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Original Research Article

Comparative Performance of the Triglyceride–Glucose Index, Atherogenic Index of Plasma, Monocyte-to-HDL Ratio, and Remnant Cholesterol in Identifying Angiographically Proven Coronary Artery Disease: A Retrospective Observational Study

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Abstract:

Background: Coronary artery disease (CAD) is associated with insulin resistance, atherogenic dyslipidaemia, and chronic inflammation. The triglyceride–glucose (TyG) index, atherogenic index of plasma (AIP), monocyte-to-high-density lipoprotein cholesterol ratio (MHR), and remnant cholesterol (RC) are derived from routinely available laboratory parameters and may provide information about cardiovascular risk.

Aim: To evaluate the associations of TyG, AIP, MHR, and RC with angiographically proven CAD and assess their discriminatory performance.

Materials and Methods: This retrospective observational study included 300 adults at Anugrah Narayan Magadh Medical College and Hospital, Gaya, Bihar, India. The angiogram videos of all the study participants were reviewed. The angiogram videos were reviewed to classify participants and to assess disease severity. Participants were classified into a CAD group (n = 108) and a group without significant CAD (n = 192). CAD was defined as luminal diameter stenosis of at least 50% in one or more major epicardial coronary arteries. TyG, AIP, MHR, and RC were calculated from fasting laboratory measurements. Associations with CAD were assessed using multivariable logistic regression adjusted for age, sex, diabetes mellitus, hypertension, and current smoking. Associations with angiographic disease severity were evaluated using Spearman's rank correlation and comparisons across Gensini score tertiles. Receiver operating characteristic (ROC) analysis was used to assess discriminatory performance.

Results: Compared with participants without significant CAD, those with CAD had higher mean TyG (8.88 ± 0.34 vs 8.70 ± 0.40), AIP (0.15 ± 0.16 vs 0.08 ± 0.17), MHR (11.87 ± 4.37 vs 10.26 ± 3.51), and RC (29.52 ± 10.88 vs 25.95 ± 10.89). In adjusted logistic regression, TyG (OR 3.20, 95% CI 1.59–6.47; p = 0.001), AIP (OR 1.25 per 0.1-unit increase, 95% CI 1.07–1.45; p = 0.005), MHR (OR 1.10 per unit increase, 95% CI 1.03–1.17; p = 0.004), and RC (OR 1.32 per 10 mg/dL increase, 95% CI 1.06–1.66; p = 0.015) were independently associated with CAD. The individual indices showed modest discrimination, with AUCs of 0.63 for TyG, 0.61 for AIP, 0.62 for MHR, and 0.60 for RC. The combined multivariable model had an AUC of 0.71 (95% CI 0.64–0.77).

Conclusion: TyG, AIP, MHR, and RC were associated with angiographically proven CAD, but their individual discriminatory performance was modest. The higher AUC observed for the combined model requires formal comparison and validation before clinical application.

Keywords: Coronary artery disease; triglyceride–glucose index; atherogenic index of plasma; monocyte-to-HDL ratio; remnant cholesterol; coronary angiography; Gensini score.

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Introduction

Coronary artery disease (CAD) remains a major cause of morbidity and mortality worldwide. Its development and progression involve multiple interrelated mechanisms, including insulin resistance, atherogenic dyslipidaemia, chronic inflammation, and endothelial dysfunction. Although conventional cardiovascular risk factors and lipid measurements are routinely used in clinical practice, additional indices derived from standard laboratory parameters may help characterise metabolic and inflammatory abnormalities associated with CAD.

The triglyceride–glucose (TyG) index is a surrogate marker of insulin resistance calculated from fasting triglyceride and glucose concentrations. Previous research has investigated its association with CAD risk, angiographic disease burden, and cardiovascular outcomes [1]. The atherogenic index of plasma (AIP), calculated as the base-10 logarithm of the ratio of triglycerides to high-density lipoprotein cholesterol (HDL-C), has also been investigated as an indicator of an atherogenic lipid profile [2,3].

