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Correlation between obesity evaluation parameters and urinary albumin-to-creatinine ratio in middle-aged and elderly patients with type 2 diabetes mellitus

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Abstract: Objective To explore the correlation between obesity evaluation parameters[including body mass index (BMI), waist circumference (WC), visceral fat area (VFA), and subcutaneous fat area (SFA)]and urinary albumin-to-creatinine ratio (UACR)in middle - aged and elderly patients with type 2 diabetes mellitus (T2DM). **Methods** A retrospective analysis was conducted on 1 034 middle - aged and elderly T2DM patients who were admitted to the Geriatric Hospital of Nanjing Medical University from August 2022 to June 2025. General data, obesity evaluation parameters, biochemical indicators and UACR were measured. UACR⩾30 mg/g was defined as albuminuria. The patients were divided into two groups according to the presence or absence of albuminuria: albuminuria group (n=293) and non-albuminuria group (n=741), and the correlation between obesity assessment parameters and various clinical indicators were analyzed. Receiver operating characteristic (ROC)curves were drawn to evaluate the efficacy of various parameters in predicting albuminuria. **Results** Age, duration of diabetes, the proportions of smoking, systolic blood pressure, BMI, WC, utilization rate of angiotensin-converting enzyme inhibitors (ACEI)/angiotensin receptor blocker (ARB), fasting plasma glucose (FPG), glycated hemoglobin (HbA_{1C}), triglyceride (TG), low-density lipoprotein cholesterol (LDL-C), blood urea nitrogen (BUN), serum creatinine, UACR, VFA, and SFA in the albuminuria group were significantly higher than those in non-albuminuria group (P<0.05). After adjusting for confounding factors in binary line regression analysis, the risk factors for albuminuria in middle - aged and elderly patients with T2DM were high VFA (OR=1.010, 95%CI: 1.004-1.016, P=0.001), high SFA (OR=1.005, 95%CI: 1.002-1.009, P=0.002), high BMI (OR=1.107, 95%CI: 1.036-1.182, P=0.003)and high WC (OR=1.048, 95%CI: 1.024-1.074, P<0.01). The area under curve (AUC) of VFA, SFA, BMI and WC for predicting albuminuria was 0.620, 0.584, 0.592 and 0.613, with the optimal cut-off value of 79.2 cm^2, 162.9 cm^2, 24.3 kg/m^2 and 87.5 cm, respectively. **Conclusion** Elevated VFA, SFA, BMI and WC were the risk factors for albuminuria in middle-aged and elderly patients with T2DM. The predictive efficacy of VFA for albuminuria is superior to SFA, BMI, and WC.

Keywords: Type 2 diabetes mellitus; Urinary albumin-to-creatinine ratio; Visceral fat area; Subcutaneous fat area; Body mass index; Waist circumference; Albuminuria
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In recent years, the prevalence of type 2 diabetes mellitus (T2DM) in China has continued to rise, with the prevalence rate among adults reaching as high as 12.8%, accounting for approximately 125 million people, making China the country with the largest number of T2DM patients worldwide [1]. Diabetic kidney disease (DKD) refers to chronic kidney disease (CKD) caused by diabetes mellitus and is also the most common microvascular complication of diabetes. The prevalence of DKD among T2DM patients in China is approximately 40% [2]. Clinically, a urinary albumin-to-creatinine ratio (UACR)⩾30 mg/g is generally used as one of the diagnostic criteria for DKD.

Early identification and management of risk factors for DKD are important measures to prevent its occurrence and improve prognosis. Studies have shown that obesity, especially abdominal obesity, is one of the risk factors for DKD [3]. Traditional obesity assessment indicators include body mass index (BMI) and waist circumference (WC), while visceral fat area (VFA) and subcutaneous fat area (SFA) are new indicators for assessing obesity in recent years, which can more accurately reflect the degree of abdominal obesity [4]. This study aims to analyze the correlation between the above-mentioned obesity assessment parameters and UACR in middle-aged and elderly T2DM patients, so as to provide theoretical and practical basis for clinical early screening and intervention of albuminuria in T2DM patients.

1 Subjects and Methods

1.1 Study Subjects

A retrospective analysis was performed on 1034 middle-aged and elderly T2DM patients who attended the outpatient clinic or were hospitalized in the Geriatric Hospital of Nanjing Medical University from August 2022 to June 2025. The patients were aged 40-91 years, including 634 males and 400 females. Albuminuria was defined as UACR≥30 mg/g, and patients were divided into two groups according to the presence of albuminuria: 293 cases in the albuminuria group and 741 cases in the non-albuminuria group.

