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Predictive ability of GNRI, CONUT, and mNUTRIC scores for all-cause mortality and development of explainable machine learning models in critically ill patients with coronary artery disease: A retrospective analysis using the MIMIC-IV database

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Abstract

Background

Critically ill patients with coronary artery disease (CAD) frequently face poor outcomes, and nutritional risk has emerged as a pivotal factor influencing their prognosis. Effective tools are needed to identify those at high nutritional risk to improve clinical management.We aimed to evaluate the ability of Geriatric Nutritional Risk Index (GNRI), Controlling Nutritional Status (CONUT) score and modified Nutrition Risk in Critically Ill (mNUTRIC) scores to predict all-cause mortality in ICU patients with CAD, and integrated these nutritional indices to develop an explainable machine learning predictive model for 28-day all-cause mortality.

Methods

This retrospective study analyzed 7,286 patients with CAD in the ICU identified from the MIMIC-IV database. Nutritional status was assessed using the GNRI, CONUT and mNUTRIC score. The prognostic value of these indices was evaluated and compared through Kaplan–Meier survival curves, Cox regression, and restricted cubic splines (RCS). Furthermore, the least absolute shrinkage and selection operator (LASSO) regression was utilized for feature selection. Based on the identified predictors, ten machine learning models were developed to predict 28-day all-cause mortality. Finally, the best-performing model was interpreted using Shapley Additive Explanations (SHAP) to enhance clinical interpretability.

Results

All three nutritional scores were identified as independent predictors of both short-term(in-hospital and 28-day) and long-term mortality(180-day and 365-day) in ICU patients with CAD(all $P < 0.001$). Specifically, the mNUTRIC score demonstrated superior performance in predicting short-term mortality risk, whereas the GNRI and CONUT scores exhibited higher predictive accuracy for long-term outcomes.The clinical thresholds determined by restricted cubic splines (RCS) were 105.25 for GNRI, 2 for CONUT, and 4 for mNUTRIC. Among the developed machine learning models, the Random Forest (RF) algorithm exhibited the optimal discrimination (AUC 0.944 in the training set; 0.857 in the validation set). SHAP analysis revealed that the mNUTRIC score was the most critical determinant of 28-day prognosis, followed by cardiogenic shock and serum albumin levels.

Conclusions

GNRI, CONUT, and mNUTRIC serve as independent prognostic tools for ICU patients with CAD. mNUTRIC is optimal for short-term risk stratification, while GNRI and CONUT are superior for long-term prediction.

The explainable Random Forest model provides an effective tool for predicting the 28-day all-cause mortality in ICU patients with CAD.

1. Introduction

Coronary artery disease (CAD) has long been the leading cause of death worldwide[1]. Critically ill CAD patients are frequently admitted to the intensive care unit (ICU) or cardiac intensive care unit (CICU) due to acute ischemic events or related complications[2]. These patients often experience severe stress responses, acute heart failure, malignant arrhythmias, and even cardiogenic shock, culminating in high mortality rates[3, 4]. Malnutrition is highly prevalent in this population, moreover, the acute physiological burden on ICU patients with CAD typically exacerbates preexisting nutritional deficiencies, thereby negatively impacting prognosis[5, 6]. Consequently, timely identification and intervention are both critical and challenging.

According to the European Society for Clinical Nutrition and Metabolism (ESPEN) guidelines, routine nutritional risk screening is universally recommended for all patients admitted to the ICU[7]. However, traditional nutritional assessment tools, such as the Nutritional Risk Screening 2002 (NRS-2002) and Subjective Global Assessment (SGA), rely heavily on patient's medical history and presenting complaint[8, 9]. This may poses a challenge when evaluating critically ill CAD patients due to their severely compromised clinical status. Meanwhile, we have observed that several biomarker-based nutritional risk scoring tools demonstrate favorable predictive ability for mortality risk in both CAD patients and general critically ill populations[10–13], suggesting they may serve as excellent tools for predicting mortality outcomes in ICU patients with CAD.

The Nutrition Risk in Critically III (NUTRIC) score, developed by Heyland, represents the inaugural nutritional risk assessment tool designed for ICU patients[14]. It is recommended by the American Society for Parenteral and Enteral Nutrition (ASPEN)/Society for Critical Care Medicine (SCCM) guidelines[15]. The score comprises a number of variables, including age, the presence of comorbidities, number of days spent in the ICU, Acute Physiology and Chronic Health Evaluation II (APACHE II) score, Sequential Organ Failure Assessment (SOFA) score and IL-6 levels[14]. Modifying the NUTRIC score (mNUTRIC) has resulted in a relaxation of the requirement for IL-6 measurement, rendering it more suitable for more efficient and routine clinical use[10, 16]. A subsequent validation have confirmed that the mNUTRIC score represents a reliable mortality risk stratification tool, effectively identifying critically ill patients who will benefit from aggressive medical nutrition therapy [17].

On the other hand, the Geriatric Nutritional Risk Index (GNRI), based on serum albumin and body weight [18], and the Controlling Nutritional Status (CONUT) score, comprising albumin, cholesterol, and lymphocyte counts[19], utilized as classic nutritional assessment tools for general inpatients or the elderly. Emerging evidence indicates that both GNRI and CONUT possess independent predictive capacity for all-cause mortality and major adverse cardiovascular events (MACE) among individuals with

general CAD and acute coronary syndromes[11–13]. However, these scores still lack systematic validation and head-to-head comparison in critically ill patients with CAD.

Alongside these conventional indices, applying machine learning (ML) algorithms to construct risk prediction models can offer a robust methodology for the early identification of high-risk individuals and the implementation of personalized risk stratification [20, 21].While several machine learning models exist for ICU patients with CAD, existing models rarely incorporate established nutritional scores[22, 23].

Therefore, we aim to systematically compare the prognostic value of the GNRI, CONUT, and mNUTRIC scores in ICU patients with CAD. Furthermore, by integrating these nutritional scores, we developed an explainable machine learning model to predict 28-day all-cause mortality, thereby assisting clinicians in better identifying patients at high nutritional risk and formulating targeted nutritional intervention strategies.

2. Methods and Materials

2.1 Study Population

In this retrospective study, clinical data were extracted from the Medical Information Mart for Intensive Care IV (MIMIC-IV) database. Developed and maintained by the MIT Laboratory for Computational Physiology, this large, publicly available critical care database encompasses comprehensive medical records of patients admitted to the ICU at Beth Israel Deaconess Medical Center (BIDMC)[24]. To ensure patient privacy, all personally identifiable information was strictly de-identified. The Institutional Review Board of BIDMC approved the study protocol and waived the requirement for informed consent. One of the authors obtained formal certification for database access and data extraction (Certification Number: 62192466).

Patients with an admission diagnosis of coronary artery disease (CAD) were enrolled in this study. Of the 21,995 CAD patients admitted to the ICU between 2008 and 2019, individuals were excluded if they had missing records for differential white blood cell counts (n = 9,746), height (n = 4,960), or weight (n = 3). Ultimately, a total of 7,286 patients were enrolled in the final analysis (Fig. 1).

2.2 Data Extraction

Covariate data were extracted using PostgreSQL (version 14). Baseline demographics, laboratory parameters, and medication profiles were retrieved via Structured Query Language (SQL) based on specific item identifiers within the MIMIC-IV database. These records were then precisely matched to individual patients using unique hospital admission identifiers (hadm_id). To mitigate potential confounding factors and temporal bias, all physiological measurements and laboratory parameters were strictly acquired within the first 24 hours of ICU admission[24].

The extracted variables encompassed six dimensions: (1) demographics: age, sex, and body mass index (BMI); (2) comorbidities (identified using ICD-9 and ICD-10 diagnosis codes derived from electronic health records; Supplementary Table S1): heart failure (HF), atrial fibrillation (AF), chronic kidney disease (CKD), liver disease, stroke, malignancies, hypertension, diabetes mellitus, and cardiogenic shock; (3) history of coronary interventions: coronary artery bypass grafting (CABG) and percutaneous coronary intervention (PCI); (4) medications and supportive treatments: antiplatelet therapy (single or dual), lipid-lowering agents (statins and fibrates), angiotensin-converting enzyme inhibitors (ACEIs)/angiotensin receptor blockers (ARBs), beta-blockers, insulin, mechanical ventilation, and intra-aortic balloon pump (IABP) utilization; (5) laboratory parameters: white blood cell (WBC) count, lymphocyte count, red blood cell (RBC) count, hemoglobin (HGB), platelet (PLT) count, serum creatinine, blood glucose, total cholesterol, and serum albumin; and (6) disease severity scores: Acute Physiology Score III (APS III) and Sequential Organ Failure Assessment (SOFA). Following the screening process, all 7,286 patients ultimately included in the analysis possessed complete datasets, with no missing values observed. The selection of all covariates was driven by their established clinical relevance in CAD populations, as corroborated by prior literature[25, 26].

2.3 Definition of Nutritional Risk Exposure and Study Outcomes

The GNRI was calculated from serum albumin levels and the ratio of actual to ideal body weight using the formula:
$\mathrm{GNRI} = 14.89 \times \text{serum albumin (g/dL)} + 41.7 \times (\text{actual weight} / \text{ideal weight})$, where ideal weight (kg) was defined as $22 \times \text{height (m)}^2$. If actual weight exceeded ideal weight, the ratio was set to 1. According to established cutoffs, GNRI < 82 indicates severe nutritional risk, 82–91 moderate risk, 92–98 mild risk, and > 98 normal nutritional status, with lower scores reflecting higher risk of malnutrition[18].

The CONUT score is derived from serum albumin, total cholesterol, and lymphocyte count, with a total range of 0–12 points. Scores of 0–1 indicate normal nutrition, 2–4 mild malnutrition, 5–8 moderate malnutrition, and 9–12 severe malnutrition (Table 1)[19].

Table 1
Evaluation of CONUT score

Parameter	Score			
Serum albumin (g/dL)	≥ 3.5	3.0-3.4	2.5–2.9	< 2.5
Albumin score	0	2	4	6
Total cholesterol (mg/dL)	≥ 180	140–179	100–139	< 100
Cholesterol score	0	1	2	3
Total lymphocytes (10^9/L)	≥ 1.600	1.200-1.599	0.800-1.199	< 0.800
Lymphocyte score	0	1	2	3

The mNUTRIC score incorporates age, Acute Physiology and Chronic Health Evaluation II (APACHE II), Sequential Organ Failure Assessment (SOFA), number of comorbidities, and days from hospital to ICU admission, with a total range of 0–9[10]. Given the data extraction limitations of the APACHE II score in modern electronic health records, this study employed the equivalent Acute Physiology Score III (APS III) as a reliable surrogate to calculate the mNUTRIC score[27, 28]. A score ≥ 5 is generally used to define high nutritional risk, suggesting a greater likelihood of adverse outcomes.

The primary outcome was all-cause mortality within 28 days of ICU admission. Secondary outcomes included all-cause in-hospital mortality, and all-cause mortality at 180 days and 365 days.

