Cardiovascular Topics

The predictive value of triglyceride–glucose index for assessing the severity and MACE of premature coronary artery disease

Ling Yang, Yu Peng, Zheng Zhang

Abstract

Objective: The aim of this study was to investigate the predictive value of the triglyceride–glucose (TyG) index to assess the severity and major adverse cardiovascular events (MACE) of patients in hospital with premature coronary artery disease (PCAD).

Methods: A total of 300 patients with PCAD, diagnosed by coronary angiography (CAG), were enrolled in this study. According to the tertiles of TyG index, the 300 patients were divided into a T1 (n = 100), T2 (n = 100) and T3 group (n = 100). According to the presence or absence of MACE, the 300 patients were divided into a MACE (n = 80) and a non-MACE group (n = 220). The patients' clinical data were compared between the groups, the relationship between TyG index and the severity of PCAD and MACE were analysed through multivariable logistic regression analysis, and their predictive value was detected using receiver operating characteristic (ROC) curves.

Results: Multivariable logistic regression analysis showed that the TyG index was an independent risk factor for the severity of PCAD and MACE. The area under the ROC curve was 0.833 and 0.807, respectively (all $p < 0.05$).

Conclusion: The TyG index was independently associated with the severity of PCAD and MACE, and had a good predictive value.

Keywords: premature coronary artery disease, triglyceride–glucose index, severity, major adverse cardiovascular events

Submitted 10/9/23; accepted 8/11/23

Cardiovasc J Afr 2024; online publication www.cvja.co.za

DOI: 10.5830/CVJA-2023-060

The First Clinical Medicine School of Lanzhou University, Lanzhou, China
Ling Yang, MMed

The Heart Center of the First Hospital of Lanzhou University, and the Key Laboratory of Cardiovascular Diseases of Gansu Province, Lanzhou, China
Yu Peng, MD
Zheng Zhang, MD, zhangccu@163.com

Coronary artery disease (CAD) is the most important cause of morbidity and mortality all over the world.[1,2] Although coronary artery disease occurs mainly in the elderly, with the change in lifestyle and dietary habits, young individuals with CAD have become more prevalent in recent years. The onset age of CAD is also becoming younger and younger, which has become a problem that cannot be ignored.[3]

Premature coronary artery disease (PCAD) is a special type of CAD, which is defined as the onset of CAD before the age of 55 years in males and 65 years in females.[4] In contrast to mature coronary artery disease, PCAD patients have more severe coronary artery stenosis, more vascular occlusion, higher incidence of acute coronary syndrome (ACS) and major adverse cardiovascular events (MACE).[3,5] The loss of the labour force caused by PCAD will bring a heavy burden to society and families, so it is of great significance to prevent the occurrence and adverse outcomes of PCAD.

Simental-Mendia *et al.* first discovered that the triglyceride–glucose (TyG) index was related to insulin resistance (IR), and current studies have confirmed that the TyG index is related to cardiovascular disease.[6] However, most of the current studies on TyG index and cardiovascular disease have been conducted in the elderly, and there are few studies on TyG index and PCAD.

We mainly explored the association between TyG index and the severity and MACE of PCAD, and analysed the predictive value of TyG index for both. This has ensured a better understanding of the clinical value of the TyG index for PCAD, and allowed us to find a simple, economical and reliable predictor of PCAD, so as to improve the clinical diagnosis and treatment of PCAD patients.

Methods

This was a single-centre, retrospective study. From January 2021 to June 2022, a total of 300 patients with PCAD, diagnosed by coronary angiography (CAG) at the Heart Center of the First Hospital of Lanzhou University, were selected as the subjects. CAD was defined as the presence of obstructive stenosis of ≥ 50% of the vessel lumen diameter in any of the main coronary arteries, including the left main coronary artery, left anterior descending artery, left circumflex coronary artery and right coronary artery, or the main branches of the vascular system.

