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Association of the Triglyceride-glucose Index and Remnant Cholesterol with Retinopathy among Community- dwelling Older Adults in China

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Article

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Abstract

Background and Purpose: The increasing burden of microvascular eye diseases due to aging and metabolic diseases is a significant concern. However, evidence of the independent association between the triglyceride-glucose (TyG) index and remnant cholesterol (RC) and retinal arteriosclerosis in older adults remains limited. This study aimed to analyze the prevalence of retinal arteriosclerosis among community-dwelling older adults and explore the correlation and predictive value of these indicators for retinal artery stenosis.

Methods: A cross-sectional study design was used. From March to October 2025, older adults aged ≥ 65 years from seven communities on a street within the Suzhou High-tech Zone were selected as study participants. Data were collected through questionnaire surveys, biochemical lipid testing, and Keith–Wagener–Barker fundus grading examinations to analyze the association between the relevant indicators and retinal artery stenosis.

Results: A total of 990 elderly individuals were included in this study. Fundus grading results indicated that 39 cases (3.9%) were normal, 440 cases (44.4%) were classified as grade I, 439 cases (44.3%) were classified as grade II, 66 cases (6.7%) were classified as grade III, and 6 cases (0.6%) were classified as grade IV. Participants were categorized into groups based on the presence or absence of retinal artery stenosis. The two groups exhibited statistically significant differences in gender, body mass index, smoking history, hypertension, diabetes, TyG index, and RC levels (all $P < 0.05$). Spearman's rank correlation analysis revealed a positive correlation between TyG index and RC with the grade of fundus lesions ($r = 0.190$, $P < 0.001$; $r = 0.169$, $P< 0.001$). Multivariable logistic regression revealed that gender (odds ratio [OR] = 0.709), body mass index (BMI) (OR = 1.058), and diabetes (OR = 1.555) were independent risk factors for retinal arteriolar stenosis (all $P< 0.05$). After further adjustment for TyG index and RC, both markers revealed significantly elevated risks in the highest tertile (TyG Q3: OR = 2.012; RC Q3: OR = 2.036, both $P < 0.001$), with RC Q2 also demonstrating a significant increase (OR = 1.614, $P = 0.002$), and both exhibited significant linear trends across tertiles (P for trend < 0.001). Notably, the effects of gender, BMI, and diabetes were partially attenuated and became non-significant after adjustment (all $P > 0.05$). The area under the curves (AUCs) of TyG index and RC for predicting retinal arteriolar stenosis were 0.613 and 0.604, respectively.

Conclusion: The prevalence of retinal arteriosclerosis in this community-based elderly population is notably high. TyG index and RC have been identified as independent risk factors for retinal arteriolar stenosis, exhibiting significant dose-response relationships (P for trend < 0.001). However, their predictive performance as standalone markers is limited (AUC = 0.60), suggesting that they may function more effectively as complementary metrics alongside conventional risk factors rather than as independent diagnostic tools.

INTRODUCTION

Against the backdrop of global population aging, the prevalence of chronic metabolic disorders—notably hypertension and diabetes—has been rising steadily. The microvascular damage resulting from these conditions has given rise to a spectrum of ocular diseases that now pose a major public health concern, placing considerable strain on both patients and healthcare systems worldwide [1]. Among these, retinal arteriosclerosis and diabetic retinopathy (DR) represent the predominant forms of microvascular fundus pathology, each capable of causing substantial visual deterioration and profoundly diminishing patients' quality of life.

From a histopathological perspective, retinal arteriosclerosis is driven by hyaline changes within the arteriolar wall, which lead to progressive wall thickening and luminal compromise; in advanced stages, this process may culminate in total vascular obstruction. Notably, the retinal vasculature constitutes one of the few human microcirculatory beds amenable to direct, non-invasive in vivo observation, offering a unique window into the cumulative impact of systemic microvascular injury. Hence, accurate grading of retinal arteriosclerotic severity carries significant clinical value for the early detection and timely management of microvascular disorders [2–4].

