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ORIGINAL RESEARCH

The Association Between Triglyceride Glucose-Body Mass Index and Kidney Impairment in Patients with Type 2 Diabetes Mellitus

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Purpose: Insulin resistance is associated with kidney impairment in patients with type 2 diabetes mellitus (T2DM). The triglyceride glucose-body mass index (TyG-BMI), which combines the TyG index with body mass index (BMI), has received significant attention as a tool for evaluating insulin resistance. Thus, the aim of this study was to explore the association between TyG-BMI and kidney impairment in patients with type 2 diabetes mellitus (T2DM).

Patients and Methods: The cross-sectional analysis included 1080 patients with T2DM, and data were collected retrospectively. TyG-BMI was calculated by fasting blood glucose, triglyceride, and body mass index.

Results: TyG-BMI was significantly higher in T2DM patients with albuminuria than those without albuminuria (232.16 [206.52–268.02] vs 229.83 [206.11–255.64], p =0.023). T2DM patients with chronic kidney disease (CKD) showed a significantly higher value of TyG-BMI compared with those without CKD (232.23 [206.46–268.28] vs 229.73 [206.11–255.49], p=0.014). Correlation analysis showed a significantly positive association between TyG-BMI and metabolic parameters including BMI (r = 0.866, $p < 0.001$), TG (r = 0.630, $p < 0.001$), TC (r = 0.119, $p < 0.001$), HDL-C (r = −0.374, $p < 0.001$), FBG (r = 0.297, $p < 0.001$), and HbA1c (r = 0.116, $p < 0.001$) in patients with T2DM. The binary logistic regression analysis found that TyG-BMI was an independent factor for albuminuria (OR = 1.004, 95% CI: 1.001–1.008, p = 0.010) and CKD (OR = 1.005, 95% CI: 1.001–1.008, p = 0.005) in patients with T2DM respectively.

Conclusion: The study suggests that TyG-BMI is associated with kidney impairment in patients with T2DM. Given that TyG-BMI is a novel parameter of insulin resistance, the study results indicates that clinicians should pay close attention to screening for kidney impairment in T2DM patients with insulin resistance.

Keywords: type 2 diabetes mellitus, TyG-BMI, insulin resistance, kidney impairment

Introduction

Type 2 diabetes mellitus (T2DM) is a common chronic disease characterized by hyperglycemia.[1] T2DM often leads to various complications, including diabetic retinopathy, diabetic nephropathy, and diabetic neuropathy.[2] Diabetic nephropathy is the most prevalent complication of T2DM, and it is a main cause of end-stage kidney disease worldwide.[3] However, due to its insidious onset, lack of early symptoms, and insufficient patient awareness, diabetic nephropathy is often unnoticed, leading to the underestimation of its morbidity.[4] Moreover, early kidney damage in patients with T2DM

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may gradually progress to chronic kidney disease (CKD) which poses a serious threat to their health.[5] Clinically, the assessments of early diabetic nephropathy mainly depend on monitoring urinary protein, with microalbuminuria (MAU) being a sensitive marker for early kidney impairment in patients with T2DM.[6] Nevertheless, the measurement of urinary protein can be affected by factors such as exercise, menstruation, infection, and fever, making it challenging to ensure the stability and specificity of detection.[7] Estimation of glomerular filtration rate (eGFR), as a calculated value based on age and serum creatinine (Cr) levels, may not detect early kidney impairment due to the high compensatory capacity of the kidneys and the lack of changes in serum Cr levels during the early stages of kidney damage.[8] Therefore, exploring additional markers are important for identifying early-stage of kidney damage, which has practical clinical significance for early warning and prevention of kidney damagein patients with T2DM.

The triglyceride glucose (TyG), a calculated index derived from fasting triglycerides (TG) and fasting blood glucose (FBG), has been shown to be a reliable marker for insulin resistance.[9] Several studies have demonstrated a close correlation between TyG and kidney impairment in patients with T2DM, indicating that TyG serves as a biomarker for diabetic nephropathy. It has reported that TyG is progressively associated with the risk of diabetic nephropathy.[10–12] In recent years, the triglyceride glucose-body mass index (TyG-BMI), a combination of TyG index and body mass index (BMI), has been received more attention. TyG-BMI has been reported to be a better marker for reflecting insulin resistance.[13] And insulin resistance has been demonstrated to be associated with kidney impairment in patients with T2DM.[14,15] Thus, the purpose of this study was to evaluate the association between TyG-BMI and kidney impairment in patients with T2DM.