The inclusion criteria were as follows: their age had to meet the requirements of PACD (males ≤ 55 years, females ≤ 65 years);

and all patients had to have CAG records and results at the Heart Center of our hospital. The exclusion criteria were as follows: patients with history of coronary artery revascularisation; those with heart diseases, such as myocarditis, congenital heart disease or valvular disease; those with severe liver or kidney insufficiency; those with infectious diseases; those with malignancies or other auto-immune rheumatic diseases or connective tissue diseases; and those who had recently taken medications lowering their blood lipids.

This study was reviewed and approved by the ethics committee of the First Hospital of Lanzhou University. All patients were exempt from written informed consent.

Clinical data were collected from the medical records by trained clinicians who were blinded to the study aim. The data included patients' demographics (age, gender, height, weight, history of smoking and drinking), past history of hypertension and diabetes, and family history of CAD.

All peripheral venous blood samples were collected early in the morning after overnight fasting (eight hours minimum) and the results were collected retrospectively from the medical records. The laboratory indicators mainly included fasting blood glucose (FBG), total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C).

The TyG index was calculated as: ln [fasting TG (mg/dl) × FBG (mg/dl)/2].[7]

The unit conversion of blood glucose: 1 mmol/l = 18.0 mg/dl, unit conversion of TG: 1 mmol/l = 88.6 mg/dl.

According to the tertiles of TyG index, the 300 patients were divided into a T1 group (TyG index ≤ 8.7994, n = 100), a T2 group (8.8133 < TyG index ≤ 9.4635, n = 100) and a T3 group (TyG index > 9.4635, n = 100).

The results of CAG were collected, and the number of coronary artery lesions and the degree of stenosis of each vessel were recorded. The total Gensini score was calculated according to *The Guide for Gensini Score Calculation*.[8] The Gensini score was used to evaluate the severity of PCAD. According to the median of the Gensini score, a score ≤ 24 was defined as mild CAD, and a score > 24 was defined as severe CAD.

We followed up the 300 patients for 15 months. Patients who underwent planned coronary stent re-implantation were excluded from the study. All re-admitted patients presented with symptoms of cardiogenic chest pain as their primary complaints. Each re-admitted patient underwent a routine cardiology examination and CAG. For patients with multiple re-admissions, the endpoint was determined as the hospitalisation time at which MACE occurred during the follow up.

The primary endpoint of our study was the occurrence of MACE, which included re-admission with chest pain, coronary artery revascularisation, in-stent restenosis, heart failure, arrhythmias and haemorrhagic events. According to the presence or absence of MACE, the 300 patients were divided into a MACE group (n = 80) and a non-MACE group (n = 220).

Statistical analysis

IBM SPSS version 26.0 software was used for statistical analysis. The Shapiro–Wilk and Kolmogorov–Smirnov tests were performed to determine whether the research data had conformed to a normal distribution. Continuous variables are expressed as mean ± standard deviation (SD) or median interval and interquartile (IQR) values, and compared using the Student's t-test or ANOVA test in the case of normal distribution, or the Mann–Whitney U-test or Kruskal–Wallis H-test in the case of non-normal distribution. Categorical variables are expressed as counts and percentages and were compared using the chi-squared or Fisher exact test.

The relationship between the TyG index and the severity and MACE of PCAD were analysed through multivariable logistic regression analysis, and the predictive value was detected using receiver operating characteristic (ROC) curves. A p-value of less than 0.05 was considered to be statistically significant.

Results

The variables were compared between the three groups (T1, T2 and T3). The results showed that among the three groups, the patients' proportion of smoking, drinking, hypertension, diabetes, body mass index (BMI), and levels of FBG, TC, TG, HDL-C, LDL-C and Gensini score showed significant differences (all $p < 0.05$), but age, male gender and family history of CAD showed no significant differences (all $p > 0.05$) (Table 1).

On multivariable logistic regression analysis, with the T1 group as the reference group, the higher tertile of the TyG index was significantly associated with severity of PCAD after unadjusting for any factors (OR: 3.273, 95% CI: 1.745–6.137 for the T2 group, and OR: 5.211, 95% CI: 2.758–9.845 for the T3 group). After further adjustment for other confounding factors, the increased TyG index was associated with an increased risk of suffering from severe PCAD (all $p < 0.05$) (Fig. 1).

