Original Article

Predictive value of GNRI and TyG index for poor prognosis in NSTE-ACS patients post-PCI

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Background and Objectives: This study aimed to assess the predictive power of the Geriatric Nutritional Risk Index (GNRI) and the triglyceride-glucose (TyG) index for poor prognosis in non-ST segment elevation acute coronary syndrome (NSTE-ACS) patients post-percutaneous coronary intervention (PCI). **Methods and Study Design:** A cohort of 393 NSTE-ACS patients who underwent PCI at the People's Hospital of Nanjing Jiangbei from 2016 to 2022 was analyzed. Major adverse cardiovascular events (MACEs), including death, non-fatal myocardial infarction, and target vessel revascularization, served as the primary outcome. Relationships between GNRI, TyG index, and MACEs were explored using univariate and multivariate logistic regression, with results presented as odds ratios (OR) and 95% confidence intervals (CI). The predictive value was further evaluated using the area under the curve (AUC) from the receiver operating characteristic (ROC) curve. **Results:** MACEs occurred in 34 patients. A TyG index ≥1.36 was associated with a significantly increased risk of MACEs (OR=5.07, 95%CI: 1.64-15.71), while a GNRI ≥108 indicated a decreased risk (OR=0.17, 95%CI: 0.04-0.68). These associations were consistent across various subgroups, including age, gender, and specific pre-existing conditions. The combined predictive value of TyG index and GNRI was higher than each alone (AUC=0.711, 95%CI: 0.642-0.779). **Conclusions:** In post-PCI patients with NSTE-ACS, the TyG index and GNRI are significant predictors of MACEs, with the TyG index indicating higher risk and GNRI lower risk. Their combined use may enhance the predictive accuracy for MACEs in this patient population.

Key Words: Non-ST segment elevation myocardial infarction, percutaneous coronary intervention, major adverse cardiovascular and cerebrovascular events, Geriatric Nutritional Risk Index, triglyceride-glucose index

INTRODUCTION

Non-ST segment elevation acute coronary syndrome (NSTE-ACS), including unstable angina and non-ST elevation myocardial infarction (NSTEMI), represents a significant cause of morbidity and mortality worldwide.[1] The global cardiovascular disease burden has shifted to low and middle-income countries, accounting for more than 80% of cardiovascular deaths worldwide.[2] Despite the rapid development and extensive use of Percutaneous Coronary Intervention (PCI),[3] identifying patients at higher risk of poor prognosis, including major adverse cardiovascular events (MACEs), remains a clinical challenge.

The triglyceride-glucose (TyG) index and the Geriatric Nutritional Risk Index (GNRI) have emerged as potential prognostic markers in cardiovascular disease. TyG index, derived from fasting triglyceride (TG) and glucose levels, serves as a marker of insulin resistance and metabolic dysfunction. Elevated TyG index has been linked to heightened risks of coronary artery disease (CAD) and MACEs. Mao et al.[4] reported that the TyG index was closely related to the complexity of coronary lesions and the incidence of MACEs in a 12-month follow-up period of patients with NSTE-ACS. Luo et al. reported an elevated TyG index may be an indicator of poor prognosis in patients with ST elevation myocardial infarction (STEMI) after PCI.[5] Elevated TyG index also be found as an indicator of poor prognosis of patients with NSTE-ACS, and combined with other indicators could significantly improve risk prediction capabilities.[6, 7]

The GNRI, initially developed to assess nutritional risk in elderly individuals, integrates serum albumin level and body weight, reflecting both nutritional status and inflammatory burden.[8] Low GNRI scores have been associated with adverse clinical outcomes in several diseases.[9, 10] Malnutrition is also common in patients with CAD. Basta et al. found nutritional status could affect the prognosis of elderly patients with ST-elevation myocardial infarction (MI), with almost 55% of the elderly being malnutrition.[11] GNRI was linked to the progression of cardiac rehabilitation in patients with heart failure, stroke, end-stage kidney disease, and cardiovascular surgery.[9-14] Lower GNRI was a significant predictive factor for adverse prognosis in patients with NSTE-ACS after PCI,

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and combined with other indicators also could improve risk prediction capabilities.[15]

However, there is no data regarding the predictive value of GNRI and TyG on clinical outcomes in patients with NSTE-ACS after PCI. Thus, our study aims to investigate the relationship between GNRI or TyG and MACEs on the poor prognosis in patients with NSTE-ACS after PCI.

METHODS

Study population

Patients who have NSTE-ACS after PCI, visited Nanjing Jiangbei Hospital between January 2016 to January 2022, were enrolled in this retrospective cohort study. Participants were included of those having NSTE-ACS and underwent PCI. Patients with any of the conditions as follow were excluded: (1) patients with diagnosed or suspected type 1 diabetes, (2) impaired kidney function with estimated glomerular filtration rate <30 mL/(min•1.73m^2) or receiving continuous renal replacement therapy, (3) severely impaired liver function with alanine aminotransferase (ALT) or aspartate aminotransferase (AST) 5 times higher than the normal limit, (4) history of coronary artery bypass grafting (CABG), cardiogenic shock, chronic infectious disease, or malignant tumor, (5) PCI failure, complications, or death in hospital, (6) history of cerebrovascular disease and surgery, and (7) missing data on TG, fasting blood glucose (FBG), aspartate aminotransferase (ALB), height, and weight. Finally, a total of 393 eligible patients were included (Figure 1).

Data collection

Data were acquired according to medical records or computer tracking systems. The information collected included demographic information, disease history, complications, laboratory examinations, medication taken before and after admission, data on PCI, data on angiographic, and MACEs. Demographic information included age, gender, height, systolic blood pressure, diastolic blood pressure, pulse, heart rate, smoking, and drinking status. Disease history included family history of coronary heart disease (CHD), history of PCI/CABG, acute MI, and stroke. Complications information included type 2 diabetes mellitus, hyperlipemia, and CHD. Laboratory examinations were hemoglobin, red blood cell, white blood cell, neutrophil, monocyte, lymphocyte, platelet, platelet distribution width (PDW), red cell distribution width (RDW), creatine kinase isoenzymes, TG, total cholesterol (TC), low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, ALT, AST, ALB, FBG, hemoglobin A1c, serum creatinine, urinary acid, and fibrosis. Before and after admission, medication taken information was collected about angiotensin-converting enzyme inhibitors, angiotensin II receptor blockers, dual antiplatelet therapy, aspirin, clopidogrel, beta-blockers, statins, proton pump inhibitors, oral hypoglycemic drugs, and other drug.

TyG and GNRI measurement

TyG index = ln [fasting TG (mg/dL) * FBG (mg/dL)]. 16

GNRI = 1.489 * ALB (g/L) + 41.7 * present weight/ideal weight (kg).[8, 17]

The ideal body weight was calculated based on the Lorentz equations: 0.75×height (cm) – 62.5 for men, and 0.60 × height (cm) – 40 for women. When the present weight/ideal body weight was ≥1, the ratio was set to 1. The cut-off values of TyG and GNRI were 1.36 and 108.

