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Association between the preoperative triglyceride-glucose index and myocardial injury following non-cardiac surgery: a cross-sectional study

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ABSTRACT

Objective An elevated triglyceride-glucose (TyG) index positively correlates with adverse cardiovascular events. However, its association with myocardial injury after non-cardiac surgery (MINS) remains unclear. This study aimed to examine the association between the preoperative TyG index and MINS.

Design A cross-sectional study.

Setting Meizhou People's Hospital.

Participants Adult patients under general anaesthesia and with MINS.

Main exposure measure The preoperative TyG index, calculated using triglyceride (TG) and fasting blood glucose (FBG) levels.

Main outcome measure The occurrence of MINS, defined using postoperative troponin measurements.

Results 889 patients were included, with an 8.3% incidence of MINS (74/889). The median TyG index was 8.57 (8.13, 9.02). TyG exhibited higher discriminatory ability for MINS than TG and FBG, with an area under the curve of 0.624, 0.544 and 0.500, respectively. Fully adjusted logistic regression indicated that an elevated TyG index was independently associated with MINS (OR 1.75, 95% CI 1.21 to 2.52; p=0.003). A multivariate restricted cubic spline suggested a linear relationship between TyG and MINS (p value for non-linearity=0.059). Subgroup analyses showed results consistent with the primary analysis, with no significant interaction effects between subgroups.

Conclusion An elevated preoperative TyG index is independently associated with an increased incidence of MINS. Monitoring the TyG index perioperatively may improve the management of patients at risk for MINS.

Trial registration number ChiCTR2400082834.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Postoperative troponin levels were used to diagnose myocardial injury after non-cardiac surgery (MINS) to enhance the diagnostic objectivity and accuracy.
⇒ We demonstrated a non-linear and independent association between the triglyceride-glucose (TyG) index and MINS through rigorous adjustment for multiple confounding variables overlooked in previous research.
⇒ This study enhances the applicability of the TyG index-MINS relationship across broader age demographics, while addressing a critical gap in previous research.
⇒ A causal relationship cannot be established between preoperative TyG and MINS due to the study design.

INTRODUCTION

Myocardial injury after non-cardiac surgery (MINS) occurs in approximately 3%–16% of surgical cases[1–3] and is a significant cause of mortality within 30 days postoperatively.[1 4] The pathophysiology of MINS includes the disruption of atherosclerotic coronary plaques and an imbalance between myocardial oxygen supply and demand. Preoperative coronary angiography is not mandatory for individuals with coronary artery disease (CAD) who do not exhibit apparent myocardial ischaemic symptoms, making it challenging to identify high-risk patients preoperatively. Therefore, clinicians need a convenient and practical index for this purpose. Significant risk factors for CAD include dyslipidaemia and hyperglycaemia. Both obesity[5] and hyperglycaemia[6] have been strongly associated with subclinical myocardial injury (SCeMI) and adverse cardiovascular events (ACEs).

The triglyceride-glucose (TyG) index, derived from triglycerides (TGs) and fasting blood glucose (FBG), has been linked to the severity of CAD and ACEs.[7–10] Elevated TyG index levels are associated with increased severity of coronary artery stenosis and a higher number of diseased vessels in patients with acute coronary syndrome (ACS).[11 12] The TyG index is a robust predictor of subclinical CAD, even without traditional cardiovascular risk factors (CVRFs).[13] Furthermore, Kim *et al* demonstrated a correlation between higher TyG index levels and the presence of coronary artery calcification plaques in healthy

adults.[14] This observation suggests that patients indicated for operation who have a high TyG index and undergo general anaesthesia may possess underlying coronary artery atherosclerosis and a heightened risk of MINS, regardless of CVRFs. Since dyslipidaemia and hyperglycaemia are routinely detectable and modifiable preoperatively, understanding the relationship between MINS and the TyG index is crucial for perioperative management. However, there is limited research on this issue. Therefore, the clinical records from Meizhou People's Hospital were reviewed to investigate whether preoperative TyG levels were associated with MINS. Elevated preoperative TyG index was hypothesised as an independent risk factor for developing MINS.

METHODS AND MATERIALS

Data source

This study used medical records from Meizhou People's Hospital, including the electronic medical record system, surgical anaesthesia system, prescription system and laboratory and examination systems. The department of medical data and the department of medical administration granted access to these records. WC and FL were responsible for data extraction and cleaning, adhering to the study protocol.

