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Article

Predictive Role of Preoperative Controlled Nutritional Status Score on Prolonged Mechanical Ventilation after Heart Valve Surgery

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Abstract

Background: Postoperative prolonged mechanical ventilation (MV) in patients with heart valve disease (HVD) is usually concomitant with poor prognosis. Its relationship with preoperative nutritional status still remains unclear. The present study intends to explore the influence of preoperative controlled nutritional status (CONUT) score on early postoperative outcomes and its predictive role in prolonged MV. **Methods**: HVD patients receiving cardiac surgeries in our department from January 2022 to December 2023 were retrospectively selected. CONUT score was calculated according to the level of serum albumin, total cholesterol and lymphocyte counts. When the CONUT score was greater than or equal to 3, patients were included in high CONUT group, and the other patients were included in low CONUT score group. Propensity score matching (PSM) was used to adjust baseline characteristics. **Results**: A total of 411 patients were included, of which 129 patients had the preoperative CONUT score greater than or equal to 3 points, accounting for 31.4%. After adjustment at a ratio of 1:2, 103 patients were included in high CONUT group while 206 patients were included in low CONUT group. The incidence of postoperative ventilator associated pneumonia (VAP) in high CONUT group was significantly higher than that in low CONUT group ($p = 0.039$). Length of ICU stay showed up a significant extension in high CONUT group compared with low CONUT group ($p = 0.041$). Significantly prolonged MV time could be observed in high CONUT group compared with low CONUT group ($p = 0.022$). The proportion of patients receiving MV over 48 h and 72 h in high CONUT group significantly increased ($p = 0.020$ and 0.009 respectively) except for MV over 24 h. MV time of all patients was found to be significantly correlated with CONUT score ($r = 0.186$, $p = 0.001$). The area under the curve (AUC) for CONUT predicting MV >48 h was 0.625 ($p = 0.008$), with sensitivity of 0.419 and specificity of 0.808. The AUC for CONUT predicting MV >72 h was 0.691 ($p = 0.003$), with sensitivity of 0.545 and specificity of 0.801. **Conclusions**: Preoperative CONUT score had an accurate predictive role of postoperative prolonged MV and early poor prognosis in HVD patients, which deserves much attention to improve clinical outcomes.

Keywords

controlled nutritional status; heart valve surgery; prolonged mechanical ventilation; nutritional status

Introduction

At present, there are about 209 million heart valve disease (HVD) patients in the world and an estimated 25 million HVD patients in China, of which 55.1% are rheumatic and 21.3% are degenerative [1]. Despite the rapid development of interventional valve techniques, cardiopulmonary bypass (CPB) surgery is still the main treatment for HVD. Postoperative mechanical ventilation (MV) is needed to help patients recover cardiopulmonary function. However, it has been reported that up to 22.7% of patients are difficult to wean from ventilator after cardiac surgery due to either cardiac or noncardiac problems [2]. Prolonged MV can lead to diaphragm and lung injuries, such as infection or atelectasis, contributing to increased morbidity and mortality and healthcare costs following surgery [3,4]. Therefore, early identification of risk factors for prolonged intubation is important to promote early extubation, reduce the occurrence of pulmonary complications and improve prognosis.

Patients with HVD usually have some element of malnutrition. Preoperative malnutrition is an important factor affecting the clinical outcome of surgical patients. Malnourished patients suffer from impaired immune response and reduced tolerance to surgery, which will not only lead to delayed wound healing and an increased risk of postoperative complications, but also prolong the length of hospital stay [5,6]. For HVD patients, poor nutritional status may be related to increased pulmonary complications, thus prolonging MV time. However, it still needs to be confirmed by clinical researches. To date, a variety of scales have been developed to evaluate the nutritional status of patients, of which controlled nutritional status (CONUT) score has received increased attention. The CONUT score is a comprehensive indicator of nutritional status calculated based on serum albumin, total cholesterol and lymphocyte counts. This score shows superior efficacy in predicting

disease prognosis, and provides a more accurate picture of nutrition and the inflammatory response compared to other scores [7,8]. Nevertheless, there is limited evidence of its application in patients undergoing cardiac surgery.