Outcomes and follow-up

The outcome measured was the incidence of MACE during follow-up, including all-cause mortality, non-fatal MI, and target vessel revascularization (TVR).[18] MI was characterized by typical chest pain, ST-segment deviation, T wave changes, and creatine kinase-myocardial band levels exceeding three times the normal upper limit.[19] TVR, involving interventions on both target and non-target vessels through PCI or CABG, was conducted for patients with severe in-stent restenosis or newly developed coro-

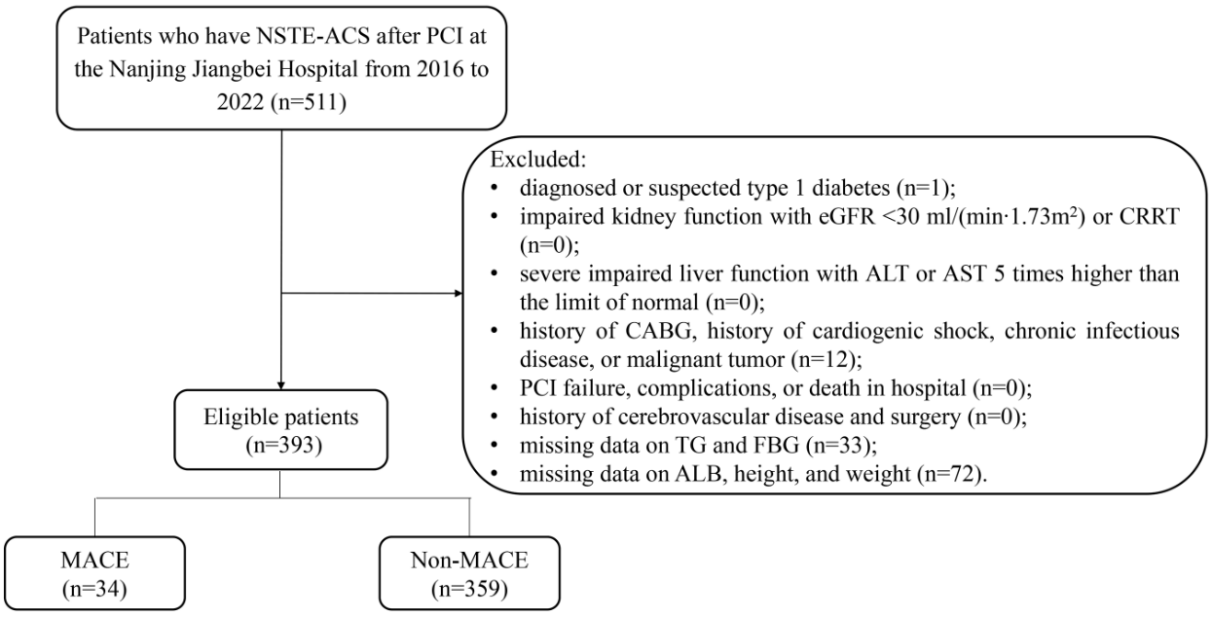

Figure 1. Selection process of the patients with NSTE-ACS

nary lesions (luminal diameter narrowing ≥70%).[18] Patients were followed up through telephone or outpatient visits at 3, 6, 12 18, and 24 months after hospital discharge. For analysis, the initial MACE occurrence during the follow-up period was selected. In cases where patients experienced multiple adverse outcomes simultaneously, the most severe event was prioritized (all-cause mortality > non-fatal MI > target vessel revascularization).

Statistical analysis

Continuous variable was shown as mean ± standard deviation (S.D) or median [interquartile range: 25th to 75th percentiles]. The normality of continuous variable was assessed using skewness and kurtosis, while homogeneity was detected by the Levene test. The comparison between the two groups was performed according to Student's t-tests and Satterthwaite t-tests for normality distribution, with Wilcoxon rank sum tests for non-normality distribution. Categorical variable was reported as frequencies and percentages (%), Chi-square tests or Fisher exact tests were utilized to compare differences between two groups. Potential covariates were screened by univariate logistic regression model and two-way stepwise method. The relationships of TyG, GNRI, with MACE was explored using univariate and multivariate logistic regression models. Odds ratios (ORs) and 95% confidence intervals (CIs) were utilized to present results. Maximally selected test statistics were employed to determine the cut-off value of TyG and GNRI. The area under the curve (AUC) was performed to compare the predictive value of TyG, GNRI, and combined indexes. The Delong test was also performed. Restrict cubic spline (RCS) was used to show the non-linear relationship of TyG, GNRI, with MACE. The associations of TyG, GNRI, with MACE were further explored in different ages, genders, pre-diffuse lesion, pre-bifurcation lesion, pre-in stent restenosis, and pre-complete revascularization subgroups. All analyses were employed using Python 3.9.12 and R version 4.3.1. A p value <0.05 was considered statistically difference.

Ethics statement

The study was approved by the Ethics Committee of the People's Hospital of Nanjing Jiangbei (Approval number: 2021031). All patients provided an informed consent before the study.

RESULTS

Characteristics of patients with NSTE-ACS

In total, 393 patients were enrolled in our study. Among them, the mean age was 64.70 (10.17) years, and 245 (62.34%) were males. The mean scores of TyG and GNRI were 1.58 (0.76) and 102.54 (6.11) respectively. Statistically significant between MACE and no-MACE groups were observed in PDW, RDW, TG, TC, pre-single vessel disease, pre-triple vessel disease, pre-diffuse lesion, pre-bifurcation lesion, pre-in stent restenosis, pre-complete revascularization, pre-number of supports, and TyG (all p<0.05). Characteristics of patients with NSTE-ACS were illustrated in Table 1.

Associations between TyG, GNRI, and MACE in patients with NSTE-ACS

The relationships between TyG, GNRI, and MACE were shown in Table 2. In model 2, we adjusted PDW, TC, pre-diffuse lesion, pre-bifurcation lesion, pre-in stent restenosis, and pre-complete revascularizations. TyG ≥1.36 was related to elevated odds of MACE (OR=5.07, 95%CI: 1.64-15.71) in patients with NSTE-ACS. While GNRI ≥108 was linked to increased incidence of MACE (OR=5.07, 95%CI: 1.64-15.71). Restricted cubic splines suggested non-linear relationships between TyG or GNRI and the incidence of MACE (Supplementary Figure 1). A positive trend was found in the incidence of MACE as RCS increased. No obvious trend was observed in the occurrence of MACE as GNRI increased. Supplementary Figure 2 illustrates the distribution of MACE in different TyG and GNRI levels. In patients with different TyG levels, there was a statistical difference between the no-MACE and MACE groups (p <0.05).

Associations between TyG, GNRI, and MACE in different subgroups

The associations of TyG, GNRI, with MACE were also investigated in different ages, gender, pre-diffuse lesion, pre-bifurcation lesion, pre-in stent restenosis, and pre-complete revascularization subgroups (Figure 2 and Supplementary Table 1). Compared to patients with TyG <1.36, higher TyG was linked to increased incidence of MACE in those aged ≥65 years (OR=6.44, 95%CI: 1.59-44.47), males (OR=4.94, 95%CI: 1.38-24.68), pre-diffuse lesion (OR=4.06, 95%CI: 1.02-16.16), without pre-bifurcation lesion (OR=7.73, 95%CI: 1.89-55.49), without pre-in stent restenosis (OR=5.32, 95%CI: 1.73-23.31), and without pre-complete revascularization (OR=5.32, 95%CI: 1.56-25.24). When compared to patients with GNRI <108, GNRI ≥108 was related to decreased incidence of MACE in those age ≥65 years (OR=0.08, 95%CI: 0.00-0.59), males (OR=0.06, 95%CI: 0.00-0.36), without pre-bifurcation lesion (OR=0.15, 95%CI: 0.02-0.65), without pre-in stent restenosis (OR=0.21, 95%CI: 0.04-0.75), and without pre-complete revascularization (OR=0.08, 95%CI: 0.00-0.55).

ROC curves of TyG, GNRI, and combination of two indexes

We use TyG, GNRI, and the combination of TyG and GNRI to predict MACE in Figure 3. ROC curves show that the AUC of TyG, GNRI, and combined were 0.665 (95%CI:0.605-0.726), 0.559 (95%CI:0.506-0.612), and 0.711 (95%CI:0.642-0.779) respectively. Among the three indicators, the combination indicator had the highest AUC of 0.711 (compared with TyG alone and CNRI alone, both p < 0.01, Delong test). The result indicates that a combination of TyG and GNRI can increase the predictive value of MACE.