2.4 Statistical Analysis

Patients were initially stratified based on their baseline GNRI, CONUT, and mNUTRIC scores. Continuous variables with normal distribution are presented as mean ± standard deviation (SD) and were compared using one-way analysis of variance (ANOVA). Non-normally distributed continuous variables are expressed as medians with interquartile ranges (IQR) and were compared using the Kruskal-Wallis H test. Categorical variables are reported as frequencies and percentages (n, %) and were analyzed using the Chi-square test. Kaplan-Meier survival curves were plotted, and differences in survival rates among groups were assessed using the Log-rank test. For each nutritional score, the lowest-risk category served as the reference group. Univariable Cox proportional hazards models were employed to identify potential risk factors affecting medium-to-long-term mortality (28 days, 180 days, and 365 days). To prevent the premature exclusion of potentially relevant variables, factors with a $P < 0.1$ in the univariable analysis were incorporated into a multivariable Cox model to determine independent risk factors. Multicollinearity was strictly mitigated by excluding variables with a Variance Inflation Factor (VIF) > 5. Additionally, multivariable logistic regression was utilized specifically to evaluate the association between nutritional scores and in-hospital mortality.

Restricted cubic spline (RCS) models were applied to evaluate the dose-response relationship between nutritional scores and mortality risk. The optimal number of knots was determined by minimizing the Akaike Information Criterion (AIC), and a likelihood ratio test was used to assess potential non-linear

associations. Based on the non-linear trajectories of the RCS curves, optimal cut-off values for predicting adverse outcomes were identified for each score. Subsequent subgroup analyses were conducted to explore the prognostic impact of these scores across various clinical strata, including sex, heart failure, hypertension, atrial fibrillation, diabetes, chronic kidney disease, stroke, age, and BMI.

For the construction of machine learning (ML) models, the entire cohort was randomly partitioned into a training set (n = 5100) and a testing set (n = 2186) at a 7:3 ratio. Given that we directly integrated macroscopic nutritional scores with microscopic clinical indicators, Least Absolute Shrinkage and Selection Operator (LASSO) regression with L1 regularization was applied for feature selection to effectively handle potential multicollinearity within the high-dimensional data. Using the selected features, 10 candidate machine learning models (Random Forest, XGBoost, LightGBM, CatBoost, GBM, AdaBoost, Extra Trees, SVM, KNN, and Neural Networks) were developed. Hyperparameter optimization was strictly performed via grid search combined with 10-fold cross-validation. To benchmark their predictive performance, traditional APACHE III and SOFA scores were subsequently calculated as clinical references, utilizing the worst physiological and laboratory parameters within the first 24 hours of ICU admission. Model performance was comprehensively evaluated using the area under the receiver operating characteristic curve (AUC), sensitivity, specificity, recall, F1-score, and accuracy. Finally, SHapley Additive exPlanations (SHAP) analysis was applied to elucidate and visualize the decision-making process of the best-performing model. All statistical analyses were performed using RStudio (version 4.3) and Python (version 3.12.9). A two-sided $P < 0.05$ was considered statistically significant.

3. Results

3.1 Baseline Characteristics and Clinical Outcomes

A total of 7,286 ICU patients with CAD were enrolled in this study, comprising 4,976 males (68.3%) and 2,310 females (31.7%). Over the 365-day follow-up period, the primary endpoint (28 days all-cause mortality from ICU admission) occurred in 1,136 patients (15.6%). Secondary endpoints included 993 in-hospital deaths (13.6%), 1,864 deaths at 180 days (25.6%), and 2,168 deaths at 365 days (29.8%). The cumulative incidence of mortality progressively increased with extended follow-up duration.

Baseline characteristics stratified by GNRI, CONUT, and mNUTRIC scores are presented in Tables 2, 3, and 4. Across all three scoring systems, patients with high nutritional risk shared similar clinical profiles:they were significantly older ($P < 0.001$), had a higher proportion of females, and exhibited lower body mass index (BMI) ($P < 0.001$). They also bore a heavier burden of comorbidities (such as increased rates of heart failure, chronic kidney disease, stroke, malignancy, and cardiogenic shock, all $P < 0.01$) and presented with greater disease severity upon admission, as reflected by significantly elevated APS III and SOFA scores ($P < 0.001$).

Laboratory results showed that high-risk patients had higher white blood cell counts, but lower red blood cell counts, hemoglobin, and serum albumin levels (all $P < 0.01$). Clinically, these patients were

significantly less likely to receive standard cardiovascular treatments, such as ACEI/ARBs, beta-blockers, and lipid-lowering therapies (all $P < 0.001$). Notably, across all follow-up milestones (in-hospital, 28-day, 180-day, and 365-day), high-risk status defined by all three nutritional scoring systems was profoundly associated with elevated all-cause mortality rates (all $P < 0.001$).

Table 2
Basic demographic characteristics of the original cohort according to GNRI.

Age	Overall (N = 7286)	Q1 (GNRI < 82, N = 529)	Q2 (82 ≤ GNRI < 92, N = 986)	Q3 (92 ≤ GNRI ≤ 98, N = 847)	Q4 (GBRI > 98, N = 4924)	p-value	Significance
Mean (SD)	**70.98 (11.37)**	**73.86 (11.85)**	**73.91 (11.71)**	**73.89 (11.12)**	**69.59 (11.02)**	**< 0.001**	**
Gender (%)							
Female	**2310 (31.70%)**	**182 (34.40%)**	**364 (36.92%)**	**262 (30.93%)**	**1502 (30.50%)**	**< 0.001**	**
Male	**4976 (68.30%)**	**347 (65.60%)**	**622 (63.08%)**	**585 (69.07%)**	**3422 (69.50%)**		
BMI							
Mean (SD)	**29.05 (6.51)**	**21.28 (3.24)**	**24.10 (3.42)**	**25.96 (3.58)**	**31.41 (6.20)**	**< 0.001**	**
APSIII							
Median [Q1, Q3]	**43.00 [32.00, 59.00]**	**56.00 [43.00, 71.00]**	**51.00 [40.00, 65.00]**	**47.00 [36.00, 61.50]**	**39.00 [29.00, 54.00]**	**< 0.001**	**
SOFA							
Median [Q1, Q3]	**5.00 [3.00, 8.00]**	**6.00 [4.00, 9.00]**	**6.00 [4.00, 9.00]**	**5.00 [3.00, 8.00]**	**5.00 [3.00, 8.00]**	**< 0.001**	**
Mechanical ventilation use (%)							
YES	**4498 (61.73%)**	**292 (55.20%)**	**523 (53.04%)**	**446 (52.66%)**	**3237 (65.74%)**	**< 0.001**	**
NO	**2788 (38.27%)**	**237 (44.80%)**	**463 (46.96%)**	**401 (47.34%)**	**1687 (34.26%)**		
CABG (%)							

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose;P > 0.05: not marked□0.001 < P < 0.05 :*□P < 0.001:*

Age	Overall (N = 7286)	Q1 (GNRI < 82, N = 529)	Q2 (82 ≤ GNRI < 92, N = 986)	Q3 (92 ≤ GNRI ≤ 98, N = 847)	Q4 (GBRI > 98, N = 4924)	p-value	Significance
YES	**1292 (17.73%)**	**8 (1.51%)**	**54 (5.48%)**	**88 (10.39%)**	**1142 (23.19%)**	**< 0.001**	**
NO	**5994 (82.27%)**	**521 (98.49%)**	**932 (94.52%)**	**759 (89.61%)**	**3782 (76.81%)**		
PCI (%)							
YES	**122 (1.67%)**	**7 (1.32%)**	**20 (2.03%)**	**10 (1.18%)**	**85 (1.73%)**	**0.48**	
NO	**7164 (98.33%)**	**522 (98.68%)**	**966 (97.97%)**	**837 (98.82%)**	**4839 (98.27%)**		
IABP (%)							
YES	**436 (5.98%)**	**14 (2.65%)**	**52 (5.27%)**	**47 (5.55%)**	**323 (6.56%)**	**< 0.01**	*
NO	**6850 (94.02%)**	**515 (97.35%)**	**934 (94.73%)**	**800 (94.45%)**	**4601 (93.44%)**		
Heart failure (%)							
YES	**3573 (49.04%)**	**302 (57.09%)**	**602 (61.05%)**	**489 (57.73%)**	**2180 (44.27%)**	**< 0.001**	**
NO	**3713 (50.96%)**	**227 (42.91%)**	**384 (38.95%)**	**358 (42.27%)**	**2744 (55.73%)**		
Hypertension (%)							
YES	**5920 (81.25%)**	**417 (78.83%)**	**762 (77.28%)**	**683 (80.64%)**	**4058 (82.41%)**	**< 0.001**	**
NO	**1366 (18.75%)**	**112 (21.17%)**	**224 (22.72%)**	**164 (19.36%)**	**866 (17.59%)**		

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose;P > 0.05: not marked□0.001 < P < 0.05 :*□P < 0.001:*

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Atrial fibrillation (%)							
YES	**1762 (24.18%)**	**95 (17.96%)**	**259 (26.27%)**	**231 (27.27%)**	**1177 (23.90%)**	**< 0.001**	**
NO	**5524 (75.82%)**	**434 (82.04%)**	**727 (73.73%)**	**616 (72.73%)**	**3747 (76.10%)**		
Diabetes (%)							
YES	**3085 (42.34%)**	**176 (33.27%)**	**341 (34.58%)**	**337 (39.79%)**	**2231 (45.31%)**	**< 0.001**	**
NO	**4201 (57.66%)**	**353 (66.73%)**	**645 (65.42%)**	**510 (60.21%)**	**2693 (54.69%)**		
Renal disease (%)							
YES	**2370 (32.53%)**	**206 (38.94%)**	**367 (37.22%)**	**327 (38.61%)**	**1470 (29.85%)**	**< 0.001**	**
NO	**4916 (67.47%)**	**323 (61.06%)**	**619 (62.78%)**	**520 (61.39%)**	**3454 (70.15%)**		
Stroke (%)							
YES	**742 (10.18%)**	**59 (11.15%)**	**107 (10.85%)**	**93 (10.98%)**	**483 (9.81%)**	**0.5**	
NO	**6544 (89.82%)**	**470 (88.85%)**	**879 (89.15%)**	**754 (89.02%)**	**4441 (90.19%)**		
Malignancy (%)							
YES	**893 (12.26%)**	**120 (22.68%)**	**188 (19.07%)**	**141 (16.65%)**	**444 (9.02%)**	**< 0.001**	**

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose;P > 0.05: not marked□0.001 < P < 0.05 :*□P < 0.001:*

Age	Overall (N = 7286)	Q1 (GNRI < 82, N = 529)	Q2 (82 ≤ GNRI < 92, N = 986)	Q3 (92 ≤ GNRI ≤ 98, N = 847)	Q4 (GBRI > 98, N = 4924)	p-value	Significance
NO	**6393 (87.74%)**	**409 (77.32%)**	**798 (80.93%)**	**706 (83.35%)**	**4480 (90.98%)**		
Cardiogenic shock (%)							
YES	**886 (12.16%)**	**59 (11.15%)**	**162 (16.43%)**	**131 (15.47%)**	**534 (10.84%)**	**< 0.001**	**
NO	**6400 (87.84%)**	**470 (88.85%)**	**824 (83.57%)**	**716 (84.53%)**	**4390 (89.16%)**		
WBC ($\times10^9$/L)							
Median [Q1, Q3]	**8.90 [6.80, 12.60]**	**10.80 [7.30, 15.50]**	**10.45 [7.50, 14.80]**	**9.90 [7.10, 13.90]**	**8.50 [6.70, 11.60]**		
RBC ($\times10^9$/L)							
Mean (SD)	**3.80 (0.78)**	**3.28 (0.70)**	**3.41 (0.71)**	**3.54 (0.71)**	**3.98 (0.75)**	**< 0.001**	**
Platelet ($\times10^9$/L)							
Median [Q1, Q3]	**199.00 [154.00, 253.00]**	**206.00 [142.00, 289.00]**	**186.50 [131.25, 254.00]**	**193.00 [145.00, 257.50]**	**202.00 [159.00, 250.00]**		
Hemoglobin (g/L)							
Mean (SD)	**11.32 (2.34)**	**9.71 (2.04)**	**10.18 (2.09)**	**10.53 (2.10)**	**11.86 (2.26)**	**< 0.001**	**
Blood creatinine (mg/dL)							

