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ORIGINAL RESEARCH

Prognostic Value of the Triglyceride-Glucose Index Combined with Non-HDL-C/HDL-C Ratio for Predicting Coronary Microvascular Dysfunction in ACS Patients Post-PCI

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Background: Coronary microvascular dysfunction (CMD) after percutaneous coronary intervention (PCI) is a critical prognostic factor in acute coronary syndrome (ACS). This study aimed to evaluate the combined predictive value of the triglyceride-glucose index (TyG) and non-HDL-C/HDL-C ratio (NHHR) for CMD in ACS patients post-PCI.

Methods: A retrospective analysis of 542 ACS patients undergoing PCI (2021–2023) was conducted. Patients were classified into CMD (n=273) and non-CMD (n=269) groups based on CMD presence post-PCI. Baseline characteristics and biochemical markers were analyzed. TyG index and NHHR were calculated, and univariate and multivariate analyses were performed to identify predictors of CMD. ROC curves evaluated the predictive value of TyG combined with NHHR, while net reclassification index (NRI) and integrated discrimination improvement (IDI) assessed incremental predictive value.

Results: CMD patients exhibited significantly higher levels of TyG and NHHR compared to non-CMD patients. Multivariate logistic regression indicated that TyG (OR = 1.89, 95% CI: 1.24–2.88, $P = 0.003$) and NHHR (OR = 1.34, 95% CI: 1.11–1.62, $P = 0.011$) were independent predictors of CMD. The combined model showed significant improvement in discrimination (C-statistic increased from 0.750 to 0.782, $P < 0.001$) and reclassification (NRI = 0.458, IDI = 0.051, both $P < 0.001$).

Conclusion: TyG and NHHR are novel predictors of CMD post-PCI, with combined use improving risk stratification. Given the retrospective nature of the study, further multicenter prospective research is required to validate these findings.

Keywords: NHHR, triglyceride-glucose index, acute coronary syndrome, coronary microvascular dysfunction, percutaneous coronary intervention

Introduction

With the increasing incidence of cardiovascular diseases, acute coronary syndrome (ACS) remains a leading global cause of mortality and disability despite therapeutic advances.[1] Percutaneous coronary intervention (PCI), while effective in restoring epicardial coronary flow, fails to address microvascular complications in a significant proportion of patients.[2] Coronary microvascular dysfunction (CMD) post-PCI manifests as impaired myocardial perfusion, contributing to adverse clinical outcomes including heart failure progression and recurrent ischemic events.[3–5] Early identification of this complication is critical for optimizing post-procedural management and improving long-term prognosis.

Current risk stratification tools for CMD remain suboptimal. Traditional predictors including diabetes mellitus, hypertension, and inflammatory markers like high-sensitivity C-reactive protein (hs-CRP) demonstrate limited discriminative capacity.[6,7] Emerging biomarkers such as endothelial function indices (eg, flow-mediated dilation) and microRNA profiles show promise but face implementation challenges due to technical complexity and cost constraints.[8,9] This

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underscores the need for readily accessible prognostic tools combining pathophysiological insights with clinical practicality. Dyslipidemia's central role in ACS pathophysiology has driven interest in novel lipid indices. The non-high-density lipoprotein cholesterol to HDL-C ratio (NHHR) integrates atherogenic and protective lipoprotein components, demonstrating superior predictive value for cardiovascular events compared to conventional lipid parameters.[10,11] Concurrently, the triglyceride-glucose index (TyG) has emerged as a robust surrogate for metabolic dysregulation, independently associated with coronary artery calcification progression and atherosclerotic plaque vulnerability.[12,13] Notably, both biomarkers reflect distinct yet complementary pathways - NHHR quantifying lipid homeostasis and TyG capturing glucose-lipid axis interactions - suggesting potential synergistic prognostic value.

Although previous studies have individually examined TyG and NHHR in cardiovascular risk prediction,[14,15] their combined utility for post-PCI CMD detection remains unexplored. This study investigates the hypothesis that integrated assessment of TyG and NHHR enhances risk stratification for microvascular complications in ACS patients undergoing PCI. By evaluating this biomarker combination through advanced statistical modeling, we aim to provide clinicians with a practical tool for personalized post-procedural management.

Methods

Study Subjects

This study is a single-center, retrospective analysis conducted on patients with ACS who received PCI at the Second Affiliated Hospital of Xuzhou Medical University between January 2021 and December 2023. The retrospective nature and single-center focus of the study may introduce biases, and the findings should be interpreted with caution. Future multi-center, prospective studies are needed to validate these results.