DISCUSSION

TyG combined with GNRI may be a valuable predictive indicator for MACE in patients with NSTE-ACS after PCI. We found the cut-off values were 1.36 and 108 for TyG and GNRI, respectively. The predictive value of TyG combined GNRI was superior to that of these

Table 1. Characteristics of patients with NSTE-ACS after PCI

Variables	Total (n=393)	No-MACE (n=359)	MACE (n=34)	*p*
Age, Mean (±SD)	64.7 (±10.2)	64. 6 (±10.2)	66.2 (±9.94)	0.359†
Gender, n (%)				0.318§
Female	148 (37.7)	132 (36.8)	16 (47.1)	
Male	245 (62.3)	227 (63.2)	18 (52.9)	
Height, Mean (±SD)	1.64 (±0.08)	1.64 (±0.08)	1.64 (±0.08)	0.773†
Weight, Mean (±SD)	67.7 (±10.8)	67.5 (±10.5)	70.0 (±13.4)	0.206†
SBP, Mean (±SD)	139 (±18.7)	139 (±18.1)	141 (±24.4)	0.607‡
DBP, Mean (±SD)	81.0 (±11.4)	81.2 (±11.4)	79.4 (±11.3)	0.365†
Pulse, Mean (±SD)	72.2 (±13.4)	72.1 (±13.6)	72.4 (±11.6)	0.901†
Heart rate, Mean (±SD)	72.0 (±13.3)	72.0 (±13.4)	72.4 (±11.6)	0.840†
NSTEACS, n (%)				0.922§
NSTEMI	101 (25.7)	93 (25.9)	8 (23.5)	
UA	292 (74.3)	266 (74.1)	26 (76.5)	
Killip level, n (%)				1.000§
I & II & III	65 (16.5)	59 (16.4)	6 (17.7)	
Unknown	328 (83.5)	300 (83.6)	28 (82.4)	
LVEF, Mean (±SD)	59.5 (±6.02)	59.34 (±6.19)	61.2 (±3.25)	0.089†
Smoking, n (%)				0.988§
No	249 (63.4)	228 (63.5)	21 (61.8)	
Yes	144 (36.6)	131 (36.5)	13 (38.2)	
Drinking, n (%)				0.674§
No	317 (80.7)	291 (81.1)	26 (76.5)	
Yes	76 (19.3)	68 (18.9)	8 (23.5)	
Family history CHD, n (%)				1.000††
No	382 (97.2)	349 (97.2)	33 (97.1)	
Yes	11 (2.8)	10 (2.79)	1 (2.94)	
History PCI/CABG, n (%)				0.059††
No	343 (87.3)	317 (88.3)	26 (76.5)	
Yes	50 (12.7)	42 (11.7)	8 (23.5)	
History AMI, n (%)				0.275††
No	366 (93.1)	336 (93.6)	30 (88.2)	
Yes	27 (6.87)	23 (6.41)	4 (11.8)	
History stroke, n (%)				0.950§
No	293 (74.6)	267 (74.4)	26 (76.5)	
Yes	100 (25.5)	92 (25.6)	8 (23.5)	
Type-II diabetes, n (%)				0.978§
No	284 (72.3)	260 (72.4)	24 (70.6)	
Yes	109 (27.7)	99 (27.6)	10 (29.4)	
Hyperlipemia, n (%)				0.379††
No	378 (96.2)	346 (96.4)	32 (94.1)	
Yes	15 (3.82)	13 (3.62)	2 (5.88)	
CHD, n (%)				0.518††
No	8 (2.04)	7 (1.95)	1 (2.94)	
Yes	385 (98.0)	352 (98.1)	33 (97.1)	
Pre-ACEI, n (%)				1.000††
No	374 (95.2)	341 (95.0)	33 (97.1)	
Yes	19 (4.83)	18 (5.01)	1 (2.94)	
Pre-ARB, n (%)				0.993§
No	295 (75.1)	270 (75.2)	25 (73.5)	
Yes	98 (25.0)	89 (24.8)	9 (26.5)	
Pre-DAPT, n (%)				1.000††
No	360 (91.6)	329 (91.6)	31 (91.2)	
Yes	33 (8.4)	30 (8.36)	3 (8.82)	

SD: standard deviation; M: median; Q_1: 1st quartile; Q_3: 3st quartile, PCI: percutaneous coronary intervention, SBP: systolic blood pressure, DBP: diastolic blood pressure, NSTE-ACS: non-ST elevation acute coronary syndromes, NATEMI: non-ST-elevation myocardial infarction, UA: unstable angina, LVEF: left ventricular ejection fraction, CHD: coronary heart disease, CABG: coronary artery bypass grafting, AMI: acute myocardial infarction, ACEI: angiotensin-converting enzyme inhibitor, ARB: angiotensin II receptor blockers, DAPT: dual antiplatelet therapy, RBC: red blood cell count, WBC: white blood cell count, PDW: platelet distribution width, RDW: red cell distribution width, CK-MB: creatine kinase isoenzymes, TG: triglyceride, TC: total cholesterol, LDL-C: low density lipoprotein cholesterol, HDL-C: high density lipoprotein cholesterol, ALT: alanine aminotransferase, AST: aspartate aminotransferase, ALB: albumin, FBG: fasting blood glucose, HbA1c: hemoglobin A1c, Scr: serum creatinine, FIB: fibrosis, TyG: triglyceride-glucose index, GNRI: Geriatric Nutritional Risk Index, MACE: major adverse cardiac event.

†Student's t test; ‡Satterthwaite t test; §Chi-square test; ¶Wilcoxon rank sum test; ††Fisher's exact test.

Table 1. Characteristics of patients with NSTE-ACS after PCI (cont.)