According to the presence or absence of MACE, the 300 patients were divided into a MACE group (n = 80) and a

Table 1. Clinical characteristics and laboratory tests of patients with different TyG levels

Variables	*T1 group (n = 100)*	*T2 group (n = 100)*	*T3 group (n = 100)*	*F/χ²/Z*	p-*value*
Age (year), mean ± SD	49.83 ± 7.24	50.32 ± 8.06	49.89 ± 7.12	0.128	0.880
Males, *n* (%)	65 (65.00)	69 (69.00)	68 (68.00)	0.394	0.821
Smoking, *n* (%)	18 (18.00)[ab]	32 (32.00)[c]	46 (46.00)	18.015	< 0.001
Drinking, *n* (%)	13 (13.00)[ab]	25 (25.00)[c]	39 (39.00)	17.751	< 0.001
Hypertension, n (%)	31 (30.00)[ab]	46 (46.00)[c]	62 (62.00)	19.331	< 0.001
Diabetes, *n* (%)	9 (9.00)[ab]	20 (20.00)[c]	37 (37.00)	23.193	< 0.001
Family history of CAD, *n* (%)	24 (24.00)	28 (28.00)	30 (30.00)	0.940	0.625
BMI (kg/m²), mean ± SD	24.44 ± 3.59[ab]	26.23 ± 3.12[c]	27.19 ± 3.10	18.129	< 0.001
FBG (mmol/l), mean (min–max)	4.95[ab] (4.39–5.61)	5.44[c] (4.95,6.73)	7.69 (6.19–10.36)	94.158	< 0.001
TC (mmol/l), mean (min–max)	3.67[ab] (3.15–4.22)	3.87[c] (3.38,4.44)	4.32 (3.64–5.01)	23.765	< 0.001
TG (mmol/l), mean (min–max)	1.18[ab] (0.94–1.48)	1.96[c] (1.66–2.47)	3.30 (2.61–4.38)	201.300	< 0.001
HDL-C (mmol/l), mean ± SD	1.12 ± 0.23[ab]	1.01 ± 0.20[c]	0.91 ± 0.21	25.068	< 0.001
LDL-C (mmol/l), mean ± SD	2.50 ± 0.74[b]	2.69 ± 0.88	2.91 ± 0.92	5.601	0.004
Gensini score, mean (min–max)	17.50[ab] (10.00–22.00)	24.00[c] (12.50–36.00)	47.00 (32.00–60.00)	90.874	< 0.001

CAD: coronary artery disease, BMI: the body mass index, FBG: fasting plasma glucose, TC: total cholesterol, TG: triglycerides, HDL-C: high-density lipoprotein cholesterol, LDL-C: low-density lipoprotein cholesterol.
[a]T2 group vs T1 group, $p < 0.05$; [b]T3 group vs T1 group, $p < 0.05$; [c]T3 group vs T2 group, $p < 0.05$.

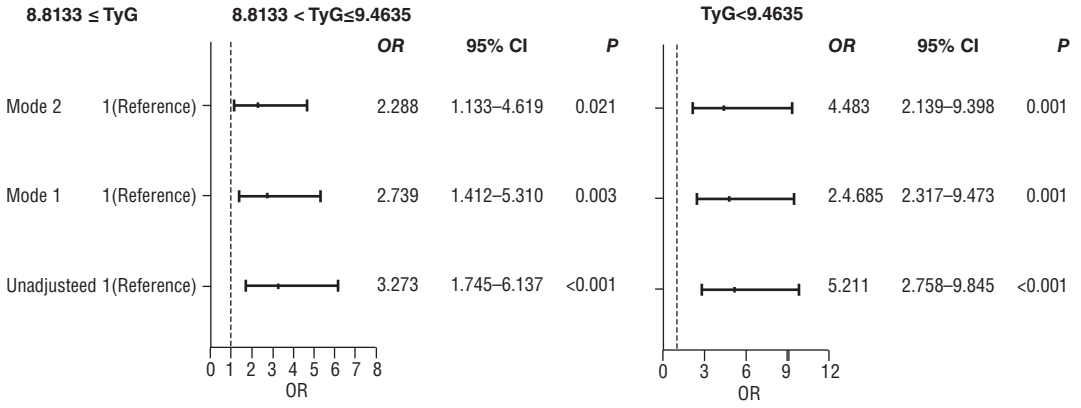

Fig. 1. Multivariable regression analysis for association of TyG index with the severity of PCAD. Model 1: adjusted for smoking, drinking, hypertension, diabetes. Model 2: Model 1+ adjusted for BMI, TC, HDL-C.