In the present study, HVD patients after cardiac surgery with CPB were retrospectively studied. Using propensity score matching (PSM) to adjust baseline characteristics, we intend to explore the influence of preoperative CONUT score on early postoperative outcomes and its predictive role in prolonged MV.

Materials and Methods

Patients Selection

This retrospective study was carried out in a tertiary general hospital in southwestern China. HVD patients receiving cardiac surgeries in our department from January 2022 to December 2023 were selected. Inclusion criteria: (1) adult patients over 18 years old; (2) patients were diagnosed with HVD preoperatively by echocardiography; (3) valve replacement or valvuloplasty was performed under CPB; (4) patients received MV support after HVD surgery. Exclusion criteria: (1) coronary artery bypass grafting surgery or aortic surgery was performed at the same time; (2) patients had pulmonary infection preoperatively; (3) patients were supported with MV preoperatively; (4) clinical data was incomplete. All patients gave informed consent and the study complied with the Declaration of Helsinki.

Data Collection

Clinical data were collected through the electronic medical record system. Preoperative data included age, gender, body mass index (BMI), smoking, left ventricular ejection fraction (LVEF), New York Heart Association (NYHA) cardiac function class, chronic bronchitis, serum albumin (Alb), total cholesterol (TC) and lymphocyte counts. Intraoperative data included CPB time and aortic clamping time. Postoperative data included 24-h drainage (including pericardial and mediastinal drainage), intra-aortic ballon pump (IABP) support, continuous renal replacement therapy (CRRT) support, ventilator associated pneumonia (VAP), length of intensive care unit (ICU) stay, total length of stay, in-hospital death, MV time and reintubation.

CONUT Score

Fasting venous blood was collected from all patients the next day after admission, and the CONUT score was calculated according to the level of Alb, TC and peripheral blood lymphocytes [9]. (1) Alb level: $>$3.5, between 3.0 and 3.49, between 2.5 and 2.99, $<$2.5 g/dL was scored 0, 2, 4, 6 points respectively; (2) TC level: $>$180, between 140 and 179, between 100 and 139, $<$100 mg/dL was scored 0, 1, 2, 3 points respectively; (3) lymphocytes level: $>$1600, between 1200 and 1599, between 800 and 1199, $<$800/mm^3 was scored 0, 1, 2, 3 respectively. The sum of these three indices was the final score. The total score was 0–12, with higher scores indicating worse nutritional status. When the CONUT score was greater than or equal to 3, patients were included in the high CONUT group, and the other patients were included in the low CONUT score group.

Statistical Analysis

SPSS software v25.0 (IBM corporation, Armonk City, NY, USA) and R software v4.3.2 (R Foundation for Statistical Computing, Vienna City, Austria) were used to perform statistical analysis. PSM was used to minimize deviations between groups. Patients were matched by using the "nearest" approach at a ratio of 1:2 to balance the baseline characteristics with caliper of 0.2. Normality of measurement data was evaluated by the Kolmogorov-Smirnov test. Normally distributed data were expressed as the mean $\pm$ standard deviation, while abnormally distributed data were expressed as the median (P_{25}, P_{75}). Comparisons between groups were analyzed by t tests or the Mann Whitney U test respectively. The Chi-square test was used to compare enumeration data between groups. Correlation analysis was performed by using Spearman's correlation coefficient. We plotted a receiver operating characteristic (ROC) curve to visually represent the predictive ability, by calculating the area under the curve (AUC). A two tailed p value < 0.05 was considered to indicate statistical significance.