Variables	Total (n=393)	No-MACE (n=359)	MACE (n=34)	*p*
Pre-aspirin, n (%)				0.794††
No	340 (86.5)	311 (86.7)	29 (85.3)	
Yes	53 (13.5)	48 (13.4)	5 (14.7)	
Pre-clopidogrel, n (%)				1.000††
No	390 (99.2)	356 (99.2)	34 (100)	
Yes	3 (0.76)	3 (0.84)	0 (0)	
Pre-beta blocker, n (%)				0.599††
No	340 (86.5)	309 (86.1)	31 (91.2)	
Yes	53 (13.5)	50 (14.0)	3 (8.82)	
Pre-statins, n (%)				0.996§
No	318 (81.0)	291 (81.1)	27 (79.4)	
Yes	75 (19.1)	68 (19.0)	7 (20.6)	
Pre-proton pump inhibitor, n (%)				0.312††
No	380 (96.7)	348 (97.0)	32 (94.1)	
Yes	13 (3.31)	11 (3.06)	2 (5.88)	
Pre-oral hypoglycemic drug, n (%)				0.858§
No	311 (79.1)	285 (79.4)	26 (76.5)	
Yes	82 (20.9	74 (20.6)	8 (23.5)	
Pre-other drug, n (%)				0.810§
No	233 (59.3)	214 (59.6)	19 (55.9)	
Yes	160 (40.7)	145 (40.4)	15 (44.1)	
Hemoglobin, M (Q_1, Q_3)	134 (122-144)	134 (122-144)	132 (121-147)	0.959¶
RBC, M (Q_1, Q_3)	4.43 (4.06-4.78)	4.42 (4.06-4.78)	4.44 (4.06-4.78)	0.911¶
WBC, M (Q_1, Q_3)	6.3 (5.2-7.7)	6.28 (5.2-7.75)	6.65 (5.73-7.58)	0.419¶
Neutrophil, M (Q_1, Q_3)	4.17 (3.31-5.31)	4.16 (3.28-5.38)	4.61 (3.65-5.07)	0.495¶
Monocyte, M (Q_1, Q_3)	0.38 (0.31-0.49)	0.38 (0.31-0.5)	0.38 (0.32-0.45)	0.895¶
Lymphocyte, M (Q_1, Q_3)	1.49 (1.17-1.85)	1.48 (1.12-1.86)	1.52 (1.27-1.79)	0.463¶
Platelet, Mean (±SD)	183 (±54.2)	182 (±54.3)	190 (±53.8)	0.456†
PDW, Mean (±SD)	28.2 (±18.6)	27.3 (±18.2)	37.3 (±20.2)	0.003†
RDW, Mean (±SD)	31.3 (±14.3)	32.0 (±14.1)	24.9 (±14.3)	0.006†
CK-MB, M (Q_1, Q_3)	10 (2.95-14)	10 (2.78-14)	10 (4.12-14)	0.473¶
TG, M (Q_1, Q_3)	1.51 (1.01-2.17)	1.41 (0.97-2.1)	2 (1.61-3.02)	<0.001¶
TC, Mean (±SD)	4.61 (±1.26)	4.55 (±1.25)	5.18 (±1.14)	0.005†
LDL-C, Mean (±SD)	2.62 (±0.95)	2.61 (±0.96)	2.77 (±0.84)	0.331†
HDL-C, M (Q_1, Q_3)	1.08 (0.92-1.26)	1.07 (0.92-1.26)	1.1 (1-1.31)	0.282¶
ALT, M (Q_1, Q_3)	19 (14-29)	19 (14-29)	21 (13-34)	0.520¶
AST, M (Q_1, Q_3)	21 (17-29)	21 (17-28.5)	23.5 (17-33.8)	0.456¶
ALB, Mean (±SD)	41.2 (±3.82)	41.3 (±3.83)	40.6 (±3.60)	0.323†
FBG, M (Q_1, Q_3)	5.73 (5.03-7.45)	5.73 (5.01-7.41)	5.77 (5.19-7.61)	0.468¶
HbA1c, Mean (±SD)	6.41 (±1.36)	6.40 (±1.38)	6.56 (±1.12)	0.499†
SCr, Mean (±SD)	73.7 (±17.7)	73.5 (±17.6)	76.3 (±18.6)	0.382†
Uric acid, Mean (±SD)	334 (±97.2)	334 (±96.9)	343 (±102)	0.598†
FIB, Mean (±SD)	3.30 (±0.90)	3.28 (±0.91)	3.54 (±0.83)	0.110†
Pre-left main disease, n (%)				1.000††
No	369 (93.9)	337 (93.9)	32 (94.1)	
Yes	24 (6.11)	22 (6.13)	2 (5.88)	
Pre-single vessel disease, n (%)				0.015§
No	268 (68.2)	238 (66.3)	30 (88.2)	
Yes	125 (31.8)	121 (33.7)	4 (11.8)	
Pre-bivessel disease, n (%)				0.878 §
No	267 (68.0)	243 (67.7)	24 (70.6)	
Yes	126 (32.1)	116 (32.3)	10 (29.4)	

SD: standard deviation; M: median; Q_1: 1st quartile; Q_3: 3st quartile, PCI: percutaneous coronary intervention, SBP: systolic blood pressure, DBP: diastolic blood pressure, NSTE-ACS: non-ST elevation acute coronary syndromes, NATEMI: non-ST-elevation myocardial infarction, UA: unstable angina, LVEF: left ventricular ejection fraction, CHD: coronary heart disease, CABG: coronary artery bypass grafting, AMI: acute myocardial infarction, ACEI: angiotensin-converting enzyme inhibitor, ARB: angiotensin II receptor blockers, DAPT: dual antiplatelet therapy, RBC: red blood cell count, WBC: white blood cell count, PDW: platelet distribution width, RDW: red cell distribution width, CK-MB: creatine kinase isoenzymes, TG: triglyceride, TC: total cholesterol, LDL-C: low density lipoprotein cholesterol, HDL-C: high density lipoprotein cholesterol, ALT: alanine aminotransferase, AST: aspartate aminotransferase, ALB: albumin, FBG: fasting blood glucose, HbA1c: hemoglobin A1c, Scr: serum creatinine, FIB: fibrosis, TyG: triglyceride-glucose index, GNRI: Geriatric Nutritional Risk Index, MACE: major adverse cardiac event.

†Student's t test; ‡Satterthwaite t test; §Chi-square test; ¶Wilcoxon rank sum test; ††Fisher's exact test.

Table 1. Characteristics of patients with NSTE-ACS after PCI (cont.)

Variables	Total (n=393)	No-MACE (n=359)	MACE (n=34)	*p*
Pre-triple vessel disease, n (%)				0.006§
No	253 (64.4)	239 (66.6)	14 (41.2)	
Yes	140 (35.6)	120 (33.4)	20 (58.8)	
Pre-chronic complete occlusion, n (%)				0.160††
No	346 (88.0)	319 (88.9)	27 (79.4)	
Yes	47 (12.0)	40 (11.1)	7 (20.6)	
Pre-diffuse lesion, n (%)				<0.001§
No	277 (70.5)	265 (73.8)	12 (35.3)	
Yes	116 (29.5)	94 (26.2)	22 (64.7)	
Pre-bifurcation lesion, n (%)				0.046§
No	293 (74.6)	273 (76.0)	20 (58.8)	
Yes	100 (25.5)	86 (24.0)	14 (41.2)	
Pre-in stent restenosis, n (%)				0.049††
No	376 (95.7)	346 (96.4)	30 (88.2)	
Yes	17 (4.33)	13 (3.62)	4 (11.8)	
Pre-Drug eluting stent implantation, n (%)				0.518††
No	8 (2.04)	7 (1.95)	1 (2.94)	
Yes	385 (98.0)	352 (98.1)	33 (97.1)	
Pre-use balloon, n (%)				1.000††
No	10 (2.54)	10 (2.79)	0 (0)	
Yes	383 (97.5)	349 (97.2)	34 (100)	
Pre-complete revascularization, n (%)				0.010§
No	200 (50. 9)	175 (48.8)	25 (73.5)	
Yes	193 (49.1)	184 (51.3)	9 (26.5)	
Pre-number of supports, Mean (±SD)	1.33 (±0.59)	1.30 (±0.58)	1.59 (±0.66)	0.018‡
Post-ACEI, n (%)				0.403††
No	347 (88.3)	315 (87.7)	32 (94.1)	
Yes	46 (11.7)	44 (12.3)	2 (5.88)	
Post-ARB, n (%)				0.245§
No	205 (52.2)	191 (53.2)	14 (41.2)	
Yes	188 (47.8)	168 (46.8)	20 (58.8)	
Post-DAPT, n (%)				0.609††
No	11 (2.8)	11 (3.06)	0 (0)	
Yes	382 (97.2)	348 (96.9)	34 (100)	
Post-aspirin, n (%)				1.000††
No	391 (99.5)	357 (99.4)	34 (100)	
Yes	2 (0.51)	2 (0.56)	0 (0)	
Post-clopidogrel, n (%)				1.000††
No	385 (98.0)	351 (97.8)	34 (100)	
Yes	8 (2.04)	8 (2.23)	0 (0)	
Post-beta blocker, n (%)				0.111§
No	148 (37.7)	140 (39)	8 (23.5)	
Yes	245 (62.3)	219 (61)	26 (76.5)	
Post-statins, n (%)				0.609††
No	11 (2.8)	11 (3.06)	0 (0)	
Yes	382 (97.2)	348 (97.0)	34 (100)	
Post-proton pump inhibitor, n (%)				0.987§
No	248 (63.1)	226 (63.0)	22 (64.7)	
Yes	145 (36.9)	133 (37.1)	12 (35.3)	