non-MACE group (n = 220). Subjects with MACE showed a higher proportion of smoking, drinking, hypertension and diabetes, and also higher levels of BMI, FBG, TG, Gensini score and TyG index, but lower HDL-C levels (all $p < 0.05$) (Table 2).

Univariable logistic regression analyses showed smoking, drinking, hypertension, diabetes, BMI, FBG, TG, HDL-C and TyG index were associated with MACE. The variables selected by univariable logistic regression ($p < 0.05$) were analysed in the multivariable logistic regression analysis. FBG, TG and Gensini score were excluded because the TyG index had a strong correlation with FBG, TG and Gensini score (r_s = 0.596, 0.881, 0.601; $p < 0.001$). Multivariable logistic regression analysis showed smoking (OR: 2.387, 95% CI: 1.034–5.510; p = 0.042), hypertension (OR: 2.156, 95% CI: 1.114–4.172; p = 0.023), diabetes (OR: 2.351, 95% CI: 1.151–4.805; p = 0.019) and TyG index (OR: 4.653, 95% CI: 2.541–8.522; $p < 0.001$) were possible independent risk factors for MACE. HDL-C (OR: 0.130, 95% CI: 0.021–0.808; p = 0.029) was an independent protective factor for MACE (Table 3).

The results showed that among the three groups, re-admission, coronary artery revascularisation and in-stent restenosis showed significant differences (all $p < 0.05$). However, heart failure, arrhythmia and haemorrhagic events showed no significant differences (all $p > 0.05$) (Table 4).

Patients with a high Gensini score (> 24) and patients with MACE were defined as positive, and possessed sensitivity analysis. The area under the ROC curve for predicting severity of PCAD, sensitivity, specificity and Youden index were 0.833 (95% CI: 0.789–0.877), 0.678, 0.801 and 0.479, respectively (Table 5, Fig. 2). The area under the ROC curve for predicting MACE of PCAD, sensitivity, specificity and Youden index were 0.807 (95%

Table 2. Comparison of baseline characteristics of MACE and non-MACE patients

Variables	*MACE group* (n = *80*)	*non-MACE group* (n = *220*)	*t*/χ^2/*Z*	p-*value*
Age (year), mean ± SD	49.18 ± 6.75	50.32 ± 7.70	1.174	0.241
Males, *n* (%)	57 (71.25)	145 (65.91)	0.761	0.383
Smoking, *n* (%)	44 (55.00)	52 (23.64)	26.521	< 0.001
Drinking, *n* (%)	32 (40.00)	45 (20.45)	11.747	0.001
Hypertension, *n* (%)	56 (70.00)	83 (37.73)	24.573	< 0.001
Diabetes, *n* (%)	35 (43.75)	31 (14.10)	30.074	< 0.001
Family history of CAD, *n* (%)	26 (32.50)	56 (25.45)	1.466	0.226
BMI (kg/m^2), mean ± SD	26.90 ± 3.01	25.61 ± 3.55	–2.898	0.004
FBG (mmol/l), mean (min–max)	7.48 (5.40–10.25)	5.30 (4.71–6.56)	–6.047	< 0.001
TC (mmol/l), mean (min–max)	4.11 (3.37–4.91)	3.88 (3.38–4.52)	–1.272	0.203
TG (mmol/l), mean (min–max)	2.91 (1.99–4.56)	1.71 (1.22–2.48)	–6.810	< 0.001
HDL-C (mmol/l), mean ± SD	0.89 ± 0.19	1.06 ± 0.22	6.034	< 0.001
LDL-C (mmol/l), mean ± SD	2.73 ± 0.91	2.69 ± 0.85	–0.397	0.692
Gensini score, mean (min–max)	46 (32–65)	20 (12–32)	–7.993	< 0.001
TyG index, mean ± SD	9.83 ± 0.79	8.96 ± 0.59	–8.920	< 0.001

CAD: coronary artery disease, BMI: the body mass index, FBG: fasting plasma glucose, TC: total cholesterol, TG: triglycerides, HDL-C: high-density lipoprotein cholesterol, LDL-C: low-density lipoprotein cholesterol.

