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The utility of HACOR score in predicting failure of high-flow nasal oxygen in acute hypoxemic respiratory failure

Abstract

Objectives: To assess the diagnostic performance of HACOR scoring system using bedside variables and to predict failure of HFNO in patients with acute hypoxemic respiratory failure (AHRF).

Material and methods: 150 patients with AHRF who were receiving HFNO were enrolled in this study; to predict HFNO treatment failure. A scoring scale (HACOR score) consisted of Heart rate (beats/minute), acidosis (assessed by pH), consciousness (assessed by Glasgow coma score), oxygenation, and respiratory rate. Failure was defined as the need for intubation or death.

Results: Patients were analyzed according to the success or failure of HFNO. Total 150 patients, of which 100 (66.7%) had a successful treatment while 50 (33.3%) failed with such intervention. There was an improvement in HR and RR, and PaO_2/FiO_2 within the first hour (T1) in the success group and these parameters continued to improve even after 24 hours (T2) of HFNO treatment. Patients with HFNO failure had a higher HACOR score at initiation and after 1, 12, 24 and 48 hours. Before intubation, the highest value of the HACOR score was reached in the failure group. At 1 h of HFNO assessment, the area under the receiver operating characteristic curve was 0.86, showing good predictive power for failure. We found that HACOR score at a cutoff point > 6 had 81.2% sensitivity and 91% specificity, 92.5% positive predictive value, and 71.4% negative predictive value with a diagnostic accuracy was 85%. Furthermore, the overall diagnostic accuracy exceeded 87% when the HACOR score was assessed at 1, 12, 24 or 48 h of HFNO.

Conclusions: The HACOR scale is a clinically useful bedside tool for the prediction of HFNO failure in hypoxemic patients. A HACOR score < 6 after 1 hour of HFNO highlights patients with $< 85\%$ risk of failure.

Key words: hypoxemic respiratory failure, critical care

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Introduction

High-flow nasal oxygen (HFNO) is an innovative system that allows for delivering a high flow of heated and humidified gas up to 60 L/min^{-1} and 0.21–1.0 of FiO_2 through a special nasal cannula [1].

HFNO has been increasingly conducted to treat acute hypoxemic respiratory failure (AHRF) patients [2]. Recent studies have compared the efficacy and outcome of HFNO with conventional oxygen therapy in (ICU) settings; indicate that HFNO demonstrates beneficial effects in terms of better oxygenation, as well as reduction of respiratory rate and dyspnoea, resulting in improving patient comfort [2, 3].

Using of HFNO can avoid intubation in patients with respiratory failure by temporarily supporting ventilation during initial treatment, but many subjects failed and ultimately need intubation. Patients at risk for HFNO failure may benefit from early intubation or close observation. There is a limited prediction tool to help clinicians to determine clinical outcomes and success rate in patients treated with HFNO.

Duan *et al*. have derived and validated a scoring system which accurately predicts patients that would be at risk of noninvasive (NIV) failure such that the clinician can plan for the decision to implement invasive mechanical ventilation. In a derivation cohort of 449 patients, the authors used stepwise multivariable regression analysis

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to identify variables predicting NIV failure. Each of the five parameters identified — heart rate, acidosis, consciousness (defined by the Glasgow Coma Scale [GCS] score), Oxygenation, and Respiratory rate (HACOR) — was assigned points, that added together to give an overall HACOR score. Hypothesizing that, the combination of these bedside variables has the potential to increase the predictive power for the prediction of NIV failure [4].

Hence, this study aims to assess a bedside scoring system based on five variables easily assessed in the emergency room (the HACOR score: heart rate, acidosis, consciousness, oxygenation, respiratory rate), to predict failure risk in patients with hypoxemic ARF treated with HFNO, the need for intubation. Hence the clinician can plan for the decision to implement invasive mechanical ventilation.