Materials and Methods

Patients

The cross-sectional analysis included 1080 patients with T2DM who visited the National Metabolic Management Center of the Zhongda Hospital, Southeast University (Nanjing, China) between January 2021 and December 2022. The diagnosis of T2DM was based on the American Diabetes Association criteria.[16] T2DM patients with following conditions were excluded: systemic autoimmune disease, urinary tract infection, and cancer. The study was approved by the Ethics Committees at Zhongda Hospital, Southeast University and was in compliance with the Helsinki Declaration. Patients' informed consent was waived by Ethics Committees at Zhongda Hospital, Southeast University, because the study data were collected retrospectively. The study confirmed that participants' privacy was strictly protected.

Data

The study data were obtained retrospectively from electronic information records. Demographic and clinical information comprised gender, age, height, weight, and medical history. The biochemical data comprised triglyceride (TG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), fasting blood glucose (FBG), hemoglobin A1c (HbA1c), blood creatinine (Cr), urine Cr, and urine albumin. The results of biochemical tests were from fasting overnight blood and random urine samples in this study.

Definition of Index

The body mass index (BMI)=weight (kg)/height $(m)^2$. TyG-BMI = BMI × TyG index, TyG index = Ln [1/2FBG (mg/dL) × TG (mg/dL)].[13] Urine albumin to urine Cr ratio (ACR) = urine albumin (mg/L)/ urine Cr (mg/dL). The patients with T2DM were classified as patients with albuminuria and those without albuminuria according to the laboratory reference range of ACR (0–30 mg/g). The patients without albuminuria were defined as ACR ≤ 30 mg/g, and the patients with albuminuria were defined as ACR > 30 mg/g. The estimated glomerular filtration rate (eGFR) was calculated by modified glomerular filtration rate estimating equation with adjustment for Chinese, and the chronic kidney diseases (CKD) in T2DM patients was defined as eGFR < 60 mL/min/1.73m2 and (or) ACR > 30 mg/g.[17]

Statistical Analyses

Continuous variables of non-normal distribution are presented as median (interquartile range), and categorical variables are presented as numbers (percentages). Mann–Whitney *U*-test or Chi-square test was used to compare the statistical

significance between the two groups. Correlations were assessed by Spearman's test. Binary logistic regression analysis was performed to examine the factors associated dependent variable. A $p < 0.05$ was considered statistically significant. The statistical analyses were performed with SPSS 25.0 software version.

Results

The Comparison of Characteristics in T2DM Patients with and those without Early Kidney Impairment

The characteristics were compared in T2DM patients with albuminuria and those without albuminuria, as shown in Table 1. The TyG-BMI was significantly elevated in T2DM patients with albuminuria compared with those without albuminuria (232.16 [206.52–268.02] vs 229.83 [206.11–255.64], p =0.023). There were significantly differences in age (p=0.048), hypertension history ($p < 0.001$), TG ($p < 0.001$), HDL-C ($p = 0.015$), LDL-C ($p = 0.007$), FBG ($p = 0.016$), and HbA1c ($p = 0.025$) between T2DM patients with albuminuria and those without albuminuria.

The Comparison of Characteristics in T2DM Patients with CKD and those Without CKD

The characteristics were compared in T2DM patients with CKD and those without CKD, as shown in Table 2. Compared with T2DM patients without CKD, the TyG-BMI was significantly elevated in T2DM patients with CKD (232.23 [206.46–268.28] vs 229.73 [206.11–255.49], $p = 0.014$). There were significantly differences in age ($p = 0.013$), hypertension history ($p < 0.001$), TG ($p < 0.001$), HDL-C ($p = 0.010$), LDL-C ($p = 0.005$), FBG ($p = 0.019$), and HbA1c ($p = 0.021$) between T2DM patients with CKD and those without CKD.