SD: standard deviation; M: median; Q_1: 1st quartile; Q_3: 3st quartile, PCI: percutaneous coronary intervention, SBP: systolic blood pressure, DBP: diastolic blood pressure, NSTE-ACS: non-ST elevation acute coronary syndromes, NATEMI: non-ST-elevation myocardial infarction, UA: unstable angina, LVEF: left ventricular ejection fraction, CHD: coronary heart disease, CABG: coronary artery bypass grafting, AMI: acute myocardial infarction, ACEI: angiotensin-converting enzyme inhibitor, ARB: angiotensin II receptor blockers, DAPT: dual antiplatelet therapy, RBC: red blood cell count, WBC: white blood cell count, PDW: platelet distribution width, RDW: red cell distribution width, CK-MB: creatine kinase isoenzymes, TG: triglyceride, TC: total cholesterol, LDL-C: low density lipoprotein cholesterol, HDL-C: high density lipoprotein cholesterol, ALT: alanine aminotransferase, AST: aspartate aminotransferase, ALB: albumin, FBG: fasting blood glucose, HbA1c: hemoglobin A1c, Scr: serum creatinine, FIB: fibrosis, TyG: triglyceride-glucose index, GNRI: Geriatric Nutritional Risk Index, MACE: major adverse cardiac event.
†Student's t test; ‡Satterthwaite t test; §Chi-square test; ¶Wilcoxon rank sum test; ††Fisher's exact test.

Table 1. Characteristics of patients with NSTE-ACS after PCI (cont.)

Variables	Total (n=393)	No-MACE (n=359)	MACE (n=34)	*p*
Post-oral hypoglycemic drug, n (%)				1.000 [§]
No	300 (76.3)	274 (76.3)	26 (76.5)	
Yes	93 (23.7)	85 (23.7)	8 (23.5)	
Post-other drug, n (%)				0.610 [††]
No	57 (14.5)	51 (14.2)	6 (17.7)	
Yes	336 (85.5)	308 (85.8)	28 (82.4)	
TyG, Mean (±SD)	1.58 (±0.76)	1.55 (±0.75)	1.94 (±0.74)	0.004 [†]
GNRI, Mean (±SD)	103 (±6.11)	103 (±6.19)	102 (±5.32)	0.640 [†]
TyG, n (%)				<0.001 [§]
<1.359	165 (42.0)	161 (44.9)	4 (11.8)	
≥1.359	228 (58.0)	198 (55.2)	30 (88.2)	
GNRI, n (%)				0.153 [§]
<107.514	316 (80.4)	285 (79.4)	31 (91.2)	
≥107.514	77 (19.6)	74 (20.6)	3 (8.82)	

SD: standard deviation; M: median; Q_1: 1st quartile; Q_3: 3st quartile, PCI: percutaneous coronary intervention, SBP: systolic blood pressure, DBP: diastolic blood pressure, NSTE-ACS: non-ST elevation acute coronary syndromes, NATEMI: non-ST-elevation myocardial infarction, UA: unstable angina, LVEF: left ventricular ejection fraction, CHD: coronary heart disease, CABG: coronary artery bypass grafting, AMI: acute myocardial infarction, ACEI: angiotensin-converting enzyme inhibitor, ARB: angiotensin II receptor blockers, DAPT: dual antiplatelet therapy, RBC: red blood cell count, WBC: white blood cell count, PDW: platelet distribution width, RDW: red cell distribution width, CK-MB: creatine kinase isoenzymes, TG: triglyceride, TC: total cholesterol, LDL-C: low density lipoprotein cholesterol, HDL-C: high density lipoprotein cholesterol, ALT: alanine aminotransferase, AST: aspartate aminotransferase, ALB: albumin, FBG: fasting blood glucose, HbA1c: hemoglobin A1c, Scr: serum creatinine, FIB: fibrosis, TyG: triglyceride-glucose index, GNRI: Geriatric Nutritional Risk Index, MACE: major adverse cardiac event.
[†]Student's t test; [‡]Satterthwaite t test; [§]Chi-square test; [¶]Wilcoxon rank sum test; [††]Fisher's exact test.

Table 2. Associations between TyG, GNRI, and MACE in patients with NSTE-ACS after PCI

Variables	n (%)	Model 1		Model 2	
		OR (95% CI)	*p*	OR (95% CI)	*p*
TyG					
<1.359	165 (41.98)	Ref		Ref	
≥1.359	228 (58.02)	6.10 (2.35-20.85)	0.001	5.07 (1.64-15.71)	0.005
GNRI					
<107.514	316 (80.41)	Ref		Ref	
≥107.514	77 (19.59)	0.37 (0.09-1.08)	0.110	0.17 (0.04-0.68)	0.013

Ref: reference; OR: odds ratio; CI: confidence interval.
Model 1 was crude model.
Model 2 adjusting PDW, TC, pre-diffuse lesion, pre-bifurcation lesion, pre-in stent restenosis, and pre-complete revascularizations.

indicators alone. By calculating these indicators in NSTE-ACS patients, we can identify those at high risk of MACE, and provide a basis for early intervention to improve prognosis.

Our results suggested the associations of increased incidence of MACE with elevated TyG or lower GNRI in patients with NSTE-ACS after PCI. A meta-analysis reported the association of increased TyG index with higher incidence of MACE in patients who underwent PCI.[20] The TyG index is an independent predictor of CAD severity and MACEs.[4] The increased risk of MACE in patients with elevated TyG index levels is likely due to insulin resistance (IR).[21, 22] IR and glucose metabolism disturbances lead to oxidative stress, inflammation, and impaired immune regulation, which accelerate arteriosclerosis and promoting plaque formation. The violin plot shows the TyG scores in the MACE group were higher than those in the non-MACE group, which further validates our findings. Similarly, the predictive value of GNRI on all-cause mortality and MACE in patients with CAD has been reported.[23, 24] Malnutrition, evaluated by the GNRI score upon admission, independently predicted MACE in chronic artery occlusion patients after PCI.[25] The GNRI, which combines serum albumin and body weight, is frequently utilized to assess the nutritional status of hospitalized elderly patients. Malnutrition was related to all-cause mortality and MACE.[26] Notably, our analysis using restricted cubic splines indicated non-linear relationships between TyG or GNRI and the occurrence of MACEs. Specifically, there was a discernible positive trend in MACE incidence with increasing TyG values, suggesting a potential threshold effect beyond TyG ≥ 1.36. While the relationship between GNRI and MACE incidence did not display a clear trend as GNRI values increased.