Results

Clinical Baseline Characteristics

A total of 411 patients met the inclusion and exclusion criteria, of which 129 patients had a preoperative CONUT score greater than or equal to 3 points, accounting for 31.4%. Age, male, BMI, smoking, LVEF $<$40%, NYHA grading IV, chronic bronchitis, CPB time and aortic clamping time were used as variables for balancing and matching groups for PSM. After adjustment at a ratio of 1:2, 103 patients were included in the high CONUT group while 206 patients were included in the low CONUT group. Clinical characteristics of the included patients after PSM were shown in Table 1.

Influence of Preoperative CONUT Score on Early Postoperative Clinical Outcome

As Table 2 showed, the incidence of postoperative VAP in the high CONUT group was significantly higher than that in the low CONUT group (p = 0.039). Length of ICU stay was significantly increased in the high CONUT

Table 1. Clinical characteristics of included patients before and after PSM.

	Before PSM			After PSM		
	High CONUT group (n = 129)	Low CONUT group (n = 282)	*p* value	High CONUT group (n = 103)	Low CONUT group (n = 206)	*p* value
Age (y)	61.2 ± 6.3	62.7 ± 6.1	0.023*	61.4 ± 6.7	62.5 ± 5.9	0.141
Male	23	49	0.911	21	45	0.768
BMI (kg/m^2)	22.1 ± 4.7	22.6 ± 4.3	0.289	22.4 ± 4.5	22.2 ± 4.0	0.692
Smoking	18	31	0.390	16	26	0.481
LVEF <40%	5	27	0.045*	5	17	0.274
NYHA grading IV	10	29	0.416	9	17	0.885
Chronic bronchitis	7	14	0.843	6	10	0.717
CPB time (min)	113.6 ± 17.4	118.3 ± 18.9	0.017*	113.9 ± 15.5	117.8 ± 19.3	0.075
Aortic clamping time (min)	67.9 ± 12.5	69.1 ± 15.2	0.434	67.3 ± 12.4	68.5 ± 14.6	0.475

PSM, propensity score matching; COUNT, control nutritional status score; BMI, body mass index; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; CPB, cardiopulmonary bypass.

* indicates difference is significant.

Table 2. Comparison of early postoperative clinical outcome between two groups.

	High CONUT group (n = 103)	Low CONUT group (n = 206)	*p* value
24-h drainage (mL)	193.5 (110.0–304.7)	201.3 (93.5–331.0)	0.331
IABP support	15	20	0.204
CRRT support	12	19	0.503
VAP	10	8	0.039*
Length of ICU stay (d)	3.5 (2.0–6.0)	2.0 (1.5–5.5)	0.041*
Total length of stay (d)	20.5 (18.0–24.5)	19.0 (17.5–22.0)	0.196
In-hospital death	2	2	0.859

COUNT, control nutritional status score; IABP, intra-aortic ballon pump; CRRT, continuous renal replacement therapy; VAP, ventilator associated pneumonia; ICU, intensive care unit.

* indicates difference is significant.

group compared with the low CONUT group (p = 0.041). There was no significant difference in 24-h drainage, IABP support, CRRT support, total length of stay and in-hospital death between the two groups.

Influence of Preoperative CONUT Score on Postoperative MV

As Table 3 showed, a significantly prolonged MV time could be observed in the high CONUT group compared with the low CONUT group (p = 0.022). The proportion of patients receiving MV over 48 h and 72 h in the high CONUT group was significantly increased (p = 0.020 and 0.009 respectively) except for MV over 24 h. The comparison of re-intubation between the two groups was not significantly different. MV time of all patients was found to be significantly correlated with the CONUT score (r = 0.186, p = 0.001, Fig. 1A). The AUC for CONUT predicting MV >48 h was 0.625 (p = 0.008, Fig. 1B), with a sensitivity of 0.419 and specificity of 0.808. The AUC for CONUT predicting MV >72 h was 0.691 (p = 0.003, Fig. 1C), with sensitivity of 0.545 and specificity of 0.801.

