Original Article

Lung ultrasound score versus HACOR score as a predictor for weaning outcome in patients at high risk for extubation failure

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ABSTRACT

Background: Pulmonary complications from mechanical ventilation are a significant concern in intensive care. Reducing the duration of respiratory support is vital to minimize these risks. Extubation, the final step in the weaning process, is critical. Most weaning indices rely on complex ventilatory parameters. This study aimed to evaluate the utility of the heart rate, acidosis, Glasgow Coma Scale, oxygenation, respiratory rate (HACOR) score, and Lung Ultrasound Score (LUS) as predictors of weaning outcomes in the intensive care unit. **Methods:** This prospective observational study was conducted in the Department of Critical Care Medicine at Sri Ramachandra Institute of Higher Education and Research, involving 100 patients aged 18 years and above. Both the HACOR score and LUS were assessed at the 30th minute during a 60-minute spontaneous breathing trial (SBT). **Results:** Of the 100 patients, 65 (65%) were successfully weaned, while 35 (35%) experienced weaning failure. The median HACOR score was 3 (interquartile range: 0–3) in the successful group and 6 (IQR: 5–8) in the failed group. The median LUS was 10 (IQR: 8–10) in the successful group and 16 (IQR: 13–16) in the failed group. A HACOR score ≥5 predicted weaning failure with a sensitivity of 87.7%, specificity of 77.1%, and area under the curve of 0.824. The LUS had an area under curve of 0.831, sensitivity of 86.2%, specificity of 80% at a threshold of ≥13 for failure. **Conclusion:** A HACOR score of ≥5 and a Lung Ultrasound Score of ≥13 are excellent predictors of weaning failure and can be incorporated into ICU weaning strategies.

KEY WORDS: Acidosis, consciousness, HACOR-heart rate, oxygenation, respiratory rate

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INTRODUCTION

Weaning from mechanical ventilation (MV) is a critical phase in managing critically ill patients. Both early and late extubation can lead to complications such as infections, prolonged ICU stays, and higher mortality. Studies show that about 20% of patients fail their first weaning attempt, with weaning accounting for 40–50% of total MV duration.[1] Prolonged ventilation is linked to complications like ventilator-associated pneumonia (VAP) and ventilator-induced lung injury (VILI), which increase recovery time and mortality.[2]

Weaning Criteria and Predictors: Weaning guidelines require patients to meet specific criteria, including a frequency-to-tidal volume (f/V_T) ratio

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of <105 breaths/min/L and a respiratory rate (RR) <35 breaths/min. Despite these criteria, weaning failure remains a challenge, contributing to extended ICU stays. Key predictors of failure include older age, COPD, pulmonary edema, pneumonia, a high APACHE II score, and multiple comorbidities.[3]

Predictive tools for weaning success: Several tools are used to assess readiness for extubation

Rapid shallow breathing index (RSBI)

RSBI is widely used, with high sensitivity for predicting success, but less reliable in certain conditions like COPD or neurological impairments.[4]

Lung ultrasound

A non-invasive tool assesses lung aeration, with high sensitivity and specificity for predicting extubation success. However, it requires specialized training.[5-7]

HACOR score

A simple score is based on heart rate, pH, Glasgow Coma Scale, PaO2/FiO2, and RR. It has been shown to predict weaning failure effectively, especially in resource-limited settings.[8]

This study aims to compare the effectiveness of the HACOR score and lung ultrasound in predicting weaning outcomes in ICU patients.

MATERIALS AND METHODS

Study design

This was a prospective observational study conducted at the tertiary care hospital intensive care unit from December 2023–September 2024, following clearance from the ethical committee and Clinical Trials Registry – India (CTRI).

Inclusion criteria

Adult intubated patients above 18 years of age on invasive MV who were ready for weaning with one or more of the risk factors for extubation failure (age >65, COPD, pulmonary edema, pneumonia as an indication for intubation, high APACHE II, more than one comorbidity).

Exclusion criteria

Pregnant women, self-extubated patients, patients who are not willing to be enrolled in the study, and patients who did not tolerate initial 30 minutes of SBT (Respiratory distress, RR >35/min, SpO2 <90%, heart rate increase >20% from baseline, systolic blood pressure >180 mmHg or <90 mmHg, diaphoresis, or paradoxical breathing).