A substantial body of evidence has established retinal microvascular anomalies as reliable indicators of end-organ microcirculatory impairment resulting from hypertension and generalized vascular disease [5–7]. Nevertheless, the bulk of these investigations have concentrated on conventional lipid measures. In contrast, the potential relationship between emerging metabolic markers—particularly the triglyceride-glucose (TyG) index and remnant cholesterol (RC)—and retinal arteriosclerosis has received relatively limited attention.

To address this gap, the present cross-sectional investigation was designed to evaluate retinal arteriosclerosis among community-residing older adults (aged ≥ 65 years) recruited from a subdistrict within the Suzhou High-tech Zone, using the standardized Keith–Wagener–Barker (KWB) fundus grading scheme. The primary objectives were to estimate the prevalence of retinal arteriosclerosis in this population and to examine its independent associations with the TyG index and RC, with the ultimate goal of informing early preventive and interventional strategies tailored to this demographic.

METHODS

1.1 Study Object

This investigation employed a cross-sectional design. Between March and October 2025, a stratified sampling approach was used to recruit older adults (aged ≥ 65 years) from seven communities located within a designated subdistrict of the Suzhou High-tech Zone. All participants underwent a structured questionnaire interview and provided fasting blood samples for biochemical testing. After excluding those with incomplete records, 990 participants were retained for final analysis, consisting of 579 females (58.5%) and 411 males (41.5%), with a mean age of 76.43 ± 5.36 years (range: 69–98 years). Based on the KWB fundus grading system, participants were dichotomized into a control group (grades

0–I, n = 479) and a stenosis group (grades II–IV, n = 511). The study protocol was approved by the Ethics Committee of Suzhou Xiangcheng People's Hospital, and written informed consent was obtained from all participants before enrollment.

1.2 Eligibility Criteria

Participants were required to meet the following inclusion criteria: (1) permanent residency within the target subdistrict of the Suzhou High-tech Zone for at least six months, and (2) age of 65 years or older. Individuals were excluded if they presented with (1) acute or chronic inflammatory ocular conditions, or (2) severe psychiatric disorders that precluded cooperation, or if they declined to participate in the survey.

1.3 Data Collection

A structured questionnaire was used to collect baseline demographic and clinical data, including sex, age, BMI, smoking history (previous or current), self-reported physician-diagnosed hypertension and diabetes, and family history of stroke in first-degree relatives. All self-reported medical histories were subsequently cross-checked against electronic health records. Fasting venous blood samples were analyzed for serum lipid profiles—TC, TG, LDL-C, and HDL-C—as well as fasting plasma glucose levels.

1.4 Related definitions

1. TyG index is defined as TyG = ln [TG (mg/dL) × FPG (mg/dL)/2] [8]. The subjects were categorized into three groups (Q1–3) based on the TyG index tertiles. (2) RC was calculated as RC = TC−LDL-C − HDL-C [9]. Similarly, the subjects were divided into three groups (Q1–3) according to the RC tertiles.
2. The KWB fundus grading method [10] was used to capture fundus photographs of both eyes using an AFC-330 fundus camera (NIDEK, Japan) with automatic focusing centered on the optic disc. The grading criteria were as follows: Grade I indicates retinal arteriolar narrowing with a reduced arteriovenous ratio; Grade II denotes marked arteriolar narrowing, arteriovenous crossing compression signs, and enhanced arterial wall reflex (copper- or silver-wire changes); Grade III includes the aforementioned changes along with retinopathy, including retinal edema, hemorrhage, or cotton-wool spots; Grade IV signifies papilledema in addition to Grade III changes. Subjects with normal findings or Grade I changes were assigned to the control group. In contrast, those with Grade II–IV changes were categorized as belonging to the retinal arteriolar stenosis group.

1.5 Statistical Approach

SPSS version 24.0 (IBM Corp.) was used for all analyses. For normally distributed continuous variables, data are expressed as mean ± standard deviation ($\bar{x} \pm s$), with independent-samples t-tests applied for between-group comparisons. Categorical variables are reported as frequencies and percentages [n (%)] and compared using the chi-square test. The bivariate associations of the TyG index and RC with retinopathy severity were examined by Spearman's rank correlation.