Discussion

Our study focused on the population with HVD and retrospectively included all postoperative patients in our department. By using PSM method to eliminate the selection bias, patients were classified into high CONUT group or low CONUT group at a ratio of 1:2 based on their preoperative CONUT socres. We found that patients in high CONUT group had prolonged MV time and length of ICU stay as well as increased incidence of VAP. Preoperative CONUT score was correlated with postoperative MV time, and could predict the occurrence of MV >48 h and 72 h. Findings in the present study firstly clarified the relationship between preoperative CONUT score and postoperative MV in HVD patients.

The preoperative nutritional status of patients undergoing cardiac surgery can influence the prognosis. A prospective cohort study including 69 patients revealed that nutritional status was significantly associated with worse long-term survival [10]. Preoperative malnutrition was proven to be the independent predictor for prolonged hospitalization, a postoperative bedridden state and acute kidney injury [11,12]. Preoperative nutritional status could reflect

Table 3. Comparison of postoperative MV between two groups.

	High CONUT group (n = 103)	Low CONUT group (n = 206)	*p* value
MV time (h)	27.0 (17.0–44.0)	23.0 (12.7–36.0)	0.022*
Re-intubation	4	5	0.719
MV >24 h	56	94	0.147
MV >48 h	21	22	0.020*
MV >72 h	12	8	0.009*

MV, mechanical ventilation.

* indicates difference is significant.

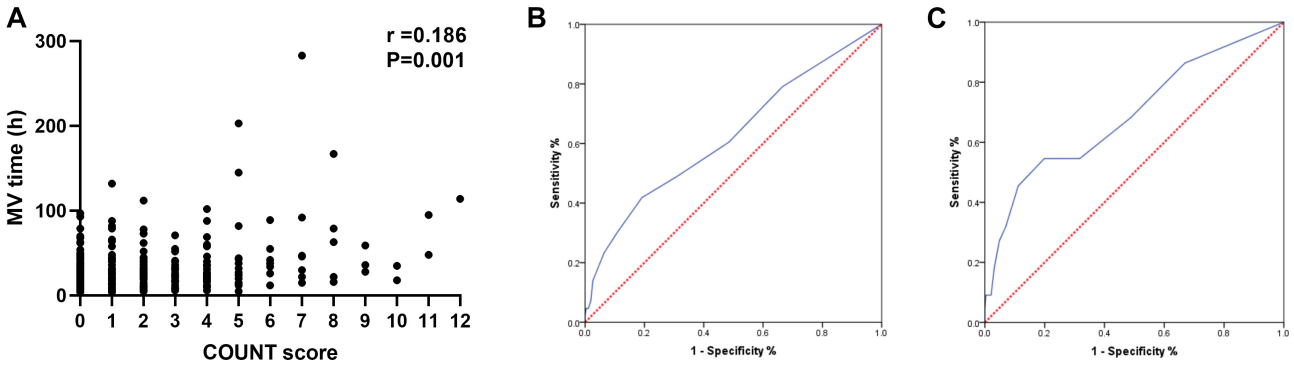

Fig. 1. Predictive role of preoperative controlled nutritional status (CONUT) score on postoperative mechanical ventilation (MV). (A) The correlation between postoperative MV time and preoperative CONUT score. Receiver operating characteristic (ROC) curve of preoperative CONUT score in predicting postoperative MV time over 48 h (B) and 72 h (C).

perioperative physical function, and is helpful for postoperative rapid recovery [13,14]. Therefore, nutritional support is essential for patients undergoing cardiac surgery. Due to the lack of conclusive evidence, programs for nutritional management for this particular population have not been established.

In the present study, the PSM method was used to eliminate the influence of confounding factors on the results. We found that poor preoperative nutritional status could significantly increase MV time, length of ICU stay and the incidence of VAP. Patients with good nutritional status before surgery usually have stronger physical functions and immunity, and are better able to cope with the stress brought about mainly by CPB, thus speeding up the postoperative recovery. This includes the recovery of the respiratory system, allowing the patient to return to earlier normal respiratory function. Preoperative malnutrition may make patients more susceptible to postoperative lung complications, such as lung infection and atelectasis [15]. These complications can further affect the patient's respiratory function, prolonging the recovery time. Malnutrition may also affect a patient's ability to clear sputum, making respiratory secretions difficult to expel and increasing the risk of lung infections. In addition, the pulmonary function of malnourished patients may be affected resulting in a low vital capacity [16].