Inclusion criteria: (1) Aged≥40 years, regardless of gender; (2) Conforming to the diagnostic criteria for T2DM issued by the Chinese Diabetes Society in 2024 [5]. Exclusion criteria: (1) Type 1 diabetes mellitus, latent autoimmune diabetes in adults, secondary diabetes mellitus, and special types of diabetes mellitus; (2) Gestational diabetes mellitus or diabetes mellitus complicated with pregnancy; (3) Confirmed renal injury caused by other causes, such as chronic glomerulonephritis and systemic lupus erythematosus; (4) Presence of diseases or conditions affecting UACR levels, such as urinary tract infection and high fever; (5) Use of antiprotein drugs such as finerenone and *Huangkui* Capsule in the past 3 months; (6) Implantation of metal objects or cardiac pacemakers; (7) Incomplete data. This study was approved by the Ethics Committee of Geriatric Hospital of Nanjing Medical University [(2022) YLSH No. 029], and informed consent was obtained from all patients.

1.2 Study Methods

General clinical data of patients were collected, including age, gender, duration of diabetes, smoking and drinking history, height, weight, WC, systolic blood pressure (SBP), diastolic blood pressure (DBP), glucose-lowering regimen, and blood pressure-lowering regimen. The glucose-lowering regimen included the use of sodium-glucose cotransporter 2 inhibitor (SGLT-2i) and glucagon-like peptide-1 receptor agonist (GLP-1 RA). The blood pressure-lowering regimen included the use of angiotensin-converting enzyme inhibitor (ACEI) or angiotensin receptor blocker (ARB).

All patients fasted for 8-12 hours. The next morning, peripheral venous blood was collected to detect fasting plasma glucose (FPG), glycated hemoglobin (HbA_{1C}), four lipid profiles [total cholesterol (TC), triglycerides (TG), low density lipoprotein cholesterol (LDL-C), high density lipoprotein cholesterol (HDL-C)], liver function [alanine aminotransferase (ALT), aspartate aminotransferase (AST)], and renal function [blood urea nitrogen (BUN), serum creatinine (Scr)]. Morning urine was collected the next day to detect UACR. Detection of FPG, blood lipids, liver function, and renal function was performed using an automatic biochemical analyzer (Roche cobas 8000). HbA_{1C} was detected by high-performance liquid chromatography (HPLC). Urinary albumin and creatinine concentrations in morning urine samples were detected by protein turbidimetry and enzyme method, respectively, and UACR was calculated by dividing urinary albumin by urinary creatinine. VFA and SFA were measured by bioelectrical impedance analysis (Omron HDS-2000).

1.3 Statistical Methods

Statistical analysis was performed using SPSS 25.0 software. Measurement data conforming to normal distribution were expressed as $\bar{x}\pm s$, and comparisons were performed using independent samples *t*-test. Measurement data with non-normal distribution were expressed as M (P25, P75), and comparisons were performed using Mann-Whitney *U* test. Count data were expressed as case (%), and comparisons were performed using chi-square test (χ^2 test). Pearson correlation analysis was used to evaluate the correlation between obesity assessment parameters and various clinical indicators. Further binary logistic regression analysis was used to assess the correlation between obesity assessment parameters and albuminuria after adjusting for confounding factors, including age, gender, duration of diabetes, smoking history, SBP, HbA1C, TG, LDL-C, Scr, glucose-lowering regimen (use of SGLT-2i/GLP-1 RA or not), and blood pressure-lowering regimen (use of ACEI/ARB or not). Receiver operating characteristic (ROC) curves were plotted to predict albuminuria using obesity assessment parameters, and the cut-off values of each indicator were calculated. A P-value < 0.05 was considered statistically significant.

2 Results

2.1 Comparison of General Clinical Data between the Two Groups

Age, duration of diabetes, smoking rate, SBP, BMI, WC, ACEI/ARB usage rate, FPG, HbA1C, TG, LDL-C, BUN, Scr, UACR, VFA, and SFA in the albuminuria group were significantly higher than those in the non-albuminuria group (P < 0.05). See **Table 1.**