Material and methods

We conducted an observational prospective study in a 30-bed respiratory ICU at Assuit University Hospital between January 2018 and February 2020. This study was approved by the Faculty of Medicine Ethics Committee, Assiut University.

All the consecutive patients fulfilling the diagnostic criteria of acute hypoxic respiratory failure (AHRF) admitted to the ICU [5], and treated with HFNO were included after taking proper consent.

The inclusion criteria were age > 18 years, presence of clinical signs and symptoms of AHRF; defined by 1) recent dyspnea with a breathing frequency > 25 breaths/min and/or use of accessory muscles of respiration with pulmonary infiltrates on chest X-ray; 2) a PaO_2/FIO_2 of > 300 mm Hg recorded during spontaneous oxygen ventilation at 15 L/min^{-1} [5].

Patients who had an underlying chronic respiratory disease, who require emergent endotracheal intubation, Inability to protect airway (excess secretions, drowsy, or comatose patient), severe hemodynamic instability (patient on inotropic or vasopressor support), uncooperative patient, facial trauma or burns, facial surgery, or facial anatomical abnormality) were excluded [6].The demographic data of patients such as age, sex, the aetiology of acute respiratory failure, and presence of associated comorbid illnesses were recorded. The disease severity was calculated using the Acute Physiology and Chronic Health Evaluation II (APACHE II) score on admission to ICU [7].

Variables for HACOR score including; [heart rate (HR), respiratory rate (RR), consciousness (Glasgow Coma Scale (GCS), and arterial blood gases parameters collected at baseline during spontaneous ventilation with a conventional face mask and after 1, 12, 24, and 48 hours of initiation of HFNO.

These five variables were used to develop a risk-scoring system to predict HFNO failure. Each data point is assigned such that the sum represented the HACOR score. The HACOR score ranged between 0 to 25 points; higher score suggest an increased risk of HFNO failure [4]. We recorded the duration of HFNO therapy, length ICU and hospital stay and survival. Also, associated complications of HFNO were identified. Patients were followed up until death or hospital discharge.

High flow nasal oxygen settings

Patients who met inclusion criteria were treated by HFNO. The HFNO device (Optiflow, Fisher & Paykel Healthcare, Auckland, New Zealand) was applied through a heated humidifier and delivered continuously through large-bore bi-nasal prongs. HFNO was initially administered with a gas flow rate of 50 $Lmin^{-1}$ and an FiO_2 of 1.0 and subsequently adjusted to maintain SpO_2 of 92% or more.

The following criteria were used for endotracheal intubation [ETI]:

loss of consciousness; hypotension (e.g, systolic arterial blood pressure < 90 mmHg or mean arterial blood pressure < 65 mm Hg) despite adequate fluid resuscitation, or need for vasopressors;

or two of the following criteria: frank worsening of respiratory distress, RR > 40 breaths/min, $SpO_2 \leq 92\%$ despite an FiO_2 of 1.0, and/or pH < 7.35. Failure was defined by the need for endotracheal intubation [5].

Statistical analysis

Data was collected and analyzed using SPSS (Statistical Package for the Social Science, version 20, IBM, and Armonk, New York). Continuous variables were expressed as mean ± SD while nominal data was expressed in the form of frequency (percentage).

Chi-squared or Fisher's exact tests were used to determine the significance of differences in the observed data. A stepwise multivariate regression analysis performed to assess HFNO failure, and results presented as odds ratio (OR) with 95% confidence interval (CI). Diagnostic accuracy of

