ORIGINAL ARTICLE

Utility of the One-time HACOR Score as a Predictor of Weaning Failure from Mechanical Ventilation: A Prospective Observational Study

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Abstract

Aim: To determine the utility of the HACOR score in predicting weaning failure in resource-limited settings.

Objectives: The primary objective was to determine a cut-off value of the HACOR score, sensitivity, and specificity to predict failed weaning. The secondary objective was to determine which out of five components of the score was significantly different between the successful weaning and the failed weaning groups.

Introduction: Most weaning indices are either inaccurate or are dependent on complex ventilatory parameters, which are difficult to measure in resource-limited settings. This study aimed to determine the utility of the HACOR score consisting of heart rate, acidosis, consciousness level, oxygenation, and respiratory rate as a predictor of weaning in the intensive care unit.

Materials and methods: It was a prospective observational study on 120 patients between 18 and 90 years. The HACOR score was evaluated at 30 minutes of spontaneous breathing trial (SBT). The total duration of SBT was 120 minutes.

Results: Out of 120 patients, 83 (69.2%) had successful weaning, whereas 37 (30.8%) had weaning failure. The median and interquartile range (IQR) of the HACOR score in the successful weaning group was 2 (0–3) and 6 (5–8) in the failed weaning group (p-value <0.001). There was a significant difference in each of the five components of the HACOR score between the successful and failed weaning groups ($p < 0.05$). HACOR score ≥5 predicted failed weaning, sensitivity 83.8%, specificity 96.4%, area under the curve (AUC) 0.950, and 95% confidence interval (CI) [0.907–0.993], $p < 0.001$. Multivariable logistic regression analysis showed that HACOR score ≥5 is an independent predictor of weaning failure [$p < 0.001$, 95% CI (1.9–4.2), adjusted odds ratio 2.82].

Conclusion: A HACOR score ≥5 is an excellent predictor of weaning failure. This score may be useful as a weaning strategy in the intensive care unit.

Keywords: Failed weaning, HACOR score, Successful weaning.

Indian Journal of Critical Care Medicine (2022): 10.5005/jp-journals-10071-24280

Introduction

With an increase in the number of patients requiring mechanical ventilation and a shortage of intensivists, primary care physicians are also tasked with weaning.[1] Weaning strategies are either dependent on complex ventilatory parameters or ultrasound measurements or are subjective.[2] There is a need for objective scores that are easy to perform and are less resource-intensive. The HACOR score consisting of heart rate (HR), acidosis (pH), consciousness [Glasgow Coma Scale (GCS)], oxygenation, (partial pressure of oxygen in arterial blood to the fraction of inspired oxygen) (PaO_2/FiO_2), and respiratory rate (RR) was initially proposed by Duan et al., where the authors had shown its validity to predict the failure of non-invasive ventilation (NIV).[3] Among the various indices to predict weaning failure, minute ventilation recovery time (MVRT) and rapid shallow breathing index (RSBI) are commonly used.[4] These rely considerably on the measurement of ventilatory parameters.[4] The ventilatory measurements either require substantial training to be evaluated (like MVRT) or lack the multisystem approach essential for weaning.[4–6] Weaning failure has multi-systemic causes.[7] The cause are interlinked, involving respiratory, neurologic, and cardiac causes.[7] Since the HACOR score encompasses multisystem parameters, we wanted to study its utility in predicting weaning failure.

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How to cite this article: Chaudhuri S, Gupta N, Adhikari SD, Todur P, Maddani SS, Rao S. Utility of the One-time HACOR Score as a Predictor of Weaning Failure from Mechanical Ventilation: A Prospective Observational Study. Indian J Crit Care Med 2022;26(8): 900–905.

Ethical approval: Prior to the commencement of the study, Institutional Ethics Committee permission was obtained (IEC: 197/2021) and Clinical Trial Registry of India (CTRI) registration was done before recruitment (CTRI/2021/07/035139). We obtained written informed consent from the legally authorized representative prior to recruiting patients for the study.

Materials and Methods

Study Design

It was a single-center prospective observational study that was conducted at the intensive care unit (ICU) of a tertiary medical college. The study was conducted from 2nd August 2021 to 2nd February 2022.