The important finding of our study was the predictive value of TyG combined with GNRI exceeds that of TyG or GNRI alone in MACE in patients with NSTE-ACS after PCI. The superior predictive value of GNRI and TyG index for MACE in patients with NSTE-ACS after PCI likely stems from their complementary roles in different aspects of metabolic and nutritional status. TyG index reflects IR and metabolic dysfunction, both of

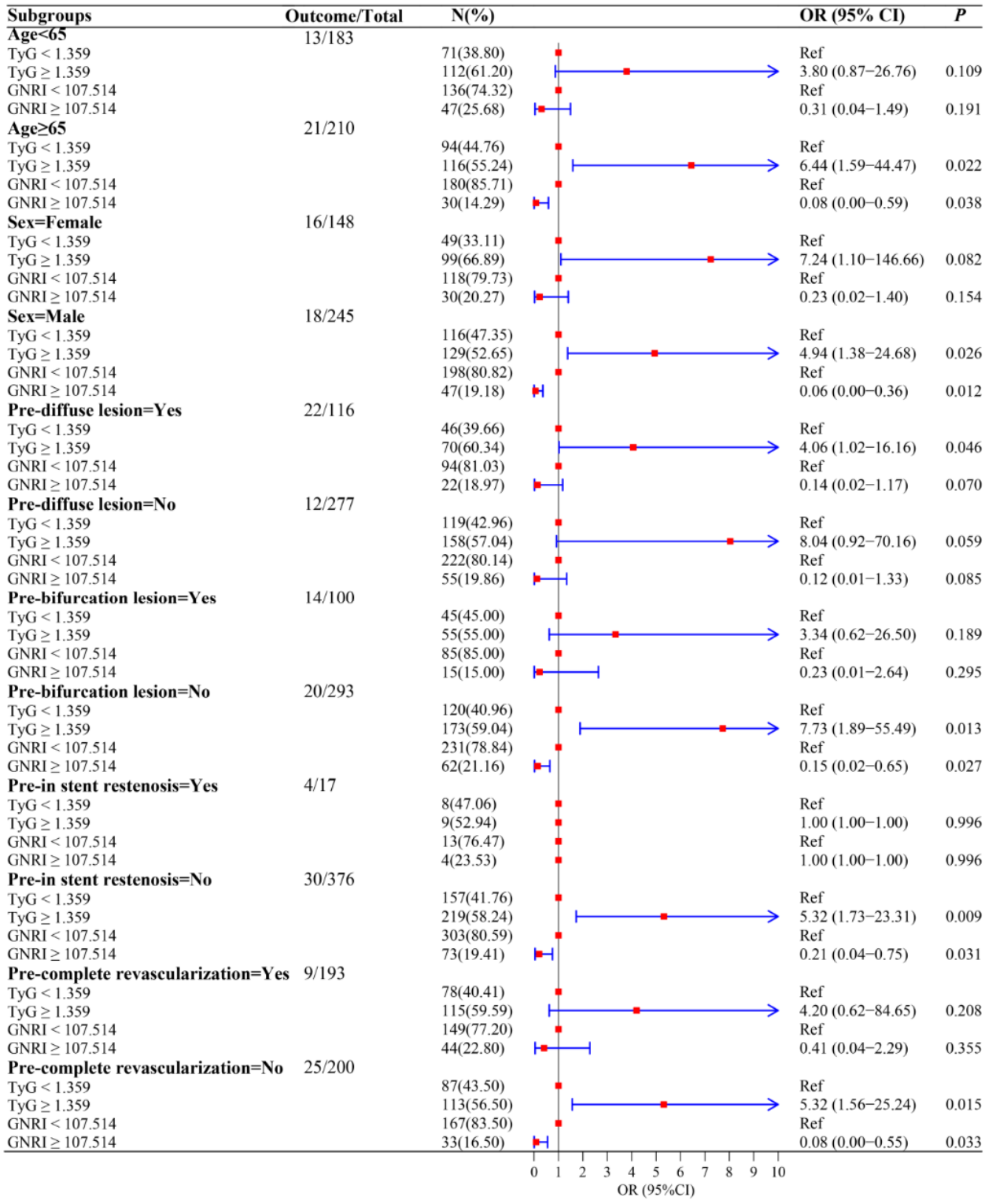

Figure 2. Associations between TyG, GNRI, and MACE in different subgroups

which contribute significantly to the pathogenesis of cardiovascular diseases.[4, 27] Elevated TyG levels have been linked to increased arterial stiffness, endothelial dysfunction, and systemic inflammation, all of which are fundamental in the progression of atherosclerosis and subsequent adverse cardiovascular events.[28, 29] In addition, GNRI assesses nutritional status and overall health resilience, factors that influence post-PCI recovery and outcomes. Poor nutritional status is associated with impaired immune function, inflammation, and increased susceptibility to infections, all of which may exacerbate the incidence of MACE.[30, 31] By combining TyG and GNRI, clinicians gain a more comprehensive assessment of metabolic health, nutritional status, and systemic inflammation, which collectively enhance risk stratification and guide targeted interventions to reduce cardiovascular risk factors.

The combination of TyG and GNRI likely enhances predictive accuracy by capturing diverse aspects of patient vulnerability. TyG emphasizes metabolic dysregulation and underlying insulin resistance, while GNRI underscores the broader health status and nutritional ade-

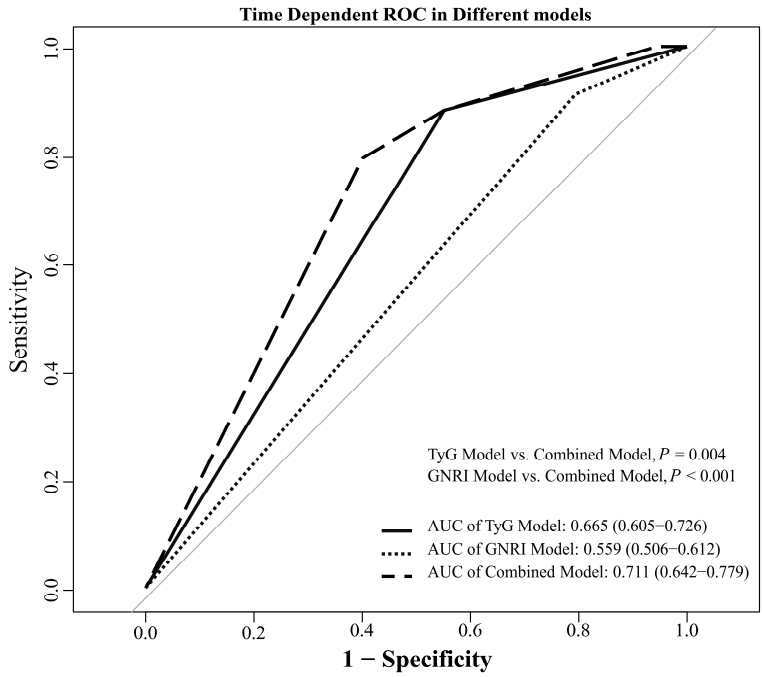

Figure 3. The ROC curves of predictive indicators in predicting the incidence of MACE.

quacy critical for recovery and prognosis after PCI. Integrating these indicators yields a more comprehensive risk profile, enabling clinicians to identify high-risk patients who could benefit from intensified monitoring or targeted interventions to mitigate adverse cardiovascular outcomes.

Several limitations warrant consideration in the current study. Firstly, due to its retrospective nature, despite adjusting for potential covariates, residual or unmeasured confounding may still exist. Secondly, limited information was available regarding changes in patients' TyG index and GNRI levels during follow-up, indicating a need for future research to explore the dynamics. Lastly, as a single-center study, this research may have selection bias, necessitating further studies to validate our findings.

Conclusions

Higher TyG and lower GNRI levels were associated with an elevated incidence of MACCE in patients with NSTE-ACS after PCI. The combination of these indicators may be a reliable, simple, cost-effective, and accessible method for predicting MACCE incidence in patients with NSTE-ACS after PCI. This helps cardiovascular specialists in patients' risk stratification and reduces the incidence of MACE.

CONFLICT OF INTEREST AND FUNDING DISCLOSURE

The authors declare no conflict of interest.