Table 3. Multivariable logistic regression analyses for MACE

Variables	β	*SE*	*Wald*	*OR*	*95% CI*	p-*value*
Smoking	0.870	0.427	4.152	2.387	1.034–5.510	0.042
Drinking	–0.268	0.449	0.355	0.765	0.318–1.844	0.551
Hypertension	0.768	0.337	5.199	2.156	1.114–4.172	0.023
Diabetes	0.855	0.365	5.496	2.351	1.151–4.805	0.019
BMI	–0.055	0.058	0.906	0.946	0.844–1.060	0.341
HDL-C	–2.037	0.931	4.792	0.130	0.021–0.808	0.029
TyG	1.538	0.309	24.799	4.653	2.541–8.522	< 0.001

BMI: body mass index, HDL-C: high-density lipoprotein cholesterol, TyG: triglyceride–glucose index.

Table 4. Comparison of MACE with different TyG levels

Variables	*T1 group* (n = *100*)	*T2 group* (n = *100*)	*T3 group* (n = *100*)	χ^2	p-*value*
Re-admission, *n* (%)	10 (10.00)	24 (24.00)	46 (46.00)	33.682	< 0.001
Coronary artery revascularisation, *n* (%)	3 (3.00)	7 (7.00)	18 (18.00)	14.259	0.001
In-stent restenosis, *n* (%)	0 (0.00)	2 (2.00)	6 (6.00)	6.566	0.031
Heart failure, *n* (%)	0 (0.00)	0 (0.00)	2 (2.00)	2.655	0.331
Arrhythmia, *n* (%)	0 (0.00)	1 (1.00)	1 (1.00)	1.249	1.000
Haemorrhagic events, *n* (%)	0 (0.00)	0 (0.00)	1 (1.00)	1.824	1.000

Table 5. Sensitivity analysis of TyG index for the severity and MACE of PCAD

Variables	*Sensitivity*	*Specificity*	*Youden index*	*Cut-off value*	*AUC*
Gensini score	0.678	0.801	0.479	9.252	0.833
MACE	0.500	0.955	0.495	9.918	0.807

AUC: area under curve, MACE: major adverse cardiovascular events.

CI: 0.752–0.862), 0.500, 0.955 and 0.495, respectively (Table 5, Fig. 2).

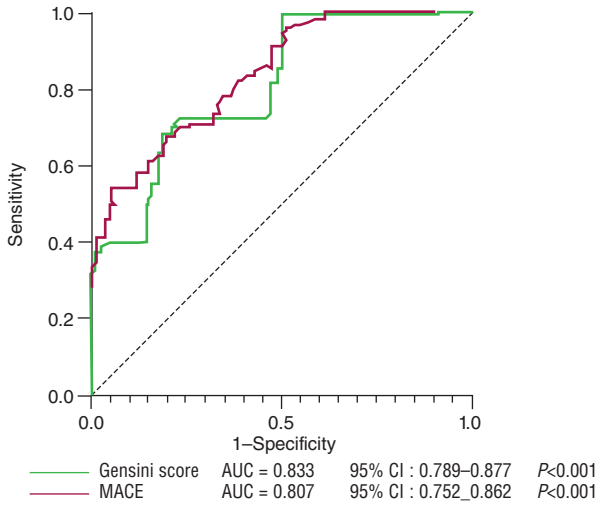

Fig. 2. ROC curve of TyG index for severity of PCAD and MACE.