To ascertain independent correlates of retinal artery stenosis, multivariable logistic regression with the Enter procedure was performed. Three sequentially adjusted models were specified: Model 1 controlled for gender, age, BMI, smoking, hypertension, and diabetes; Model 2 was further adjusted for TyG tertiles; and Model 3 additionally incorporated RC tertiles. Effect estimates are presented as odds ratios (ORs) with 95% confidence intervals (CIs). Receiver operating characteristic (ROC) curve analysis was used to evaluate the predictive ability of the TyG index and RC for retinal artery stenosis. The area under the curve (AUC) and optimal thresholds were determined using the Youden index. A two-tailed P-value < 0.05 indicated statistical significance.

RESULTS

2.1 Comparison of general information of the two groups of research subjects

The KWB fundus grading results revealed that 39 cases (3.9%) were classified as normal, 440 cases (44.4%) were classified as grade I, 439 cases (44.3%) were classified as grade II, 66 cases (6.7%) were classified as grade III, and 6 cases (0.6%) were classified as grade IV. Retinal arteriosclerosis was defined as a KWB grade of ≥ I, and in this study, 951 cases (96.1%) had a grade of ≥ I. To analyze the risk factors associated with moderate-to-severe retinal arteriosclerosis (grades II–IV), normal and grade I cases were combined into a control group (n = 479). However, grades II–IV were designated as the stenosis group (n = 511). The two groups differed significantly with respect to sex, BMI, smoking history, hypertension, diabetes mellitus, TyG index grouping, and RC grouping ($P < 0.05$; Table 1).

Table 1
Comparison of general information of the two groups of research subjects.

Characteristics	Control group (479, 48.4%)	Stenosis group (511, 51.6%)	t/x^2	*P*
Gender				
Male (n, %)	220 (45.9%)	191 (37.4%)	7.446	0.006[a]
Female (n, %)	259 (54.1%)	320 (62.6%)		
Age ($\bar{x} \pm s$)	76.21 ± 5.05	76.65 ± 5.62	–1.294	0.196
BMI ($\bar{x} \pm s$)	24.89 ± 2.90	25.32 ± 3.01	–2.304	0.021[a]
Smoking history (n, %)	113 (23.6%)	93 (18.2%)	4.361	0.037[a]
Hypertension (n, %)	462 (96.5%)	479 (93.7%)	3.869	0.049[a]
Diabetes (n, %)	108 (22.5%)	166 (32.5%)	12.200	0.000[a]
Family history of stroke (n, %)	14 (2.9%)	10 (2.0%)	0.975	0.323
TyG group				
Q1 (n, %)	194 (40.6%)	135 (26.5%)	29.821	0.000[a]
Q2 (n, %)	160 (33.5%)	170 (33.3%)		
Q3 (n, %)	124 (25.9%)	205 (40.2%)		
RC group				
Q1 (n, %)	220 (45.9%)	162 (31.7%)	24.111	0.000[a]
Q2 (n, %)	155 (32.4%)	184 (36.0%)		
Q3 (n, %)	104 (21.7%)	165 (32.3%)		

aP < 0.05.

2.2 Correlation of TyG index and RC with retinopathy grade in community-dwelling older adults

Spearman rank correlation analysis revealed that TyG index and RC were positively correlated with the retinopathy grade in this cohort of community-dwelling older adults (r = 0.190, *P* < 0.001; r = 0.169, *P* < 0.001, respectively), suggesting that higher TyG index and RC levels were associated with more severe retinopathy.

2.3 Multivariable logistic regression analysis of retinal artery stenosis in community-dwelling older adults

Three hierarchical multivariate logistic regression models were constructed with retinal artery stenosis as the dependent variable (0 = normal, 1 = stenosis) (Table 2).

Model 1 (traditional risk factors) was adjusted for gender, age, BMI, smoking, hypertension, and diabetes. Sex (OR = 0.709, $P = 0.037$), BMI (OR = 1.058, $P = 0.011$), and diabetes (OR = 1.555, $P = 0.005$) were independently associated with retinal artery stenosis.