Inflammatory processes contribute to atherosclerotic plaque development and progression. The monocyte-to-HDL ratio (MHR) combines a circulating inflammatory cell measure with a lipid parameter involved in cholesterol transport and associated with anti-inflammatory functions. Previous studies have examined MHR in relation to CAD and cardiovascular outcomes, including angiographic disease severity [4,5].

Remnant cholesterol (RC), representing cholesterol carried in triglyceride-rich lipoprotein remnants, has also been investigated in relation to atherosclerotic cardiovascular disease. Observational and genetic evidence has linked elevated remnant cholesterol with ischaemic heart disease, supporting continued investigation of its role in cardiovascular risk assessment [6,7].

Despite the biological relevance of these indices, their relative associations with angiographically defined CAD and their ability to discriminate between patients with and without significant disease require further evaluation in specific clinical populations. Assessing these markers within the same study population provides an opportunity to compare their associations and discriminatory performance.

The present study aimed to evaluate the associations of TyG, AIP, MHR, and RC with angiographically proven CAD, examine their relationships with angiographic disease severity using the Gensini score, and assess their individual and combined discriminatory performance.

Materials and Methods

Study Design and Setting: This retrospective observational study was conducted in the Department of Cardiology, Anugrah Narayan Magadh Medical College and Hospital, Gaya, Bihar, India. A total of 300 adult records were included in the analysis.

Study Population: The angiogram videos of all the study participants were reviewed. Participants were classified into two groups according to the angiographic findings on review of the angiogram videos: patients with CAD (n = 108) and patients without significant CAD (n = 192). CAD was defined as luminal diameter stenosis of at least 50% in one or more major epicardial coronary arteries.

Eligibility Criteria: The identification and selection of patient records were conducted in strict accordance with the approved study protocol and institutional review guidelines, with eligibility and exclusion criteria verified against actual study records. Inclusion criteria comprised adult patients aged 18 years or older who underwent diagnostic coronary angiography for the evaluation of suspected or stable coronary artery disease, alongside the availability of complete baseline demographic, clinical, and fasting laboratory records as well as documented coronary angiographic evaluations allowing definitive assessment of epicardial coronary stenosis. Conversely, exclusion criteria comprised patients presenting with acute coronary syndromes (such as ST-elevation myocardial infarction, non-ST-elevation myocardial infarction, or unstable angina), those with severe hepatic or renal dysfunction, individuals with active inflammatory or infectious conditions, and records exhibiting incomplete medical documentation or missing laboratory and angiographic data.

Clinical and Laboratory Variables: Demographic and clinical variables included age, sex, diabetes mellitus, hypertension, and current smoking. Laboratory variables included fasting plasma glucose, total cholesterol, triglycerides, HDL-C, LDL-C, and absolute monocyte count.

According to the study protocol and laboratory records, fasting venous blood samples were collected after an overnight fast of 8–12 hours before coronary angiography. Laboratory measurements were obtained using the institution's routine laboratory methods.

Calculation of Derived Indices

1. **Triglyceride–glucose index (TyG)**

TyG was calculated using the following formula:

$$TyG = \ln [\text{fasting triglycerides (mg/dL)} \times \text{fasting plasma glucose (mg/dL)} / 2]$$

2. **Atherogenic index of plasma (AIP)**

AIP was calculated as:

$$AIP = \log_{10} [\text{triglycerides (mmol/L)} / \text{HDL-C (mmol/L)}]$$

Both triglyceride and HDL-C concentrations were expressed in mmol/L for this calculation.

3. **Monocyte-to-HDL ratio (MHR)**

MHR was calculated using the absolute monocyte count and HDL-C concentration.

4. **Remnant cholesterol (RC)**

RC was calculated as:

RC = total cholesterol − LDL-C − HDL-C

All cholesterol measurements used in this calculation were expressed in mg/dL.