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose;P > 0.05: not marked□0.001 < P < 0.05 :*□P < 0.001:*

Age	Overall (N = 7286)	Q1 (GNRI < 82, N = 529)	Q2 (82 ≤ GNRI < 92, N = 986)	Q3 (92 ≤ GNRI ≤ 98, N = 847)	Q4 (GBRI > 98, N = 4924)	p-value	Significance
Median [Q1, Q3]	**1.10 [0.90, 1.60]**	**1.30 [0.80, 2.20]**	**1.20 [0.90, 1.90]**	**1.20 [0.90, 1.90]**	**1.10 [0.90, 1.50]**		
FPG (mg/dL)							
Median [Q1, Q3]	**126.00 [102.00, 168.00]**	**124.00 [97.00, 166.00]**	**123.00 [99.00, 164.00]**	**129.00 [102.00, 180.50]**	**126.00 [102.00, 167.00]**		
Albumin (g/dL)							
Mean (SD)	**3.42 (0.67)**	**2.35 (0.42)**	**2.84 (0.43)**	**3.11 (0.45)**	**3.70 (0.54)**	**< 0.001**	**
Blood lipid regulation (%)							
YES	**6152 (84.44%)**	**356 (67.30%)**	**743 (75.35%)**	**688 (81.23%)**	**4365 (88.65%)**	**< 0.001**	**
NO	**1134 (15.56%)**	**173 (32.70%)**	**243 (24.65%)**	**159 (18.77%)**	**559 (11.35%)**		
Antiplatelet (%)							
Double antiplatelet	**1864 (25.58%)**	**113 (21.36%)**	**269 (27.28%)**	**231 (27.27%)**	**1251 (25.41%)**	**< 0.001**	**
Single antiplatelet	**4675 (64.16%)**	**282 (53.31%)**	**542 (54.97%)**	**496 (58.56%)**	**3355 (68.14%)**		
NO	**747 (10.25%)**	**134 (25.33%)**	**175 (17.75%)**	**120 (14.17%)**	**318 (6.46%)**		
ACEI/ARB (%)							

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose;P > 0.05: not marked□0.001 < P < 0.05 :*□P < 0.001:*

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YES	**2836 (38.92%)**	**115 (21.74%)**	**320 (32.45%)**	**310 (36.60%)**	**2091 (42.47%)**	**< 0.001**	**
NO	**4450 (61.08%)**	**414 (78.26%)**	**666 (67.55%)**	**537 (63.40%)**	**2833 (57.53%)**		
β-blockers (%)							
YES	**6156 (84.49%)**	**391 (73.91%)**	**761 (77.18%)**	**690 (81.46%)**	**4314 (87.61%)**	**< 0.001**	**
NO	**1130 (15.51%)**	**138 (26.09%)**	**225 (22.82%)**	**157 (18.54%)**	**610 (12.39%)**		
In-hospital mortality (%)							
Alive	**6293 (86.37%)**	**354 (66.92%)**	**764 (77.48%)**	**685 (80.87%)**	**4490 (91.19%)**	**< 0.001**	**
Dead	**993 (13.63%)**	**175 (33.08%)**	**222 (22.52%)**	**162 (19.13%)**	**434 (8.81%)**		
28-Day mortality (%)							
Alive	**6150 (84.41%)**	**324 (61.25%)**	**719 (72.92%)**	**668 (78.87%)**	**4439 (90.15%)**	**< 0.001**	**
Dead	**1136 (15.59%)**	**205 (38.75%)**	**267 (27.08%)**	**179 (21.13%)**	**485 (9.85%)**		
180-Day mortality (%)							
Alive	**5422 (74.42%)**	**218 (41.21%)**	**554 (56.19%)**	**543 (64.11%)**	**4107 (83.41%)**	**< 0.001**	**
Dead	**1864 (25.58%)**	**311 (58.79%)**	**432 (43.81%)**	**304 (35.89%)**	**817 (16.59%)**		

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose;P > 0.05: not marked□0.001 < P < 0.05 :*□P < 0.001:*

Age	Overall (N = 7286)	Q1 (GNRI < 82, N = 529)	Q2 (82 ≤ GNRI < 92, N = 986)	Q3 (92 ≤ GNRI ≤ 98, N = 847)	Q4 (GBRI > 98, N = 4924)	p-value	Significance
365-Day mortality (%)							
Alive	**5118 (70.24%)**	**192 (36.29%)**	**501 (50.81%)**	**484 (57.14%)**	**3941 (80.04%)**	**< 0.001**	**
Dead	**2168 (29.76%)**	**337 (63.71%)**	**485 (49.19%)**	**363 (42.86%)**	**983 (19.96%)**		

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose;P > 0.05: not marked□0.001 < P < 0.05 :*□P < 0.001:*

Table 3
Basic demographic characteristics of the original cohort according to CONUT scores.

Age	Overall (N = 7286)	Q1 (CONUT scores < 2, N = 3156)	Q2 (2 ≤ CONUT scores < 5, N = 2758)	Q3 (5 ≤ CONUT scores ≤ 8, N = 1210)	Q4 (CONUT scores > 8, N = 162)	p-value	Significance
Mean (SD)	**70.98 (11.37)**	**69.53 (11.22)**	**72.28 (11.25)**	**71.70 (11.78)**	**71.95 (9.83)**	**< 0.001**	**
Gender (%)							
Female	**2310 (31.70%)**	**913 (28.93%)**	**924 (33.50%)**	**413 (34.13%)**	**60 (37.04%)**	**< 0.001**	**
Male	**4976 (68.30%)**	**2243 (71.07%)**	**1834 (66.50%)**	**797 (65.87%)**	**102 (62.96%)**		
BMI							
Mean (SD)	**29.05 (6.51)**	**29.76 (5.93)**	**28.72 (6.66)**	**28.09 (7.23)**	**27.88 (7.50)**	**< 0.001**	**
APSIII							
Median [Q1, Q3]	**43.00 [32.00, 59.00]**	**35.00 [27.00, 48.00]**	**46.00 [35.00, 60.00]**	**54.00 [42.00, 70.00]**	**60.00 [49.00, 76.00]**	**< 0.001**	**
SOFA							
Median [Q1, Q3]	**5.00 [3.00, 8.00]**	**5.00 [3.00, 7.00]**	**6.00 [3.00, 8.00]**	**7.00 [4.00, 10.00]**	**8.00 [5.00, 10.00]**	**< 0.001**	**
Mechanical ventilation use (%)							
YES	**4498 (61.73%)**	**2126 (67.36%)**	**1573 (57.03%)**	**693 (57.27%)**	**106 (65.43%)**	**< 0.001**	**
NO	**2788 (38.27%)**	**1030 (32.64%)**	**1185 (42.97%)**	**517 (42.73%)**	**56 (34.57%)**		
CABG (%)							

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose.P > 0.05: not marked;0.001 < P < 0.05 :*;P < 0.001:*

Age	Overall (N = 7286)	Q1 (CONUT scores < 2, N = 3156)	Q2 (2 ≤ CONUT scores < 5, N = 2758)	Q3 (5 ≤ CONUT scores ≤ 8, N = 1210)	Q4 (CONUT scores > 8, N = 162)	p-value	Significance
YES	**1292 (17.73%)**	**839 (26.58%)**	**396 (14.36%)**	**54 (4.46%)**	**3 (1.85%)**	**< 0.001**	**
NO	**5994 (82.27%)**	**2317 (73.42%)**	**2362 (85.64%)**	**1156 (95.54%)**	**159 (98.15%)**		
PCI (%)							
YES	**122 (1.67%)**	**41 (1.30%)**	**44 (1.60%)**	**33 (2.73%)**	**4 (2.47%)**	**< 0.01**	*
NO	**7164 (98.33%)**	**3115 (98.70%)**	**2714 (98.40%)**	**1177 (97.27%)**	**158 (97.53%)**		
IABP (%)							
YES	436 (5.98%)	188 (5.96%)	171 (6.20%)	67 (5.54%)	10 (6.17%)	0.88	
NO	6850 (94.02%)	2968 (94.04%)	2587 (93.80%)	1143 (94.46%)	152 (93.83%)		
Heart failure (%)							
YES	**3573 (49.04%)**	**1169 (37.04%)**	**1559 (56.53%)**	**753 (62.23%)**	**92 (56.79%)**	**< 0.001**	**
NO	**3713 (50.96%)**	**1987 (62.96%)**	**1199 (43.47%)**	**457 (37.77%)**	**70 (43.21%)**		
Hypertension (%)							
YES	5920 (81.25%)	2580 (81.75%)	2237 (81.11%)	967 (79.92%)	136 (83.95%)	0.43	
NO	1366 (18.75%)	576 (18.25%)	521 (18.89%)	243 (20.08%)	26 (16.05%)		
Atrial fibrillation							

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose.P > 0.05: not marked;0.001 < P < 0.05 :*;P < 0.001:*

Age	Overall (N = 7286)	Q1 (CONUT scores < 2, N = 3156)	Q2 (2 ≤ CONUT scores < 5, N = 2758)	Q3 (5 ≤ CONUT scores ≤ 8, N = 1210)	Q4 (CONUT scores > 8, N = 162)	p-value	Significance
(%)							
YES	**1762 (24.18%)**	**807 (25.57%)**	**770 (27.92%)**	**181 (14.96%)**	**4 (2.47%)**	**< 0.001**	**
NO	**5524 (75.82%)**	**2349 (74.43%)**	**1988 (72.08%)**	**1029 (85.04%)**	**158 (97.53%)**		
Diabetes (%)							
YES	**3085 (42.34%)**	**1266 (40.11%)**	**1211 (43.91%)**	**538 (44.46%)**	**70 (43.21%)**	**< 0.01**	*
NO	**4201 (57.66%)**	**1890 (59.89%)**	**1547 (56.09%)**	**672 (55.54%)**	**92 (56.79%)**		
Renal disease (%)							
YES	**2370 (32.53%)**	**761 (24.11%)**	**1041 (37.74%)**	**498 (41.16%)**	**70 (43.21%)**	**< 0.001**	**
NO	**4916 (67.47%)**	**2395 (75.89%)**	**1717 (62.26%)**	**712 (58.84%)**	**92 (56.79%)**		
Stroke (%)							
YES	**742 (10.18%)**	**312 (9.89%)**	**256 (9.28%)**	**154 (12.73%)**	**20 (12.35%)**	**< 0.01**	*
NO	**6544 (89.82%)**	**2844 (90.11%)**	**2502 (90.72%)**	**1056 (87.27%)**	**142 (87.65%)**		
Malignancy (%)							
YES	**893 (12.26%)**	**218 (6.91%)**	**397 (14.39%)**	**237 (19.59%)**	**41 (25.31%)**	**< 0.001**	**
NO	**6393 (87.74%)**	**2938 (93.09%)**	**2361 (85.61%)**	**973 (80.41%)**	**121 (74.69%)**		

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose.P > 0.05: not marked;0.001 < P < 0.05 :*;P < 0.001:*