Model 2 (TyG model) further included TyG tertiles. Compared with Q1, the TyG Q3 group revealed a significantly elevated risk (OR = 2.012, $P < 0.001$), while Q2 exhibited an increasing trend without significance (OR = 1.352, $P = 0.063$), with a significant linear trend across tertiles (P for trend < 0.001). The effects of gender, BMI, and diabetes were attenuated and lost significance after TyG adjustment (all $P > 0.05$).

Model 3 (RC model) additionally included RC tertiles. RC Q2 (OR = 1.614, $P = 0.002$) and Q3 (OR = 2.036, $P < 0.001$) revealed significantly higher risks versus Q1, with a significant linear trend (P for trend < 0.001). In this model, BMI (OR = 1.056, $P = 0.014$) and diabetes (OR = 1.564, $P = 0.005$) remained significant, whereas gender became non-significant (OR = 0.817, $P = 0.235$), suggesting that RC mediated traditional risk factors to a lesser extent than TyG.

Table 2
Multivariate logistic regression analysis of risk factors for retinal artery stenosis in community-dwelling elderly population (three hierarchical models).

Variables	Model 1 (Basic model) OR (95% CI)	Model 2 (TyG model) OR (95% CI)	Model 3 (RC model) OR (95% CI)
Traditional risk factors			
Gender (Male versus Female)	0.709 (0.513–0.979)[a]	0.766 (0.552–1.064)	0.817 (0.587–1.139)
Age	1.019 (0.995–1.044)	1.022 (0.998–1.047)	1.017 (0.993–1.042)
Body mass index (BMI)	1.058 (1.013–1.105)[a]	1.038 (0.993–1.086)	1.056 (1.011–1.103)[a]
Smoking history	0.956 (0.646–1.415)	0.971 (0.654–1.443)	0.892 (0.600–1.328)
Hypertension	0.708 (0.370–1.355)	0.683 (0.353–1.321)	0.691 (0.359–1.331)
Diabetes mellitus	1.555 (1.146–2.109)[b]	1.327 (0.967–1.821)	1.564 (1.148–2.131)[b]
Core metabolic indicators			
TyG Q2 (versus Q1)	—	1.352 (0.983–1.860)	—
TyG Q3 (versus Q1)	—	2.012 (1.439–2.812)[c]	—
TyG P for trend	—	< 0.001[c]	—
Remnant cholesterol Q2 (versus Q1)	—	—	1.614 (1.193–2.182)[b]
Remnant cholesterol Q3 (versus Q1)	—	—	2.036 (1.467–2.827)[c]
RC P for trend	—	—	< 0.001[c]

Note: Model 1 adjusted for sex, age, BMI, smoking, hypertension, and diabetes; Model 2 additionally adjusted for TyG tertiles; Model 3 additionally adjusted for RC tertiles. *P* for trend was calculated by treating tertiles as a continuous variable. a $P < 0.05$; b $P < 0.01$; c $P < 0.001$.

2.4 Predictive value of TyG index and RC for retinal artery stenosis

For predicting retinal artery stenosis, the TyG index had an AUC of 0.613, with an optimal cut-off of 1.390, a sensitivity of 65.5%, and a specificity of 51.3%. RC showed an AUC of 0.604 (95% CI: 0.569–0.639), with an optimal cut-off of 0.590, a sensitivity of 60.8%, and a specificity of 56.3% (Fig. 1).