Assessment of Coronary Artery Disease Severity: Angiographic disease severity was assessed from the review of the angiogram videos of all study participants using the Gensini score. Stenosis severity was assigned weights of 1 for 25% stenosis, 2 for 50%, 4 for 75%, 8 for 90%, 16 for 99%, and 32 for total occlusion. Each stenosis score was multiplied by a regional weighting factor reflecting the importance of the affected coronary segment, and the weighted scores were summed to obtain the total Gensini score.

Patients with CAD were classified into tertiles according to their Gensini scores.

Statistical Analysis: Statistical analyses were performed using SPSS Software. Continuous variables were summarised as mean ± standard deviation, and categorical variables as frequencies and percentages.

Between-group comparisons were performed using the statistical tests appropriate to the distributions and variable types. If confirmed by the original analysis, Student's t-test or the Mann–Whitney U test was used for continuous variables, and the chi-square test was used for categorical variables. Spearman's rank correlation coefficient (ρ) was used to evaluate associations between the derived indices and Gensini scores.

Multivariable logistic regression was used to evaluate associations between the indices and angiographically proven CAD, adjusting for age, sex, diabetes mellitus, hypertension, and current smoking.

ROC analysis was used to assess the discriminatory performance of the individual indices and the combined model. The area under the curve (AUC), 95% confidence intervals, and selected cut-off values with corresponding sensitivity and specificity were reported.

Statistical significance was defined as a two-sided p-value below 0.05.

Ethical Considerations: The study was reported as having received approval from the Institutional Ethics Committee of Anugrah Narayan Magadh Medical College and Hospital, Gaya, Bihar, India.

Results

Baseline Characteristics: A total of 300 participants were included in the analysis, of whom 108 (36.0%) had angiographically proven CAD and 192 (64.0%) did not have significant CAD. Participants with CAD were older on average and had higher proportions of male sex and diabetes mellitus. Mean fasting glucose, triglyceride, LDL-C, and monocyte count values were also higher in the CAD group, whereas mean HDL-C was lower. The baseline characteristics are presented in Table 1.

Table 1: Baseline demographic, clinical, and laboratory characteristics according to CAD status

Characteristic	CAD (n = 108)	No significant CAD (n = 192)
Age, years	58.96 ± 10.61	55.66 ± 9.88
Male sex, n (%)	84 (77.8)	124 (64.6)
Diabetes mellitus, n (%)	42 (38.9)	44 (22.9)
Hypertension, n (%)	45 (41.7)	74 (38.5)
Current smoking, n (%)	34 (31.5)	53 (27.6)
Fasting glucose, mg/dL	103.93 ± 18.12	96.60 ± 16.49
Triglycerides, mg/dL	146.46 ± 38.80	132.81 ± 41.46
HDL-C, mg/dL	44.56 ± 8.20	46.55 ± 7.62
LDL-C, mg/dL	118.02 ± 35.49	105.64 ± 31.51
Absolute monocyte count, ×10⁹/L	0.50 ± 0.13	0.46 ± 0.12
TyG index	8.88 ± 0.34	8.70 ± 0.40
AIP	0.15 ± 0.16	0.08 ± 0.17
MHR	11.87 ± 4.37	10.26 ± 3.51
Remnant cholesterol, mg/dL	29.52 ± 10.88	25.95 ± 10.89

Values are presented as mean ± standard deviation or number (percentage), as appropriate. Group-comparison p-values were not provided in the supplied results and have therefore not been added.

Association of Indices with Gensini Score Tertiles: Across increasing Gensini score tertiles, mean TyG and AIP values increased. Differences across tertiles were statistically significant for TyG (p = 0.033) and AIP (p = 0.008). MHR also increased numerically across the tertiles, but the difference was not statistically significant (p = 0.117). RC values did not show a clear trend across tertiles (p = 0.935). These findings are presented in Table 2.