The CONUT score is a simple and effective nutritional assessment tool designed to quantitatively assess the nutritional status of patients by serum biochemical indicators. CONUT not only reflects the current nutritional status, but also indirectly assesses the patient's immune function, inflammatory level, and prognostic risk. A recent meta-analysis including 12 trials examined the association between the CONUT score and major adverse cardiovascular events (MACE) in patients with coronary artery disease (CAD) [17]. The results showed that a higher CONUT score independently predicts the risk of MACE and all-cause mortality. In heart failure patients receiving left ventricular assist device (LVAD) implantation, a higher CONUT score exhibited a significantly higher mean right atrial pressure and was associated with a lower survival rate [18]. Compared with traditional nutrition assessment methods, the CONUT score can be obtained through routine blood tests, without complicated nutrition investigation and body composition determination. The CONUT score is quantitatively evaluated based on objective biochemical indicators, avoiding the bias caused by subjective judgment. In addition, the CONUT score integrates the nutritional status information of multiple aspects such as energy reserve, protein synthesis and immune function, which could more comprehensively reflect the nutritional status of patients.

First proposed in 2005, the CONUT score combines three measures of Alb, TC and peripheral blood lymphocytes [19]. Each index is graded according to the normal range, and the total score is calculated to evaluate the nutritional status of patients. The results from the present study indicated that the preoperative CONUT score was closely related to postoperative MV time and could accu-

rately predict the occurrence of prolonged MV. In patients with HVD, lung compliance is further reduced after CPB, which requires longer mechanical ventilation due to respiratory and hemodynamic instability, leading to a higher incidence of postoperative prolonged MV. Preoperative malnutrition and a low level of serum Alb can lead to decreased plasma colloid osmotic pressure, resulting in the leakage of intravascular fluid into the body's tissues. The decrease in blood volume will affect the perfusion of various organs, especially the lung, and lead to over-dependence on ventilators after surgery. In recent years, researchers have developed multiple predictive models for prolonged MV after cardiac surgery that combine a variety of influencing factors through statistical methods [20,21]. However, the accuracy and practicability of these models need to be further verified and perfected. Our findings provide a new way to study prolonged MV after cardiac surgery, and demonstrates that preoperative nutritional status can also be an important predictor.

Although CONUT has shown significant advantages in nutritional assessment, there are still some research limitations and future directions to explore. In addition to nutritional status, many factors such as disease status and medication may also affect the results of CONUT score. Futhermore, the duration of mechanical ventilation is related to some other factors, such as kidney function, blood oxygen and so on, which was also ignored the the present study.

Conclusions

In summary, our study suggested that the preoperative CONUT score had an accurate role in predicting postoperative prolonged MV and early poor prognosis in HVD patients, which deserves much attention to improve clinical outcomes. In the future, combined with big data analysis and artificial intelligence technology, a more accurate CONUT scoring system can be applied to achieve automated assessment and real-time monitoring of on-going changes in the patients' nutritional status.

Availability of Data and Materials

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

Author Contributions

LY: Data curation, Validation, Writing-Original Draft; LC: Validation, Visualization. JC: Formal analysis, Writing-Original Draft. YL: Data curation, Validation. CL: Data curation, Validation. XY: Conceptualization, Writing-Reviewing and Editing. XC: Conceptualization, Supervision, Writing-Reviewing and Editing. All authors read and approved the final manuscript. All authors contributed to editorial changes in the manuscript. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

The present study was approved by the ethical committee of the General Hospital of Western Theater Command (No. 2021EC2-21). Informed consent was obtained from all patients.

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Conflict of Interest

The authors declare no conflict of interest.

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