Inclusion Criteria

- Adult intubated patients between 18 and 90 years on invasive mechanical ventilation who were ready for weaning.
- Patients who fit the criteria for undergoing SBT.

Exclusion Criteria

- Patients who did not tolerate the initial 30 minutes of SBT, and arterial blood gas (ABG) at 30 minutes are unavailable for calculating the HACOR score.

Sample Size

The sample size estimated was 120 patients, as per the formula:

$N = Z(1\text{-}\alpha/2)^2 * \text{Sensitivity} * (1\text{-Sensitivity})/d^2 * \text{Prevalence}$. For a 95% confidence interval, Z (1-α/2) value of 1.96, a sensitivity of HACOR score to predict weaning success being at least 50% (0.5), precision (d) of 10%, and the prevalence of successful weaning being about 80%, the sample size was 120.

Methodology

Patients who met the following criteria were given SBT on pressure support ventilation (PSV) of 8 cm H_2O, FiO_2 <0.5, positive end-expiratory pressure (PEEP) ≤5 cm H_2O, minute ventilation <10 L/minute, PaO_2/FiO_2 ratio ≥150 mm Hg, absence of hemodynamic instability, off sedation and awake with a good cough and absence of electrolyte abnormalities. The total duration of SBT was 120 minutes. At the end of 30 minutes duration of SBT, ABG was analyzed, and the HACOR score was recorded. The HACOR score calculation (maximum score of 25) was done as follows:[3]

- HR ≤120 beats/minute as 0 point and ≥120 beats/minute as 1 point.
- pH ≥7.35 as 0 point, 7.30–7.34 as 2 points, 7.25–7.29 as 3 points, and <7.25 as 4 points.
- GCS 15 as 0 point, 13–14 as 2 points, 11–12 as 5 points, and ≤10 as 10 points.
- PaO_2/FiO_2 ≥201 as 0 point, 176–200 as 2 points, 151–175 as 3 points, 126–150 as 4 points, and 101–125 as 5 points.
- RR ≤30 breaths/minute as 0 point, 31–35 breaths/minute as 1 point, 36–40 breaths/minute as 2 points, 41–45 breaths/minute as 3 points, and ≥46 breaths/minute as 4 points.

For the assessment of GCS in the intubated patients, the following formula was used to calculate the verbal component of the GCS score:[8]

Derived verbal score = –0.3756 + Eye Score * (0.4233) + Motor Score * (0.5713).[8]

The links to the verbal score calculator in intubated patients (link 1) as well as the link for the HACOR score calculator (link 2) have been provided. These links were developed by our team as “Link 1 for calculating verbal score in intubated patients” is https://scutils.github.io/DerivedVerbalScoreGCS/ and “Link 2 for the HACOR score calculation” is https://scutils.github.io/HacorScoreCalculator/.

Source of support: Nil
Conflict of interest: None

The decision to consider the SBT as success or failure was as per the treating intensivist, who was oblivious of the HACOR score. The criteria followed by intensivists to terminate SBT was a subjective analysis of the evidence of respiratory distress post-SBT initiation, along with standard parameters of SBT termination like (RSBI >105, RR >35/min, drop in pulse oximetry saturation <90%, rise in heart rate >20% of the baseline, and systolic blood pressure >180 mm Hg or <90 mm Hg). Patients were followed up for the need for re-intubation in the next 48 hours. Successful weaning was considered when SBT of 120 minutes was tolerated; the patient was extubated and did not require re-intubation within 48 hours of extubation. Failed weaning was considered as either the failure of SBT at 120 minutes or requirement of re-intubation within 48 hours of extubation.[7]

Data Collection

Data of age of the patients, gender, Charlson comorbidity index (CCI) score, days of ventilator support prior to the day of first SBT, Sequential Organ Failure Assessment (SOFA) score on the day of SBT, the incidence of successful and failed weaning, and outcome of the ICU stay were noted.