Sample size

The sample size was calculated using the formula $n = z^2.p\,(1\text{-}p)/d^2$ where Z is 1.96 for a 95% confidence level, P is 0.80 for the prevalence of successful weaning, and d is 0.10 for the desired precision, resulting in a minimum required sample size of 100.

Methodology

This was a single-center, prospective observational study conducted at the Department of Critical Care Medicine, in a tertiary care center, to compare the Lung Ultrasound Score (LUS) and HACOR score in predicting weaning outcomes in patients at high risk for extubation failure. A total of 100 patients who met inclusion criteria underwent a 60-minute spontaneous breathing trial (SBT) with pressure support ventilation (PSV) of 8 cm H2O, FIO2 of 40%, and PEEP of 6 cm H2O. Arterial blood gas (ABG) was obtained to calculate the HACOR score after 30 minutes of SBT, while lung ultrasound was performed by an intensivist to determine the LUS after 30 minutes of SBT.

HACOR score

Heart Rate: <120/min – 0 points, >120/min – 1 point, Acidosis (pH): <7.25 – 4 points, 7.25–7.29 – 3 points, 7.30–7.34 – 2 points, ≥7.35 – 0 points consciousness (Glasgow Coma Scale): ≤10 – 6 points, 11–12 – 5 points, 13–14 – 2 points, 15 – 0 points PaO2/FiO2 ratio: ≥201 – 0 points, 176–200 – 2 points, 126–150 – 4 points, 101–125 – 5 points; RR: ≤30 – 0 points, 31–35 – 1 point, 36–40 – 2 points, 41–45 – 3 points, ≥46 – 4 points. The verbal component of GCS is calculated using: Derived Verbal Score = −0.3756 + ({Motor Score} * 0.5713) + ({Eye Score} * 0.4233).

Lung Ultrasound Score

The LUS method divides each hemithorax (left and right sides of the chest) into six distinct regions: anterior, lateral, and posterior zones, both superior and inferior, resulting in a total of 12 zones for evaluation. Each zone is systematically scanned using ultrasound to assess lung aeration.

Scoring criteria

1. **Normal Aeration (Score 0):** Presence of normal lung sliding and A-lines, indicating fully aerated lungs.
2. **Separated B-lines (Score 1):** Mild loss of aeration characterized by discrete B-lines that do not merge and occupy less than 50% of the ultrasound screen.
3. **Coalescent B-lines (Score 2):** Marked loss of aeration with B-lines merging together, occupying more than 50% of the screen.
4. **Consolidation (Score 3):** Complete loss of aeration with tissue-like echotexture and potentially visible dynamic air bronchograms.

The scores from all 12 zones are summed to give a total score, with a maximum possible score of 36 (indicating severe loss of lung aeration across all zones). This scoring system allows for a quantitative assessment of lung aeration and monitoring over time, with higher scores correlating with greater lung injury or de-aeration [Figure 1].

Data collected included age, gender, Charlson Comorbidity Index, ventilator days before SBT, APACHE II score on admission, HACOR score, and LUS after 30 minutes of SBT.