Table 1. Clinical characteristics of the patients at the enrolment

Variables	Success (n = 100)	Failure (n = 50)	P
Age [year]	65.89 ± 5.67	66.78 ± 10.54	0.09
Male sex	80 (80%)	30 (60%)	0.009
Smoking status			
Smoker	55 (55%)	28 (56%)	
Ex-smoker	25 (25%)	16 (32%)	0.06
Non-smoker	20 (20%)	6 (12%)	
Causes of acute respiratory failure			
Community acquired pneumonia	80 (80%)	40 (80%)	
Pulmonary embolism	15 (15%)	5 (10%)	
Cardiogenic pulmonary edema	2 (2%)	3 (6%)	0.51
Acute respiratory distress syndrome	3 (3%)	2(4%)	
Hypertension [n%]	40 (40%)	15 (30%)	0.32
Diabetes mellitus [n%]	32 (32%)	18 (36%)	0.42
C-reactive protein	26.4 ± 8.7	28.8 ± 12.3	0.321
LDH	442 ± 321	657 ± 432	0.001
APACHE-II score	13.77 ± 3.68	19.78 ± 4.09	0.001
HACOR score	5.56 ± 2.09	7.50 ± 1.11	0.001

Data expressed as frequency (percentage), mean (SD). HFNO — high flow nasal oxygen; LDH — lactate dehydrogenase; APACHE-II — acute physiology and chronic health evaluation; HACOR — heart rate, acidosis, consciousness, oxygenation, and respiratory rate

HACOR scale in the prediction of failed HFNO was determined with a ROC curve. Level of confidence was kept at 95% and hence, the P-value was significant if < 0.05.

Results

150 patients with acute hypoxemic respiratory failure, who were receiving HFNO, were enrolled in the study, out of them 100 (66.7%) subjects had successful HFNO while 50 (33.3%) patients had failed HFNO. Patient's clinical data were presented in Table 1. There were no significant differences found in age, sex, and aetiology of respiratory failure at the time of admission. Patients who failed HFNO had significantly higher LDH, APACHE-II and HACOR score.

Changes of physiological parameters between baseline T0 (on the initiation of HFNO), the first hour after enrolment (T1) and after 24 hours (T2) in nasal oxygen success and failure groups are shown in Table 2.

One hour after the enrolment (T1), HR, and RR improved in success group as compared to failure group (111 ± 16 *vs* 120 ± 20 beats/minute, 29 ± 12 *vs* 34 ± 14 breath/minute), respectively. Improvement was maintained after 24 hours of therapy (T2). There was also improvement in PaO_2/FiO_2 after one hour in success group (185.58 ± 58.5 *vs* 155.07 ± 52.7), which was maintained after 24 (201.53 ± 66.9 *vs* 175.6 ± 63.1) hours of therapy. No difference was found in blood pressure and $PaCO_2$.

A summary of HACOR scores at different time point from the initiation of HFNO treatment to 48 h of HFNO is shown in Table 3. Patients with HFNO failure had a higher HACOR score at initiation and after 1, 12, 24 and 48 hr than those with success group. Before intubation, the highest value of the HACOR score was reached in patients with HFNO failure.

As presented in Table 4, the predictors for failure of HFNO were HACOR score (odds ratio = 4.44, 95% confidence interval = 3.09–8.07; P < 0.001) and APACHE-II score (odds ratio = 1.43, 95% confidence interval = 2.01–5.78; P < 0.001) with adjusted R^2 was 0.65.

The predictive power of HFNO failure diagnosed by HACOR score is summarized in Table 5. After 1 hr of HFNO assessment, the area under the receiver operating characteristic curve was 0.86, showing good predictive power for failure. It was noticed that using HACOR score at cut off point > 6 had 81.2% sensitivity, 91% specificity, 92.5% positive predictive value, and 71.4% negative predictive value for prediction of HFNO failure with a diagnostic accuracy was 85%. Moreover, the overall diagnostic accuracy exceeded 87% when the HACOR score was assessed at 1, 12, 24 or 48 hr of HFNO.

