9.5–12.0, AUC 0.86–0.90). Its predictive values were also superior (PPV 88–92%; NPV 84–88%).
While individual components, especially oxygenation, had reasonable predictive accuracy, the combined HACOR score consistently provided the most robust prediction of NIV failure, supporting its clinical utility over isolated parameters.

Discussion

The current study evaluated the predictive capacity of the HACOR score comprised of Heart Rate, Acidosis (pH), Consciousness (GCS), Oxygenation (PaO_2/FiO_2), and Respiratory Rate in determining the likelihood of NIV failure in patients with COPD. The findings affirm that the HACOR score is a valuable clinical tool in forecasting NIV outcomes, particularly when assessed at multiple time points during the initial 24 hours of therapy[14].
Our data demonstrated that the total HACOR score and its individual components had statistically significant associations with NIV failure at all three time intervals (initiation, 1 hour, and 24 hours). Notably, the total HACOR score achieved the highest predictive power, with AUC values of 0.90, 0.88, and 0.86 respectively. These high AUC values reflect excellent diagnostic accuracy, particularly within the first hour of NIV, emphasizing the score's usefulness for early clinical decision-making[15].
Among individual parameters, oxygenation and acidosis (pH) were the most robust predictors of failure. Patients with lower PaO_2/FiO_2 ratios and persistent acidosis were significantly more likely to require escalation to invasive ventilation. This aligns with previous literature, which identifies severe hypoxemia and respiratory acidosis as primary risk factors for NIV failure in AECOPD (Acute Exacerbation of COPD) patients. Oxygenation alone showed an odds ratio of 10 at initiation and maintained high predictive value across all time points, reinforcing its clinical importance[16].
The analysis of HACOR score components demonstrates variable predictive accuracy for NIV failure. Oxygenation consistently showed the highest predictive value, with strong odds ratios, AUCs, and predictive values, confirming hypoxemia as a key determinant of NIV outcomes. Acidosis and respiratory rate also performed well, reflecting the importance of ventilatory failure and compensatory mechanisms. In contrast, heart rate and consciousness had only moderate predictive

ability, likely because they represent secondary rather than primary indicators of respiratory deterioration[17].

Notably, the composite HACOR score outperformed all individual components at initiation, 1 hour, and 24 hours, achieving the highest accuracy across all predictive indices. This reinforces the value of a multidimensional approach that integrates oxygenation, ventilation, cardiovascular, and neurological parameters, offering clinicians a more reliable tool for anticipating NIV failure. While oxygenation remains the strongest single marker, the HACOR score provides the most comprehensive and clinically useful assessment[18].

Conclusion:

This study confirms the effectiveness of the HACOR score as a reliable, practical, and non-invasive clinical tool for predicting NIV failure in COPD patients. By evaluating key physiological parameters—heart rate, acidosis, consciousness, oxygenation, and respiratory rate—the HACOR score demonstrated strong predictive accuracy, particularly when assessed at initiation and after one hour of NIV therapy. A higher HACOR score was significantly associated with increased odds of NIV failure, indicating the need for early intervention and possible transition to invasive ventilation. Among individual components, oxygenation and pH were the strongest predictors. Incorporating the HACOR score into routine ICU assessment can aid clinicians in timely decision-making, potentially improving outcomes and reducing complications related to delayed intubation. This score provides a standardized approach to stratifying risk and optimizing respiratory support strategies in COPD patients experiencing acute respiratory failure. Future research should focus on multi-center validation and integration into clinical decision support systems.

Limitations:

This study has several limitations. Firstly, it was conducted at a single tertiary care center, limiting the generalizability of the findings to other settings. Secondly, the sample size, though adequate, may not fully capture the variability seen in broader COPD populations. Thirdly, the use of non-probability purposive sampling introduces potential selection bias. Additionally, we did not assess long-term outcomes such as hospital readmissions or mortality beyond the acute phase. Variability in clinician experience and NIV settings may also have influenced results. Future multicenter studies with larger and more diverse populations are needed to validate and refine the HACOR score's clinical utility.

Implications:

The findings of this study have important clinical implications for the management of COPD patients with acute respiratory failure. The HACOR score offers a simple, bedside tool that can help clinicians identify patients at high risk of NIV failure early in the treatment course. Timely identification allows for prompt decisions regarding escalation to invasive ventilation, potentially reducing complications and improving patient outcomes. Its routine use can standardize assessment protocols in ICUs, especially in resource-limited settings. Furthermore, integrating the HACOR score into clinical guidelines and electronic health systems could enhance decision-making, optimize resource allocation, and support personalized respiratory care strategies.

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