Discussion

PCAD is an aggressive disease with high rates of recurrent events and mortality. The coronary artery lesions of PCAD are unstable plaques, which are prone to develop from single-vessel lesions into new multi-vessel lesions at an early stage. This high rate of MACE has persisted despite the advent of drug-eluting stents, and antiplatelet and lipid-lowering drugs.[9] Therefore, compared with treatment of the disease, early prevention of coronary atherosclerosis is very important.

CAG is the gold standard for the diagnosis of CAD, but it is a costly and invasive procedure.[10] Therefore exploring a relatively simple, economical, reliable, non-invasive biomarker to predict the severity of CAD would benefit patients, and would also be of great significance for prevention and control of the disease, and reducing the medical burden.

The TyG index, which is a composite indicator composed of fasting TG and FBG levels, is a simple and reliable surrogate for IR, which has been proven to be a risk factor for cardiovascular disease.[11] In this study we grouped the enrolled patients based on the tertiles of the TyG index. The results showed sequential increases from low to high in the differences of BMI, FBG, TC, TG and LDL-C of different TyG level groups. The opposite trend was found for HDL-C levels. These data revealed disorders of glucose and lipid metabolism in the studied patients.

The metabolic disorder is one of the main causes of CAD, and can affect the development of CAD.[12] In our study we also found that with an increase in TyG index, the risk of severe CAD in PCAD patients gradually increased, and this relationship still existed after adjusting for related confounding factors.

Li *et al*. recruited asymptomatic subjects with type 2 diabetes who underwent coronary CT angiography, and the authors found that the incidence of severe coronary stenosis increased along with the TyG index tertiles. These results indicated that the highest and middle tertiles of the TyG index were independently associated with the severity of CAD after adjustment for other related confounding factors.[13]

Mao *et al.* evaluated 438 patients with non-ST-elevation acute coronary syndrome and found the TyG index was an independent predictor of a high SYNTAX score (OR: 6.055, 95% CI: 2.915–12.579). With an increase in the TyG index, the degree of coronary artery stenos also increased.[14] Thai *et al*. found that a higher TyG index was associated with the number of narrowed coronary arteries and the degree of coronary stenosis.[15] These earlier studies are consistent with the results of our study, which showed that the TyG index was associated with the severity of CAD in these patients, and that the TyG index could be used as an independent predictor of the severity of PCAD.

Previous studies have shown that the TyG index can predict cardiovascular events.[16,17] Our study found that compared with the non-MACE group, the MACE group had a higher proportion of hypertension and diabetes, higher BMI, FBG and TG levels, and higher TyG index, and a lower HDL-C level. It is well known that individuals with IR are predisposed to developing several metabolic disorders, such as hypertension, hyperglycaemia and dyslipidaemia, all of which are strongly associated with adverse cardiovascular events and outcomes.[18]

After adjusting for confounding factors, it was found that smoking, hypertension, diabetes and the TyG index were independent risk factors for MACE in PCAD. Wu *et al*. also proved that smoking, hypertension, diabetes and the TyG index were independent risk factors for MACE in PCAD. In 526 PCAD patients, a high TyG index was independently related to MACE in PCAD.[19] This was similar to the results of our study.

In a cohort study including 662 elderly patients with ACS, Yang *et al.* found that the MACE rate of patients increased significantly with an increase in TyG index. The TyG index, as a continuous or categorical variable, was an independent risk factor for MACE.[20] We also found a higher incidence of MACE in patients with a high TyG index, especially for re-admission for chest pain, coronary artery revascularisation and in-stent restenosis.

Two previous studies have confirmed that a high TyG index was associated with coronary artery revascularisation. Wu *et al*. found that a high TyG index was an independent risk factor for coronary artery revascularisation in patients with PCAD.[19] Guo *et al*. conducted a follow-up study of 1 414 patients with CAD after percutaneous coronary intervention and found that an elevated TyG index was associated with an increased risk of coronary artery revascularisation and in-stent restenosis.[21] Zhu *et al*. retrospectively enrolled 1 574 ACS patients who were treated with drug-eluting stents and found that the high TyG index group had a higher rate of in-stent restenosis, and a high TyG index was an independent risk factor for in-stent restenosis.[22]