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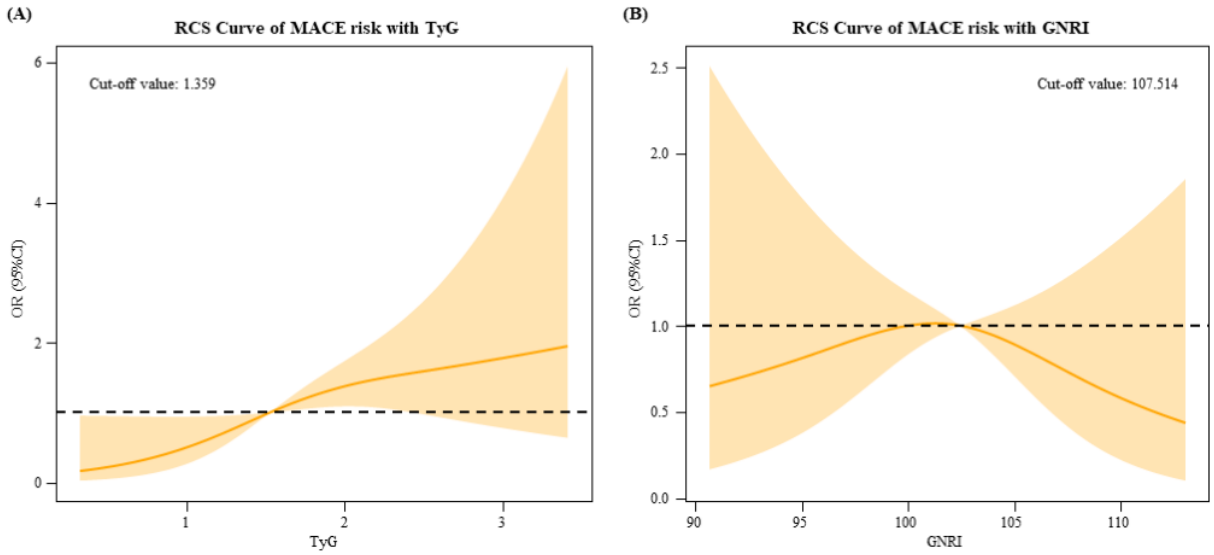
REFERENCES

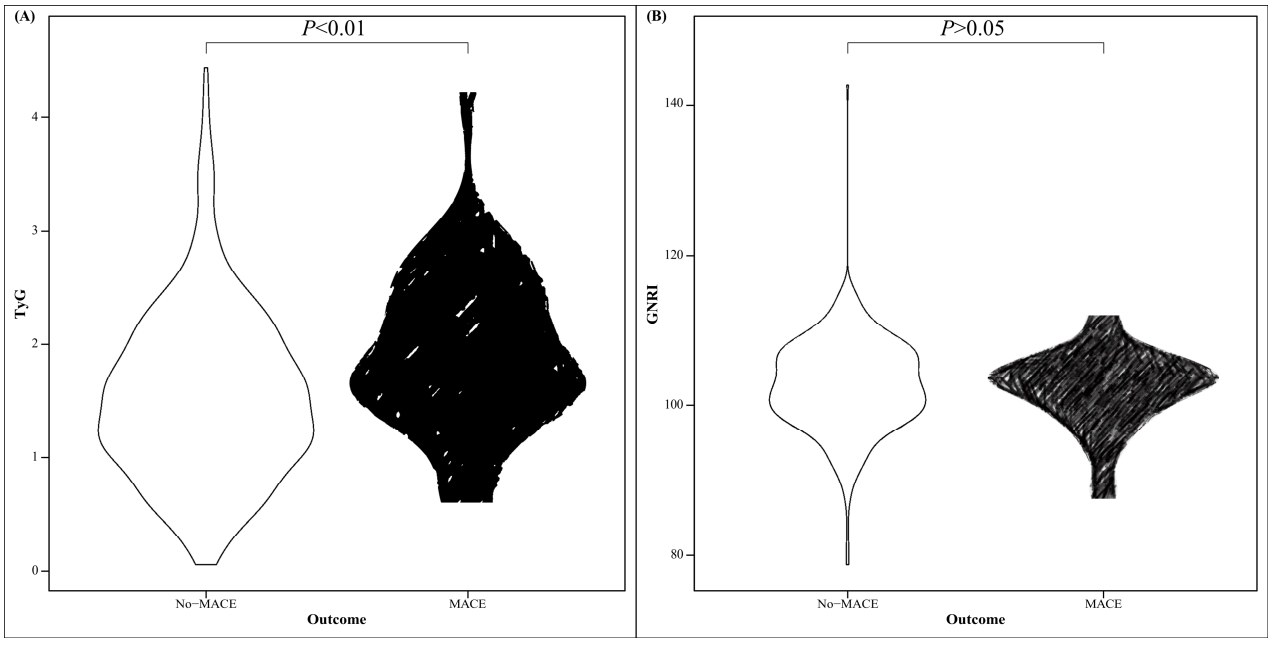
1. Williams MC, Dweck MR, Newby DE. Coronary Computed Tomography Angiography to Triage Patients With Non-ST-Segment Elevation Acute Coronary Syndrome. J Am Coll Cardiol. 2021; 77:1053-6. doi: 10.1016/j.jacc.2020.12.050.
2. Murray CJ, Barber RM, Foreman KJ, Abbasoglu Ozgoren A, Abd-Allah F, Abera SF et al. Global, regional, and national disability-adjusted life years (DALYs) for 306 diseases and injuries and healthy life expectancy (HALE) for 188 countries, 1990-2013: quantifying the epidemiological transition. Lancet. 2015; 386:2145-91. doi: 10.1016/s0140-6736(15)61340-x.
3. Eisen A, Giugliano RP, Braunwald E. Updates on Acute Coronary Syndrome: A Review. JAMA Cardiol. 2016; 1:718-30. doi: 10.1001/jamacardio.2016.2049.
4. Mao Q, Zhou D, Li Y, Wang Y, Xu SC, Zhao XH. The Triglyceride-Glucose Index Predicts Coronary Artery Disease Severity and Cardiovascular Outcomes in Patients with Non-ST-Segment Elevation Acute Coronary Syndrome. Dis Markers. 2019; 2019:6891537. doi: 10.1155/2019/6891537.
5. Luo E, Wang D, Yan G, Qiao Y, Liu B, Hou J, Tang C. High triglyceride-glucose index is associated with poor prognosis in patients with acute ST-elevation myocardial infarction after percutaneous coronary intervention. Cardiovasc Diabetol. 2019; 18:150. doi: 10.1186/s12933-019-0957-3.
6. Zhao Q, Zhang TY, Cheng YJ, Ma Y, Xu YK, Yang JQ, Zhou YJ. Impacts of triglyceride-glucose index on prognosis of patients with type 2 diabetes mellitus and non-ST-segment elevation acute coronary syndrome: results from an observational cohort study in China. Cardiovasc Diabetol. 2020; 19:108. doi: 10.1186/s12933-020-01086-5.
7. Zhao Q, Zhang TY, Cheng YJ, Ma Y, Xu YK, Yang JQ, Zhou YJ. Triglyceride-Glucose Index as a Surrogate Marker of Insulin Resistance for Predicting Cardiovascular Outcomes in Nondiabetic Patients with Non-ST-Segment Elevation Acute Coronary Syndrome Undergoing Percutaneous Coronary Intervention. J Atheroscler Thromb. 2021; 28:1175-94. doi: 10.5551/jat.59840.
8. Bouillanne O, Morineau G, Dupont C, Coulombel I, Vincent JP, Nicolis I, Benazeth S, Cynober L, Aussel C. Geriatric Nutritional Risk Index: a new index for evaluating at-risk elderly medical patients. Am J Clin Nutr. 2005; 82:777-83. doi: 10.1093/ajcn/82.4.777.