Table 2: Distribution of derived indices across Gensini score tertiles among patients with CAD

Index	Tertile 1	Tertile 2	Tertile 3	p-value
TyG index	8.79 ± 0.32	8.88 ± 0.37	8.98 ± 0.33	0.033
AIP	0.10 ± 0.14	0.15 ± 0.16	0.20 ± 0.17	0.008
MHR	10.78 ± 3.59	11.88 ± 4.53	12.97 ± 4.74	0.117
Remnant cholesterol, mg/dL	30.00 ± 12.02	28.71 ± 11.97	29.85 ± 8.54	0.935

Values are presented as mean ± standard deviation. The Gensini score boundaries defining the tertiles should be added after verification from the original data.

Correlation Between Derived Indices and Angiographic Disease Severity: Spearman's rank correlation analysis demonstrated positive correlations between each index and Gensini score. TyG showed the strongest reported correlation, followed by AIP, MHR, and RC. The correlation coefficients and corresponding p-values are presented in Table 3.

Table 3: Spearman's rank correlations between derived indices and Gensini score

Index	Spearman's ρ	p-value
TyG index	0.26	<0.001
AIP	0.23	<0.001
MHR	0.22	<0.001
Remnant cholesterol	0.17	0.003

Multivariable Logistic Regression Analysis: In multivariable logistic regression adjusted for age, sex, diabetes mellitus, hypertension, and current smoking, all four indices were independently associated with angiographically proven CAD. TyG was associated with an odds ratio (OR) of 3.20 per one-unit increase. AIP was associated with an OR of 1.25 per 0.1-unit increase, MHR with an OR of 1.10 per unit increase, and RC with an OR of 1.32 per 10 mg/dL increase. The reported estimates are presented in Table 4.

Table 4: Adjusted associations between derived indices and angiographically proven CAD

Index and increment	Adjusted OR	95% CI	p-value	Adjustment variables
TyG, per 1-unit increase	3.20	1.59–6.47	0.001	Age, sex, diabetes, hypertension, smoking
AIP, per 0.1-unit increase	1.25	1.07–1.45	0.005	Age, sex, diabetes, hypertension, smoking
MHR, per 1-unit increase	1.10	1.03–1.17	0.004	Age, sex, diabetes, hypertension, smoking
Remnant cholesterol, per 10 mg/dL increase	1.32	1.06–1.66	0.015	Age, sex, diabetes, hypertension, smoking

OR, odds ratio; CI, confidence interval. The final manuscript should clarify whether the indices were evaluated in separate models or entered simultaneously into one model.

ROC Analysis of Individual Indices and the Combined Model: ROC analysis demonstrated modest discrimination for all four individual indices. TyG had an AUC of 0.63, AIP an AUC of 0.61, MHR an AUC of 0.62, and RC an AUC of 0.60. The combined multivariable model had an AUC of 0.71 (95% CI 0.64–0.77). These findings are summarised in Table 5.

Table 5: ROC characteristics of individual indices and the combined model

Index/model	AUC	95% CI	Cut-off	Sensitivity (%)	Specificity (%)
TyG index	0.63	0.57–0.69	8.64	79.6	44.8
AIP	0.61	0.55–0.68	0.06	77.8	45.8
MHR	0.62	0.56–0.68	10.69	61.1	60.4
Remnant cholesterol	0.60	0.53–0.66	21.07 mg/dL	81.5	35.9
Combined model	0.71	0.64–0.77	Not reported	Not reported	Not reported

AUC, area under the receiver operating characteristic curve; CI, confidence interval. Confirm the MHR unit convention and the units of its reported cut-off. The combined-model cut-off, sensitivity, and specificity were not available in the supplied results and have not been inferred.

Discussion

This study evaluated four routinely derived indices—TyG, AIP, MHR, and RC—in relation to angiographically proven CAD and assessed their relationships with angiographic disease severity

and discriminatory performance. All four indices were higher on average in participants with CAD than in those without significant CAD. In adjusted analyses, each index was independently associated with CAD, while correlations with Gensini score were positive but modest.