Inclusion Criteria: (1) Age>18 years; (2) Diagnosis of ACS, including unstable angina, ST-elevation myocardial infarction (STEMI), and non-ST-elevation myocardial infarction (NSTEMI), according to the criteria outlined in the "ACS Emergency Rapid Diagnosis and Treatment Guidelines.";[16] (3) Received PCI treatment within 12 hours of symptom onset; (4) No prior history of PCI or coronary artery bypass grafting (CABG); (5) Complete clinical and laboratory data available for the patient.

Exclusion Criteria: (1) Severe liver or kidney dysfunction; (2) Concurrent malignancy; (3) Severe infectious diseases.

Definition of CMD: CMD was defined as a coronary microvascular resistance index (IMR) ≥25 measured via invasive pressure wire post-PCI, combined with angiographic evidence of no-reflow (TIMI flow grade ≤2 or TIMI myocardial perfusion grading ≤2).[17]

In total, 542 ACS patients who underwent PCI at the Second Affiliated Hospital of Xuzhou Medical University between January 2021 and December 2023 were included in the final analysis. The patients were divided into two groups based on the occurrence of CMD post-PCI: the non-CMD group (269 patients) and the CMD group (273 patients) (Figure 1). This study adheres to the principles outlined in the Declaration of Helsinki and was approved by the Ethics Committee of the Second Affiliated Hospital of Xuzhou Medical University (Approval No. 2020120205). Given the retrospective nature of this study, the ethics committee waived the requirement for informed consent.

Data Collection

Baseline clinical data were collected, including demographic information (age, gender), medical history (smoking, drinking, hypertension, diabetes mellitus), and laboratory tests. The following laboratory parameters were measured: peripheral blood leukocyte count (WBC), hemoglobin (Hb), platelet count (PLT), fasting blood glucose (FBG), uric acid (UA), creatinine (Cr), total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), lipoprotein(a) (Lpa), and glycated hemoglobin (HbA1c). Left ventricular ejection fraction (LVEF) was measured by echocardiography. The number of coronary artery lesions during PCI was also recorded.

The TyG was calculated using the formula: $TyG = \ln[(TG\ mg/dL) \times (FBG\ mg/dL) / 2]$

The NHHR was defined as the ratio of non-HDL-C to HDL-C, where non-HDL-C = TC - HDL-C.

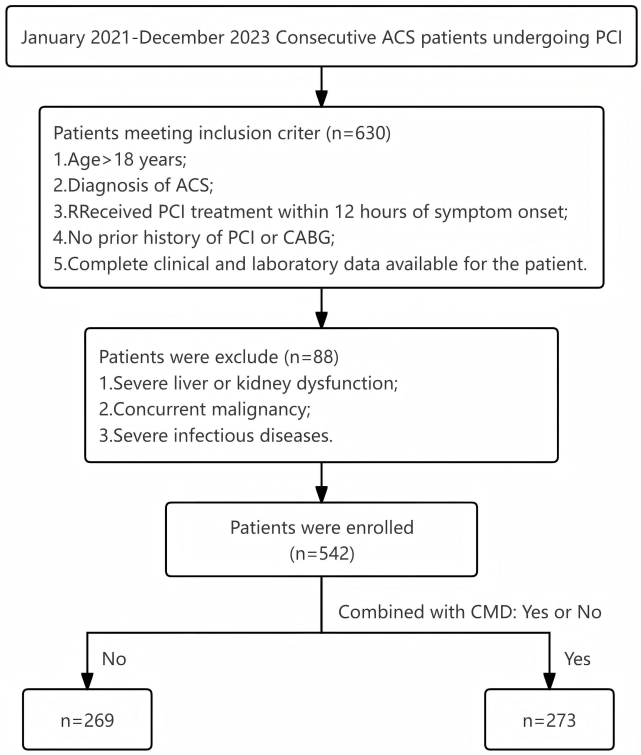

Figure 1 Flow chart of the study population.

Statistical Analysis

Statistical analysis was performed using SPSS 26.0 and R 4.2.2. The normality of the data was assessed using the Shapiro–Wilk test. Normally distributed continuous data were expressed as means ± standard deviations (SD), and group comparisons were made using the *t*-test. Non-normally distributed continuous data were expressed as medians (interquartile range) [M (Q_1, Q_3)], and group comparisons were made using the Mann–Whitney *U*-test. Categorical variables were expressed as frequencies and percentages [n (%)], and group comparisons were performed using the Chi-square test or Fisher's exact test.To identify predictors of CMD, univariate logistic regression analysis was first conducted. Significant variables with $P < 0.05$ in the univariate analysis were included in the multivariate logistic regression model. The results were presented as odds ratios (OR) with 95% confidence intervals (CI). The predictive ability of the TyG and NHHR for CMD was evaluated using the area under the receiver operating characteristic (ROC) curve (AUC), calculated by the C-statistic. Additionally, the net reclassification index (NRI) and integrated discrimination improvement (IDI) were used to further analyze the added predictive value of these markers. A *P*-value of <0.05 was considered statistically significant for all analyses.