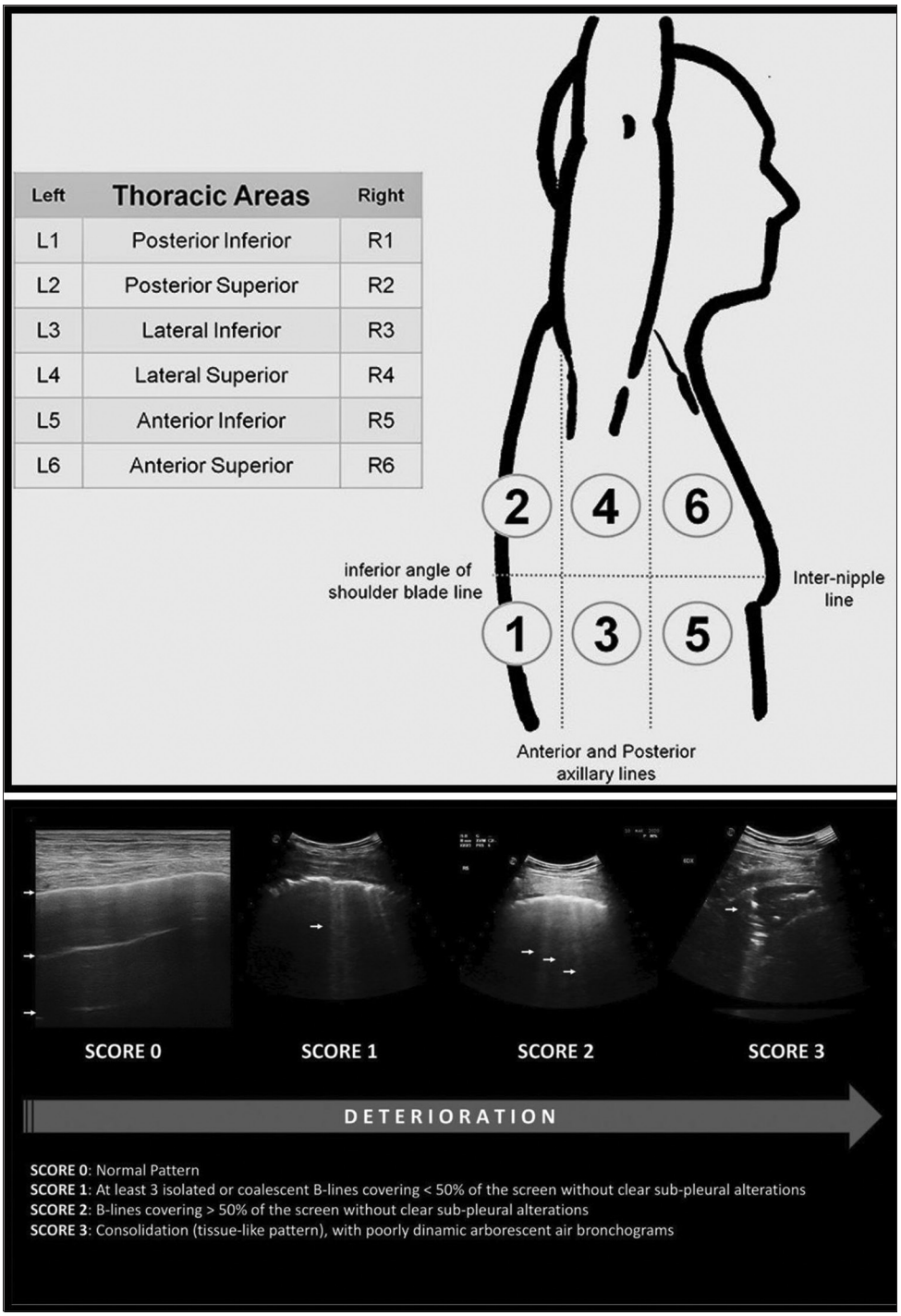

Figure 1: Lung Ultrasound Score

Weaning success or failure was also recorded. Successful weaning was defined as tolerance of a 60-minute SBT, extubation, and no reintubation within 48 hours. Patients who pass the SBT are extubated to non-invasive ventilation (NIV) and gradually weaned off. Failed weaning was defined as failure to complete the SBT, reintubation within 48 hours, or death from respiratory failure. Patients who fail weaning are either returned to pressure control ventilation or reintubated.

Statistical analysis

Data analysis was performed using IBM SPSS Statistics, version 22.0. A *P* value of <0.05 was considered statistically significant and was calculated using the Chi-square test, independent student's *t*-test, and Mann-Whitney U test. For parametric data, mean and standard deviation (SD) were reported, while median and interquartile range (IQR) were used for non-parametric data. Univariate and multivariate analyses examined variables such as age, gender, Charlson

Comorbidity Index (CCI), APACHE II score, ventilator days before SBT, HACOR score, and LUS to predict weaning failure. Odds ratios (OR) were calculated, and a receiver operating characteristic (ROC) curve was plotted to identify the optimal cut-off value for predicting weaning failure.