Study population

Inclusion criteria: patients indicated for operation aged ≥40 years, who were administered general anaesthesia and those with troponin measurements recorded within 3 postoperative days. Exclusion criteria: (1) patients <40 years; (2) patients admitted without FBG and TG measurements; (3) patients lacking prescription information.

Exposure of interest

The primary exposure was the preoperative TyG index, calculated using the formula: TyG=ln (TG (mg/dL)×FBG (mg/dL)/2).[15 16] The conversion formulae used were FBG (mg/dL)=FBG (mmol/L)×18.0 and TG (mg/dL)=TG (mmol/L)×88.6. If FBG and TG were measured multiple times preoperatively, the closest measurements to the operation time were used.

Variables

The potential variables were categorised into four groups: (1) demographic characteristics, including age, gender and body mass index (BMI); (2) preoperative comorbidities, including congestive heart failure, hypertension, CAD, chronic obstructive pulmonary disease (COPD), diabetes, history of stroke and peripheral vascular disease (PVD); (3) preoperative laboratory results, including haemoglobin and estimated glomerular filtration rate (eGFR); (4) surgical information, including the American Society of Anesthesiologists Physical Status Classification System, highest intraoperative heart rate to mean arterial pressure, duration of anaesthesia and surgical categories.

Outcomes

The outcome of interest was MINS, defined by postoperative troponin levels exceeding the 99th percentile upper reference limit without non-ischaemic causes.[17 18]

Statistical analysis

This study included as many individuals as possible; therefore, no power calculation was conducted. The random forest algorithm was used for multiple imputations of variables with <20% missing data. Variables with >20% missing data were excluded to avoid bias. Patients were categorised into four groups based on the TyG index quartiles. Categorical variables were expressed as proportions. χ^2 test and Fisher's exact test were used for unordered categorical variables and Kruskal-Wallis tests for ordered categorical variables. Continuous variables, expressed as median (IQR) due to non-normal distribution (per Shapiro-Wilk test), were analysed using the Mann-Whitney U test or Kruskal-Wallis rank sum tests. The diagnostic performance of TyG for MINS was assessed using receiver operating characteristic (ROC) curves to determine the best cut-off value. Logistic regression analysis identified factors influencing MINS across three models. Model 1: unadjusted; Model 2: adjusted for variables with a p value <0.2 in the univariate analysis, along with clinically relevant variables; Model 3: adjusted for all predefined variables. OR and 95% CI were calculated for TyG and the outcome. The linear trend (p value trend) was assessed, and a multivariate restricted cubic spline (RCS) model analysed the non-linear relationship between baseline TyG and MINS. Post-hoc subgroup analyses were stratified by age (≤69 years and >69 years), gender, BMI (<25 kg/m^2 and ≥25 kg/m^2), hypertension and surgical category, with interaction effects tested between subgroups.

A p value <0.05 indicated statistical significance in two-tailed tests. Based on the open-source R, all statistical analyses were conducted using Stata software (https://www.mstata.com/).

Patient and public involvement

This study did not involve members of the public or patients.

RESULTS

Reporting guideline

This study adheres to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.[19]

Patient characteristics

A total of 889 patients undergoing general anaesthesia were included in the study (figure 1). Patients were categorised into four groups based on their TyG index (table 1). The TyG ranges for each group are specified in table 1. More than half of the patients were men, with a median age of 64 years. The overall median TyG index for all patients was 8.57, and the incidence of MINS was 8.3%. The fourth quartile (Q4) group generally exhibited

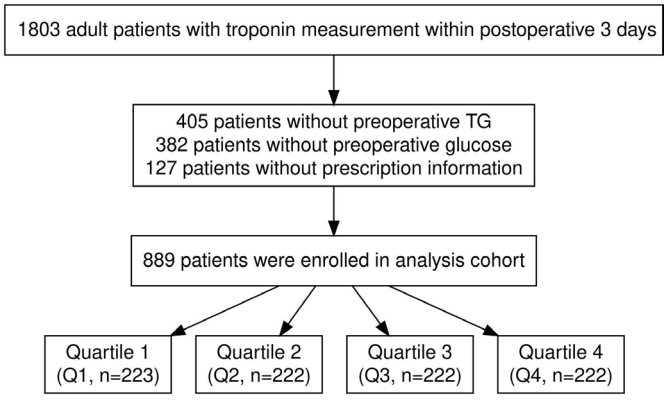

Figure 1 Flowchart of the study population. Flow diagram illustrating the inclusion and exclusion of cases. TG, triglyceride.

a higher BMI and a higher prevalence of preoperative hypertension, diabetes and history of stroke. Patients with a lower TyG index exhibited a lower incidence of MINS than those with a higher TyG index (p=0.009).