Statistical Analysis

We used the statistical software IBM SPSS (Statistical Package for the Social Sciences) software (IBM Corp. Released 2012. IBM SPSS Statistics for Windows version 22.0 Armonk, NY: IBM) for the data analysis. For the variables following parametric distribution, mean and standard deviation (SD) were calculated, and for non-parametric distribution, median, and interquartile range (IQR) were calculated. The Chi-square test was used to compare the categorical variables. The means of continuous variables with parametric distribution were compared using the independent Student t-test. For those continuous variables with non-parametric distribution, the median values were compared using the Mann–Whitney U test. A p-value <0.05 was considered significant. The receiver operating characteristic (ROC) curve was plotted to calculate the cut-off value with the highest sensitivity and specificity in predicting weaning failure. For the univariate analysis, the variables age, gender, CCI, SOFA score on the day of SBT, days of ventilator support before SBT, and HACOR score were analyzed to predict failed weaning, and the odds' ratio (OR) was calculated. The multivariable logistic regression analyzed those variables with a p-value <0.05 in the univariate analysis to calculate the adjusted OR.

Results

The total number of patients included in the study was 124. There were four patients in whom SBT was terminated prior to 30 minutes duration. The number of patients who tolerated at least 30 minutes of SBT was 120. The number of patients with successful weaning was 83 (69.2%), whereas 37 (30.8%) had weaning failure (failed SBT at 120 minutes or required re-intubation within 48 hours of extubation). In the failed weaning group, 32 patients had failed the SBT by 120 minutes, and five patients required re-intubation within 48 hours of extubation. The flowchart depicting this is given (Flowchart 1).

At the end of the ICU stay, 105/120 (87.5%) survived. The primary cause for which mechanical ventilation was initiated in the patients is depicted (Table 1).

Flowchart 1: Depiction of the participant recruitment for the study

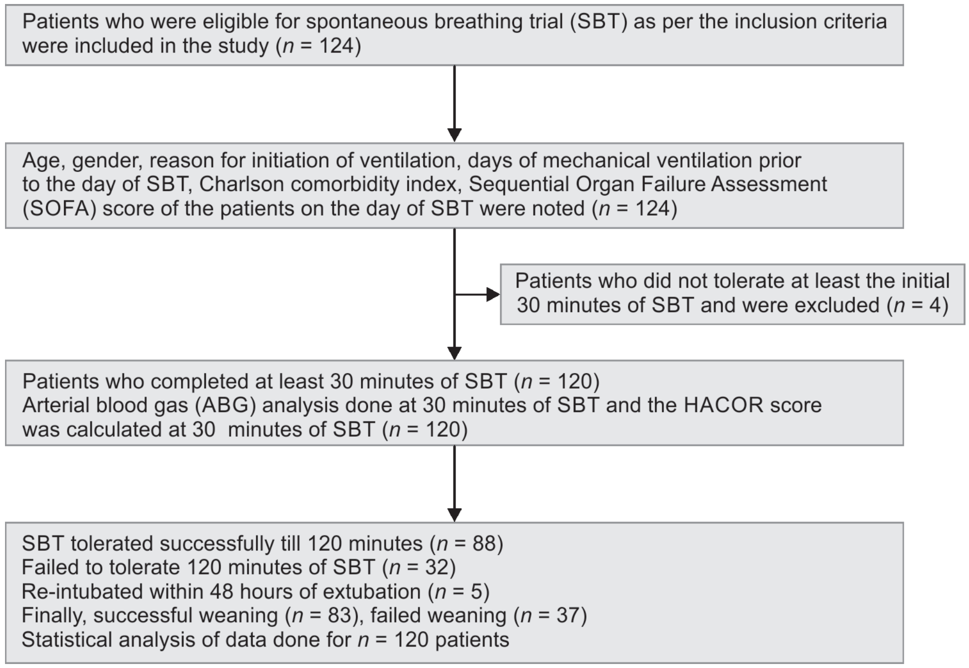

Table 1: Depiction of the primary cause of mechanical ventilation initiation in the study population

The primary cause for which mechanical ventilation was initiated	*Number of patients (N)*
Respiratory	39 (32.5%)
Cardiac	12 (10%)
Neurologic	11 (9.16%)
Trauma	9 (7.5%)
Postoperative	19 (15.8%)
Sepsis/Septic shock	26 (21.6%)
Poisoning	3 (2.5%)
Hemorrhagic shock	1 (0.83%)

The median and IQR of the number of ventilator days prior to the day of SBT, SOFA score on the day of SBT, and the HACOR score after 30 minutes of SBT were significantly less in the patients in the successful weaning group, as compared to the failed weaning group ($p < 0.05$, Mann–Whitney *U* test) (Table 2). There was no statistical difference between the patients in the two groups in terms of gender ($p = 0.157$, Chi-square test), age ($p = 0.691$, independent Student *t*-test), and CCI score ($p = 0.726$, Mann–Whitney *U* test) (Table 2).