RESULTS

In this study, 100 consecutive patients who tolerated SBT were enrolled. Out of 100 patients included in the study, 65 (65%) patients were in the successful weaning group, and 35 (35%) had failed weaning (failed SBT at 60 minutes or requiring NIV/reintubation within 48 hours) Among the primary indication respiratory issues (36%), sepsis/septic shock (26%) were the most common [Figure 2].

The successful weaning group had a significantly lower mean age (59.09 yrs vs. 62.22 yrs, $P < 0.05$), fewer ventilator days (median 3 vs. 5.5 days, $P < 0.05$), and a lower CCI (median 2 vs. 6, $P < 0.001$). Additionally, their median APACHE II score on the day of admission was lower (13 vs. 19, $P < 0.001$), and the HACOR score (median 3 vs. 6, $P < 0.001$) and LUS (median 10 vs. 16, $P < 0.001$) were significantly lower in these patients when compared to failed weaning group [Table 1].

Among the failed weaning group ($n = 35$), 14 patients (40%) had respiratory etiology, nine patients (25.7%) had cardiac etiology, and the remaining 12 patients (34.3%) had other conditions. Of those who failed weaning, 32 patients (91.4%) required reintubation, and three patients (8.6%) continued on NIV support. At the end of their ICU stay, 91 patients (91%) survived, while nine patients (25.7%) in the failed weaning group died.

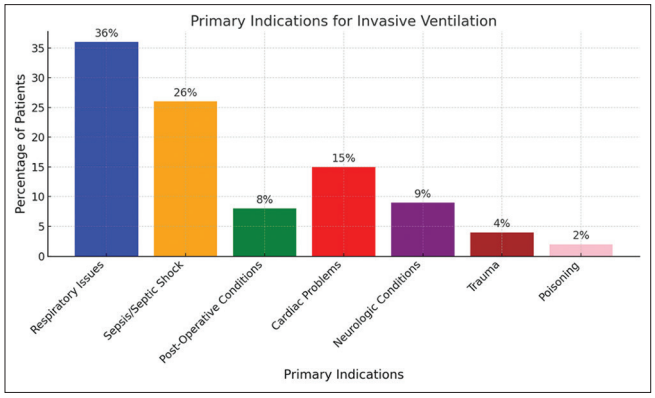

Figure 2: Primary indication for mechanical ventilation

The comparison of HACOR score variables between patients who successfully weaned from MV and those who did not revealed significant differences. The successful weaning group had a higher percentage of patients with a heart rate of ≤120 beats/min (62% vs. 22%, $P < 0.05$). Additionally, a greater proportion of the successful group had arterial blood pH ≥7.35 (58% vs. 18%, $P < 0.05$), a Glasgow Coma Scale score of 15 (55% vs. 8%, $P < 0.05$), and a PaO2/FiO2 ratio of ≥201 (58% vs. 24%, $P < 0.05$). The successful group also had a significantly higher percentage of patients with a RR of ≤30 (64% vs. 2%, $P < 0.05$). All variables showed statistically significant differences between the groups [Table 2].

Univariate analysis of age, gender, CCI, days of ventilator support before SBT, APACHE II score on the day of admission, HACOR score, and LUS to predict failed weaning showed that age ($P < 0.05$), days of ventilator support before SBT ($P < 0.05$)), CCI ($P < 0.001$), APACHE II ($P < 0.001$), HACOR score ($P < 0.001$), and LUS ($P < 0.001$) were significant [Table 3]. Multivariable logistic regression analysis was performed for the variables which showed statistical significance in the univariate analysis [Table 3]. It showed that age, duration of ventilator support before SBT, CCI, APACHE II score on the day of admission, HACOR score, and LUS at the end of 30 minutes of SBT were a significant predictor of failed weaning ($P < 0.05$) [Table 3].

ROC analysis evaluated the predictive performance of the HACOR score and LUS for weaning failure. The HACOR score had an AUC of 0.824, with a sensitivity of 87.7% and specificity of 77.1% at a threshold of ≥5 (95% CI: 0.766–0.882, $P < 0.05$). The LUS showed an AUC of 0.831, with a sensitivity of 86.2% and specificity of 80% at a threshold of ≥13 (95% CI: 0.817–0.918, $P < 0.05$). Both scores demonstrated similar predictive accuracy, suggesting they are equally useful in weaning strategies [Figure 3].