Baseline characteristics of patients with and without MINS

Online supplemental table S1 details the differences between the MINS and non-MINS groups. The median TyG index was significantly higher in the MINS group than in the non-MINS group (p<0.001). The two groups significantly differed in preoperative eGFR (p=0.002). Moreover, the MINS group exhibited a significantly higher occurrence of COPD, a history of stroke and PVD. Preoperative statin use was significantly lower in the non-MINS group (p=0.027).

ROC analysis

The TyG index demonstrated higher discriminatory accuracy for MINS than TG and FBG, with an area under the curve of 0.624, 0.544 and 0.500, respectively (online supplemental figure S1). The optimal cut-off value for the TyG index was identified as 8.73 (63.2% specificity and 60.8% sensitivity).

Multivariable logistic regression

The continuous TyG index was positively associated with MINS in the crude and adjusted models (table 2). Neither the Q2 nor the Q3 group exhibited a significantly different risk of MINS than the Q1 group. However, the Q4 group exhibited a substantially increased risk of MINS across all models. A significant linear (p value) trend was observed across Models 1, 2 and 3.

RCS analysis

The RCS analysis revealed a linear increase in the risk of MINS with rising TyG index values (p value for non-linearity=0.059) (figure 2). The reference point was set at 8.58, consistent with the optimal cut-off value of 8.73 derived from the ROC analysis.

Subgroup analysis

For clinical application, patients were categorised into two groups based on the TyG index (≤8.73 vs >8.73) to examine subgroup heterogeneity (figure 3). A TyG index >8.73 was particularly prominent in the following subgroups: patients ≤69 years, female patients, patients with a BMI <25 kg/m², patients without hypertension and patients undergoing non-thoracic surgery. There was no considerable interaction effect among these subgroups.

DISCUSSION

This study reveals that an elevated preoperative TyG index is independently associated with MINS. Our research provides a novel perspective for risk stratification and management strategies related to MINS. Previous research on the relationship between the preoperative TyG index and postoperative ACEs has been limited.

The TyG index demonstrates greater clinical utility than the homeostasis model assessment of insulin resistance (HOMA-IR) for evaluating insulin resistance (IR) and predicting metabolic disease risk.[20] Its key advantage lies in operational efficiency: HOMA-IR requires fasting insulin measurements, which are often unavailable in low-resource settings, thereby limiting its clinical accessibility. In contrast, the TyG index can be calculated using two routinely measured preoperative parameters—TG and FBG. Recent studies have confirmed a significant positive association between elevated TyG index and several cardiovascular disorders,[21] including heart failure,[22] ACS and CAD,[9 23] arterial stiffness,[24] stroke,[25 26] ACEs[27] and atrial fibrillation.[28] However, the relationship between the preoperative TyG index and MINS remains ambiguous. According to Liu *et al*, the TyG index is a significant biomarker of SCeMI.[29] Similarly, our study demonstrates a correlation between an elevated preoperative TyG index and a greater risk of MINS, complementing these findings. Compared with FBG and TG, the TyG index demonstrates more robust diagnostic efficacy for MINS, possibly because it more comprehensively reflects the body's metabolic status and arterial disease state. The linear association between the preoperative TyG index and MINS suggests that the TyG index could be used to predict the incidence of MINS in patients indicated for operation. Consistent with previous studies,[29 30] a high TyG index is associated with MINS, even among patients without diabetes and with normal BMI. However, subgroup analysis suggests that the predictive value of the TyG index is weakened in patients with obesity, diabetes and hypertension. These results may be attributed to differences in population characteristics and disease states, including cardiovascular system damage caused by hyperlipidaemia, diabetes and hypertension, and the interference of therapeutic drugs (statins, antidiabetics and antihypertensive drugs). Complex disease states may limit the predictive ability of the TyG index. In high-risk patients, individualised risk assessment requires a combination of multiple indicators to improve predictive accuracy.