Tab 1 Comparison of clinical characteristics between two groups

Index	Albuminuria group (n=293)	Non-albuminuria group (n=741)	$\chi^2/t/Z$ value	P value
Male/Female (case)	193/100	441/300	3.576	0.059
Age (year)[a]	65.94±10.88	64.29±10.61	2.229	0.026
Duration of diabetes (month)[b]	130.00 (46.00,238.00)	90.00 (16.00,159.50)	4.326	<0.001
Smoking history [case (%)]	78 (26.62)	147 (19.83)	5.211	0.022
Drinking history [case (%)]	59 (20.14)	161 (21.73)	0.317	0.573
SBP (mmHg)[a]	138.29±16.59	133.49±15.71	4.352	<0.001
DSP (mmHg)[a]	78.82±10.74	78.90±10.69	0.112	0.911
BMI (kg/m²)[a]	25.61±3.20	24.61±3.25	4.463	<0.001
WC (cm)[a]	93.22±9.06	89.76±8.76	5.625	<0.001
Hypoglycemic regimen [case (%)]				
SGLT-2i	107 (36.52)	283 (38.19)	0.250	0.617
GLP-1RA	51 (17.41)	103 (13.90)	2.036	0.154
Antihypertensive regimen [case (%)]				
ACEI/ARB	138 (47.10)	226 (30.50)	25.365	<0.001
FPG (mmol/L)[a]	7.82±2.20	7.28±2.15	3.542	<0.001
HbA_{1C} (%)[a]	8.83±1.99	8.46±1.92	2.702	0.007
TC (mmol/L)[a]	4.14±1.12	4.14±1.04	0.025	0.98
TG (mmol/L)[b]	1.46(1.04,2.22)	1.28(0.94,1.85)	3.746	<0.001
LDL-C (mmol/L)[a]	2.46±0.89	2.38±0.88	2.016	0.044
HDL-C (mmol/L)[a]	1.03±0.27	1.06±0.27	1.511	0.131
ALT (u/L)[a]	23.39±5.32	23.33±6.68	0.056	0.956
AST (u/L)[a]	20.37±8.51	19.07±8.75	1.962	0.05
BUN (mmol/L)[b]	6.00 (4.75,7.60)	5.60 (4.70,6.70)	3.496	<0.001
SCr (μmol/L)[b]	71.00 (58.00,89.75)	65.00 (55.00,77.00)	4.550	<0.001
UACR (mg/g)[b]	82.07 (45.00,211.35)	8.55 (4.58,14.83)	25.086	<0.001
VFA (cm²)[a]	101.53±40.19	86.66±37.79	5.598	<0.001
SFA (cm²)[a]	196.14± 63.98	178.24±58.97	4.292	<0.001

Note: a, the data was represent by $\bar{x}\pm s$; b, the data was represent by $M(P_{25},P_{75})$.

2.2 Correlation Analysis between Obesity Assessment Parameters and Various Clinical Indicators

VFA, BMI, and WC were each significantly positively correlated with SBP, DBP, FPG, TG, and UACR ($P < 0.05$). SFA was significantly positively correlated with SBP, DBP, TC, TG, LDL-C, and UACR ($P<0.05$). VFA, SFA, BMI, and WC were each significantly negatively correlated with HDL-C ($P<0.05$). See **Table 2.**

2.3 Binary Logistic Regression Analysis with Albuminuria as the Dependent Variable

Binary logistic regression analysis showed that after adjusting for confounding factors such as age, gender, duration of diabetes, smoking history, SBP, HbA1C, TG, LDL-C, Scr, glucose-lowering regimen, and blood pressure-lowering regimen, increased VFA, SFA, BMI, and WC were all risk factors for albuminuria in middle-aged and elderly T2DM patients ($P<0.01$). See **Table 3.**

2.4 Predictive Analysis of Obesity Assessment Parameters for Albuminuria in Middle-Aged and Elderly T2DM Patients

ROC curve analysis showed that the areas under the curve (AUC) of VFA, SFA, BMI, and WC for assessing albuminuria in middle-aged and elderly T2DM patients were 0.620, 0.584, 0.592, and 0.613, respectively, with the optimal cut-off values of 79.2 cm², 162.9 cm², 24.3 kg/m², and 87.5 cm, respectively. See **Table 4** and **Figure 1.**

Tab 2 Correlation analysis of the obesity evaluation parameters and other clinical characteristics

Index	VFA		SFA		BMI		WC	
	r value	*P* value	*r* value	*P* value	*r* value	*P* value	*r* value	*P* value
Age	0.001	0.985	0.020	0.527	0.033	0.293	0.022	0.478
SBP	0.153	<0.001	0.090	0.004	0.100	0.001	0.082	0.009
DBP	0.182	<0.001	0.122	<0.001	0.200	<0.001	0.136	<0.001
FPG	0.111	<0.001	0.034	0.283	0.086	0.007	0.085	0.008
HbA1C	-0.007	0.818	-0.052	0.051	-0.055	0.080	-0.055	0.079
TC	0.028	0.363	0.092	0.003	0.033	0.289	-0.023	0.469
TG	0.230	<0.001	0.198	<0.001	0.235	<0.001	0.193	<0.001
LDL-C	0.036	0.250	0.087	0.006	0.017	0.591	-0.025	0.419
HDL-C	-0.240	<0.001	-0.125	<0.001	-0.215	<0.001	-0.265	<0.001
UACR	0.158	<0.001	0.114	<0.001	0.131	<0.001	0.143	<0.001