Age	Overall (N = 7286)	Q1 (CONUT scores < 2, N = 3156)	Q2 (2 ≤ CONUT scores < 5, N = 2758)	Q3 (5 ≤ CONUT scores ≤ 8, N = 1210)	Q4 (CONUT scores > 8, N = 162)	p-value	Significance
Cardiogenic shock (%)							
YES	**886 (12.16%)**	**247 (7.83%)**	**380 (13.78%)**	**232 (19.17%)**	**27 (16.67%)**	**< 0.001**	**
NO	**6400 (87.84%)**	**2909 (92.17%)**	**2378 (86.22%)**	**978 (80.83%)**	**135 (83.33%)**		
WBC ($\times 10^9$/L)							
Median [Q1, Q3]	**8.90 [6.80, 12.60]**	**8.00 [6.60, 10.30]**	**9.70 [7.20, 13.80]**	**10.90 [7.60, 15.80]**	**10.80 [6.73, 15.88]**	**< 0.01**	*
RBC ($\times 10^9$/L)							
Mean (SD)	**3.80 (0.78)**	**4.15 (0.67)**	**3.59 (0.75)**	**3.42 (0.76)**	**3.24 (0.70)**	**< 0.001**	**
Platelet ($\times 10^9$/L)							
Median [Q1, Q3]	**199.00 [154.00, 253.00]**	**206.00 [165.00, 249.00]**	**196.00 [146.00, 254.00]**	**190.50 [137.00, 265.00]**	**174.00 [121.50, 251.75]**	**< 0.01**	*
Hemoglobin (g/L)							
Mean (SD)	**11.32 (2.34)**	**12.45 (2.02)**	**10.67 (2.18)**	**10.12 (2.21)**	**9.60 (2.15)**	**< 0.001**	**
Blood creatinine (mg/dL)							
Median [Q1, Q3]	**1.10 [0.90, 1.60]**	**1.00 [0.80, 1.30]**	**1.20 [0.90, 1.80]**	**1.40 [0.90, 2.30]**	**1.50 [1.00, 2.50]**	**< 0.01**	*

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose.P > 0.05: not marked;0.001 < P < 0.05 :*;P < 0.001:*

Age	Overall (N = 7286)	Q1 (CONUT scores < 2, N = 3156)	Q2 (2 ≤ CONUT scores < 5, N = 2758)	Q3 (5 ≤ CONUT scores ≤ 8, N = 1210)	Q4 (CONUT scores > 8, N = 162)	p-value	Significance
FPG (mg/dL)							
Median [Q1, Q3]	**126.00 [102.00, 168.00]**	**120.00 [101.00, 159.00]**	**128.00 [102.00, 174.00]**	**135.00 [103.00, 184.00]**	**132.50 [100.75, 194.25]**	**< 0.01**	*
Albumin (g/dL)							
Mean (SD)	**3.42 (0.67)**	**3.97 (0.33)**	**3.21 (0.42)**	**2.61 (0.48)**	**2.15 (0.34)**	**< 0.001**	**
Blood lipid regulation (%)							
YES	**6152 (84.44%)**	**2898 (91.83%)**	**2226 (80.71%)**	**909 (75.12%)**	**119 (73.46%)**	**< 0.001**	**
NO	**1134 (15.56%)**	**258 (8.17%)**	**532 (19.29%)**	**301 (24.88%)**	**43 (26.54%)**		
Antiplatelet (%)							
Double antiplatelet	**1864 (25.58%)**	**754 (23.89%)**	**750 (27.19%)**	**331 (27.36%)**	**29 (17.90%)**	**< 0.001**	**
Single antiplatelet	**4675 (64.16%)**	**2273 (72.02%)**	**1647 (59.72%)**	**648 (53.55%)**	**107 (66.05%)**		
NO	**747 (10.25%)**	**129 (4.09%)**	**361 (13.09%)**	**231 (19.09%)**	**26 (16.05%)**		
ACEI/ARB (%)							
YES	**2836 (38.92%)**	**1415 (44.84%)**	**1042 (37.78%)**	**350 (28.93%)**	**29 (17.90%)**	**< 0.001**	**

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose.P > 0.05: not marked;0.001 < P < 0.05 :*;P < 0.001:*

Age	Overall (N = 7286)	Q1 (CONUT scores < 2, N = 3156)	Q2 (2 ≤ CONUT scores < 5, N = 2758)	Q3 (5 ≤ CONUT scores ≤ 8, N = 1210)	Q4 (CONUT scores > 8, N = 162)	p-value	Significance
NO	**4450 (61.08%)**	**1741 (55.16%)**	**1716 (62.22%)**	**860 (71.07%)**	**133 (82.10%)**		
β-blockers (%)							
YES	**6156 (84.49%)**	**2871 (90.97%)**	**2264 (82.09%)**	**909 (75.12%)**	**112 (69.14%)**	**< 0.001**	**
NO	**1130 (15.51%)**	**285 (9.03%)**	**494 (17.91%)**	**301 (24.88%)**	**50 (30.86%)**		
In-hospital mortality (%)							
Alive	**6293 (86.37%)**	**3002 (95.12%)**	**2329 (84.45%)**	**867 (71.65%)**	**95 (58.64%)**	**< 0.001**	**
Dead	**993 (13.63%)**	**154 (4.88%)**	**429 (15.55%)**	**343 (28.35%)**	**67 (41.36%)**		
28-Day mortality (%)							
Alive	**6150 (84.41%)**	**2973 (94.20%)**	**2253 (81.69%)**	**833 (68.84%)**	**91 (56.17%)**	**< 0.001**	**
Dead	**1136 (15.59%)**	**183 (5.80%)**	**505 (18.31%)**	**377 (31.16%)**	**71 (43.83%)**		
180-Day mortality (%)							
Alive	**5422 (74.42%)**	**2822 (89.42%)**	**1926 (69.83%)**	**616 (50.91%)**	**58 (35.80%)**	**< 0.001**	**
Dead	**1864 (25.58%)**	**334 (10.58%)**	**832 (30.17%)**	**594 (49.09%)**	**104 (64.20%)**		
365-Day mortality (%)							

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose.P > 0.05: not marked;0.001 < P < 0.05 :*;P < 0.001:*

Age	Overall (N = 7286)	Q1 (CONUT scores < 2, N = 3156)	Q2 (2 ≤ CONUT scores < 5, N = 2758)	Q3 (5 ≤ CONUT scores ≤ 8, N = 1210)	Q4 (CONUT scores > 8, N = 162)	p-value	Significance
Alive	5118 (70.24%)	2731 (86.53%)	1783 (64.65%)	557 (46.03%)	47 (29.01%)	< 0.001	**
Dead	2168 (29.76%)	425 (13.47%)	975 (35.35%)	653 (53.97%)	115 (70.99%)		

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose.P > 0.05: not marked;0.001 < P < 0.05 :*;P < 0.001:*

Table 4
Basic demographic characteristics of the original cohort according to mNUTRIC scores.

Age	Overall (N = 7286)	Q1 (mNUTRIC < 5, N = 4037)	Q2 (mNUTRIC > = 5, N = 3249)	p-value	Significance
Mean (SD)	**70.98 (11.37)**	**67.58 (11.26)**	**75.22 (9.99)**	**< 0.001**	**
Gender (%)					
Female	**2310 (31.70%)**	**1193 (29.55%)**	**1117 (34.38%)**	**< 0.001**	**
Male	**4976 (68.30%)**	**2844 (70.45%)**	**2132 (65.62%)**		
BMI					
Mean (SD)	**29.05 (6.51)**	**29.34 (6.34)**	**28.68 (6.70)**	**< 0.001**	**
APSIII					
Median [Q1, Q3]	**43.00 [32.00, 59.00]**	**35.00 [27.00, 45.00]**	**56.00 [44.00, 73.00]**	**< 0.001**	**
SOFA					
Median [Q1, Q3]	**5.00 [3.00, 8.00]**	**4.00 [2.00, 5.00]**	**8.00 [6.00, 10.00]**	**< 0.001**	**
Mechanical ventilation use (%)					
YES	**4498 (61.73%)**	**2260 (55.98%)**	**2238 (68.88%)**	**< 0.001**	**
NO	**2788 (38.27%)**	**1777 (44.02%)**	**1011 (31.12%)**		
CABG (%)					
YES	**1292 (17.73%)**	**885 (21.92%)**	**407 (12.53%)**	**< 0.001**	**

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose.P > 0.05: not marked;0.001 < P < 0.05 :*;P < 0.001:*

Age	Overall (N = 7286)	Q1 (mNUTRIC < 5, N = 4037)	Q2 (mNUTRIC > = 5, N = 3249)	p-value	Significance
NO	**5994 (82.27%)**	**3152 (78.08%)**	**2842 (87.47%)**		
PCI (%)					
YES	**122 (1.67%)**	**80 (1.98%)**	**42 (1.29%)**	**< 0.05**	*
NO	**7164 (98.33%)**	**3957 (98.02%)**	**3207 (98.71%)**		
IABP (%)					
YES	**436 (5.98%)**	**252 (6.24%)**	**184 (5.66%)**	0.32	
NO	**6850 (94.02%)**	**3785 (93.76%)**	**3065 (94.34%)**		
Heart failure (%)					
YES	**3573 (49.04%)**	**1386 (34.33%)**	**2187 (67.31%)**	**< 0.001**	**
NO	**3713 (50.96%)**	**2651 (65.67%)**	**1062 (32.69%)**		
Hypertension (%)					
YES	**5920 (81.25%)**	**3164 (78.38%)**	**2756 (84.83%)**	**< 0.001**	**
NO	**1366 (18.75%)**	**873 (21.62%)**	**493 (15.17%)**		
Atrial fibrillation (%)					
YES	**1762 (24.18%)**	**811 (20.09%)**	**951 (29.27%)**	**< 0.001**	**
NO	**5524 (75.82%)**	**3226 (79.91%)**	**2298 (70.73%)**		
Diabetes (%)					

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose.P > 0.05: not marked;0.001 < P < 0.05 :*;P < 0.001:*

Age	Overall (N = 7286)	Q1 (mNUTRIC < 5, N = 4037)	Q2 (mNUTRIC > = 5, N = 3249)	p-value	Significance
YES	**3085 (42.34%)**	**1554 (38.49%)**	**1531 (47.12%)**	**< 0.001**	**
NO	**4201 (57.66%)**	**2483 (61.51%)**	**1718 (52.88%)**		
Renal disease (%)					
YES	**2370 (32.53%)**	**663 (16.42%)**	**1707 (52.54%)**	**< 0.001**	**
NO	**4916 (67.47%)**	**3374 (83.58%)**	**1542 (47.46%)**		
Stroke (%)					
YES	**742 (10.18%)**	**378 (9.36%)**	**364 (11.20%)**	**< 0.05**	*
NO	**6544 (89.82%)**	**3659 (90.64%)**	**2885 (88.80%)**		
Malignancy (%)					
YES	**893 (12.26%)**	**344 (8.52%)**	**549 (16.90%)**	**< 0.001**	**
NO	**6393 (87.74%)**	**3693 (91.48%)**	**2700 (83.10%)**		
Cardiogenic shock (%)					
YES	**886 (12.16%)**	**306 (7.58%)**	**580 (17.85%)**	**< 0.001**	**
NO	**6400 (87.84%)**	**3731 (92.42%)**	**2669 (82.15%)**		
WBC ($\times 10^9$/L)					
Median [Q1, Q3]	**8.90 [6.80, 12.60]**	**8.90 [6.90, 12.30]**	**9.10 [6.70, 13.10]**		

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose.P > 0.05: not marked;0.001 < P < 0.05 :*;P < 0.001:*