The exact mechanism underlying the relationship between the TyG index and MACE of PCAD remains unknown. The potential mechanisms underlying it are described as follows. On

one hand, first, the coronary artery lesions in PCAD patients are mainly thrombotic plaques, which are unstable.[23] Second, IR causes an excessive increase in the number of platelets and excessive activation of platelet adhesion factors, which lead to a hypercoagulable state and makes it easy to form coronary thrombotic obstructions.[24] Finally, IR can directly aggravate coronary plaque instability.[25]

On the other hand, IR can induce disturbances in glucose and lipid metabolism, contributing to hyperglycaemia and hyperlipidaemia, which in turn trigger inflammation, oxidative stress and increase in the numbers of macrophages. These cause damage and necrosis of the coronary endothelial cells[26] and circulatory disorders of the coronary collaterals. The coronary collaterals can exert a myocardial salvaging effect to limit the ischaemic area and preserve normal cardiac function.[27,28]

Limitations

There are some limitations to our study. First, this was a single-centre and retrospective study with a relatively small sample size, and the existing selection bias may have affected the results. Second, subjects with diabetes use different types and doses of antidiabetic drugs and insulin, which would have influenced the TyG index. In addition, we included only patients with PCAD diagnosed by CAG, and different subtypes of PCAD were also enrolled in this study. These subtypes included stable and unstable angina, non-ST-segment elevation myocardial infarction, and ST-segment elevation myocardial infarction. The presence of these two factors could also have biased the results. Finally, only the first admission and re-admission were recorded in this study, and the follow-up time was relatively short. No long-term follow up was conducted for these patients outside the hospital. Therefore, further multicentre, large-size, prospective studies could strengthen our conclusions.

Conclusion

We found that for patients with significant PCAD, the TyG index was a simple, economical and reliable surrogate index for IR. It was an independent risk factor for the severity of PCAD and MACE, and had a good ability to predict both.

The Science and Technology Program Fund of Gansu Province (18JR2FA005) and the Natural Science Fund of Gansu Province (20JR5RA357) provided funding for the study.