DISCUSSION

Retinopathy encompasses several fundus pathologies arising from multiple etiologies. Clinically, it manifests as decreased visual acuity and visual field defects and may progress to irreversible blindness in severe cases. Common types include DR, retinal vascular occlusion, macular degeneration, and retinal detachment. Among these, retinal arteriosclerosis is characterized by degenerative changes in the vascular wall, vessel wall thickening, and narrowing of the lumen as core pathological features, which may progress to vascular occlusion as the disease advances. Once the central retinal artery becomes occluded, it blocks the blood supply to the inner layers of the retina, resulting in severe impairment of visual function. Without timely intervention, permanent visual impairment may ensue [11–12]. The retinal vasculature is unique among human microcirculatory beds in that it can be directly and non-invasively visualized *in vivo*. Their anatomical and physiological characteristics are highly homologous to those of microcirculation in vital organs, including the heart, brain, and kidneys, allowing them to reflect systemic microcirculatory damage sensitively. They serve as an important window to evaluate target organ damage associated with vascular pathology and metabolic abnormalities [13–14]. The KWB grading system is a well-established classification method for retinopathy, originally designed to predict survival outcomes and serving as the foundation for multiple subsequent grading schemes. A survey conducted by Li et al. [15] involving 2,964 participants indicated a prevalence of retinal arteriosclerosis of 76.6% (2,271 cases), which included 1,747 cases (58.9%) classified as grade I, 446 cases (15.0%) classified as grade II, and 78 cases (2.6%) classified as grade III. Additionally, a study by Chen et al. [16] with 9,793 patients diagnosed with hypertension reported a retinal arteriosclerosis prevalence of 74.4% (7,290 cases), comprising 5,590 cases (57.08%) of grade I retinopathy, 1,466 cases (14.97%) of grade II, 231 cases (2.36%) of grade III, and 3 cases (0.03%) of grade IV. In the present study, retinal arteriosclerosis (≥ grade I) was identified in 951 cases (96.1%). Of these, 440 (44.4%) were grade I, 439 (44.3%) were grade II, 66 (6.7%) were grade III, and 6 (0.6%) were grade IV. This prevalence was higher than that reported in the aforementioned studies, possibly because the participants in this cohort were aged ≥ 65 years and had a greater burden of underlying diseases.

Dyslipidemia-mediated atherosclerosis is recognized as an etiological factor in retinal arteriosclerosis development, with additional contributions from oxidative stress, vascular endothelial dysfunction, and chronic low-grade inflammation [17, 18]. These pathological alterations can induce disturbances in retinal microcirculation, further exacerbating fundus vasculopathy and impairing visual function through mechanisms, including vascular wall injury, perfusion abnormalities, and luminal narrowing. The TyG index, calculated from fasting plasma glucose and triglyceride levels, serves as a sensitive marker of glucolipid metabolic disorders and insulin resistance. A growing body of evidence has linked a higher TyG index to an increased risk of various vascular diseases, including retinal vasculopathy, coronary

artery stenosis, and stroke [19–21]. However, studies specifically investigating the relationship between the TyG index and retinal arteriosclerosis in community-dwelling older adults remain scarce, and the available evidence is still insufficient. Sirakaya et al. [22] observed a significantly higher TyG index in patients with branch retinal vein occlusion (BRVO) than in controls ($P < 0.001$). In multivariable analysis, the TyG index remained an independent predictor of BRVO (OR = 2.58, $P < 0.001$; AUC = 0.749), indicating that a higher TyG index is closely associated with BRVO risk and may aid in identifying high-risk individuals. Similarly, Neelam et al. [23] found that patients with diabetic retinopathy (DR) had a markedly higher TyG index than normal participants ($P < 0.001$). After adjustment for confounders, the TyG index was significantly associated with both DR prevalence (OR = 1.4, $P = 0.002$) and incidence (OR = 1.8, $P = 0.03$), with AUCs of 0.77 and 0.66, respectively, reflecting good predictive performance. In the present study, three hierarchical multivariate logistic regression models were constructed to assess the independent effects of the TyG index and RC. In Model 2 (the basic model plus TyG tertiles), the Q3 group had a significantly higher risk of retinal artery stenosis than the Q1 group (OR = 2.012, $P < 0.001$), with a significant linear trend (P for trend < 0.001). Notably, gender, BMI, and diabetes mellitus lost statistical significance in Model 2, suggesting that their effects may be partially mediated by the insulin resistance pathway captured by TyG. The TyG index revealed an AUC of 0.613 for predicting retinal artery stenosis, indicating modest predictive value for retinal arteriosclerosis risk in the elderly, although its standalone utility remains limited.