DISCUSSION

In our study, we identified several key factors that predict weaning failure in critically ill patients, reinforcing the idea that a combination of clinical variables and scores can help clinicians assess the likelihood of successful

Table 1: Comparison of demographic and severity of illness between two groups

Variables	Successful weaning group (*n*=65)	Failed weaning group (*n*=35)	*P*
Gender [Male]	(*n*=42)	(*n*=26)	0.9436
Age (Years) [Mean±SD]	59.09±6.31	62.22±6.21	<0.05
Ventilator days [Median (IQR)]	3 (0–3)	5.5 (4–6)	<0.05
Charlson Comorbidity Index [Median (IQR)]	2 (0–2)	6 (4–7)	<0.001
Apache II Score on day of admission [Median (IQR)]	13 (10–13)	19 (16–19)	<0.001
HACOR score [Median (IQR)]	3 (0–3)	6 (5–8)	<0.001
Lung Ultrasound Score [Median (IQR)	10 (8–10)	16 (13–16)	<0.001

SD=Standard deviation, IQR=Interquartile range

Table 2: Individual variables in the HACOR score (HR, PH, GCS, PAO2/FIO2, RR) as a predictor of weaning

Variables	HACOR score	Successful weaning group *n*=65 (65%)	Failed weaning group *n*=35 (35%)	*P*
Heart rate (beats/min)	0 (≤120)	62%	22%	<0.05
	1 (≤121)	3%	13%	
pH (arterial blood)	0 (≥7.35)	58%	18%	<0.05
	2 (7.30–7.34)	4%	13%	
	3 (7.25–7.29)	3%	2%	
	4 (<7.25)	0	2%	
Glasgow Coma	0 (GCS–15)	55%	8%	<0.05
Scale (GCS)	2 (GCS – 13–14)	7%	22%	
	5 (GCS – 11–12)	2%	4%	
	10 (GCS – ≤10)	1%	1%	
Pao2/Fio2 ratio	0 (≥201)	58%	24%	<0.05
	2 (176–200)	4%	6%	
	3 (151–175)	3%	2%	
	4 (126–150)	0	1%	
	5 (101–125)	0	1%	
	6 (≤100)	0	1%	
Respiratory rate (per	0 (≤30)	64%	2%	<0.05
Minute)	1 (31–35)	1%	12%	
	2 (36–40)	0	20%	
	3 (41–45)	0	1%	
	4 (≥46)	0	0	

Table 3: Logistic regression analyses of predictors of weaning

Variables	Univariate analysis Odds ratio (OR) [95% CI] *P*	Multivariate logistic regression. Adjusted OR [95%] *P*
Age (Years)	1.05 [1.02–1.08] <0.05	1.05 [1.02–1.08] 0.003
Ventilator days	1.10 [1.02–1.19] <0.05	1.12 [1.03–1.22] 0.015
Charlson Comorbidity Index	1.30 [1.20–1.40] <0.001	1.38 [1.23–1.54] <0.001
APACHE II score on the day of admission	1.15 [1.10–1.20] <0.001	1.14 [1.09–1.19] <0.001
HACOR score	1.25 [1.15–1.35] <0.001	1.24 [1.12–1.37] 0.002
Lung Ultrasound Score	1.20 [1.10–1.30] <0.001	1.22 [1.11–1.34] 0.001