References

1. Roth G A, Mensah G A, Fuster V. The global burden of cardiovascular diseases and risks: a compass for global action. *J Am Coll Cardiol* 2020; **76**(25): 2980–2981.
2. The Writing Committee of the Report on Cardiovascular Health and Diseases in China. Report on Cardiovascular Health and Diseases in China 2021: an updated summary. *Biomed Environ Sci* 2022; **35**(7): 573–603.
3. Qu Y, Zhang F, Yang J, *et al*. Clinical characteristics and outcomes in asian patients with premature coronary artery disease: insight from the FOCUS Registry. *Angiology* 2019; **70**(6): 554–560.
4. Xie J, Qi J, Mao H, *et al.* Coronary plaque tissue characterization in patients with premature coronary artery disease. *Int J Cardiovasc Imaging* 2020; **36**(6): 1003–1011.
5. Zeitouni M, Clare R M, Chiswell K, *et al*. Risk factor burden and long-term prognosis of patients with premature coronary artery disease. *J Am Heart Assoc* 2020; **9**(24): e017712.
6. Tao L C, Xu J N, Wang T T, *et al*. Triglyceride–glucose index as a marker in cardiovascular diseases: landscape and limitations. *Cardiovasc Diabetol* 2022; **21**(1): 68.
7. Simental-Mendía LE, Guerrero-Romero F. The correct formula for the triglycerides and glucose index. *Eur J Pediatr* 2020; **179**(7): 1171.
8. Rampidis G P, Benetos G, Benz D C, *et al*. A guide for Gensini Score calculation. *Atherosclerosis* 2019; **287**: 181–183.
9. Collet J P, Zeitouni M, Procopi N, *et al*. Long-term evolution of premature coronary artery disease. *J Am Coll Cardiol* 2019; **74**(15): 1868–1878.
10. Niknam Sarabi H, Farsi Z, Butler S, *et al*. Comparison of the effectiveness of position change for patients with pain and vascular complications after transfemoral coronary angiography: a randomized clinical trial. *BMC Cardiovasc Disord* 2021; **21**(1): 114.
11. Beverly J K, Budoff M J. Atherosclerosis: pathophysiology of insulin resistance, hyperglycemia, hyperlipidemia, and inflammation. *J Diabetes* 2020; **12**(2): 102–104.
12. Poznyak A, Grechko A V, Poggio P, *et al*. The Diabetes mellitus-atherosclerosis connection: the role of lipid and glucose metabolism and chronic inflammation. *Int J Mol Sci* 2020; **21**(5): 1835.
13. Lee EY, Yang HK, Lee J, *et al*. Triglyceride glucose index, a marker of insulin resistance, is associated with coronary artery stenosis in asymptomatic subjects with type 2 diabetes. *Lipids Health Dis* 2016; **15**(1): 155.
14. Mao Q, Zhou D, Li Y, *et al*. 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.
15. Thai P V, Tien H A, Van Minh H, *et al.* Triglyceride glucose index for the detection of asymptomatic coronary artery stenosis in patients with type 2 diabetes. *Cardiovasc Diabetol* 2020; **19**(1): 137.
16. Jin JL, Cao YX, Wu LG, *et al.* Triglyceride glucose index for predicting cardiovascular outcomes in patients with coronary artery disease. *J Thorac Dis* 2018; **10**(11): 6137–6146.
17. Hu C, Zhang J, Liu J, *et al.* Discordance between the triglyceride glucose index and fasting plasma glucose or HbA_{1c} in patients with acute coronary syndrome undergoing percutaneous coronary intervention predicts cardiovascular events: a cohort study from China. *Cardiovasc Diabetol* 2020; **19**(1): 116.
18. Hill M A, Yang Y, Zhang L, *et al.* Insulin resistance, cardiovascular stiffening and cardiovascular disease. *Metabolism* 2021; **119**: 154766.
19. Wu Z, Liu L, Wang W, *et al*. Triglyceride–glucose index in the prediction of adverse cardiovascular events in patients with premature coronary artery disease: a retrospective cohort study. *Cardiovasc Diabetol* 2022; **21**(1): 142.
20. Jiao Y, Su Y, Shen J, *et al*. Evaluation of the long-term prognostic ability of triglyceride–glucose index for elderly acute coronary syndrome patients: a cohort study. *Cardiovasc Diabetol* 2022; **21**(1): 3.
21. Guo X, Shen R, Yan S, *et al*. Triglyceride–glucose index for predicting repeat revascularization and in-stent restenosis in patients with chronic coronary syndrome undergoing percutaneous coronary intervention. *Cardiovasc Diabetol* 2023; **22**(1): 43.
22. Zhu Y, Liu K, Chen M, *et al*. Triglyceride–glucose index is associated with in-stent restenosis in patients with acute coronary syndrome after percutaneous coronary intervention with drug-eluting stents. *Cardiovasc Diabetol* 2021; **20**(1): 137.
23. Abderrahman H A, Al-Abdallat I M, Idhair A K. Age threshold for proper definition of premature coronary artery disease in males. *J*

Forensic Leg Med 2018; **58**: 45–49.

24. Gerrits A J, Koekman C A, Van Haeften T W, *et al*. Platelet tissue factor synthesis in type 2 diabetic patients is resistant to inhibition by insulin. *Diabetes* 2010; **59**(6): 1487–1495.
25. Wu S, Liu W, Ma Q, *et al*. Association between insulin resistance and coronary plaque vulnerability in patients with acute coronary syndromes: insights from optical coherence tomography. *Angiology* 2019; **70**(6): 539–546.
26. Yang Q, Vijayakumar A, Kahn BB. Metabolites as regulators of insulin sensitivity and metabolism. *Nat Rev Mol Cell Biol* 2018; **19**(10): 654–672.
27. Paccosi S, Pala L, Cresci B, *et al.* Insulin resistance and obesity affect monocyte-derived dendritic cell phenotype and function. *Diabetes Res Clin Pract* 2020; **170**: 108528.
28. Gao A, Liu J, Hu C, *et al*. Association between the triglyceride glucose index and coronary collateralization in coronary artery disease patients with chronic total occlusion lesions. *Lipids Health Dis* 2021; **20**(1): 140.