Results

Baseline Characteristics of Patients

A total of 542 patients were included in the study, consisting of the non-CMD group (Controls, 269 cases) and the CMD group (Cases, 273 cases). The baseline demographic and clinical characteristics of both groups are systematically presented in Table 1. Statistically significant differences were observed in parameters with established clinical relevance to cardiovascular pathophysiology. Specifically, the CMD group exhibited a higher proportion of female patients (40.66% vs 31.23%, P=0.022), which aligns with epidemiological evidence suggesting gender-specific vascular response patterns. Notably, diabetes mellitus prevalence was significantly elevated in the CMD cohort (55.68% vs 23.79%, P<0.001), consistent with the known association between insulin resistance and microvascular dysfunction. Metabolic biomarkers including TyG index and NHHR demonstrated marked elevation in CMD patients, reflecting their combined utility in

Table 1 Baseline Characteristics of Patients

Variables	Controls (n=269)	Cases (n=273)	Z/χ^2	*P*-Value
Age/(years)	69.00 (60.00, 74.00)	68.00 (57.00, 73.00)	−1.13	0.260
Gender, n(%)			5.23	0.022
Female	84 (31.23)	111 (40.66)		
Male	185 (68.77)	162 (59.34)		
Smoking, n(%)			0.58	0.446
No	178 (66.17)	189 (69.23)		
Yes	91 (33.83)	84 (30.77)		
Drinking, n (%)			0.26	0.609
No	211 (78.44)	219 (80.22)		
Yes	58 (21.56)	54 (19.78)		
Hypertension, n(%)			0.46	0.497
No	92 (34.20)	101 (37.00)		
Yes	177 (65.80)	172 (63.00)		
Diabetes mellitus, n(%)			57.47	<0.001
No	205 (76.21)	121 (44.32)		
Yes	64 (23.79)	152 (55.68)		
Number of diseased vessels, n(%)			0.22	0.898
1-vessel disease	133 (49.44)	133 (48.72)		
2-vessel disease	85 (31.60)	91 (33.33)		
3-vessel disease	51 (18.96)	49 (17.95)		
WBC ($\times10^9$/L)	6.38 (5.21, 7.66)	6.32 (5.24, 7.85)	−0.59	0.559
Hb (g/L)	135.00 (124.00, 145.00)	136.00 (126.00, 149.00)	−1.57	0.115
PLT/ ($\times10^9$/ L)	190.00 (154.00, 238.00)	202.00 (168.00, 250.00)	−2.47	0.014
FBG (mmol/L)	5.22 (4.69, 5.81)	6.12 (5.01, 7.24)	−7.01	<0.001
UA (umol/L)	320.00 (263.30, 388.70)	318.90 (260.20, 389.60)	−0.13	0.895
Cr (umol/L)	68.00 (60.00, 81.00)	67.00 (59.00, 79.00)	−0.86	0.387
TC (mmol/L)	3.92 (3.39, 4.60)	4.56 (3.84, 5.44)	−7.17	<0.001
TG (mmol/L)	1.23 (0.88, 1.65)	1.51 (1.11, 2.09)	−5.58	<0.001
HDL-C (mmol/L)	1.08 (0.92, 1.25)	1.09 (0.93, 1.31)	−0.74	0.461
LDL-C (mmol/L)	1.80 (1.44, 2.29)	2.48 (1.83, 3.04)	−8.57	<0.001
Lpa (mg/dl)	14.20 (6.30, 24.50)	22.20 (9.80, 45.80)	−5.20	<0.001
HbA1c (%)	5.90 (5.50, 6.30)	6.40 (5.80, 7.40)	−6.90	<0.001
LVEF (%)	59.00 (57.00, 60.00)	59.00 (57.00, 60.00)	−1.09	0.275
TyG index	8.51 (8.22, 8.82)	8.94 (8.51, 9.32)	−7.72	<0.001
NHHR	2.65 (1.97, 3.35)	3.23 (2.46, 4.12)	−6.22	<0.001