Each of the variables in the HACOR score was found to be significantly different between the patients in the successful weaning and failed weaning groups ($p < 0.05$, Chi-square test) (Table 3).

The ROC was plotted for the HACOR score as a predictor of failed weaning, and the AUC was 0.950, sensitivity 83.8%, specificity 96.4%, 95% confidence interval (CI) 0.907–0.993, $p < 0.001$, and cut-off HACOR score ≥5 (Fig. 1).

Univariate analysis of the variables gender, CCI, days of ventilator support before SBT, SOFA score on the day of SBT, and HACOR score to predict failed weaning showed that days of ventilator support before SBT ($p = 0.001$), SOFA score ($p = 0.004$), and HACOR score ($p < 0.001$) were significant (Table 4). Multivariable logistic regression analysis was done for the three variables which showed statistical significance in the univariate analysis (Table 4). It showed that only the HACOR score at the end of 30 minutes of SBT was a significant predictor of failed weaning ($p < 0.001$) (Table 4).

Table 2: Comparison of the mean and median values of the variables between the two groups—successful weaning versus failed weaning

Variables	*Successful weaning N = 83 (69.2%)*	*Failed weaning N = 37 (30.8%)*	*p-value*
Gender	Male *n* = 47 (39.17%)	Male *n* = 26 (21.7%)	0.157*
Age (years) Mean ± SD	53.8 ± 16.2	55 ± 14.5	0.691**
Ventilator days Median (IQR)	3 (2–4)	4 (3–6)	<0.001***
CCI score Median (IQR)	3 (1–4)	3 (1–4)	0.726***
SOFA score on the day of SBT Median (IQR)	3 (2–5)	4 (3–7)	0.001***
HACOR score Median (IQR)	2 (0–3)	6 (5–8)	<0.001***

p-value <0.05 is significant; *Chi-square test; **Independent Student *t* test, ***Mann–Whitney *U* test; CCI, Charlson comorbidity index; IQR, interquartile range; SOFA, Sequential Organ Failure Assessment; HACOR, heart rate, acidosis, consciousness, oxygenation, respiratory rate

Discussion

The successful weaning process requires adequate functioning of airways, lungs, brain, heart, and diaphragm.[7] Unlike the HACOR score, most of the other weaning indices do not incorporate all these components.[4] The HACOR score, which is easy to calculate in resource-limited settings, has the ability to reflect this multiorgan dysfunction as per a stratified multisystem approach.[7]

Table 3: The comparison of each of the five variables in the HACOR score (HR, pH, GCS, PaO_2/FiO_2, RR) between the successful weaning group and failed weaning group

Variables in HACOR scoring	*Score as per HACOR*	*Successful weaning n = 83 (69.2%)*	*Failed weaning n = 37 (30.8%)*	*p-value*
HR (beats/min)	0 (≤120)	79 (65%)	27 (22.5%)	**<0.001***
	1 (≥121)	4 (3.3%)	10 (8.3%)	
pH (arterial blood)	0 (≥7.35)	68 (56.6%)	14 (11.7%)	**<0.001***
	2 (7.30–7.34)	11 (9.16%)	11(9.16%)	
	3 (7.25–7.29)	4 (3.3%)	6 (5%)	
	4 (<7.25)	0 (0%)	6 (5%)	
GCS	0 (15)	65 (54.16%)	13 (10.83%)	**<0.001***
	2 (13–14)	16 (13.3%)	15 (12.5%)	
	5 (11–12)	1 (0.83%)	7 (5.83%)	
	10 (≤10)	1 (0.83%)	2 (1.67%)	
PaO_2/FiO_2 ratio	0 (≥201)	65 (55.16%)	22 (18.33)	**0.036***
	2 (176–200)	16 (13.33%)	9 (7.5%)	
	3 (151–175)	2 (1.67%)	3 (2.5%)	
	4 (126–150)	0 (0%)	1 (0.83%)	
	5 (101–125)	0 (0%)	2 (1.67%)	
	6 (≤100)	0 (0%)	0 (0%)	
RR (breaths/min)	0 (≤30)	75 (62.5%)	6 (5%)	**<0.001***
	1 (31–35)	8 (6.67%)	11 (9.16%)	
	2 (36–40)	0 (0%)	18 (15%)	
	3 (41–45)	0 (0%)	1 (0.83%)	
	4 (≥46)	0 (0%)	1 (0.83%)	
HACOR score Median (IQR)		2 (0–3)	6 (5–8)	**<0.001****