Table 2. Comparisons of physiological parameters between high flow nasal oxygen success and failure groups

	Success (n = 100)	Failure (n = 50)	P
SBP [mm Hg]			
Baseline (T0)	120.7 ± 13.8	120.7 ± 12.1	0.32
After one hour (T1)	123.5 ± 16.5	121.5 ± 14.5	0.43
After 24 hours (T2)	124.5 ± 18.9	123.5 ± 16.9	0.61
DBP [mm Hg]			
Baseline (T0)	72.3 ± 12.7	70.9 ±12.4	0.36
After one hour (T1)	76.2 ± 14.5	73.2 ± 12.8	0.31
After 24 hours (T2)	76.2 ±13.7	76.6 ± 14.0	0.34
Heart rate [beat/minute]			
Baseline (T0)	124 ± 22	123 ± 23	0.32
After one hour (T1)	111 ± 16	120 ± 20	0.01
After 24 hour (T2)	98 ± 13	110 ± 18	0.01
RR [breath/minute]			
Baseline (T0)	34 ± 14	33 ± 16	0.321
After one hour (T1)	29 ± 12	34 ± 14	0.001
After 24 hours (T2)	22 ±10	30 ±13	0.001
pH^+			
Baseline (T0)	7.39 ± 0.11	7.38 ± 0.10	0.04
After one hour (T1)	7.40 ± 0.09	7.38 ± 0.09	< 0.001
After 24 hour (T2)	7.43 ± 0.08	7.39 ± 0.10	0.01
PaO_2/FiO_2			
Baseline (T0)	144.7 ± 56.8	139.8 ± 44.5	< 0.001
After one hour (T1)	185.58 ± 58.5	155.07 ± 52.7	< 0.001
After 24 hours (T2)	201.53 ± 66.9	175.6 ± 63.1	< 0.001
$PaCO_2$			
Baseline (T0)	38.3 ± 13.7	38.9 ±14.4	0.51
After one hour (T1)	39.2 ± 12.6	38.2 ± 12.8	0.42
After 24 hours (T2)	40.0 ±9.7	37.6 ± 13.0	0.21
GCS			
Baseline (T0)	14.2 ± 1.4	14.3 ± 1.2	0.32
After one hour (T1)	14.4 ± 1.2	14.5 ± 1.4	0.23
After 24 hours (T2)	14.5 ±1.2	14.1 ±1.1	0.41

Data expressed as mean (SD). P value was significant if < 0.05. (T0) — at initiation of HFNO; SBP — systolic blood pressure; DBP — diastolic blood pressure; $PaCO_2$ — arterial carbon dioxide tension; FiO_2 — fraction of inspired oxygen; GCS — Glasgow Coma Scale

Table 3. HACOR score at different time point

Time points	Success (n = 100)	Failure (n = 50)	P value
Initiation of HFNO	4.8 ± 2.3	7.4 ± 3.4	0.001
After 1 hour	2.5 ± 2.2	7.5 ± 3.7	0.001
After 12 hours	2.0 ± 2.1	8.3 ± 4.1	0.001
After 24 hours	1.6 ± 1.7	8.1 ± 4.3	0.001
After 48 hours	1.3 ± 1.4	8.4 ± 4.1	0.001
Intubation	—	9.5 ± 4.3	—

HFNO — high flow nasal oxygen; HACOR — heart rate, acidosis, consciousness, oxygenation, and respiratory rate

Table 4. Predictors of failure of HFNO

Predictors	OR	95% CI	P value
APACHE-II	1.43	1.01–3.78	< 0.001
HACOR	4.44	3.09–8.07	< 0.001
LDH	1.21	1.11–2.03	0.324
C- reactive protein	1.01	0.9–1.9	0.541
Variables after 1 hour of HFNO			
$pH^+ \geq 7.35$	2.32	1.3–3.2	0.432
$PaO_2/FiO_2 \geq 200$	2.03	1.2–3.6	0.02

OR — odds ratio; CI — confidence interval; LDH — lactate dehydrogenase; APACHE-II — acute physiology and chronic health evaluation; HFNO — high flow nasal oxygen; HACOR — heart rate, acidosis, consciousness, oxygenation, and respiratory rate

Table 5. Predictive power of HACOR score assessed at 1, 12, 24, and 48 hours in prediction of failed HFNO