The Correlation Between TyG-BMI and Metabolic Parameters in Patients with T2DM

TyG-BMI showed a significant correlation with metabolic parameters in Table 3, including BMI (r = 0.866, $p < 0.001$), TG (r = 0.630, $p < 0.001$), TC (r = 0.119, $p < 0.001$), HDL-C (r = −0.374, $p < 0.001$), FBG (r = 0.297, $p < 0.001$), and HbA1c (r = 0.116, $p < 0.001$) in patients with T2DM. However, there was no correlation between TyG-BMI and LDL-C (r = −0.003, $p = 0.912$) in these patients.

Multivariable Analysis of Risk Factors Associated with Albuminuria and CKD in Patients with T2DM

Two multivariable analyses were constructed to assess whether TyG-BMI was associated with albuminuria and CKD in patients with T2DM, as shown in Tables 4 and 5. Sex, age, hypertension history, HDL-C, LDL-C, HbA1c, and TyG-BMI were

Table 1 Characteristics of Type 2 Diabetes Mellitus Patients with Albuminuria and those Without Albuminuria

	T2DM with Albuminuria (N =384)	T2DM without Albuminuria (N =696)	*p* value
Male (n, %)	298 (77.60)	507 (72.84)	0.086
Age (years)	58 (50–65)	57 (48–64)	0.048
Hypertension history (n, %)	224 (58.33)	293 (42.10)	< 0.001
BMI (kg/m^2)	25.05 (22.85–27.75)	25.00 (23.17–26.00)	0.757
TG (mmol/L)	1.55 (1.10–2.42)	1.36 (2.03–0.96)	< 0.001
TC (mmol/L)	4.38 (3.60–5.25)	4.43 (3.74–5.18)	0.823
HDL-C (mmol/L)	1.06 (0.88–1.25)	1.11 (0.92–1.30)	0.015
LDL-C (mmol/L)	2.35 (1.80–2.99)	2.58 (2.00–3.05)	0.007
FBG (mmol/L)	8.38 (6.33–11.97)	7.69 (6.15–10.67)	0.016
HbA1c (%)	8.88 (7.56–10.57)	8.64 (7.09–10.14)	0.025
TyG-BMI	232.16 (206.52–268.02)	229.83 (206.11–255.64)	0.023

Abbreviations: BMI, Body Mass Index; TG, Triglycerides; TC, Total Cholesterol; HDL-C, High-Density Lipoprotein Cholesterol; LDL-C, Low-Density Lipoprotein Cholesterol; FBG, Fasting Blood Glucose; HbA1c, Hemoglobin A1c; TyG-BMI, Triglyceride Glucose-Body Mass Index.

Table 2 Characteristics of Type 2 Diabetes Mellitus Patients with and those without Chronic Kidney Disease

	T2DM with CKD (N =391)	T2DM without CKD (N =689)	*p* value
Male (n, %)	302 (77.24)	503 (73.00)	0.125
Age (years)	58 (50–66)	57 (48–64)	0.013
Hypertension history (n, %)	230 (58.82)	287(41.65)	< 0.001
BMI (kg/m^2)	25.06 (22.85–27.76)	24.98 (23.17–26.99)	0.648
TG (mmol/L)	1.55 (1.10–2.43)	1.36 (0.96–2.03)	< 0.001
TC (mmol/L)	4.38 (3.62–5.26)	4.43 (3.73–5.16)	0.883
HDL-C (mmol/L)	1.06 (0.88–1.25)	1.11 (0.92–1.30)	0.010
LDL-C (mmol/L)	2.35 (1.80–2.98)	2.59 (2.00–3.06)	0.005
FBG (mmol/L)	8.36 (6.33–11.92)	7.69 (6.15–10.70)	0.019
HbA1c (%)	8.89 (7.55–10.56)	8.63 (7.08–10.13)	0.021
TyG-BMI	232.23 (206.46–268.28)	229.73 (206.11–255.49)	0.014

Abbreviations: BMI, Body Mass Index; TG, Triglycerides; TC, Total Cholesterol; HDL-C, High-Density Lipoprotein Cholesterol; LDL-C, Low-Density Lipoprotein Cholesterol; FBG, Fasting Blood Glucose; HbA1c, Hemoglobin A1c; TyG-BMI, Triglyceride Glucose-Body Mass Index.