Age	Overall (N = 7286)	Q1 (mNUTRIC < 5, N = 4037)	Q2 (mNUTRIC > = 5, N = 3249)	p-value	Significance
RBC (×10^9/L)					
Mean (SD)	**3.80 (0.78)**	**3.95 (0.77)**	**3.61 (0.76)**	**< 0.001**	**
Platelet (×10^9/L)					
Median [Q1, Q3]	**199.00 [154.00, 253.00]**	**206.00 [162.00, 259.00]**	**191.00 [143.00, 246.00]**		
Hemoglobin (g/L)					
Mean (SD)	**11.32 (2.34)**	**11.79 (2.32)**	**10.74 (2.24)**	**< 0.001**	**
Blood creatinine (mg/dL)					
Median [Q1, Q3]	**1.10 [0.90, 1.60]**	**1.00 [0.80, 1.30]**	**1.40 [1.00, 2.30]**	**< 0.01**	*
FPG (mg/dL)					
Median [Q1, Q3]	**126.00 [102.00, 168.00]**	**123.00 [101.00, 162.00]**	**131.00 [102.00, 178.00]**	**< 0.001**	**
Albumin (g/dL)					
Mean (SD)	**3.42 (0.67)**	**3.54 (0.65)**	**3.27 (0.67)**	**< 0.001**	**
Blood lipid regulation (%)					
YES	**6152 (84.44%)**	**3487 (86.38%)**	**2665 (82.03%)**	**< 0.001**	**
NO	**1134 (15.56%)**	**550 (13.62%)**	**584 (17.97%)**		
Antiplatelet (%)					

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose.P > 0.05: not marked;0.001 < P < 0.05 :*;P < 0.001:*

Age	Overall (N = 7286)	Q1 (mNUTRIC < 5, N = 4037)	Q2 (mNUTRIC > = 5, N = 3249)	p-value	Significance
Double antiplatelet	**1864 (25.58%)**	**970 (24.03%)**	**894 (27.52%)**	**< 0.001**	**
Single antiplatelet	**4675 (64.16%)**	**2700 (66.88%)**	**1975 (60.79%)**		
NO	**747 (10.25%)**	**367 (9.09%)**	**380 (11.70%)**		
ACEI/ARB (%)					
YES	**2836 (38.92%)**	**1718 (42.56%)**	**1118 (34.41%)**	**< 0.001**	**
NO	**4450 (61.08%)**	**2319 (57.44%)**	**2131 (65.59%)**		
β-blockers (%)					
YES	**6156 (84.49%)**	**3518 (87.14%)**	**2638 (81.19%)**	**< 0.001**	**
NO	**1130 (15.51%)**	**519 (12.86%)**	**611 (18.81%)**		
In-hospital mortality (%)					
Alive	**6293 (86.37%)**	**3817 (94.55%)**	**2476 (76.21%)**	**< 0.001**	**
Dead	**993 (13.63%)**	**220 (5.45%)**	**773 (23.79%)**		
28-Day mortality (%)					
Alive	**6150 (84.41%)**	**3753 (92.97%)**	**2397 (73.78%)**	**< 0.001**	**
Dead	**1136 (15.59%)**	**284 (7.03%)**	**852 (26.22%)**		

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose.P > 0.05: not marked;0.001 < P < 0.05 :*;P < 0.001:*

Age	Overall (N = 7286)	Q1 (mNUTRIC < 5, N = 4037)	Q2 (mNUTRIC > = 5, N = 3249)	p-value	Significance
180-Day mortality (%)					
Alive	**5422 (74.42%)**	**3458 (85.66%)**	**1964 (60.45%)**	**< 0.001**	**
Dead	**1864 (25.58%)**	**579 (14.34%)**	**1285 (39.55%)**		
365-Day mortality (%)					
Alive	**5118 (70.24%)**	**3309 (81.97%)**	**1809 (55.68%)**	**< 0.001**	**
Dead	**2168 (29.76%)**	**728 (18.03%)**	**1440 (44.32%)**		

BMI: body mass index, CABG: coronary artery bypass grafting, PCI: percutaneous coronary intervention, IABP: intra-aortic balloon pump, ACEI: angiotensin-converting enzyme inhibition, ARB: angiotensin receptor blocker, SOFA: Sepsis-Organ Failure Assessment Score, APSIII: Acute Physiology Score III, WBC: white blood cells, RBC: red blood cells, PLT: platelets, HGB: hemoglobin, FPG: fasting plasma glucose.P > 0.05: not marked;0.001 < P < 0.05 :*;P < 0.001:*

3.2 Association Between Nutritional Risk and Clinical Outcomes

Kaplan-Meier survival curves for 28-day and 365-day all-cause mortality were plotted based on the established risk strata of each nutritional score (Fig. 2). Survival rates differed significantly among risk groups for all three scoring systems (Log-rank P < 0.001). Specifically, Higher nutritional risk according to the GNRI (Fig. 2A and 2B) and CONUT score (Fig. 2C and 2D) correlated with progressive declines in survival probability. The mNUTRIC score showed similar prognostic value (Fig. 2E and 2F). Patients with high mNUTRIC scores (≥ 5) experienced an early and steep drop in survival compared to the low-risk group. This lower survival probability persisted throughout the one-year follow-up. These findings confirm that greater nutritional risk predicts higher short-term and long-term mortality regardless of the assessment tool used. The 180 days survival analysis showed consistent results (Supplementary Fig S2).

The results of the multivariable Cox proportional hazards regression analysis are shown in Table 5. In the GNRI and CONUT models, covariates included age, sex, Acute Physiology Score III (APS III), SOFA score, and heart failure. Compared to the severe nutritional risk group (GNRI < 82), the normal nutrition group (GNRI ≥ 98) demonstrated a significantly lower risk of 28-day mortality (HR 0.54; 95% CI 0.45–0.64; P <

0.001). This significant protective effect was maintained throughout the 365-day follow-up period (HR 0.49; 95% CI 0.43–0.56).Analyses based on the CONUT score demonstrated a consistent trend. The high nutritional risk group (CONUT > 8) had a significantly higher risk of 28-day mortality compared to the reference group (HR 2.73; 95% CI 2.05–3.65; P < 0.001). Notably, this hazard ratio did not attenuate over time, remaining at a high level at both 180 days (HR 3.09; 95% CI 2.45–3.89) and 365 days (HR 2.92; 95% CI 2.35–3.63) post-admission.For the mNUTRIC model, to avoid multicollinearity, age, APS III, and SOFA scores—which are inherent components of the scoring system—were excluded from the covariates, while the remaining adjustment factors were identical to the aforementioned models. The mNUTRIC score demonstrated the strongest short-term predictive performance. Patients in the high nutritional risk group (mNUTRIC ≥ 5) had a significantly increased risk of 28-day mortality (HR 3.13; 95% CI 2.70–3.63). Furthermore, multivariable logistic regression analysis revealed a substantially higher risk of in-hospital mortality in this group (OR 4.39; 95% CI 3.65–5.31). Although this risk decreased slightly at the 180-day and 365-day follow-ups, it remained statistically significant (365-day HR 2.00; 95% CI 1.81–2.21).

Table 5
Multivariable Cox Regression Analyses for 28-Day, 180-Day, and 365-Day Mortality, and Multivariable Logistic Regression Analysis for In-Hospital Mortality in Patients with Critical Coronary Heart Disease

Geriatric nutritional risk index*	**28-Day mortality**	**180-Day mortality**	**365-Day mortality**	**In-hospital mortality**
Q1 (< 82)	Ref	Ref	Ref	Ref
Q2 (82, 92)	0.78 (0.65 ~ 0.94)	0.75 (0.65 ~ 0.88)	0.75 (0.66 ~ 0.87)	0.69 (0.52 ~ 0.92)
Q3 (92, 98)	0.77 (0.63 ~ 0.94)	0.73 (0.62 ~ 0.85)	0.76 (0.65 ~ 0.88)	0.77 (0.57 ~ 1.04)
Q4 (> 98)	0.54 (0.45 ~ 0.64)	0.48 (0.42 ~ 0.55)	0.49 (0.43 ~ 0.56)	0.46 (0.36 ~ 0.60)
P for trend	< 0.001	< 0.001	< 0.001	< 0.001
Controlling Nutritional Status score*				
Q1 (< 2)	Ref	Ref	Ref	Ref
Q2 (2, 5)	1.70 (1.43 ~ 2.03)	1.69 (1.48 ~ 1.94)	1.60 (1.42 ~ 1.81)	1.83 (1.47 ~ 2.29)
Q3 (5, 8)	1.95 (1.61 ~ 2.36)	2.15 (1.86 ~ 2.49)	2.01 (1.76 ~ 2.30)	2.54 (1.99 ~ 3.26)
Q4 (> 8)	2.73 (2.05 ~ 3.65)	3.09 (2.45 ~ 3.89)	2.92 (2.35 ~ 3.63)	3.91 (2.58 ~ 5.91)
P for trend	< 0.001	< 0.001	< 0.001	< 0.001
Modified-Nutrition Risk in the Critically Ill score				
Q1 (< 5)	Ref	Ref	Ref	Ref
Q2 (> = 5)	3.13 (2.70 ~ 3.63)	2.27 (2.03 ~ 2.53)	2.00 (1.81 ~ 2.21)	4.39 (3.65 ~ 5.31)
P for trend	< 0.001	< 0.001	< 0.001	< 0.001

Model* was adjusted for Age, Gender, APS III (Acute Physiology Score III), SOFA Score (Sequential Organ Failure Assessment Score), CABG (Coronary Artery Bypass Grafting), PCI (Percutaneous Coronary Intervention), IABP (Intra-Aortic Balloon Pump), Heart Failure, Renal Disease, Stroke, Malignancy, Cardiogenic Shock, WBC (White Blood Cell), RBC (Red Blood Cell), Hemoglobin, Creatinine, Glucose, Blood Lipid Regulation Therapy, Antiplatelet Therapy Score, ACEI/ARB (Angiotensin-Converting Enzyme Inhibitors/Angiotensin II Receptor Blockers), and β-Blockers.

Model& was adjusted for Gender, CABG (Coronary Artery Bypass Grafting), PCI (Percutaneous Coronary Intervention), IABP (Intra-Aortic Balloon Pump), Heart Failure, Renal Disease, Stroke, Malignancy, Cardiogenic Shock, WBC (White Blood Cell), RBC (Red Blood Cell), Hemoglobin, Creatinine, Glucose, Blood Lipid Regulation Therapy, Antiplatelet Therapy Score, ACEI/ARB (Angiotensin-Converting Enzyme Inhibitors/Angiotensin II Receptor Blockers), and β-Blockers.

3.3 Dose-response relationship

Restricted cubic spline (RCS) models were constructed to evaluate the dose-response relationships between the continuous GNRI, CONUT, and mNUTRIC scores and short-term (in-hospital, 28-day) and long-term (365-day) all-cause mortality (Fig. 3). As shown in Fig. 3A, 3B, and 3C, mortality risk demonstrated a significant L-shaped, non-linear increase with worsening nutritional status defined by the GNRI (P for non-linearity < 0.05 at 28 days; P < 0.001 at 365 days). Specifically, the risk of mortality increased significantly when the GNRI dropped below 105.25.

Analyses based on the CONUT score (Fig. 3D, 3E, and 3F) revealed that mortality risk increased continuously with higher scores. This non-linear relationship was significant for both 28-day and 365-day outcomes (P for non-linearity < 0.01), with the risk inflection point precisely identified at a score of 2.