Table 1 Baseline characteristics for patients stratified by TyG index quartiles

	Overall, n=889	Q1, n=223	Q2, n=222	Q3, n=222	Q4, n=222	P value
TyG index range	5.03–11.33	5.03–8.13	8.14–8.57	8.58–9.02	9.03–11.33	/
TyG index quartile	8.57 (8.13, 9.02)	7.85 (7.71, 8.03)	8.37 (8.25, 8.47)	8.75 (8.65, 8.89)	9.44 (9.21, 9.75)	<0.001
Age (years)	64 (55, 72)	64 (55, 73)	64 (55, 72)	65 (58, 73)	60 (54, 69)	<0.001
Sex (male)	533 (60.0)	137 (61.4)	148 (66.7)	115 (51.8)	133 (59.9)	0.015
BMI (kg/m^2)	22.1 (20.0, 24.6)	20.4 (18.7, 22.5)	21.9 (19.7, 24.0)	22.8 (20.8, 25.1)	23.5 (21.3, 25.5)	<0.001
Preoperative lab results						
Haemoglobin (g/L)	129 (112, 140)	124 (109, 137)	128 (112, 138)	130 (116, 140)	131 (114, 145)	0.010
eGFR (mL/min/1.73 m^2)	80 (68, 92)	81 (70, 93)	80 (70, 91)	78 (65, 91)	81 (68, 96)	0.220
Preoperative medical history						
CHF	19 (2.1)	4 (1.8)	4 (1.8)	7 (3.2)	4 (1.8)	0.753
Hypertension	199 (22.4)	27 (12.1)	40 (18.0)	60 (27.0)	72 (32.4)	<0.001
CAD	43 (4.8)	9 (4.0)	7 (3.2)	17 (7.7)	10 (4.5)	0.135
COPD	71 (8.0)	23 (10.3)	21 (9.5)	17 (7.7)	10 (4.5)	0.112
Diabetes	88 (9.9)	4 (1.8)	12 (5.4)	22 (9.9)	50 (22.5)	<0.001
Stroke	50 (5.6)	4 (1.8)	12 (5.4)	11 (5.0)	23 (10.4)	0.001
PVD	58 (6.5)	11 (4.9)	13 (5.9)	18 (8.1)	16 (7.2)	0.538
Preoperative medications						
Rate-controlling	38 (4.3)	9 (4.0)	8 (3.6)	14 (6.3)	7 (3.2)	0.362
Aspirin	26 (2.9)	6 (2.7)	6 (2.7)	7 (3.2)	7 (3.2)	0.983
Statins	81 (9.1)	16 (7.2)	18 (8.1)	25 (11.3)	22 (9.9)	0.442
ASA classification						0.888
I-II	57 (6.4)	12 (5.4)	17 (7.7)	13 (5.9)	15 (6.8)	
III	555 (62.4)	141 (63.2)	139 (62.6)	143 (64.4)	132 (59.5)	
IV-V	277 (31.2)	70 (31.4)	66 (29.7)	66 (29.7)	75 (33.8)	
Duration of anaesthesia (min)	200 (135, 260)	205 (140, 266)	200 (135, 274)	205 (140, 259)	184 (135, 245)	0.134
The highest intraoperative HMR	1.32 (1.13, 1.62)	1.30 (1.10, 1.54)	1.32 (1.11, 1.64)	1.33 (1.16, 1.65)	1.33 (1.15, 1.65)	0.248
Surgical procedures						0.002
Low-risk	47 (5.3)	12 (5.4)	13 (5.9)	3 (1.4)	19 (8.6)	
Thoracic	201 (22.6)	60 (26.9)	55 (24.8)	53 (23.9)	33 (14.9)	
Non-thoracic major	641 (72.1)	151 (67.7)	154 (69.4)	166 (74.8)	170 (76.6)	
Intraoperative bleeding (ml)	50 (20, 100)	50 (20, 100)	50 (20, 100)	50 (20, 100)	50 (15, 100)	0.405
Outcomes						
MINS within postoperative 3 days	74 (8.3)	10 (4.5)	15 (6.8)	20 (9.0)	29 (13.1)	0.009
Other variables						
TG (mmol/L)	1.19 (0.82, 1.68)	0.70 (0.59, 0.82)	1.04 (0.90, 1.22)	1.46 (1.20, 1.70)	2.16 (1.65, 3.07)	<0.001
Glucose (mmol/L)	5.38 (4.65, 6.83)	4.63 (4.15, 5.30)	5.13 (4.60, 6.04)	5.52 (4.96, 6.63)	7.22 (5.73, 10.25)	<0.001

ASA, American Society of Anesthesiologist; BMI, body mass index; CAD, coronary arterial disease; CHF, Congestive Heart Failure; COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate (CKD-EPI formula); HMR, heart rate to mean arterial pressure; TyG index, triglyceride-glucose index; MINS, myocardial injury after non-cardiac surgery; PVD, peripheral vascular disease.