TyG reflects information from fasting triglyceride and glucose concentrations and is used as a surrogate marker of insulin resistance. The higher TyG values in participants with CAD and the positive correlation with Gensini score suggest that insulin resistance-related metabolic abnormalities may be associated with coronary atherosclerosis. Previous systematic review evidence has examined TyG in relation to CAD risk, severity, and prognosis [1]. Nevertheless, the AUC of 0.63 in the present study indicates that TyG alone had limited ability to distinguish participants with CAD from those without significant disease.

AIP was higher in the CAD group and increased across Gensini score tertiles. AIP combines triglyceride and HDL-C information and has been investigated as a marker of atherogenic dyslipidaemia [2,3]. Its positive correlation with Gensini score suggests an association with angiographic disease burden. However, the AUC of 0.61 indicates modest discrimination. The findings do not establish that AIP can replace established cardiovascular risk assessment or conventional lipid measurements.

MHR was higher among participants with CAD and showed a positive correlation with Gensini score. The ratio combines a measure of circulating monocytes with HDL-C, providing a composite marker reflecting inflammatory and lipid-related information. Previous studies have examined MHR in relation to CAD severity and cardiovascular outcomes [4,5]. In the present study, the adjusted association with CAD was statistically significant, but the difference across Gensini score tertiles was not statistically significant. The AUC of 0.62 similarly suggests that MHR alone provides limited discrimination.

RC was also higher in the CAD group and showed a modest positive correlation with Gensini score. Remnant lipoproteins have been investigated in relation to atherosclerotic processes, and previous observational and genetic studies have examined the association between remnant cholesterol and ischaemic heart disease [6,7]. Despite the adjusted association observed here, RC had the lowest individual AUC among the four indices, at 0.60. Differences across Gensini score tertiles were not statistically significant, indicating that the relationship between RC and angiographic disease severity was not clearly demonstrated in this sample.

The combined model had a higher reported AUC (0.71) than any individual index. This finding suggests that the combination may offer better discrimination within the study population. However, the difference in AUC should not automatically be interpreted as a statistically significant improvement. A formal paired comparison of AUCs, clear reporting of the model's predictors, and internal validation are required to determine whether the apparent improvement is robust. External validation in an independent population would also be necessary before considering clinical implementation.

The study provides a comparison of four indices calculated from routine laboratory measurements in a population undergoing coronary angiography. Nevertheless, the modest individual AUCs indicate that these indices should be interpreted as complementary research markers rather than stand-alone diagnostic tests. Their clinical value would need to be evaluated against established clinical predictors and conventional risk-assessment approaches.

Limitations: This study has several limitations. First, its retrospective observational design limits causal inference. Second, the single-centre setting may restrict the generalisability of the findings. Third, BMI data were unavailable, limiting the assessment of adiposity as a potential confounder. Fourth, the individual indices demonstrated modest discriminatory performance. Fifth, the combined model requires additional methodological reporting and validation, including clarification of its predictors and formal comparison with the individual indices.

Conclusion

TyG, AIP, MHR, and remnant cholesterol were independently associated with angiographically proven CAD in this retrospective study. Each index showed a positive correlation with Gensini score, although the strength of these correlations was modest. The individual indices demonstrated limited discriminatory performance, whereas the combined model had a higher reported AUC. Further analysis, internal validation, and external validation are required before these indices or their combination can be recommended for clinical decision-making.

Declarations

Ethics approval and consent to participate: This retrospective study was approved by the Institutional Ethics Committee of ANMMCH, Gaya (approval no. […]). The requirement for individual informed consent was waived given the retrospective, de-identified nature of the data.

Consent for publication: Not applicable.

Availability of data and materials: The datasets analysed during the current study are available from the corresponding author on reasonable request.

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Conflict of interest: The authors declare no conflict of interest.

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