Indices	1 h	12 h	24 h	48 h
		Cut off point > 6		
Sensitivity [%]	81.2	78.2	75.4	75.2
Specificity [%]	91	90	88	88
Positive predictive value [%]	92.5	90.2	91.3	91.1
Negative predictive value [%]	71.4	72.2	70.4	70.2
Diagnostic accuracy [%]	85	84	85	87
AUC [95% CI]	0.86 (0.84–0.90)	0.84 (0.82–0.90)	0.82 (0.80–0.88)	0.83 (0.82–0.86)

HACOR — heart rate, acidosis, consciousness, oxygenation, and respiratory rate; AUC — area under the curve of receiver operating characteristics; CI — confidence interval

Table 6. Mortality rate, length of stay and incidence of complications associated with HFNO

	Success (n = 100)	Failure (n = 50)	P
Duration of high-flow nasal oxygen treatment [days]	4.1±1.3	3.5 ± 2.5	0.229
Length of ICU stay [days]	4.7 ± 2.22	12.2 ± 3.30	0.001
Length of hospital stay [days]	8.2 ± 3.2	15.1 ± 5.1	0.001
Mortality at day 28 [n %]	3 (3%)	7 (14%)	0.01
In-hospital mortality, n° [%]	3 (3%)	12 (24%)	0.001
Complications associated with HFNO			
Gastric distension	10 (10%)	24 (48%)	0.001

Data expressed as mean (SD), frequency (percentage)

The mean lengths of ICU and hospital stay were significantly higher in HFNO failure in comparison to the success group Table 6. In-hospital mortality rate was higher in HFNO failure patients compared to success group [12 (24 %) *vs* 3 (3%); p = 0.008] respectively. The only reported complication associated with HFNO was gastric distension in 24 (48%) failure patients *vs* 10 (10 %) in success groups (p = 0.001; Table 5).

Discussion

HFNO has been gaining traction as an initial treatment in patients with acute hypoxemic respiratory failure. High-flow nasal oxygen was associated with an increased degree of comfort, a reduction in the severity of dyspnea, and a decreased respiratory rate [8]. However, many patients fail HFNO and ultimately need intubation. Early intubation or close observation can benefit patients at risk for HFNO failure [9]. Hence, we evaluate the diagnostic performance of the HACOR score to predict HFNO failure in patients with hypoxemic respiratory failure admitted to a respiratory ICU to avoid delaying intubation and decreased hospital mortality.

This score takes into account heart rate, acidosis, consciousness, oxygenation, and respiratory rate. Because the parameters in the HACOR score are simple bedside measurements, it can serve as a rapid and useful tool for predicting HFNO failure. The current study revealed that 33% of patients ultimately failed HFNO and predicting the need for intubation. Moreover, we noted that HACOR score at the first hour of initiation and a cutoff point of 6 has a sensitivity of 81% and a specificity of 91%, with a good diagnostic accuracy 85%.

In agreement with our results, a study conducted by Duan et al. who assessed the usefulness of HACOR scale for prediction of NIV failure in patients with acute hypoxemic respiratory failure. The authors found that HACOR score of > 5 had a higher risk of NIV failure. Thus, recognition of high risk patients and early intubation may presumably reduce hospital mortality [4].

