Postprint: Development and Application of a Cardiac Arrest Risk Prediction Model for Mechanically Ventilated ICU Patients

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Abstract

Objective To investigate the factors influencing cardiac arrest risk and establish a Logistic regression prediction model. Methods A total of 238 patients receiving mechanical ventilation admitted to the hospital from September 2019 to January 2020 were selected as study subjects. Various factors were compared between the cardiac arrest group (n=72) and the non-cardiac arrest group (n=166). A risk prediction model was established through Logistic regression analysis, and the predictive efficacy of the model was evaluated using ROC curve analysis. Results This study incorporated six influencing factors to construct the risk prediction model: arrhythmia, hypoxemia, acid-base imbalance, septic shock, history of cardiac arrest, and multiple organ dysfunction syndrome. The area under the ROC curve was 0.909. At the optimal cutoff value of 0.343, the sensitivity was 0.819 and the specificity was 0.855. Conclusion This model demonstrates favorable predictive performance and is applicable to clinical practice. Application of this model in mechanically ventilated patients can provide reference for clinical healthcare professionals to implement timely preventive management measures.

Full Text

The Development and Application of a Risk Prediction Model for Cardiac Arrest in ICU Patients with Mechanical Ventilation

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Abstract

Objective: To investigate the risk factors for cardiac arrest and establish a logistic regression prediction model for cardiac arrest in mechanically ventilated ICU patients.

Methods: A convenience sample of patients undergoing mechanical ventilation in a tertiary hospital ICU were selected from September [year] to January [year]. Patients were divided into a cardiac arrest group (n=[number]) and a non-cardiac arrest group (n=[number]). Multiple clinical indicators were compared between groups. Logistic regression analysis was used to construct a risk prediction model, and the model's predictive performance was evaluated using ROC curve analysis.

Results: The study ultimately included arrhythmia, hypoxemia, acid-base imbalance, septic shock, history of cardiac arrest, and multiple organ dysfunction syndrome (MODS) as factors to construct the risk prediction model. The area under the ROC curve was [value]. When the optimal cutoff value was [value], the sensitivity was [value] and the specificity was [value].

Conclusion: This prediction model demonstrates good predictive performance and is suitable for clinical practice. Application of this model in mechanically ventilated patients can provide clinical staff with a reference for timely implementation of preventive management measures.

Keywords: ICU; mechanical ventilation; cardiac arrest; prediction

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Introduction

Cardiac arrest refers to the sudden cessation of cardiac ejection function, disappearance of arterial pulsation, and cessation of respiration and circulation, with high fatality rates. A domestic study [1] showed that the rate of return of spontaneous circulation after resuscitation is only [value]%. Mechanical ventilation is a therapeutic measure that uses mechanical assistance to improve respiratory failure in critically ill patients. However, mechanically ventilated patients often have low resistance and complications such as electrolyte and acid-base balance disturbances. Foreign studies [2] have shown that mechanical ventilation is an independent predictor of patient mortality. Previous research [3] has used mortality risk factors in mechanically ventilated patients as an important basis for healthcare providers to implement interventions and assess prognosis, aiming to improve survival rates. Therefore, it is necessary to actively explore prediction tools that align with the characteristics of cardiac arrest in mechanically ventilated patients to help healthcare providers assess risk and implement preventive treatments in advance, thereby reducing the incidence of cardiac arrest. Currently, however, there are few studies on risk prediction models for cardiac arrest specifically in mechanically ventilated patients. This study aims to construct a risk prediction model for cardiac arrest in this population to provide a basis for predicting and managing cardiac arrest risk.

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1. Materials and Methods

1.1 Participants

Using convenience sampling, we investigated patients admitted to the ICU of a tertiary hospital who underwent mechanical ventilation. Inclusion criteria: age [value] years; mechanical ventilation time > [value] hours. Exclusion criteria: incomplete medical records. A total of [value] mechanically ventilated patients were enrolled, including [value] males ([value]%) and [value] females ([value]%), with ages ranging from [value] to [value] years and a mean age of ($x \pm s$) years. Among them, [value] patients experienced cardiac arrest.

1.2 Data Collection

Inclusion of influencing factors: The selection of influencing factors was primarily based on the Acute Physiology and Chronic Health Evaluation System II (APACHE II) assessment content. Through literature review [4-6] and research team discussion, we ultimately identified the following influencing factors for cardiac arrest in mechanically ventilated patients: age, mean arterial pressure, arrhythmia, respiratory abnormalities, hypoxemia, acid-base imbalance, electrolyte disturbances, hematocrit abnormalities, septic shock, history of cardiac arrest, diabetes, and multiple organ dysfunction syndrome (MODS). Cardiac arrest occurrence was used as the dependent variable, with the above factors as independent variables for data collection.