The RCS curves for the mNUTRIC score (Fig. 3G, 3H, and 3I) exhibited a positive non-linear trend. For in-hospital mortality, the risk curve demonstrated a J-shaped, non-linear increase (28-day P for non-linearity < 0.05). Mortality risk increased sharply when the mNUTRIC score exceeded 4.

These findings confirm the high value of these three nutritional scores for risk stratification in critically ill patients with CAD. Furthermore, the identified inflection points suggest that relying solely on conventional cut-offs may underestimate mortality risk in patients with early-stage malnutrition. The 180-day mortality outcomes were consistent with these findings, further validating the robustness of the models (Supplementary Fig S3).

3.4 Subgroup analysis

Figures 4 and 5 present the subgroup analyses for 28-day and 365-day all-cause mortality.Higher nutritional risk was consistently associated with increased both short-term and long-term mortality across all subgroups, regardless of age, sex, BMI, hypertension, diabetes, atrial fibrillation, heart failure, chronic kidney disease, or stroke history. Interaction tests revealed specific variations in prognostic performance under certain clinical conditions. In the GNRI model (Fig. 4A and 5A) BMI modified the predictive efficacy for 28-day mortality (P for interaction = 0.039). This interaction is likely attributable to the inherent weight dependence in the GNRI formula. At 365-day comorbid heart failure (P for interaction = 0.005) or chronic kidney disease (P < 0.001) attenuated the prognostic impact of GNRI. In the CONUT model (Fig. 4B and 5B) heart failure and kidney disease amplified the mortality risk at both 28-day (P for interaction 0.012 and 0.013) and 365-day (both P for interaction < 0.001). The mNUTRIC score (Fig. 4C and 5C) demonstrated the most pronounced mortality risk increase at 28-day (overall HR

3.09). A history of stroke significantly modified this short-term outcome (P = 0.031). For 365-day mortality heart failure (P = 0.002) and chronic kidney disease (P = 0.001) acted as key long-term risk modifiers.

3.5 Machine Learning Model Development and Interpretability

We applied Least Absolute Shrinkage and Selection Operator (LASSO) regression with L1 regularization for feature selection to predict mortality. This mathematical approach effectively addressed potential multicollinearity among nutritional scores and biochemical indicators. The algorithm identified 12 optimal predictors (Fig. 6A and 6B). These included the mNUTRIC score, GNRI, CONUT score, serum albumin, blood glucose, cardiogenic shock, prior stroke, coronary artery bypass grafting (CABG) history, and four pharmacological interventions (ACEI/ARBs, antiplatelets, beta-blockers, and lipid-lowering drugs). The discriminative performance of the 10 developed ML models was compared with that of the APACHE III and SOFA scores(Fig. 6C and 6D). Model performance was evaluated primarily using the area under the receiver operating characteristic curve (AUC). The Random Forest (RF) model demonstrated the highest discriminative ability. It achieved an AUC of 0.944 in the training set and 0.857 in the testing set. The RF model outperformed XGBoost, LightGBM, and traditional logistic regression. It also showed significantly better predictive value than established clinical tools such as the APACHE III and SOFA scores. Supplementary Table S3 further confirms the robust performance of the RF model. It achieved an accuracy of 0.924 and a Matthews correlation coefficient (MCC) of 0.637 for predicting mortality. This model provided an optimal balance between sensitivity and specificity. The neural network model yielded the highest recall (0.682) for identifying high-risk patients. However its overall discrimination remained inferior to the RF model. Other algorithms including XGBoost (testing AUC 0.848) and CatBoost (testing AUC 0.863) also performed well. Basic algorithms like SVM and KNN showed limited predictive value.

We applied SHapley Additive exPlanations (SHAP) to interpret the decision-making process of the best-performing RF model (Fig. 6E and 6F). The SHAP attribution analysis revealed that the mNUTRIC score was the most critical feature driving mortality predictions. Furthermore cardiogenic shock, serum albumin levels, ACEI/ARB therapy, the CONUT score, antiplatelet use, and beta-blocker administration made substantial contributions to the final model output.

4. Discussion

In this study, we demonstrated that the GNRI, CONUT, and mNUTRIC scores consistently predict in-hospital and out-of-hospital (28 days, 180 days, and 365 days) all-cause mortality risks in ICU patients with CAD. Specifically, high nutritional risk status is associated with a significantly increased mortality risk regardless of the scoring tool utilized. These results underscore the significance of nutritional assessment in those patients. RCS analysis revealed that the sharp increase in mortality risk occurs earlier than the standards defined by traditional cut-offs. This suggests that the fatal threat of early malnutrition emerges sooner in these severely ill patients. Furthermore, we developed machine learning

predictive models integrating these nutritional scores. The Random Forest model performed best in predicting 28-day mortality and outperformed the traditional APS III and SOFA scores. SHAP interpretability analysis further established the mNUTRIC score, cardiogenic shock, and serum albumin as the most critical factors driving acute-phase mortality. These findings underscore the clinical urgency of implementing early nutritional screening and stratified interventions for critically ill cardiovascular patients.

Patients with severe CAD often present with multiple severe comorbidities and are prone to rapid disease progression[3, 29]. Driven by the dual insults of persistent ischemic stress and multiple complications, inflammatory and neuroendocrine responses become profoundly overactivated, rapidly shifting the body into a hypermetabolic state characterized by accelerated protein degradation and excessive energy expenditure [6, 30]. Therefore, malnutrition in these patients is essentially not merely a simple lack of intake, but rather a key clinical manifestation of disease-driven systemic inflammation and metabolic dysfunction[31]. Therefore, early and precise risk prediction is crucial for guiding clinical decision-making and improving outcomes in ICU patients with CAD.

Our study demonstrate that objective nutritional scores serve as strong independent predictors of all-cause mortality in these patients. More importantly, they exhibited complementary time-dependent trends in risk stratification. The mNUTRIC score demonstrated excellent predictive performance for short-term mortality (in-hospital and 28 days). Tseng CC et al. found that this robust short-term efficacy is primarily driven by its integration of acute severity markers such as the SOFA score, which sensitively capture the initial stress phase and acute metabolic derangements[32]. However, this prognostic value significantly attenuated over time. A plausible explanation is that once critically ill patients survive the acute physiological crisis, these baseline acute indicators fail to reflect ongoing chronic nutritional depletion, resulting in diminished long-term predictive power[33]. Conversely, the CONUT and GNRI scores demonstrated durable long-term prognostic efficacy. Unlike mNUTRIC's reliance on acute severity, CONUT and GNRI integrate objective biochemical markers such as albumin, lymphocytes, cholesterol, and body weight[18, 19]. In ICU patients with CAD who survive the acute crisis, these markers serve as more reliable indicators of systemic inflammation levels and immunological exhaustion[6, 34]. Therefore, in clinical practice, adopting a combined scoring assessment strategy may provide a more comprehensive and dynamic risk assessment for ICU patients with CAD.

The exposure to nutritional risk among ICU patients with CAD occurs significantly earlier than indicated by conventional clinical cut-offs. Raposeiras Roubín S et al. demonstrated that even mild nutritional depletion in patients with acute coronary syndrome significantly increases the risk of long-term all-cause mortality and adverse cardiovascular events[6]. Similarly, Arero et al. confirmed through a large-scale meta-analysis that a CONUT score within the traditional "mild risk" range (≥ 2) acts as an independent risk factor driving fatal cardiovascular outcomes[12]. This indicates that patients with coronary artery disease (especially the ICU patients with CAD population) are exquisitely sensitive to early substrate depletion and micro-inflammatory imbalances. Our findings also confirm this trend. Specifically, the risk inflection point for GNRI was identified at a remarkably high 105.25, while the CONUT score exhibited a

non-linear, precipitous rise in mortality risk at a threshold as low as 2. Furthermore, the mNUTRIC score displayed a distinct time-dependent prognostic signature: for 28-day mortality, scores exceeding 4 triggered a J-shaped exponential surge, whereas this relationship transitioned into a stable linear risk accumulation over the 365-day follow-up (P for non-linearity = 0.42). This suggests that continuing to use conventional cut-off values may result in the misdiagnosis of patients at high risk of malnutrition in the ICU patients with CAD population, and may even delay the timing of critical nutritional interventions.

To accurately identify fatal risks in ICU patients with CAD during the acute phase, we developed an explainable machine learning framework specifically optimized for the 28-day all-cause mortality endpoint. This integrated model exhibited superior discriminative performance (validation AUC = 0.857), significantly surpassing conventional scoring systems. SHAP-based feature attribution identified the mNUTRIC score as the dominant predictor, reaffirming its clinical utility as a robust composite proxy for both disease severity and systemic inflammatory burden.

Furthermore, the central role of cardiogenic shock in the feature attribution establishes a high degree of consistency between the model and clinical reality. As the ultimate manifestation of acute hemodynamic failure, the prognostic gravity of CS has been profoundly documented across landmark trials[35–37]. Despite the continuous evolution of revascularization strategies and mechanical circulatory support, CS persists as the most lethal clinical phenotype defined by ESC guidelines[38, 39]. Intriguingly, our analysis revealed that the individual contribution of serum albumin surpassed that of composite scores (GNRI and CONUT) which incorporate it. Consistent with Cabré M et al.[40], our results indicate that the predictive sensitivity of composite nutritional indices is often compromised during the acute phase. Specifically, volume overload and fluid retention commonly encountered in the ICU frequently confound weight-based GNRI assessments[41]. Concurrently, the lymphocyte component of the CONUT score typically exhibits a response lag under acute immunological stress[42]. By contrast, standalone albumin concentrations circumvent these systemic confounders and can offer a more direct and time-sensitive reflection of prognostic risk. Consequently, a single, unconfounded biomarker may equally demonstrate superior predictive value during the acute phase in ICU patients with CAD, offering a practical and rapid bedside risk assessment.

Our study has several limitations. As a single-center retrospective analysis of the MIMIC-IV database, residual confounding, such as specific angiographic details including the SYNTAX score, cannot be completely ruled out despite robust multivariable adjustments. Furthermore, nutritional and immunological indices were derived from a single baseline measurement at ICU admission. This static snapshot fails to capture dynamic longitudinal changes, which are often compounded by acute fluid shifts and metabolic volatility during the ICU stay, thereby limiting our assessment of cumulative prognostic effects. Additionally, because our design focused strictly on risk prediction, we lacked data regarding specific nutritional support protocols. Whether identifying high-risk CAD patients through this model translates into survival benefits following targeted interventions requires confirmation via randomized controlled trials. Finally, while the machine learning framework achieved excellent internal discrimination, it lacks external validation across diverse clinical settings. Future research must

incorporate calibration and decision curve analyses to rigorously evaluate its net clinical benefit prior to bedside implementation.

5. Conclusion

This study confirms the significant value of the GNRI, CONUT, and mNUTRIC scores in predicting short- and long-term mortality among ICU patients with CAD, revealing their distinct time-varying prognostic patterns.Furthermore, the explainable machine learning model integrating these indices confirmed the pivotal prognostic driving roles of the mNUTRIC score and cardiogenic shock for short-term mortality. Despite certain limitations, our findings offer a practical reference for evaluating nutritional risk among critically ill patients with CAD.

Declarations

Data availability

The data underpinning the findings of this study can be obtained from the corresponding author upon reasonable request.

Clinical trial number

Not applicable.