9. Honda Y, Nagai T, Iwakami N, Sugano Y, Honda S, Okada A et al. Usefulness of Geriatric Nutritional Risk Index for Assessing Nutritional Status and Its Prognostic Impact in Patients Aged ≥65 Years With Acute Heart Failure. Am J Cardiol. 2016; 118:550-5. doi: 10.1016/j.amjcard.2016.05.045.
10. Zheng HL, Lu J, Li P, Xie JW, Wang JB, Lin JX et al. Effects of Preoperative Malnutrition on Short- and Long-Term Outcomes of Patients with Gastric Cancer: Can We Do Better? Ann Surg Oncol. 2017; 24:3376-85. doi: 10.1245/s10434-017-5998-9.
11. Basta G, Chatzianagnostou K, Paradossi U, Botto N, Del Turco S, Taddei A, Berti S, Mazzone A. The prognostic impact of objective nutritional indices in elderly patients with ST-elevation myocardial infarction undergoing primary coronary intervention. Int J Cardiol. 2016; 221:987-92. doi: 10.1016/j.ijcard.2016.07.039.
12. Nakamura T, Matsumoto M, Haraguchi Y, Ishida T, Momomura SI. Prognostic impact of malnutrition assessed using geriatric nutritional risk index in patients aged ⩾80 years with heart failure. Eur J Cardiovasc Nurs. 2020; 19:172-7. doi: 10.1177/1474515119864970.
13. Sato M, Ido Y, Yoshimura Y, Mutai H. Relationship of Malnutrition During Hospitalization With Functional Recovery and Postdischarge Destination in Elderly Stroke Patients. J Stroke Cerebrovasc Dis. 2019; 28:1866-72. doi: 10.1016/j.jstrokecerebrovasdis.2019.04.012.
14. Xiong J, Wang M, Zhang Y, Nie L, He T, Wang Y, Huang Y, Feng B, Zhang J, Zhao J. Association of Geriatric Nutritional Risk Index with Mortality in Hemodialysis Patients: A Meta-Analysis of Cohort Studies. Kidney Blood Press Res. 2018; 43:1878-89. doi: 10.1159/000495999.
15. Zhao Q, Zhang TY, Cheng YJ, Ma Y, Xu YK, Yang JQ, Zhou YJ. Impacts of geriatric nutritional risk index on prognosis of patients with non-ST-segment elevation acute coronary syndrome: Results from an observational cohort study in China. Nutr Metab Cardiovasc Dis. 2020; 30:1685-96. doi: 10.1016/j.numecd.2020.05.016.
16. Tao LC, Xu JN, Wang TT, Hua F, Li JJ. Triglyceride-glucose index as a marker in cardiovascular diseases: landscape and limitations. Cardiovasc Diabetol. 2022; 21:68. doi: 10.1186/s12933-022-01511-x.
17. Shi T, Wang Y, Peng Y, Wang M, Zhou Y, Gu W, Li Y, Zou J, Zhu N, Chen L. Advanced lung cancer inflammation index combined with geriatric nutritional risk index predict all-cause mortality in heart failure patients. BMC Cardiovasc Disord. 2023; 23:565. doi: 10.1186/s12872-023-03608-x.
18. Yang ZK, Shen Y, Dai Y, Wang XQ, Hu J, Ding FH, Zhang RY, Lu L, Shen WF. Impact of coronary collateralization on long-term clinical outcomes in type 2 diabetic patients after successful recanalization of chronic total occlusion. Cardiovasc Diabetol. 2020; 19:59. doi: 10.1186/s12933-020-01033-4.
19. Thygesen K, Alpert JS, Jaffe AS, Chaitman BR, Bax JJ, Morrow DA, White HD. Fourth universal definition of myocardial infarction (2018). Eur Heart J. 2019; 40:237-69. doi: 10.1093/eurheartj/ehy462.
20. Kohar K, Sanjaya IS, Amirah S, Yumnanisha DA, Ambari AM. The potential of triglyceride-glucose index in improving the prediction of post-percutaneous coronary intervention clinical outcomes: a systematic review and meta-analysis. Acta Cardiol. 2024; 1-9. doi: 10.1080/00015385.2024.2349829.
21. Brito ADM, Hermsdorff HHM, Filgueiras MS, Suhett LG, Vieira-Ribeiro SA, Franceschini S, Novaes JF. Predictive capacity of triglyceride-glucose (TyG) index for insulin resistance and cardiometabolic risk in children and adolescents: a systematic review. Crit Rev Food Sci Nutr. 2021; 61:2783-92. doi: 10.1080/10408398.2020.1788501.
22. Park K, Ahn CW, Lee SB, Kang S, Nam JS, Lee BK, Kim JH, Park JS. Elevated TyG Index Predicts Progression of Coronary Artery Calcification. Diabetes Care. 2019; 42:1569-73. doi: 10.2337/dc18-1920.
23. He F, Huang H, Xu W, Cui K, Ruan Y, Guo Y, Wang J, Bin J, Wang Y, Chen Y. Prognostic impact of malnutrition in patients with coronary artery disease: a systematic review and meta-analysis. Nutr Rev. 2024; 82:1013-27. doi: 10.1093/nutrit/nuad108.
24. Fan Y, He L, Zhou Y, Man C. Predictive Value of Geriatric Nutritional Risk Index in Patients With Coronary Artery Disease: A Meta-Analysis. Front Nutr. 2021; 8:736884. doi: 10.3389/fnut.2021.736884.
25. Cheng L, Rong J, Zhuo X, Gao K, Meng Z, Wen X et al. Prognostic value of malnutrition using geriatric nutritional risk index in patients with coronary chronic total occlusion after percutaneous coronary intervention. Clin Nutr. 2021; 40:4171-9. doi: 10.1016/j.clnu.2021.01.042.
26. Zhu XY, Zhang KJ, Li X, Su FF, Tian JW. Prognostic value of Geriatric Nutritional Risk Index and systemic immune-inflammatory index in elderly patients with acute coronary syndromes. Sci Rep. 2024; 14:3144. doi: 10.1038/s41598-024-53540-z.
27. Hill MA, Yang Y, Zhang L, Sun Z, Jia G, Parrish AR, Sowers JR. Insulin resistance, cardiovascular stiffening and cardiovascular disease. Metabolism. 2021; 119:154766. doi: 10.1016/j.metabol.2021.154766.
28. Liu F, Ling Q, Xie S, Xu Y, Liu M, Hu Q et al. Association between triglyceride glucose index and arterial stiffness and coronary artery calcification: a systematic review and exposure-effect meta-analysis. Cardiovasc Diabetol. 2023; 22:111. doi: 10.1186/s12933-023-01819-2.
29. Ramirez JL, Khetani SA, Zahner GJ, Spaulding KA, Schaller MS, Gasper WJ, Hills NK, Schafer AL, Grenon SM. Serum resistin is associated with impaired endothelial function and a higher rate of adverse cardiac events in patients with peripheral artery disease. J Vasc Surg. 2019; 69:497-506. doi: 10.1016/j.jvs.2018.05.251.
30. Arero G, Arero AG, Mohammed SH, Vasheghani-Farahani A. Prognostic Potential of the Controlling Nutritional Status (CONUT) Score in Predicting All-Cause Mortality and Major Adverse Cardiovascular Events in Patients With Coronary Artery Disease: A Meta-Analysis. Front Nutr. 2022; 9:850641. doi: 10.3389/fnut.2022.850641.
31. Luong R, Ribeiro R, Naganathan V, Blyth F, Waite LM, Handelsman DJ, Le Couteur DG, Seibel MJ, Hirani V. Empirically derived dietary patterns are associated with major adverse cardiovascular events, all-cause mortality, and congestive cardiac failure in older men: The Concord Health and Ageing in Men Project. J Nutr Health Aging. 2024; 28:100020. doi: 10.1016/j.jnha.2023.100020.

Supplementary Figures



Supplementary Figure 1. Association between TyG, GNRI and incidence of MACE using RCS analysis



Supplementary Figure 2. Violin plots of TyG and GNRI in the MACE and no-MACE groups