Notes: Data are presented as median (interquartile range, IQR) for continuous variables and as percentages (%) for categorical variables.
Abbreviations: WBC, peripheral blood leukocyte count; Hb, hemoglobin; PLT, platelet count; FBG, fasting blood glucose; UA, uric acid; Cr, creatinine; TC, total cholesterol; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; Lpa, lipoprotein(a); HbA1c, glycated hemoglobin; LVEF, Left ventricular ejection fraction; NHHR, non-high-density lipoprotein cholesterol to high-density lipoprotein cholesterol ratio; TyG, triglyceride-glucose index.

quantifying insulin resistance and atherogenic lipid profiles. Furthermore, the CMD group showed adverse profiles in PLT, FBG, TG, and Lp(a) levels (all $P<0.05$), parameters previously implicated in endothelial dysfunction and thrombotic risk.

No significant intergroup differences were observed in age, LVEF, or traditional risk factors including smoking status and hypertension prevalence (all $P>0.05$). The comparable HDL-C levels despite significant NHHR disparity suggest the particular importance of non-HDL-C fractions in this population.

Analysis of Risk Factors for CMD

Univariate and multivariate logistic regression analyses were performed to identify the predictors of CMD after PCI in ACS patients (Table 2, Figure 2). The results indicated that the risk factors for CMD included gender, diabetes mellitus, FBG, TC, TG, LDL-C, Lp, HbA1c, TyG, and NHHR (all $P<0.05$). Specifically, NHHR was significantly associated with

Table 2 Univariate and Multivariate Analysis of CMD Predictors in ACS Patients

Variables	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	*P*-Value	OR (95% CI)	*P*-Value
Age	0.99 (0.98–1.01)	0.208		
Male	0.66 (0.47–0.94)	0.022	0.68 (0.44–1.05)	0.084
Smoking	0.87 (0.61–1.25)	0.446		
Drinking	0.90 (0.59–1.36)	0.609		
Hypertension	0.89 (0.62–1.26)	0.497		
Diabetes mellitus	4.02 (2.78–5.82)	<0.001	2.17 (1.37–3.46)	<0.001
Number of diseased vessels				
2-vessel disease	1.07 (0.73–1.57)	0.726		
3-vessel disease	0.96 (0.61–1.52)	0.865		
WBC	1.05 (0.97–1.13)	0.225		
Hb	1.01 (1.00–1.02)	0.074		
PLT	1.01 (1.01–1.01)	0.050	1.00 (1.00–1.00)	0.503
FBG	1.58 (1.38–1.82)	<0.001	1.01 (0.83–1.23)	0.920
UA	1.00 (1.00–1.00)	0.995		
Cr	1.00 (1.00–1.00)	0.543		
TC	1.90 (1.59–2.27)	<0.001	1.07 (0.75–1.54)	0.700
TG	1.58 (1.28–1.95)	<0.001	0.75 (0.56–1.01)	0.056
HDL-C	1.46 (0.84–2.56)	0.182		
LDL-C	2.59 (2.03–3.31)	<0.001	2.11 (1.27–3.50)	0.064
Lpa	1.02 (1.01–1.03)	<0.001	1.02 (1.01–1.03)	<0.001
HbA1c	2.08 (1.70–2.56)	<0.001	1.47 (1.14–1.88)	0.002
LVEF	1.01 (0.98–1.05)	0.458		
TyG index	3.36 (2.40–4.69)	<0.001	1.89(1.24–2.88)	0.003
NHHR	1.69 (1.43–2.00)	<0.001	1.31 (1.06–1.61)	0.011

Abbreviations: OR, odds ratio; CI, confidence interval.

increased CMD risk in the univariate analysis (OR=1.69, 95% CI 1.43–2.00, *P*<0.001), and remained significantly associated in the multivariate analysis (OR=1.34, 95% CI 1.11–1.62, *P*=0.011). Similarly, TyG was significantly correlated with CMD risk in the univariate analysis (OR=3.36, 95% CI 2.40–4.69, *P*<0.001), and remained significantly correlated in the multivariate analysis (OR=1.89, 95% CI 1.24–2.88, *P*=0.003).