Emerging evidence aligns with our findings, demonstrating that the atherogenic index of plasma (AIP) independently predicts MINS.[31] These investigations synergistically highlight the clinical utility of preoperative metabolic profiling for stratifying postoperative ACEs. While the AIP study focused specifically on the TG-to-high density lipoprotein ratio as a lipid-centric predictor, our TyG index analysis extends this paradigm by evaluating the combined contribution of TG and glucose metabolism to perioperative cardiovascular risk. This complementary

Table 2 Univariate and multivariate logistic regression for TyG index and MINS

	Model 1		Model 2		Model 3	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Continuous TyG index per unit	1.72 (1.27 to 2.35)	<0.001	1.54 (1.11 to 2.15)	0.010	1.75 (1.21 to 2.52)	0.003
TyG index quartile group (range)						
Q1 (5.03–8.13)	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
Q2 (8.14–8.57)	1.54 (0.68 to 3.51)	0.301	1.27 (0.55 to 2.98)	0.575	1.44 (0.61 to 3.42)	0.404
Q3 (8.58–9.02)	2.11 (0.96 to 4.61)	0.062	1.90 (0.85 to 4.27)	0.118	2.21 (0.95 to 5.17)	0.066
Q4 (9.03–11.33)	3.20 (1.52 to 6.74)	0.002	2.63 (1.20 to 5.78)	0.016	3.37 (1.46 to 7.81)	0.005
P_{trend}	<0.001		0.006		0.002	

Model 1: crude. Model 2: adjusted for age, gender, COPD, PVD, CAD, history of stroke, rate-controlling medications, statins and eGFR. Model 3: adjusted for age, gender, BMI, preoperative haemoglobin, eGFR, CHF, hypertension, CAD, COPD, diabetes, history of stroke, PVD, rate-controlling medications, aspirin, statins, ASA classification, duration of anaesthesia, the highest intraoperative HMR, surgical procedures and intraoperative bleeding.
ASA, American Society of Anesthesiologist; BMI, body mass index; CAD, coronary arterial disease; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate; HMR, heart rate to mean arterial pressure; TyG index, triglyceride-glucose index; MINS, myocardial injury after non-cardiac surgery; PVD, peripheral vascular disease.

approach strengthens the rationale for incorporating multidimensional metabolic assessments into preoperative evaluation of postoperative ACEs. Our findings not only validate the TyG index's predictive capacity but crucially extend its clinical application through population diversification. Our results align with prior evidence demonstrating the TyG index's association with MINS in geriatric populations (≥65 years).[32] Notably, our investigation extends beyond this demographic by encompassing younger surgical patients (≥40 years), thereby broadening the validated clinical applicability of the TyG index across age groups under-represented in existing MINS research. This expanded patient spectrum addresses a critical knowledge gap, as current studies predominantly focus on elderly populations despite the growing prevalence of CVRFs in younger adults.[1 17 33] Moreover, our study advances the field by establishing a linear dose-response relationship between TyG index values and MINS risk—a