Table 3 The Correlation Between TyG-BMI and Metabolic Parameters in Patients with Type 2 Diabetes Mellitus

Variables	r	*p* value
BMI	0.866	< 0.001
TG	0.630	< 0.001
TC	0.119	< 0.001
HDL-C	−0.374	< 0.001
LDL-C	−0.003	0.912
FBG	0.297	< 0.001
HbA1c	0.116	< 0.001

Abbreviations: BMI, Body Mass Index; TG, Triglycerides; TC, Total Cholesterol; HDL-C, High-Density Lipoprotein Cholesterol; LDL-C, Low-Density Lipoprotein Cholesterol; FBG, Fasting Blood Glucose; HbA1c, Hemoglobin A1c; TyG-BMI, Triglyceride Glucose-Body Mass Index.

Table 4 The Presence of Albuminuria as Dependent Variable in Binary Logistic Regression Analysis

Variables	B	SE	Wald	OR (95% CI)	*p* value
Male	0.328	0.159	4.272	1.388 (1.017–1.894)	0.039
Age	0.011	0.006	2.795	1.011 (0.998–1.024)	0.095
Hypertension history	0.598	0.141	18.036	1.819 (1.380–2.398)	< 0.001
HDL-C	0.103	0.241	0.184	1.109 (0.692–1.777)	0.668
LDL-C	−0.155	0.083	3.425	0.857 (0.728–1.009)	0.064
HbA1c	0.095	0.032	8.778	1.100 (1.033–1.172)	0.003
TyG-BMI	0.004	0.002	6.633	1.004 (1.001–1.008)	0.010

Abbreviations: SE, Standard Error; HDL-C, High-Density Lipoprotein Cholesterol; LDL-C, Low-Density Lipoprotein Cholesterol; HbA1c, Hemoglobin A1c; TyG-BMI, Triglyceride Glucose-Body Mass Index.

Table 5 The Presence of Chronic Kidney Disease as Dependent Variable in Binary Logistic Regression Analysis

Variables	B	SE	Wald	OR (95% CI)	*p* value
Male	0.302	0.158	3.654	1.353 (0.992–1.844)	0.056
Age	0.014	0.006	4.569	1.014 (1.001–1.027)	0.033
Hypertension history	0.614	0.141	19.109	1.848 (1.403–2.435)	< 0.001
HDL-C	0.062	0.241	0.067	1.064 (0.664–1.706)	0.796
LDL-C	−0.152	0.083	3.331	0.859 (0.729–1.011)	0.068
HbA1c	0.099	0.032	9.537	1.105 (1.037–1.177)	0.002
TyG-BMI	0.005	0.002	7.938	1.005 (1.001–1.008)	0.005

Abbreviations: SE, Standard Error; HDL-C, High-Density Lipoprotein Cholesterol; LDL-C, Low-Density Lipoprotein Cholesterol; HbA1c, Hemoglobin A1c; TyG-BMI, Triglyceride Glucose-Body Mass Index.

included as independent variables, while albuminuria and CKD were considered as dependent variables in binary logistic regression analysis, respectively. The results showed that TyG-BMI was significantly associated with presence of albuminuria (OR = 1.004, 95% CI: 1.001–1.008, $p = 0.010$) and CKD (OR = 1.005, 95% CI: 1.001–1.008, $p = 0.005$) in patients with T2DM, respectively. Furthermore, both hypertension history and HbA1c were significantly associated with albuminuria (OR = 1.819, 95% CI: 1.380–2.398, $p = < 0.001$; OR = 1.100, 95% CI: 1.033–1.172, $p = 0.003$, respectively) and CKD (OR = 1.848, 95% CI: 1.403–2.435, $p < 0.001$; OR = 1.105, 95% CI: 1.037–1.177, $p = 0.002$, respectively) in patients with T2DM.