Ethics approval and consent to participate

The study utilized the Medical Information Mart for Intensive Care IV (MIMIC - IV) database, which had been approved by the review committee of Massachusetts Institute of Technology and Beth Israel Deaconess Medical Center. As the MIMIC - IV database contains de-identified and publicly accessible data, additional ethical approval for participant consent was not necessary for this study.

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Author contributions

YFG, BH and HY made substantial contributions to the original draft, software, resources, methodology, and investigation. ZHX, JHZ, SHX, MC, and HS took part in editing and validation. All authors agreed to submit to the current journal.

Consent for publication

Not applicable.

Conflict of Interest

The authors declare no competing interests.

Provenance and peer review

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Figures

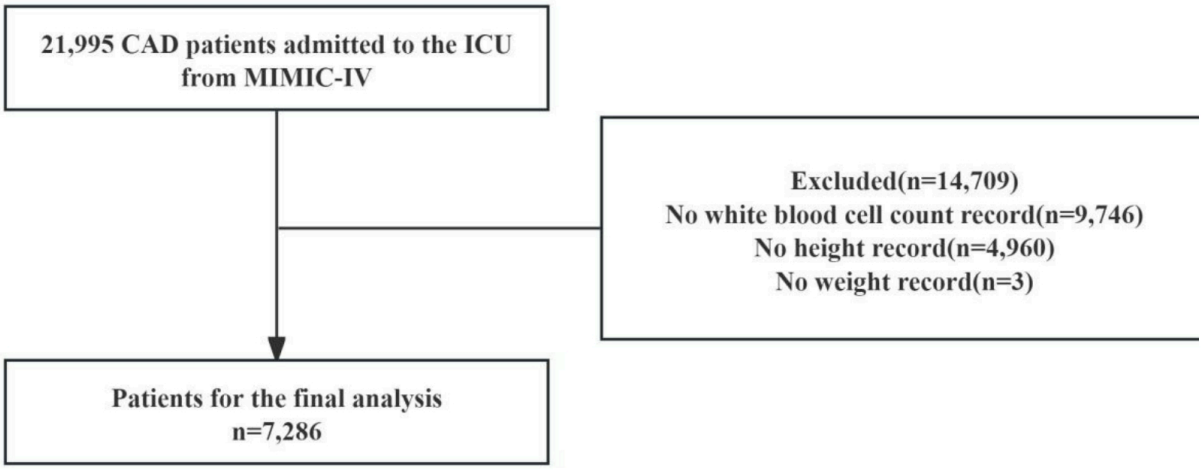


Figure 1

A flowchart showing the selection of the study sample.

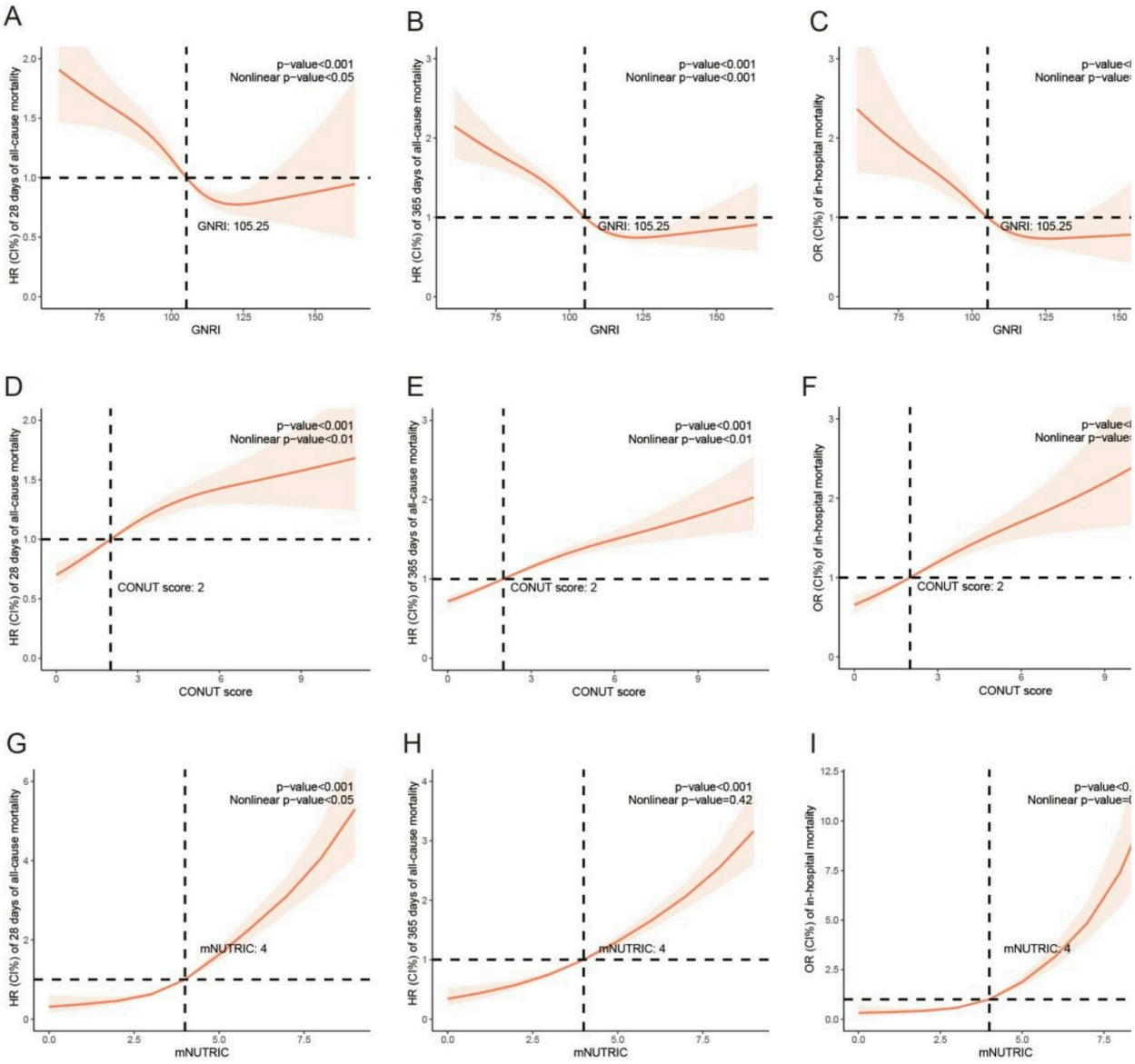


Figure 2

Restricted cubic spline analyses of the association of GNRI (A, B, C), COUNT score (D, E, F), and mNUTRIC score (G, H, I) with all-cause death in 28 days (A, D, G), B all-cause death in 365 days (B, E, H), in-hospital mortality (C, F, I). The adjustment strategy is the same as the multivariate model

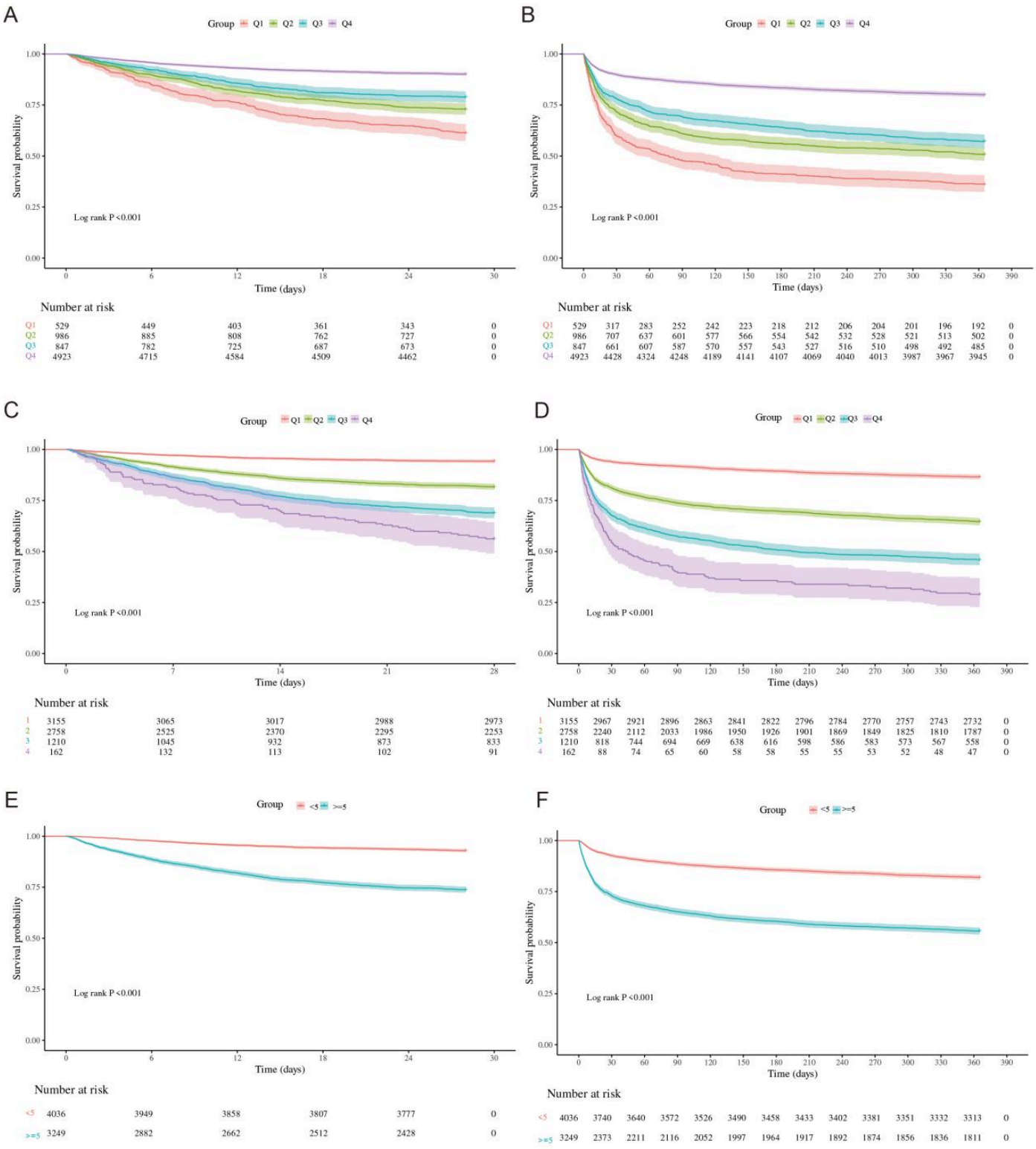


Figure 3

Kaplan–Meier curves showing cumulative probability of outcome according to GNRI (A, B), COUNT score (C, D), and mNUTRIC score (E, F) at 28 days (A, C, E), and 365 days (B, D,F).