RC, also known as remnant cholesterol, is a cholesterol fraction carried by triglyceride-rich lipoproteins. In the fasting state, it primarily comprises VLDL cholesterol and intermediate-density lipoprotein cholesterol, whereas in the non-fasting state, it mainly consists of cholesterol carried by chylomicron remnants [24].RC is generated through two distinct pathways: Endogenous, in which VLDL is synthesized by the liver, and exogenous, in which chylomicrons are synthesized by the intestine. Upon entering circulation, the triglycerides in these lipoproteins are hydrolyzed by lipoprotein lipase, gradually forming smaller remnant particles with increased atherogenic potential [25, 26]. Accumulating evidence has demonstrated that RC remnants deposited on the vascular wall can elicit local inflammatory responses, impair vascular endothelial function, and promote vascular remodeling, stiffening, and stenosis, thereby contributing to retinal microcirculatory damage and the development and progression of retinal arteriosclerosis [27–29]. Chen et al. [30] reported that RC was independently associated with DR among patients with long-standing type 2 diabetes mellitus (T2DM) (duration > 7 years). In this cohort, the highest RC quartile exhibited significantly greater central retinal artery equivalent (OR = 5.559), central retinal vein equivalent (OR = 7.620), and fractal dimension (OR = 0.013) than the lowest quartile. Such evidence implies that RC may serve as a risk factor for DR in patients with long-standing T2DM. This suggests that RC may serve as a risk factor for DR in patients with long-standing T2DM. Elevated RC levels were associated with wider retinal arterioles and venules and increased complexity of the retinal vascular network, potentially contributing to DR development and progression through retinal venular dilation.In the study by Shan et al. [31], RC levels were markedly higher among patients with DR than among those without DR ($P < 0.001$). Moreover, RC remained an independent correlate of DR risk after confounder adjustment (OR = 5.623).The combination of RC, diabetes duration, and the neutrophil-to-

lymphocyte ratio yielded an AUC of 0.758 for predicting DR, suggesting that a higher RC level may be an independent risk factor for DR and that this combined model may improve predictive performance. In Model 3, which added RC tertiles to the basic model, RC Q2 (OR = 1.614, *P* = 0.002) and Q3 (OR = 2.036, *P* < 0.001) groups exhibited significantly elevated retinal artery stenosis risks, with a clear dose-response trend (*P* for trend < 0.001). The AUC for RC was 0.604, comparable to that of the TyG index. These findings align with prior evidence, suggesting that elevated RC may contribute to retinal arteriosclerosis risk in the elderly.

TyG index and RC reflect two distinct pathways, insulin resistance and remnant cholesterol accumulation, respectively, and may theoretically provide complementary information. However, both demonstrated limited standalone predictive performance (AUC = 0.60) and may be better suited as supplementary markers to traditional risk factors. Future studies should quantify the incremental value of their combined use and further validate their feasibility and cost-effectiveness in community-based early screening for retinal artery stenosis in older adults.

The present study has several limitations. First, the cross-sectional design precludes any causal inference regarding the TyG index, RC, and retinal arteriosclerosis, so confirmation in prospective cohort studies is warranted. Second, since all participants came from a single community, the generalizability of our results to other populations may be limited. Third, part of the data relied on self-reporting and may be affected by recall bias. In addition, information on lipid-lowering and glucose-lowering medications was unavailable, and dietary habits, physical activity, and other potential confounders were not fully controlled for, which may have led to residual confounding. Fourth, the assessment of glycemic and lipid profiles was based on a single fasting blood sample, which may inaccurately reflect the long-term metabolic status of the participants. Finally, although the predictive performance of TyG index and RC alone was relatively modest, their simplicity and cost-effectiveness support their use as adjunctive screening tools for the early detection of retinal arteriosclerosis in community-dwelling older adults.

In summary, the prevalence of retinal arteriosclerosis was relatively high (96.1%) in this community-dwelling elderly population aged ≥ 65 years. TyG index and RC were positively correlated with retinopathy grade and identified as independent risk factors for retinal artery stenosis, with significant dose-response relationships (*P* for trend < 0.001). Although both indicators revealed modest predictive value for retinal arteriosclerosis risk in the elderly, their standalone performance was limited, suggesting that they are more suitable as supplementary markers to traditional risk factors rather than independent diagnostic tools. Accordingly, community-based screening for glucolipid metabolic disorders should be strengthened, and early intervention should be implemented, tailored to the metabolic characteristics of the elderly population, to reduce the risk of microvascular complications.