Measurement standards for influencing factors: Data collection began after patients were admitted to the ICU and continued until cardiac arrest occurred (at which point assessment stopped) or until ICU discharge if no cardiac arrest occurred. Research staff received unified training on data collection timing, meaning of different influencing factors and their classifications, judgment criteria, and recording methods. A total of [value] nurses participated in data collection.

Specific measurement criteria included [7-9]:
- **Arrhythmia:** Any abnormality in heart rate or rhythm, including heart rate > [value] beats/min or < [value] beats/min (frequency abnormalities), and Cheyne-Stokes respiration or intermittent breathing (rhythm abnormalities).
- **Mean arterial pressure (MAP):** Calculated as MAP = (systolic pressure + 2 × diastolic pressure)/3.
- **Hypoxemia:** Arterial partial pressure of oxygen (PaO_2) < [value] mmHg.
- **Electrolyte disturbances:** Plasma sodium concentration normal value [value] mmol/L, potassium normal value [value] mmol/L, calcium [value] mmol/L; values outside these ranges were considered abnormal.

- **Hematocrit:** Normal values: male [value]%, female [value]%; values outside these ranges were considered abnormal.

1.3 Statistical Methods

SPSS software was used for statistical analysis. Measurement data were expressed as mean ± standard deviation (x ± s) and compared between groups using t-tests. Count data were expressed as frequency and percentage (%) and compared using ^{2} tests. Logistic regression was used to construct the risk prediction model, and ROC curve analysis was performed to evaluate model predictive performance.

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2. Results

2.1 Single-Factor Analysis of Cardiac Arrest Occurrence

Patients were divided into cardiac arrest group (n=[value]) and non-cardiac arrest group (n=[value]) based on whether cardiac arrest occurred. To avoid missing potentially meaningful factors in multivariate analysis, factors with P < [value] in single-factor analysis were considered statistically significant. Results showed statistically significant differences between groups in arrhythmia, septic shock, hypoxemia, MODS, acid-base imbalance, hematocrit abnormalities, diabetes, and history of cardiac arrest (P < [value]) .

2.2 Multivariate Analysis of Cardiac Arrest Risk

Using factors with statistical significance in single-factor analysis as independent variables and cardiac arrest occurrence as the dependent variable, logistic regression analysis was performed with the following assignments: arrhythmia (0=absent, 1=present), MODS (0=absent, 1=present), hypoxemia (0=absent, 1=present), hematocrit abnormalities (0=absent, 1=present), acid-base imbalance (0=absent, 1=present), diabetes (0=absent, 1=present), history of cardiac arrest (0=absent, 1=present). The logistic regression results are shown in . The analysis revealed that arrhythmia, septic shock, hypoxemia, MODS, acid-base imbalance, and history of cardiac arrest were independent risk factors for cardiac arrest in mechanically ventilated patients.

The final regression equation was: Probability of cardiac arrest (P) = e /(1 + e), where e is the natural logarithm base, and X = -[value] + [value] × (arrhythmia assignment) + [value] × (septic shock assignment) + [value] × (MODS assignment) + [value] × (hypoxemia assignment) + [value] × (acid-base imbalance assignment) + [value] × (history of cardiac arrest assignment).

2.3 Evaluation of the Predictive Model for Cardiac Arrest Risk

ROC curve analysis was used to evaluate the predictive performance of the cardiac arrest risk model. The point corresponding to the maximum Youden index was taken as the optimal cutoff value [10]. The area under the ROC curve (AUC) was [value], with a maximum Youden index of [value]. The optimal cutoff value was [value], with sensitivity of [value] and specificity of [value] [Figure 1: see original paper].

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3. Discussion

3.1 Significance of Constructing a Cardiac Arrest Risk Prediction Model

The incidence of cardiac arrest is high among mechanically ventilated ICU patients, with high fatality rates, indicating the importance of early assessment and prevention before cardiac arrest occurs. Previous studies on cardiac arrest risk have focused on risk factors, prognosis, and early intervention, but few have developed prediction models specifically for mechanically ventilated patients. This gap limits efforts to reduce in-hospital mortality in this population.

The construction of this cardiac arrest risk prediction model shifts the focus of healthcare providers from post-arrest resuscitation to purposeful preventive interventions beginning at ICU admission. This prediction model intuitively presents the relationship between cardiac arrest-related risk factors and cardiac arrest occurrence in a formula, enabling healthcare providers to identify potential risks. The model can guide targeted interventions for high-risk patients, such as correcting hypoxemia and acid-base imbalances, thereby reducing mortality, improving prognosis and quality of life, and enhancing healthcare efficiency.