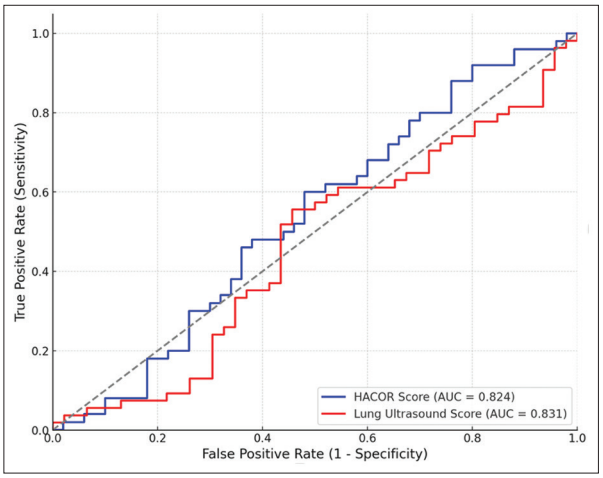

Figure 3: RoC curve for HACOR score and Lung Ultrasound Score

extubation. We defined weaning failure as the inability to pass a SBT, the need for reintubation within 48 hours, or death due to respiratory compromise. Reintubation, in particular, is a strong predictor of mortality, with hospital mortality rates exceeding 30%. These findings align with those of the previous studies which identified age, comorbidities, and disease severity as major predictors of extubation failure.[9]

Both the HACOR score and lung ultrasound scores were identified as strong predictors of weaning outcomes. The HACOR score, which incorporates heart rate, arterial blood pH, GCS, PaO2/FiO2 ratio, and RR, was significantly higher in the failed weaning group, underscoring its reliability in predicting weaning failure. While this score has been validated in multiple studies as a valuable tool for clinicians in assessing the likelihood of NIV failure, only one study to date has validated the HACOR score as a predictor of weaning failure from MV in resource-limited settings.[10] Our findings further confirm that the HACOR score is a dependable predictor of weaning failure and can be effectively integrated into weaning strategies in clinical practice. Though the HACOR score is that it is a simple tool and the major disadvantage of the HACOR score is that it does not consider other clinical factors such as underlying diseases (e.g., pneumonia, sepsis), which can influence outcomes.

Lung ultrasound scores, reflecting lung aeration, were also significantly higher in the failed weaning group. Lung ultrasound, a non-invasive tool, effectively detects conditions such as alveolar consolidation or atelectasis, which can impair successful weaning. This finding aligns with studies by Soldati *et al*.,[11] who demonstrated the utility of lung ultrasound in predicting weaning outcomes by assessing lung aeration. Physiological parameters that can alter the LUS include oxygenation status (e.g., PaO_2/FiO_2 ratio), where worsening oxygenation correlates with higher LUS due to reduced lung aeration.

Respiratory distress severity increases B-lines or consolidations on ultrasound. MV settings, such as CPAP, improve or worsen aeration, directly reflected in LUS. Additionally, pleural effusions and hemodynamic changes like fluid overload can compress lung tissue, increasing LUS. These factors highlight LUS's sensitivity to physiological and clinical changes.

Among the most prominent predictors of weaning failure in our study were older age, prolonged ventilator duration, a higher CCI, and elevated APACHE II scores. Older age, especially over 65 years, is widely recognized as a risk factor for weaning failure. This association is likely due to age-related declines in respiratory muscle function, reduced physiological reserve, and a higher incidence of comorbidities that complicate recovery. These factors limit a patient's ability to adapt to the stresses imposed by MV and hinder successful extubation.

The primary indications for initiating MV in our study included respiratory causes (36%), sepsis/septic shock (26%), postoperative reasons (8%), cardiac causes (15%), neurologic conditions (9%), trauma (4%), and poisoning (2%). These patterns reflect common ICU conditions requiring MV. Khalil *et al*.[12] reported similar findings, with respiratory failure and sepsis being the leading causes of MV. Sepsis, in particular, is associated with increased morbidity and mortality, complicating the weaning process due to multi-organ failure and VAP.

The relationship between prolonged ventilator days and weaning failure is well-documented.[13] Longer durations of MV increase the risk of complications such as VAP, diaphragmatic weakness, and respiratory muscle fatigue, all of which hinder the weaning process. Prolonged intubation weakens respiratory muscles and impairs the ability to sustain spontaneous breathing, which contributes to weaning failure. Studies consistently show that patients with extended MV are less likely to successfully wean off the ventilator and have a higher mortality risk.

The CCI, which reflects the burden of comorbid conditions, was another distinguishing factor between the successful and failed weaning groups in our study. Although some studies have questioned the role of CCI in predicting weaning outcomes.[14] Our findings indicate that a higher CCI is associated with an increased risk of weaning failure. The compounded impact of cardiovascular, renal, and metabolic disorders in patients with high CCI may impair recovery and hinder spontaneous breathing during weaning from MV.