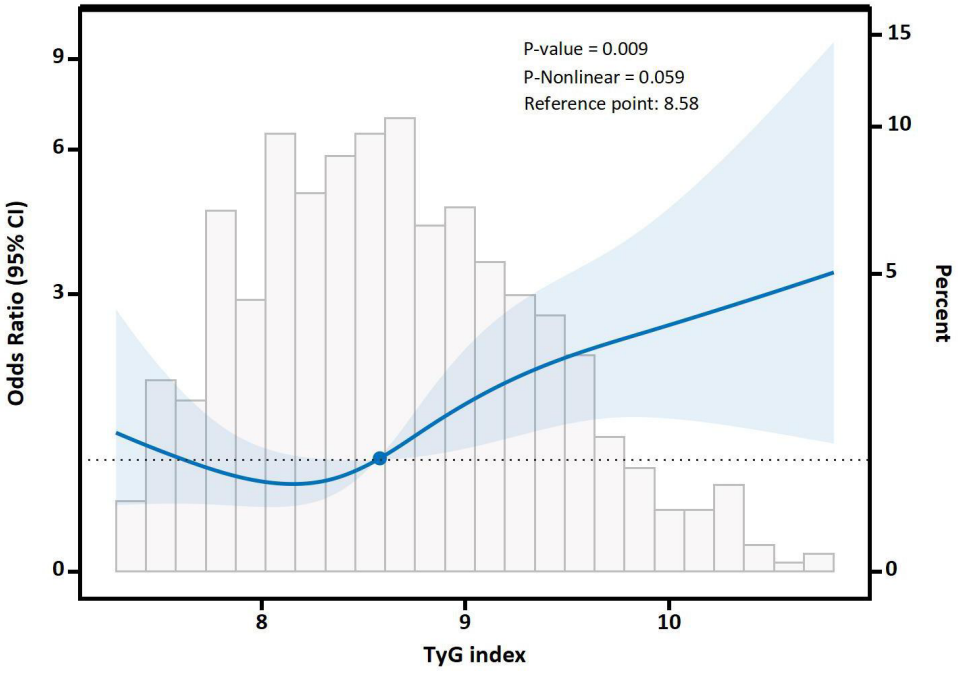

Figure 2 RCS of TyG and MINS. The central thick blue line represents the adjusted OR, with shaded bands indicating the 95% CI. The horizontal dotted line represents an OR of 1.0. The solid blue dot indicates the reference point for the TyG index (8.58). The ORs were adjusted for age, gender, CAD, COPD, stroke, PVD, rate-controlling medications, statins and eGFR. CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate; MINS, myocardial injury after non-cardiac surgery; PVD, peripheral vascular disease; RCS, restricted cubic spline; TyG index, triglyceride-glucose index.

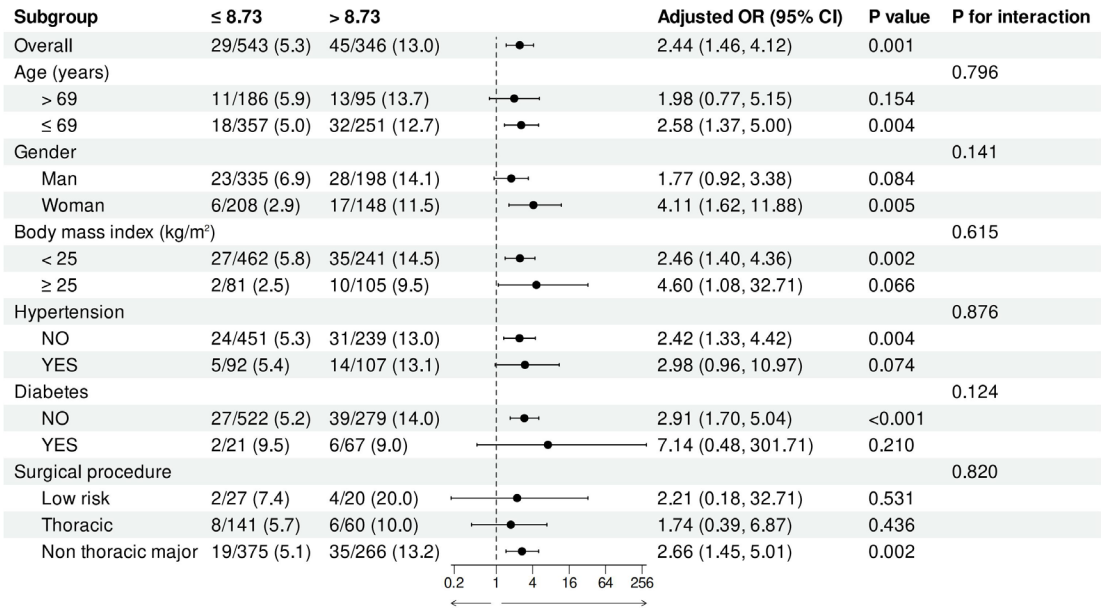

Figure 3 Post-hoc subgroup analysis. Forest plots depicting the relationship between the TyG index (≤8.73 and >8.73) and MINS. The ORs were adjusted for age, gender, CAD, COPD, stroke, PVD, rate-controlling medications, statins and eGFR. *No of events/total no. (%). CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate; MINS, myocardial injury after non-cardiac surgery; PVD, peripheral vascular disease; TyG index, triglyceride-glucose index.

finding not previously quantified in earlier investigations. These methodological refinements strengthen the TyG index's utility for preoperative risk stratification in diverse surgical populations.