3.2 Analysis of Risk Factors in the Cardiac Arrest Prediction Model

Patients with cardiopulmonary insufficiency are prone to cardiac arrest: This study showed statistically significant differences in arrhythmia and hypoxemia ($P <$ [value]), indicating that more severe cardiopulmonary function impairment is associated with higher mortality risk, consistent with previous research [11]. Patients requiring mechanical ventilation often have severe hypoxemia. While mechanical ventilation is an effective treatment for respiratory and heart failure, it can stimulate tracheal and alveolar epithelial cells, promoting inflammatory factor release and systemic inflammatory response syndrome, while also decreasing cardiac output [12]. Therefore, healthcare providers should assess cardiopulmonary function, monitor cardiac rhythm and oxygen content changes, and promptly correct arrhythmias and hypoxemia.

Patients with septic shock are prone to cardiac arrest: The risk of cardiac arrest in patients with septic shock was [value] times higher than in those without (OR = [value]), likely related to severe pulmonary infections. Research [13] shows that mortality from septic shock is as high as [value]%. ICU patients are critically ill with low resistance, and mechanical ventilation increases the risk of ventilator-associated pneumonia (VAP), prolonging hospital stay and increasing mortality [14]. Therefore, healthcare providers should closely monitor temperature changes in mechanically ventilated patients, actively prevent and manage VAP, and prevent septic shock.

Patients with multiple organ dysfunction syndrome are prone to cardiac arrest: The incidence of MODS is [value]% with a mortality rate of [value]%. Infection, shock, trauma, post-cardiopulmonary resuscitation, and severe pancreatitis are major causes of MODS, with studies showing high mortality after MODS development [15]. Barie et al. [16] found that MODS mortality accounts for [value]% of total ICU mortality. This study showed that mechanically ventilated patients with MODS had [value] times higher cardiac arrest risk (OR = [value]), consistent with domestic and international reports. Research [17] shows that lung infection accounts for [value]% of primary infections causing MODS. Lyu et al. [18] found that MODS mortality was highest when the lungs were involved. Therefore, strengthening monitoring of organ function, especially pulmonary function, and early prevention of MODS are key to reducing cardiac arrest incidence.

Patients with acid-base imbalance are prone to cardiac arrest: Studies [19] show that respiratory acidosis is the most common acid-base imbalance in mechanically ventilated patients, primarily manifesting as hypoxia and carbon dioxide retention. Li [20] reported respiratory acidosis accounted for [value]% of acid-base imbalance types, while this study found [value]%, consistent with literature reports. Acid-base imbalance affects the central nervous system and causes electrolyte disturbances, leading to weakened myocardial contraction, decreased ejection fraction, and cardiac arrest. Additionally, improper ventilator settings can cause inadequate ventilation or hyperventilation, worsening acid-base imbalance and increasing mortality [21]. Therefore, healthcare providers should strengthen monitoring of internal environment, adjust ventilator parameters promptly, and maintain stable internal environment.

Patients with history of cardiac arrest are prone to cardiac arrest: Patients successfully resuscitated from cardiac arrest still have high mortality and often develop post-resuscitation syndrome, including organ dysfunction and brain injury [22], indicating ongoing cardiac arrest risk. This study showed that history of cardiac arrest is a risk factor (OR = [value]). Therefore, implementing effective intervention plans based on the cause of previous cardiac arrest is important for preventing recurrence.

3.3 Predictive Performance of the Cardiac Arrest Risk Prediction Model

This study used ROC curve analysis to evaluate model fit. An AUC > [value] indicates good predictive value [23]. This study's AUC was [value], demonstrating excellent discriminatory ability for predicting cardiac arrest in mechanically ventilated patients. The optimal cutoff value was [value], with sensitivity of [value] and specificity of [value], indicating ideal predictive performance.

Hematocrit abnormalities and diabetes showed statistical significance in single-factor analysis but were not included in the final model, possibly due to study design, individual differences, inconsistent hematocrit levels, or uneven group sizes reducing statistical power for certain risk factors, potentially introducing bias.

3.4 Clinical Application Recommendations

This model can be used to assess cardiac arrest risk factors when mechanically ventilated patients are admitted to the ICU. For patients ventilated > [value] hours, healthcare providers can collect the most recent blood gas analysis results when the patient's condition deteriorates to complete risk assessment. When the score ≥ [value], it indicates high probability of cardiac arrest, necessitating systematic evaluation of the patient's condition and causes, with targeted interventions to prevent cardiac arrest. Additionally, when risk factors directly or indirectly related to the model change, assessment frequency should be increased and interventions implemented promptly to remove these risk factors.

In summary, this study constructed a cardiac arrest risk prediction model for mechanically ventilated patients that can be used throughout hospitalization. The influencing factors are easily and quickly obtainable, and the model has good predictive value, providing a reference for risk assessment and clinical prevention. However, some influencing factors had low incidence and small sample sizes, potentially causing bias. Moreover, this study lacked clinical validation, and the model's actual predictive ability requires further verification.

Conflict of Interest Statement: The authors declare no conflicts of interest.

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Note: Figure translations are in progress. See original paper for figures.