Discussion

The current study examined the relationship between the TyG-BMI and kidney impairment in patients with T2DM. A significantly higher TyG-BMI was observed in T2DM patients with kidney impairment compared to those without kidney impairment, and TyG-BMI was found to be substantially associated with albuminuria and CKD in these patients.

Insulin resistance is the basis for many metabolic disorders, including T2DM, where impairments in insulin signaling disrupt the entry of glucose into the adipocytes and skeletal muscle cells.[18] Insulin resistance contributes to the development of glomerular hypertrophy and renal interstitial fibrosis, which can potentially accelerate the progression of CKD.[19] Insulin resistance is a major cause of diabetes complications, and plays a crucial role in the occurrence and progression of diabetic nephropathy.[20,21] Insulin resistance is also evident in the early of renal impairment of T2DM and may accelerate the decline of kidney function.[22] A bidirectional association between insulin resistance and CKD has been suggested in T2DM, and insulin resistance is a predictor of CKD progression, while the progressive CKD with uremia is associated with the deterioration of insulin resistance.[14,23] Therefore, evaluating insulin resistance is clinically important, especially in patients with T2DM. The assessment criteria for insulin resistance includes hyper-insulinemic euglycemic clamp (HIEC) test and homeostasis model Assessment of IR (HOMA-IR).[24,25] However, recent studies have demonstrated a significant association between the TyG index and insulin resistance.[9,26,27] Compared to traditional methods for assessing insulin resistance, the TyG index is considered a simple and promising new biomarker.[9] Clinical studies have indicated that the TyG index is linked to the development of both macrovascular and microvascular complications in patients with T2DM, particularly in diabetic nephropathy.[28–30] Furthermore, TyG-BMI is calculated by TyG index and BMI index, which represents a combination of FBG, TG, and BMI. As a combined parameter, the TyG-BMI can more comprehensively reflect the insulin resistance levels compared to individual markers.[13,31,32] Our study suggested that the TyG-BMI was associated with MAU and CKD in patients with T2DM, indicating that TyG-BMI is related to kidney impairment in T2DM.

Hypertension is a well-established risk factor for kidney impairment in patients with T2DM.[33–35] In addition to the TyG-BMI, we found that a history of hypertension is significantly associated with kidney impairment in these patients. Elevated levels of HbA1c have been shown to be related with both microvascular and macrovascular events.[36,37] Lin CC et al have observed that HbA1c is associated with the presence of diabetic nephropathy in patients with T2DM.[38] Consistent with these findings, we also observed a significant association between HbA1c levels and kidney impairment in patients with T2DM.

There are several limitations to this study. First, due to its cross-sectional design, it is unclear whether TyG-BMI is a predictor of kidney impairment in patients with T2DM. Second, although the main confounders were considered, other factors such as genetic predispositions, medication use, and lifestyle habitsmay also influence the results. Third, the study only used eGFR and ACR to assess kidney impairment, and only single measurement of eGFR and ACR may not completely reflect the kidney injury in patients with T2DM. Based on the limitations mentioned above, a multicenter cohort study needs to be conducted in the future to investigate whether TyG-BMI could be a potential predictor of kidney impairment in patients with T2DM. Additionally, the comprehensive assessments of lifestyle habits, medication use, and laboratory indicators should be taken into account as potential confounding factors to explore the predictive capacity of the TyG-BMI for the onset and progression of kidney impairment in patients with T2DM.

Conclusion

The study observed that increased TyG-BMI was significantly associated with MAU and CKD, suggesting that TyG-BMI is associated with kidney impairment in patients with T2DM. Give that TyG-BMI is a novel parameter of insulin resistance, in clinical practice, the study results indicate that clinicians should pay more attention to screening for kidney impairment in T2DM patients with insulin resistance.

Data Sharing Statement

The data underlying this article is available from the corresponding author under reasonable request.

Ethics Statement

The study was reviewed and approved by the Ethics Committees at Zhongda Hospital, Southeast University and was in compliance with the Helsinki Declaration. Patients' informed consent was waived by Ethics Committees at Zhongda Hospital Southeast University, because the study data were collected retrospectively. The study confirmed that participants' privacy was strictly protected.

Disclosure

The authors declare that they have no competing interests.

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