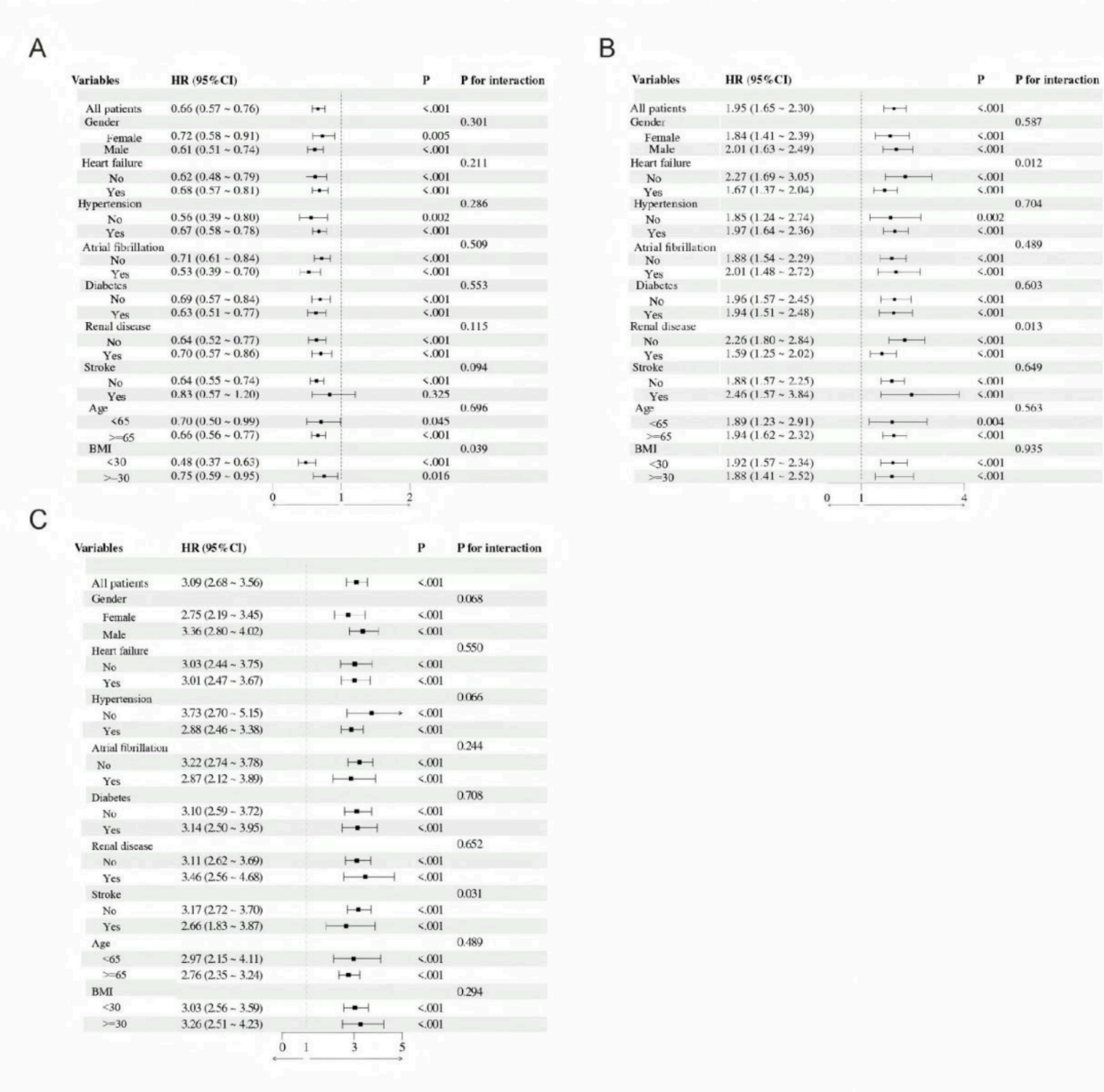


Figure 4

Forest plots of stratified analyses of GNRI (A), COUNT score (B), and mNUTRIC score (C) and 28-day mortality. With the exception of the stratified variable itself, the adjustment approach is the same as multivariate model

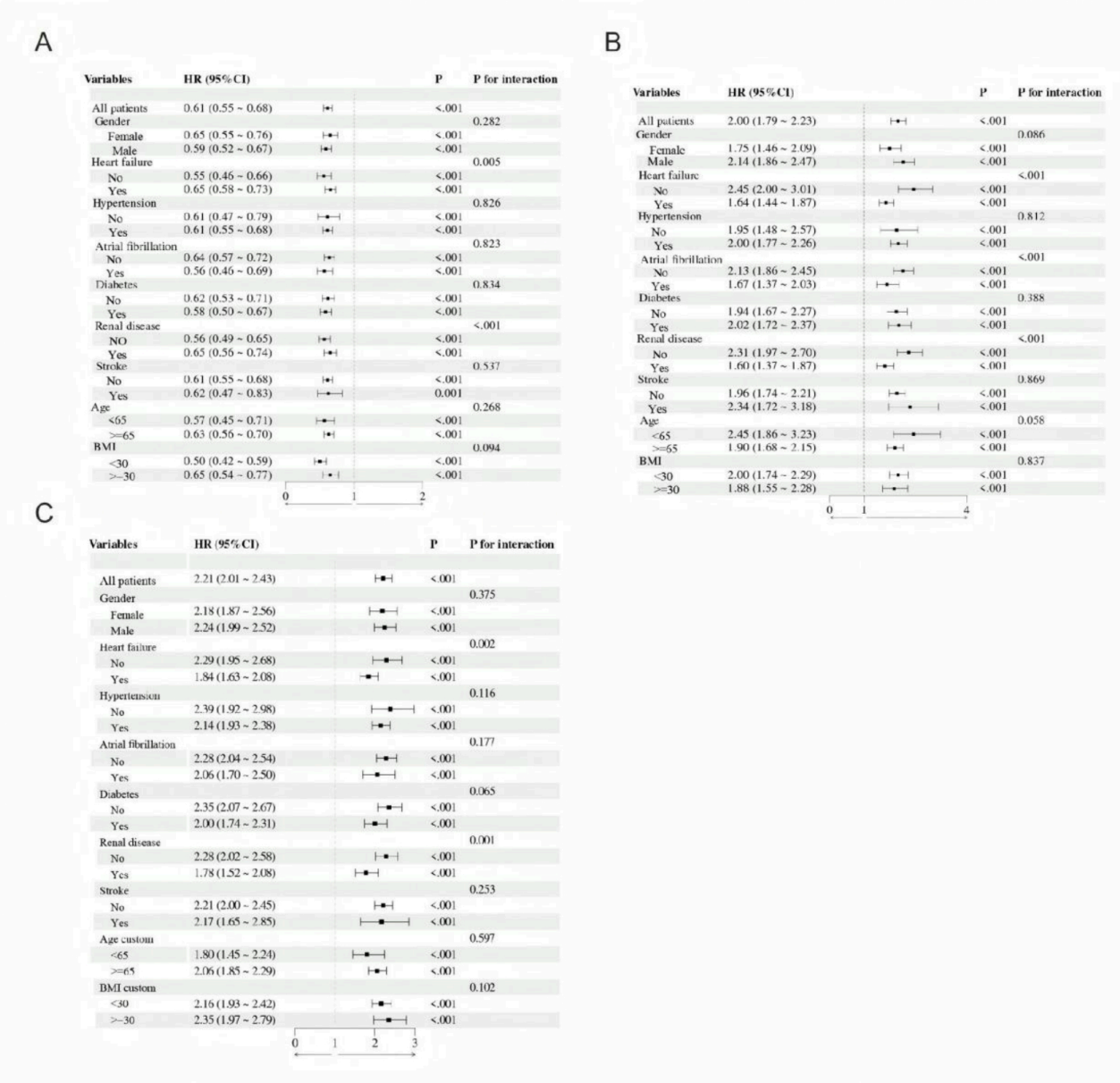


Figure 5

Forest plots of stratified analyses of GNRI (A), COUNT score (B), and mNUTRIC score (C) and 365-day mortality. With the exception of the stratified variable itself, the adjustment approach is the same as multivariate model

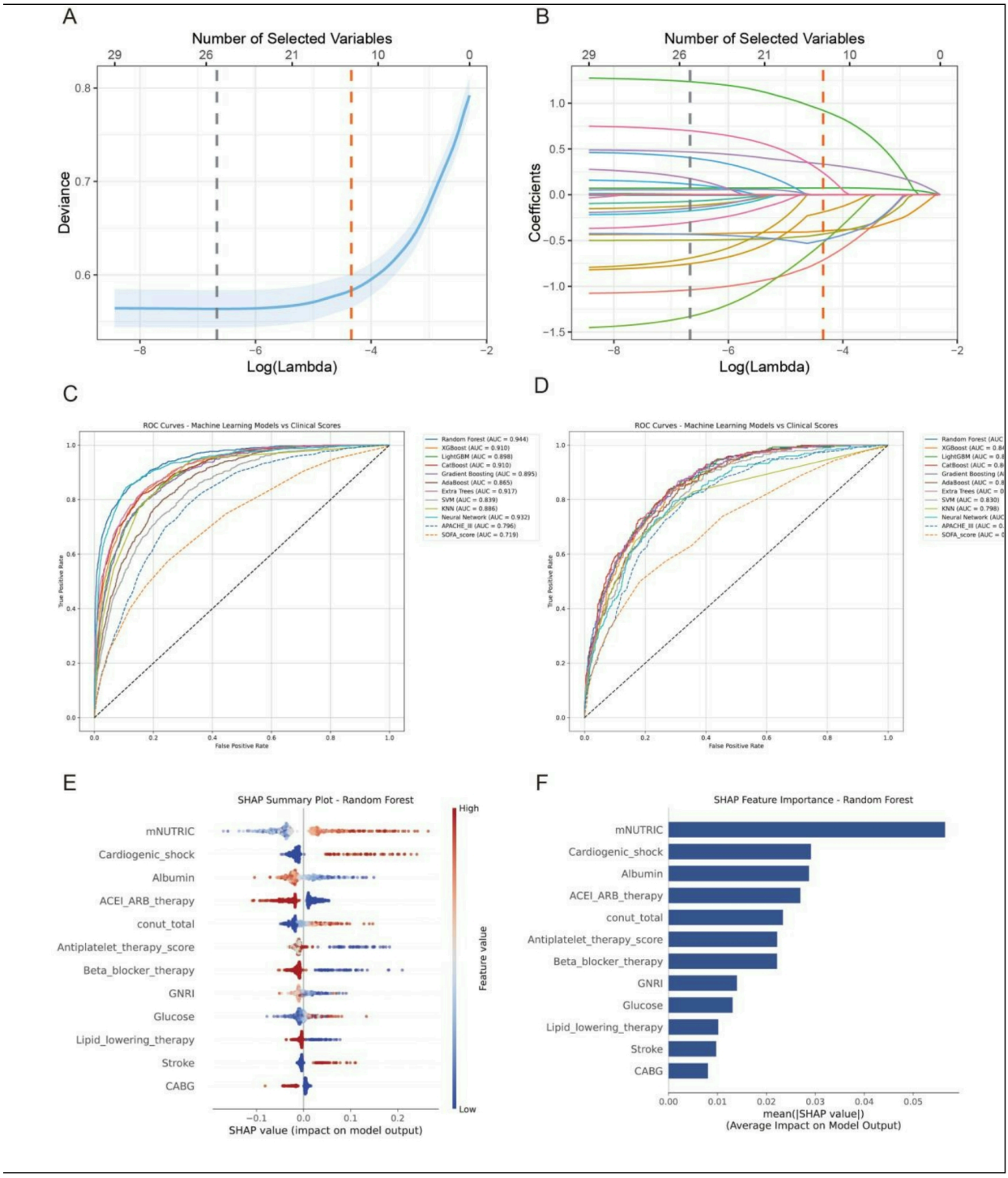


Figure 6

Lasso regression-based variable screening, ROC curves for the machine learning models, and visually interpret machine learning models using SHAP. A. Variation characteristics of variable coefficients; B. The process of selecting the optimal value of the parameter λ in the lasso regression model is carried out by the cross-validation method; C. ROC curves for the machine learning models for training sets; D.

ROC curves for the machine learning models for validation sets; E. Random forest models: SHAP summary plot; F. Random forest models: Permutation importance plot.