In addition, diabetes mellitus was significantly associated with CMD in the univariate analysis (OR=4.02, 95% CI 2.78–5.82, *P*<0.001), and also remained significantly associated in the multivariate analysis (OR=2.17, 95% CI 1.37–3.46, *P*<0.001). Lpa was significantly associated with CMD in both the univariate analysis (OR=1.02, 95% CI 1.01–1.03, *P*<0.001) and the multivariate analysis (OR=1.02, 95% CI 1.01–1.03, *P*<0.001). HbA1c was significantly

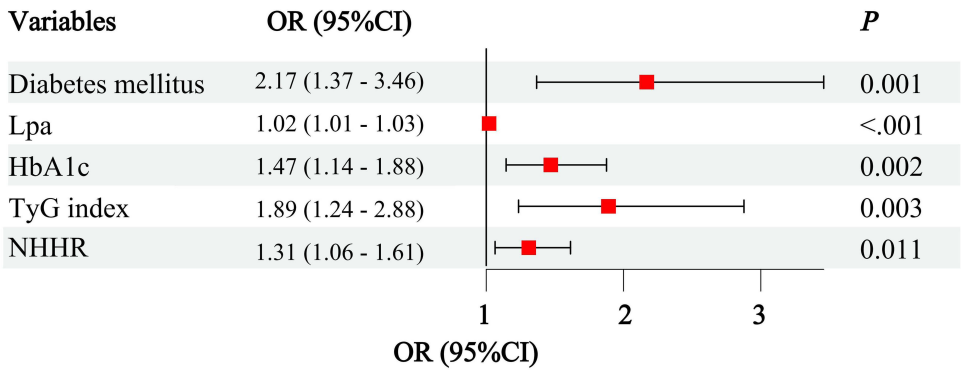

Figure 2 Multivariate analysis of CMD predictors in ACS patients.

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Table 3 Evaluation of the CMD Prediction Model

Variables	NRI		IDI		C-statistics	
	Index (95% CI)	*P*-Value	Index (95% CI)	*P*-Value	Index (95% CI)	*P*-Value
Model 1		ref		ref	0.750 (0.709–0.791)	<0.001
Model 2	0.362 (0.196–0.527)	<0.001	0.035 (0.019–0.051)	<0.001	0.772 (0.773–0.810)	<0.001
Model 3	0.429 (0.265–0.593)	<0.001	0.042 (0.025–0.059)	<0.001	0.779 (0.740–0.817)	<0.001
Model 4	0.458 (0.294–0.622)	<0.001	0.051 (0.032–0.069)	<0.001	0.782 (0.744–0.820)	<0.001

Notes: Model 1: Diabetes mellitus + Lpa + HbA1c.Model 2: Diabetes mellitus + Lpa + HbA1c + NHHR. Model 3: Diabetes mellitus + Lpa + HbA1c + TyG. Model 4: Diabetes mellitus + Lpa + HbA1c +NHHR+ TyG.

associated with CMD in the univariate analysis (OR=2.08, 95% CI 1.70–2.56, *P*<0.001), and remained significantly associated in the multivariate analysis (OR=1.47, 95% CI 1.14–1.88, *P*=0.002).

Incremental Predictive Performance of TyG Index and NHHR in CMD Risk Assessment

Table 3 and Figure 3 illustrate the synergistic effect of the TyG index and NHHR in predicting CMD in ACS patients undergoing PCI. Compared to the baseline model (Model 1) with established risk factors, the model incorporating NHHR (Model 2) significantly improved the C-statistic, increasing from 0.750 (95% CI 0.709–0.791, *P*<0.001) to 0.772 (95% CI 0.773–0.810, *P*<0.001). In the model including the TyG index (Model 3), the C-statistic was 0.779 (95% CI 0.740–0.817, *P*<0.001). Moreover, the combined model (Model 4) that included both the TyG index and NHHR showed the strongest incremental effect in predicting CMD, with the C-statistic increasing from 0.750 (95% CI 0.709–0.791, *P*<0.001) to 0.782 (95% CI 0.744–0.820, *P*<0.001).

The combined model also significantly improved reclassification performance, as evidenced by the NRI of 0.458 (95% CI 0.294–0.622, *P*<0.001) and the IDI of 0.051 (95% CI 0.032–0.069, *P*<0.001).