The association between the TyG index and MINS can be explained through atherosclerosis and metabolic abnormalities. The TyG index is a biomarker of metabolic disorders and atherosclerotic and cardiovascular diseases.[16 34 35] It reflects the degree of CAD and is independently associated with coronary atherosclerosis in healthy adult populations.[9 14] The TyG index is closely associated with IR.[36–39] IR leads to endothelial dysfunction, increased inflammatory responses, accelerated foam cell formation and smooth muscle cell proliferation, which promote atherosclerosis and vascular plaque formation.[40 41] Moreover, IR may reflect platelet reactivity and endothelial-dependent vasodilation.[42] An elevated preoperative TyG index is associated with hypertension, hyperglycaemia and hyperlipidaemia, all of which enhance the risk of vascular inflammation, coagulation and atherosclerosis. These mechanisms contribute to SCeMI.[29] Perioperative haemodynamic changes, inflammatory responses and oxidative stress may exacerbate pre-existing SCeMI, leading to MINS. Further investigations are needed to elucidate the exact mechanisms associating an elevated TyG index with MINS.

This study highlights the clinical utility of the preoperative TyG index as a simple, cost-effective tool for identifying patients at elevated risk of MINS. Preoperative troponin testing is not routine unless patients have a known history of CAD or exhibit symptoms of myocardial ischaemia. The TyG index, more accessible than preoperative troponin, could serve as an alternative screening tool. It is associated with CAD severity, subclinical CAD, SCeMI and MINS. Clinicians should consider incorporating TyG index screening into preoperative assessments for patients aged ≥40 years undergoing general anaesthesia, particularly those without overt cardiovascular symptoms. A high TyG index could be helpful for preoperative assessments, including preoperative myocardial status evaluation and guidance for intervention strategies (eg, glycaemic control and lipid management). For patients with a preoperative TyG index >8.73, heightened vigilance is warranted, including troponin testing, coronary angiography and medical therapy (such as statins and aspirin), especially for those without a clear CAD history. Our findings suggest that preoperative TyG index evaluation could refine perioperative risk stratification and guide targeted interventions to mitigate MINS-related complications. Randomised controlled trials (RCTs) are necessary to verify the optimal strategies based on the preoperative TyG index evaluation.

Limitations

This study has several limitations. First, residual confounding factors may have introduced bias, such as excluding patients <40 years old and those lacking preoperative FBG and TG measurements. Second, preoperative troponin screening was not performed for all patients indicated for surgery, potentially missing those with preoperative myocardial injury and introducing selection bias. This study limited its troponin measurements to patients with myocardial ischaemia symptoms. Since asymptomatic myocardial injury is prevalent among postoperative patients, our study may not fully capture the potential association between the

preoperative TyG index and asymptomatic myocardial injury. Current guidelines recommend troponin measurements (Class I recommendation) for patients who develop myocardial ischaemia symptoms following non-cardiac surgeries. For those at high risk but without postoperative ischaemic signs, a Class IIb recommendation is given.[43] The high rate of missing glycated haemoglobin (HbA1c) data led to its exclusion from the primary analysis. However, multivariate logistic regression analysis on the subset of data containing HbA1c yielded results consistent with the primary analysis (online supplemental table S2). Third, our study focused solely on the association between baseline TyG index and MINS. Future RCTs are essential to determine the impact of variations in the TyG index on MINS prevention, mainly through preoperative interventions targeting lipid and glucose levels.

CONCLUSION

An elevated preoperative TyG index is positively associated with a higher incidence of MINS. It can be used to assess the risk of MINS preoperatively. Further research is required to determine if controlling and monitoring the TyG index can reduce postoperative ACEs.

Contributors YZ: study design, data collection and examination, data analysis, manuscript drafting and manuscript revision; WC and FL: data examination and analysis, manuscript drafting and manuscript revision; LZ: data examination and data analysis; YL: data examination and analysis, supervision of the study process and manuscript revision; YZ (guarantor): study design, data collection, examination, data analysis, manuscript drafting, manuscript revision and supervision of the study process.

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Competing interests None declared.

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Patient consent for publication Not applicable.

Ethics approval The Ethical Review Board of Meizhou People's Hospital reviewed the study protocol and approved this study, and informed consent was not required (Ethic No. 2023-C-92). We have also registered this study at the Chinese Clinical Trial Registry (No. ChiCTR2400082834).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. The corresponding author can grant data access to this study upon request.

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