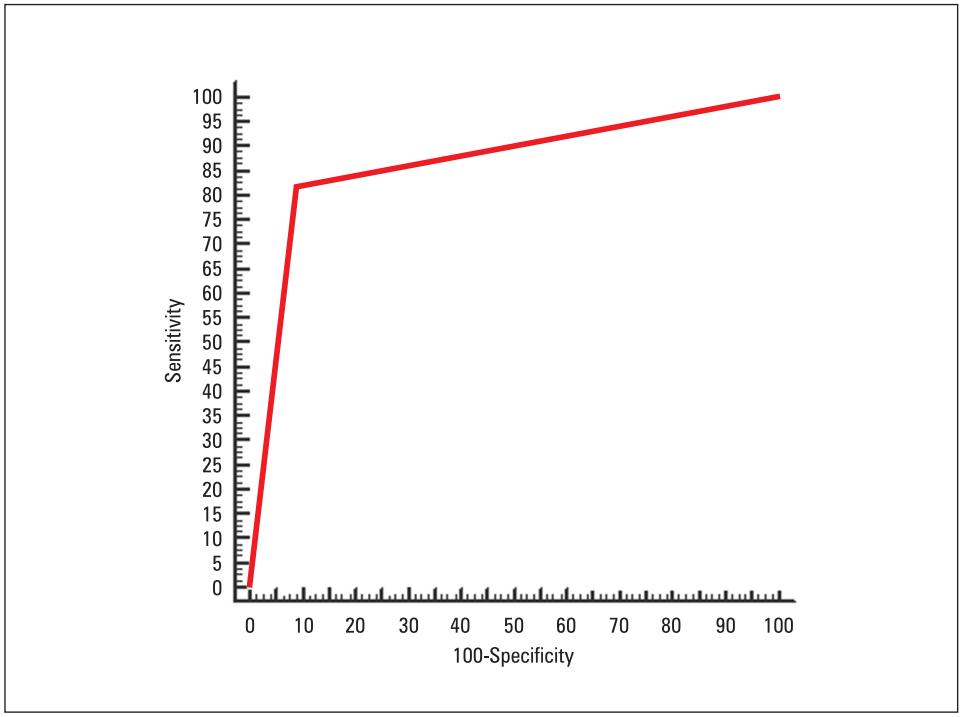

Figure 1. Accuracy of HACOR score in prediction of failed high flow nasal oxygen

Also, Duan *et al.* studied a novel and practical risk-scoring system to predict noninvasive ventilation (NIV) failure, using bedside clinical variables; 500 chronic obstructive pulmonary disease (COPD) patients were enrolled in a derivation cohort. The authors demonstrated that NIV failure rate was 18.8%, 18.9% and 8.9% in derivation, internal-validation and external-validation cohorts, respectively. In addition, the HACOR score had good diagnostic power for NIV failure when it was assessed at 1 hr of NIV initiation [10].

The present study, the overall mortality was 24% in patients with HFNO failure. Therefore, early identification of HFNO failure and intubation is a promising strategy to improve outcome. Recently, in a FLORALI study, a randomized trial consisting of 310 patients with acute hypoxemic respiratory failure allocated to HFNO and standard oxygen therapy. The authors noted that intubation and mortality rate was significantly lower in the HFNO group than in standard oxygen [11].

The points of strength in this study; we assessed the performance of a very useful and a newly developed score in hypoxemic subjects using HFNO. This score has not been previously addressed in High flow nasal oxygen aiming to improve the clinical management and patient's outcome. Limitation in this study, we didn't assess mean flow and FIO_2 used by HFNO in the studied population.

Conclusions: HACOR is a newly developed scoring system which takes into account heart rate, acidosis, consciousness, oxygenation, and respiratory rate to predict failure of HFNO in patients with hypoxemic respiratory failure. The score appears to be an effective way of predicting HFNO failure. This could be a promising tool for the clinician to recognize and detect early failure; to ensure that there is no delay in intubation. Patients with a higher HACOR score are more likely to experience failed HFNO. With a cutoff value < 6, the diagnostic accuracy of the HACOR scale was high. Thus, the HACOR score has been identified as a useful tool to pinpoint patients that will benefit from such intervention.

Ethical approval and consent to participate

The research received ethical approval from the Ethics Committee of the Faculty of Medicine. The data were confidential. All procedures in the current study were performed according to the ethical standards of the institutional research committee.

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Institutional review board statement

This study was approved by the Faculty of Medicine Ethics and Scientific Research Committees.

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of interest

None declared.

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