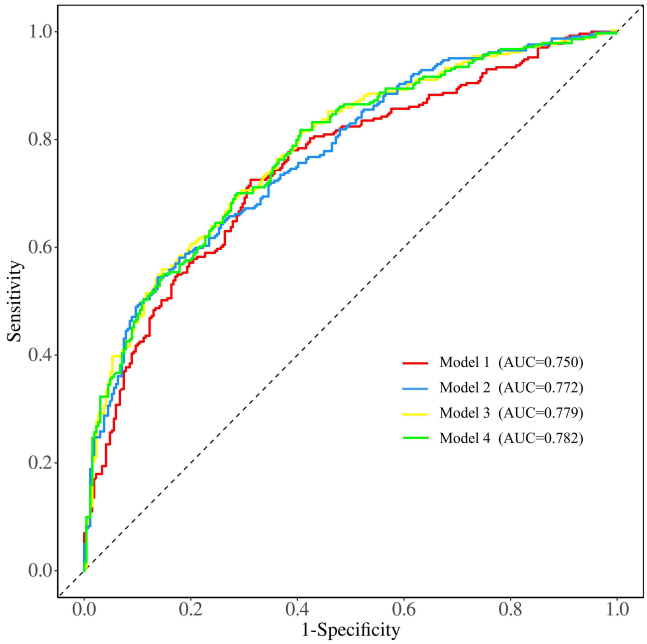

Figure 3 ROC curve analysis of four models predicting CMD after PCI treatment in ACS patients.

Subgroup Analysis

Subgroup analysis revealed that the association between NHHR and the risk of CMD was consistent across various patient subgroups stratified by gender, age, smoking, alcohol consumption, hypertension, diabetes, FBG, UA, Cr, TC, TG, HDL-C, LDL-C, Lpa, and HbA1c (P for interaction >0.05) (Figure 4). Similarly, the relationship between the TyG index and CMD risk remained consistent across these subgroups (P for interaction >0.05). However, the effect of the TyG index on CMD risk was more pronounced in individuals with low UA levels (Figure 5).

Discussion

This study investigated the predictive value of the TyG index combined with NHHR for CMD in ACS patients post-PCI. Our results demonstrate that both TyG and NHHR are independent predictors of CMD, and their integration significantly enhances risk stratification compared to individual markers. This highlights the synergistic value of assessing metabolic and lipid profiles in post-PCI management.

The TyG index, a validated marker of metabolic dysregulation, has been increasingly recognized for its prognostic utility in cardiovascular diseases.[18] In our cohort, elevated TyG was strongly associated with CMD risk, aligning with recent studies emphasizing its role in predicting adverse cardiovascular outcomes. For instance, Bilgin et al demonstrated that TyG independently predicts thrombus burden and mortality in STEMI patients, underscoring its clinical relevance in acute coronary syndromes.[19] Mechanistically, TyG reflects a proatherogenic milieu characterized by impaired glucose metabolism and endothelial dysfunction. Chronic hyperglycemia and dyslipidemia may synergistically promote microvascular inflammation and oxidative stress, contributing to impaired myocardial perfusion.[20] These findings are further corroborated by emerging evidence linking TyG to systemic inflammatory activation, as demonstrated in pulmonary thromboembolism outcomes.[21]

NHHR, integrating atherogenic and atheroprotective lipid components, emerged as another robust predictor of CMD. Our findings extend previous observations by Omar T et al, who identified homocysteine-mediated endothelial injury as a contributor to microvascular impairment in PCI patients.[22] Elevated NHHR reflects an imbalance favoring proatherogenic lipoproteins (LDL-C, VLDL-C) over protective HDL-C. This imbalance may exacerbate endothelial dysfunction through multiple pathways: 1) Enhanced oxidative modification of LDL particles promoting foam cell formation; 2) Reduced reverse cholesterol transport capacity; and 3) Activation of proinflammatory cascades via scavenger receptor interactions.[23] Notably, Bilgin et al recently highlighted the complementary prognostic value of lipid ratios in ACS, where NHHR outperformed conventional lipid parameters in mortality prediction.[24] This parallels our observation that NHHR provides incremental predictive value beyond traditional risk factors.

The combination of TyG and NHHR achieved superior discriminative performance (AUC=0.782) compared to individual biomarkers. This synergy likely stems from their complementary pathophysiological insights: TyG captures systemic metabolic dysregulation, while NHHR reflects localized lipid-driven endothelial injury.[25,26] Such integration aligns with the multifactorial nature of CMD pathogenesis, where insulin signaling defects, oxidative stress, and lipoprotein imbalances converge to impair microvascular homeostasis. Our findings are further strengthened by the significant NRI (NRI=0.458, P<0.001), suggesting clinical utility in identifying high-risk patients who may benefit from intensified metabolic optimization or novel therapies targeting microvascular function.