DECLARATIONS

Ethics approval and consent to participate:

This study was conducted in accordance with the Declaration of Helsinki. The research protocol was reviewed and approved by the Ethics Committee of Suzhou Xiangcheng People's Hospital. All participants gave informed consent before inclusion in the study.

Conflicts of Interest:

The authors declare no conflict of interest.

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Author Contribution

JY and YL contributed to the conception and design of the study. YL and JZ were responsible for data collection and curation. JY and YL performed the data analysis and interpretation. JY wrote the first draft of the manuscript. JZ and XH critically reviewed and revised the manuscript for important intellectual content. All authors read and approved the final manuscript and agree to be accountable for all aspects of this work.

Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Figures

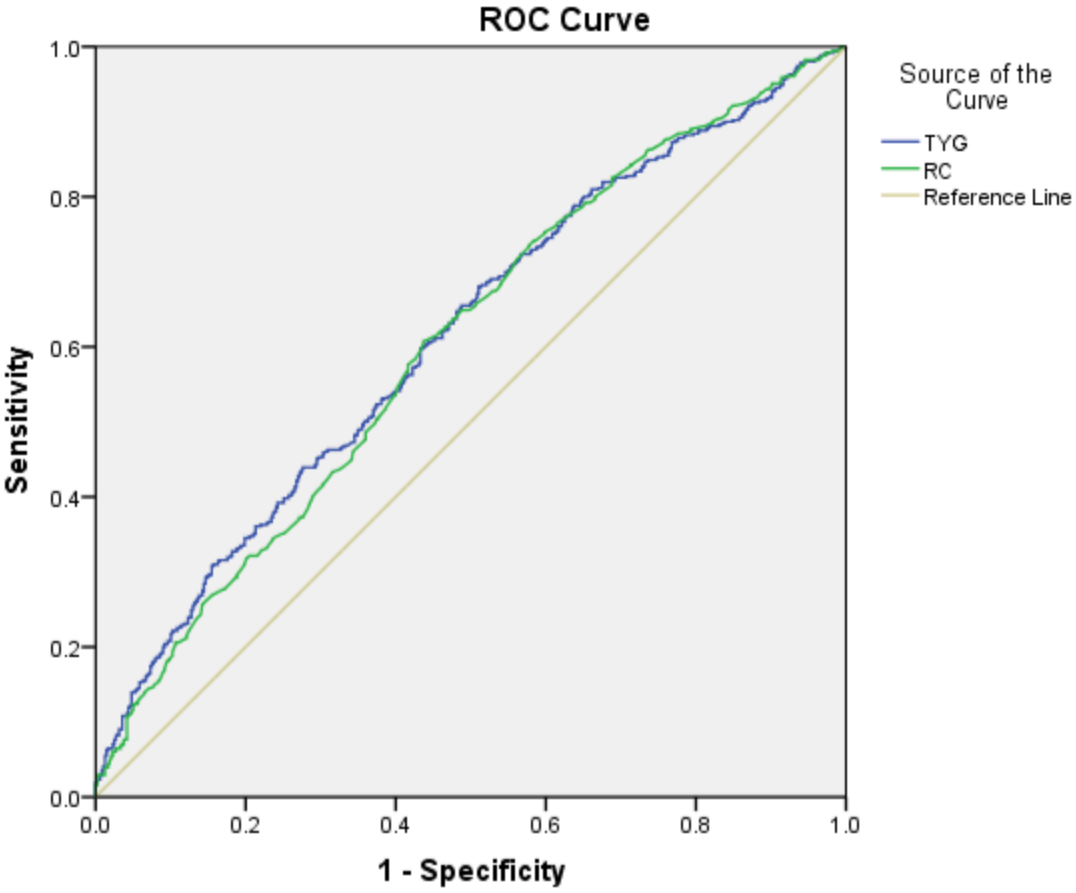

Figure 1

Predictive value of TyG index and RC for retinal artery stenosis.