p-value <0.05 is significant; *Chi-square test; **Mann–Whitney *U* test

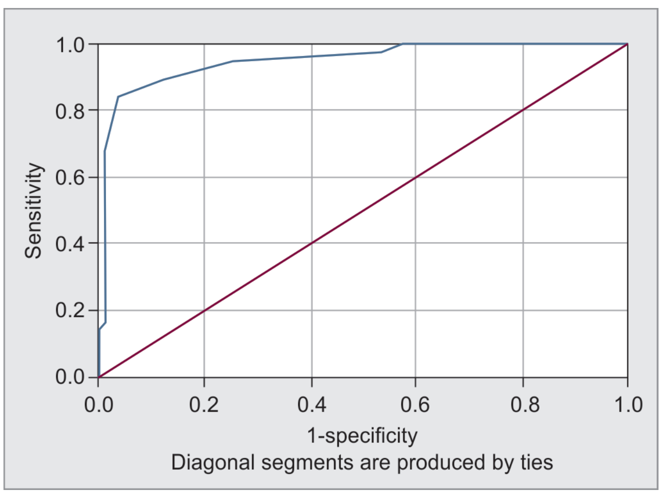

Fig. 1: ROC depicting the AUC 0.950 of HACOR score to predict failed weaning, sensitivity 83.8%, specificity 96.4%, 95% CI 0.907–0.993, cut-off HACOR score ≥5, $p < 0.001$. (AUC, area under curve; CI, confidence interval; ROC, receiver operating characteristic curve)

One of the most popular weaning indices is the RSBI, which has the advantage of the simplicity of calculation and easy repeatability during an SBT.[9] In the original study by Yang and Tobin, the AUC of the ROC of RSBI to predict weaning success was 0.890, and it showed 97% sensitivity and 64% specificity.[9] However, there are few drawbacks regarding the use of RSBI solely as a weaning predictor. Most of the SBT given nowadays are on PSV mode rather than on spontaneous respiration for 1 minute, as was done originally.[9,10] Recent studies concluded that RSBI at 30 minutes of SBT has a lesser predictive ability as compared to the study by Yang and Tobin.[9–12] This was much lesser than the prognostic value of the HACOR score in predicting weaning failure, which we found in our study (AUC 0.950, sensitivity 83.8%, and specificity 96.4%). Rapid shallow breathing index could not predict extubation outcomes in a study by Lee et al., showing it may not be sacrosanct in all scenarios.[11] Also, RSBI may not be suitable in weaning patients suffering from chronic obstructive pulmonary disease (COPD), neurological dysfunction, and those on prolonged mechanical ventilation.[6] A study compared various weaning indices for their ability to predict weaning failure–CROP index (dynamic compliance, respiratory rate, oxygenation, and maximum inspiratory pressure), CORE index (dynamic compliance, oxygenation, rate, and effort), integrative weaning index (IWI), MVRT, and RSBI.[4] In that study, amongst all the indices, RSBI and MVRT had the highest AUC to predict weaning failure of 0.72 and 0.93, respectively. However, the AUCs were lesser as compared to the AUC of HACOR score in our study (0.950) to predict weaning failure.[4]

A minute ventilation recovery time, which actually estimates the work of breathing after SBT initiation, is defined as the time period required for the minute ventilation to come back to the baseline value after SBT.[5] It is more labor intensive to perform as up to 24 hours of recordings are required before SBT.[4,5] Agitation of patients and intervention by nurses over the preceding 24 hours like bed care are factors affecting the reliability of MVRT.[5] These factors make MVRT less favorable as compared to the HACOR score as a predictor of weaning in resource-limited ICUs.