Clinically, our model addresses the unmet need for accessible CMD prediction tools. While advanced imaging modalities remain gold standards, their limited accessibility underscores the value of biomarker-based risk stratification. The TyG-NHHR model, derived from routine laboratory parameters, enables early identification of high-risk patients for targeted interventions. For example, patients with elevated TyG may benefit from SGLT2 inhibitors to improve metabolic flexibility, while those with high NHHR might require aggressive LDL-C lowering combined with HDL-C-boosting therapies. This approach could mitigate CMD-related complications and improve long-term outcomes, as suggested by recent trials demonstrating the cardiovascular benefits of metabolic-lipid dual-target therapies.[27]

NHHR				
Sub	**n (%)**	**OR (95%CI)**	***P*-value**	***P*-inter**
Gender				0.278
Female	195 (35.98)	1.96 (1.46 ~ 2.63)	<.001	
Male	347 (64.02)	1.61 (1.30 ~ 1.98)	<.001	
Age				0.989
< 63	176 (32.47)	1.68 (1.27 ~ 2.24)	<.001	
≥ 63	366 (67.53)	1.69 (1.37 ~ 2.08)	<.001	
Smokeing				0.719
no	367 (67.71)	1.74 (1.42 ~ 2.13)	<.001	
yes	175 (32.29)	1.63 (1.21 ~ 2.19)	0.001	
Drinking				0.932
no	430 (79.34)	1.70 (1.41 ~ 2.05)	<.001	
yes	112 (20.66)	1.67 (1.13 ~ 2.46)	0.010	
Hypertension				0.770
no	193 (35.61)	1.75 (1.31 ~ 2.35)	<.001	
yes	349 (64.39)	1.66 (1.35 ~ 2.04)	<.001	
Diabetes mellitus				0.167
no	326 (60.15)	1.46 (1.19 ~ 1.81)	<.001	
yes	216 (39.85)	1.89 (1.40 ~ 2.55)	<.001	
FBG				0.934
< 6.1	369 (68.08)	1.53 (1.25 ~ 1.88)	<.001	
≥ 6.1	173 (31.92)	1.51 (1.08 ~ 2.10)	0.015	
UA				0.080
< 420	445 (82.10)	1.85 (1.52 ~ 2.25)	<.001	
≥ 420	97 (17.90)	1.27 (0.89 ~ 1.82)	0.181	
Cr				0.169
< 110.5	509 (93.91)	1.77 (1.48 ~ 2.11)	<.001	
≥ 110.5	33 (6.09)	1.18 (0.70 ~ 2.00)	0.528	
TC				0.060
< 5.2	423 (78.04)	1.69 (1.38 ~ 2.08)	<.001	
≥ 5.2	119 (21.96)	1.16 (0.84 ~ 1.60)	0.366	
TG				0.229
< 1.7	370 (68.27)	1.70 (1.36 ~ 2.12)	<.001	
≥ 1.7	172 (31.73)	1.36 (1.03 ~ 1.81)	0.033	
HDL-C				0.589
< 1.8	525 (96.86)	1.82 (1.53 ~ 2.18)	<.001	
≥ 1.8	17 (3.14)	3.28 (0.37 ~ 29.11)	0.286	
LDL-C				0.412
< 3.5	490 (90.41)	1.57 (1.31 ~ 1.88)	<.001	
≥ 3.5	52 (9.59)	2.19 (0.98 ~ 4.89)	0.057	
Lpa				0.172
< 40	434 (80.07)	1.80 (1.48 ~ 2.19)	<.001	
≥ 40	108 (19.93)	1.33 (0.92 ~ 1.94)	0.131	
HbA1c				0.773
< 6	233 (42.99)	1.71 (1.31 ~ 2.23)	<.001	
≥ 6	309 (57.01)	1.63 (1.31 ~ 2.02)	<.001	

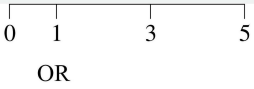

Figure 4 Analysis of subgroup and interaction between NHHR and CMD in different subgroups.