APACHE II scores, which assess disease severity and predict ICU mortality, also significantly differed between the two groups, further validating their utility as seen with the previous studies in predicting weaning outcomes.[15] Elevated APACHE II scores reflect greater physiologic instability and organ dysfunction, which likely contribute to an inability to sustain spontaneous breathing after extubation. The APACHE II score is a comprehensive measure of disease severity and is widely used to assess the likelihood of weaning failure.

Physiological variables such as heart rate, arterial blood pH, Glasgow Coma Scale (GCS) scores, and the PaO2/FiO2 ratio also played significant roles in predicting weaning success. Tachycardia, which was more frequent in the failed weaning group, signals increased metabolic demand and cardiovascular stress, both of which are associated with difficulty weaning from MV. Elevated heart rates may indicate issues such as poor circulatory status, metabolic acidosis, or respiratory distress, which complicate the weaning process. This finding aligns with studies by Coplin *et al*. and Jubran and Tobin, who identified tachycardia and heart rate variability as predictors of weaning failure.[16,17]

The difference in arterial blood pH between the two groups suggests that acid-base imbalances, particularly metabolic acidosis, are important predictors of weaning failure. Metabolic acidosis impairs respiratory muscle function and oxygen delivery, both of which are essential for successful extubation. The previous studies by Gonzalez *et al*. and Poddighe *et al*. have also highlighted the link between acid-base disturbances and weaning failure.[18,19] Metabolic acidosis, often resulting from sepsis, renal failure, or lactic acidosis, can decrease the body's capacity for adequate gas exchange and make successful extubation more challenging.

The GCS scores further emphasize the role of neurological status in weaning success. Lower GCS scores, which reflect impaired consciousness and a reduced ability to protect the airway, were associated with higher weaning failure rates. This finding is consistent with previous research by Roca *et al.* and Cheng *et al.*, who showed that impaired consciousness and airway protection contribute to weaning failure.[20,21] Patients with low GCS scores often struggle to initiate spontaneous breathing and may be at risk for aspiration, which can lead to reintubation.

Our study also found significant differences in the PaO2/FiO2 ratio between the successful and failed weaning groups. A lower PaO2/FiO2 ratio indicates impaired oxygenation, which is a well-established predictor of weaning failure. Our findings are in line with studies by Roca *et al.* and Goyal *et al*., who demonstrated a strong association between low PaO2/FiO2 ratios and poor weaning outcomes.[22,23] Patients with low oxygenation are more likely to experience respiratory compromise following extubation, leading to the need for reintubation.

The RR was significantly higher in the failed weaning group. An elevated RR reflects increased work of breathing and may indicate respiratory muscle fatigue, complicating the weaning process. This finding supports the work of Lambiase *et al.*, who showed that an increased RR is associated with weaning failure, suggesting that patients

are unable to maintain adequate ventilation without mechanical support.[24]

The study compared the predictive utility of the HACOR and LUS for weaning outcomes and explored associations with factors like APACHE II, CCI, ventilator days, and HACOR components. While these exploratory findings highlight the interplay of disease severity and comorbidities in weaning, they were not pre-specified or statistically powered, warranting cautious interpretation. Despite this, the insights offer a hypothesis-generating foundation for future research. Larger, rigorously designed studies are needed to validate these findings and optimize clinical decision-making.

CONCLUSION

Both the HACOR score and the LUS are highly sensitive and reliable for predicting weaning outcomes from MV. The HACOR score, with a threshold of ≥5 for failure, and the LUS, with a threshold of ≥13 for failure, demonstrate strong predictive performance. However, the widespread use of LUS is limited by high costs, the need for specialized training, and patient-related factors. In contrast, the HACOR score's simplicity and applicability across diverse healthcare settings make it a practical tool for predicting weaning outcomes, complementing ultrasound-based assessments.

Limitations of the study

Single-center study, underpowered exploratory analyses.

Abbreviations

ABG = Arterial Blood Gas.
LUS = Lung Ultrasound Score.
SBT = Spontaneous Breathing Trail.

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Conflicts of interest

There are no conflicts of interest.

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