Table 4: Univariate and multivariable logistic regression analysis of the variables in the study to predict failed weaning

	Univariate analysis		*Multivariable logistic regression*	
Variables in the study	*Odds ratio (OR) [95% CI]*	*p-value*	*Adjusted OR [95% CI]*	*p-value*
Days of ventilator support prior to the day of SBT	1.5 (1.2–2)	**0.001**	1.25 (0.9–1.8)	0.239
SOFA score (Day of SBT)	1.26 (1.1–1.5)	**0.004**	1.1 (0.8–1.4)	0.69
HACOR score	2.86 (1.9–4.2)	<**0.001**	2.82 (1.9–4.2)	<**0.001**
CCI	1 (0.8–1.2)	0.899		
Gender	1.8 (0.8–4.1)	0.16		

p-value <0.05 is significant; CCI, Charlson comorbidity index; CI, confidence interval; HACOR, heart rate, acidosis, consciousness, oxygenation, respiratory rate; SBT, spontaneous breathing trial; SOFA, Sequential Organ Failure Assessment

Other weaning indices like airway occlusion pressure at 1 second and the ratio of occlusion pressure to maximum inspiratory pressure necessitate the use of specialized devices and thus may not be practical across all ICUs.[13]

Weaning failure can be influenced by confounders such as the severity of organ dysfunction, advanced age, comorbidities, prolonged duration of mechanical ventilation before SBT, and neurological impairment.[13] Thus, we performed univariate and multivariable logistic regression analysis (including SOFA, CCI, and days of ventilator support prior to SBT), which showed that the HACOR score was independently accurate in predicting weaning failure.[13] A recent study showed that changes in RR, PaO_2/FiO_2, and pH from 0 to 30 minutes of SBT were the independent predictors associated with 120-minute SBT failure, which are all components of the HACOR score.[14] Since literature has shown that even though certain patients tolerate SBT at 30 minutes but fail SBT at 60 or at 120 minutes, we continued the SBT for 120 minutes in our patients.[14,15]

Ultrasound-based weaning indices are also being used by intensivists.[16] In studies on various ultrasound-based weaning indices, such as the speed of diaphragmatic contraction, diaphragmatic excursion, diaphragmatic thickening fraction, and lung ultrasound score, their predictive value to predict weaning failure was lesser than that of the HACOR score, which we found in our study.[16–18] The high cost of ultrasound equipment, lack of training for operator competency, maintenance issues, and malfunctioning equipment lead to the diminished use of ultrasound in resource-limited settings.[19] Patient-related factors like obesity, subcutaneous emphysema, and post-surgical patients with dressings over the chest, restrict the use of ultrasound-based weaning indices.[20,21]

The HACOR score can also reflect cardiac dysfunction during SBT and weaning-induced pulmonary edema (increased HR, drop-in PaO_2/FiO_2), and diaphragmatic dysfunction (drop in pH, and $PaCO_2$ rise in arterial blood).[22–24] This score may be used by even non-intensivists to objectively assess weaning outcomes in resource-limited health care set-ups. The HACOR score may also be beneficial to predict weaning failure in all healthcare settings, in addition to other weaning indices like ultrasound-based indices.

Limitations

The study was performed at a single center. A drawback of the HACOR score is that, unlike RSBI, it is difficult to calculate the HACOR score at repeated time intervals during an SBT, as that would mean multiple ABG samples. We did the HACOR score only once during the SBT process, at 30 minutes. Another limitation is that even though the HACOR score was developed and validated to predict NIV failure in patients with hypoxemia, we have used it for predicting weaning failure in mechanically ventilated patients.

Conclusion

In conclusion, the HACOR score is helpful for the assessment of weaning patterns. A score ≥5 predicts weaning failure with excellent sensitivity and specificity. It is an objective and easy-to-use tool that can be used in high-burden intensive care units as well as in resource-limited settings.

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