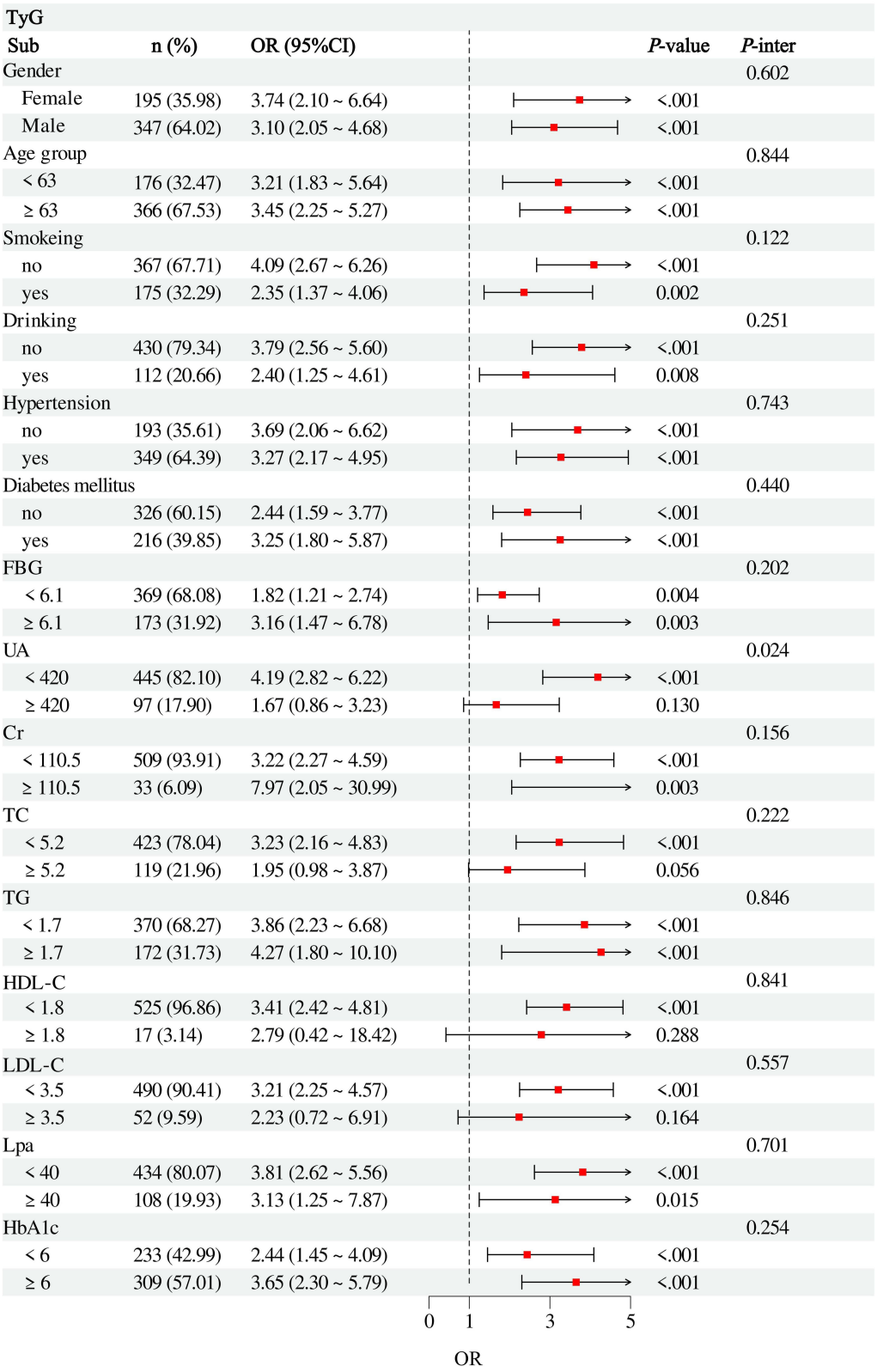

Figure 5 Analysis of subgroup and interaction between TyG and CMD in different subgroups.

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Limitations

Although this study provides important evidence for the application of the TyG and the NHHR in predicting CMD after PCI in patients with ACS, several limitations should be acknowledged. First, this study was a single-center, retrospective design with a relatively small sample size, and the results may be influenced by center effects and selection bias. Future multi-center, large-sample prospective studies will help to verify the generalizability and stability of these findings. Second, although we have adjusted for several confounding factors, there may still be unidentified potential confounders, such as patients' genetic background, long-term lifestyle, and environmental factors, which could influence the occurrence of CMD. Therefore, future studies could further explore other potential influencing factors to minimize these biases.

Conclusion

The TyG-NHHR model offers a cost-effective tool for post-PCI CMD prediction, addressing unmet needs in ACS management. By unifying metabolic and lipid axes, this approach advances precision medicine in cardiovascular care. However, the study's retrospective and single-center design may limit the generalizability of the findings. Future multi-center, prospective studies are needed to validate these results and explore their application in other cardiovascular diseases.

Data Sharing Statement

All data generated or analyzed during this study are included in this published article. On reasonable request, the data could be obtained upon request to the corresponding author.

Ethics Approval and Consent to Participate

To protect patient privacy and data confidentiality, patient data has been de-identified prior to analysis. All analyses in this retrospective study were conducted based on anonymous patient data. Due to the retrospective nature of this study, the Ethics Committee of the Second Affiliated Hospital of Xuzhou Medical University approved the study (Approval No. 2020120205) and determined that written informed consent was not required.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests.

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