Tab.3 Binary logistic regression analysis of the influencing factors for albuminuria

Index	*β*	*SE*	*P* value	*Wald*	*OR (95%CI)*
VFA	0.010	0.003	0.001	12.077	1.010 (1.004~1.016)
SFA	0.005	0.002	0.002	9.476	1.005 (1.002~1.009)
BMI	0.101	0.034	0.003	9.100	1.107 (1.036~1.182)
WC	0.047	0.012	<0.001	15.082	1.048 (1.024~1.074)

Tab 4 Evaluating values of obesity evaluation parameters for albuminuria

Index	AUC (95%*CI*)	Cut-off	Sensitivity (%)	Specificity (%)	Youden's Index
VFA	0.620 (0.585-0.655)	79.2 cm^2	72.5	54.8	0.273
SFA	0.584 (0.546-0.623)	162.9 cm^2	68.6	42.3	0.109
BMI	0.592 (0.553-0.630)	24.3 kg/m^2	64.8	51.4	0.162
WC	0.613 (0.575-0.651)	87.5 cm	77.7	39.5	0.172

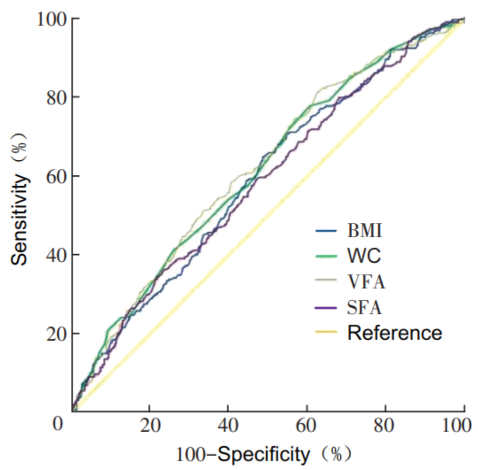

Fig.1 ROC curve of obesity evaluation parameters for formation of albuminuria in middle-aged and elderly T2DM patients

3 Discussion

DKD is the most common microvascular complication of T2DM and the primary cause of end-stage renal disease (ESRD). UACR is one of the key markers for early diagnosis of DKD, and finding simple and effective markers that can predict UACR progression is crucial for the screening and prevention of DKD.

Obesity is one of the independent risk factors for DKD [6], but the mechanism by which obesity leads to DKD has not been fully clarified. Possible mechanisms include the following: Obesity causes glomerular hyperfiltration to meet metabolic needs, thereby resulting in focal segmental glomerulosclerosis and reduced renal function [7]; Obesity leads to excessive renal fat deposition, resulting in the accumulation of harmful substances produced by fatty acid metabolism, which causes mitochondrial damage and cell apoptosis, ultimately leading to renal injury [8]; Lipids accumulated in the kidneys can induce oxidative stress, leading to glomerular injury and mesangial fibrosis [8]; Lipid metabolism disorders can directly damage podocytes, thereby accelerating the progression of DKD [9].

BMI is currently the most widely used indicator to assess obesity, but it cannot distinguish between fat, muscle, and bone. WC is the most commonly used indicator to assess abdominal obesity, but it cannot reflect the distribution of abdominal fat. Abdominal fat can be divided into two types: visceral fat and subcutaneous fat [10]. In recent years, VFA and SFA have received widespread attention as indicators that can distinguish abdominal fat distribution [11].

This study found that age, duration of diabetes, smoking rate, SBP, FPG, HbA1C, TG, LDL-C, and obesity assessment parameters (BMI, WC, VFA, SFA) in the middle-aged and elderly T2DM with albuminuria group were significantly higher than those in the middle-aged and elderly T2DM without albuminuria group (P<0.05), suggesting that advanced age, long duration of diabetes, smoking, hypertension, hyperglycemia, dyslipidemia, and obesity are all risk factors for albuminuria in T2DM patients, which is consistent with previous studies [12-15]. This indicates that T2DM patients need comprehensive management such as blood glucose control, blood pressure control, lipid control, weight control, and smoking cessation to delay the occurrence and development of DKD.

Previous domestic and foreign studies have reported inconsistent conclusions on the correlation between obesity assessment parameters and UACR. This study found that obesity assessment parameters (VFA, SFA, BMI, WC) in middle-aged and elderly T2DM patients were significantly positively correlated with UACR, and after adjusting for confounding factors, increased levels of the above obesity assessment parameters were all risk factors for albuminuria in middle-aged and elderly T2DM patients. Studies have shown that adipose tissue distribution is more critical than total fat mass in affecting the occurrence of diabetic complications [16]. This study further used ROC curve analysis to evaluate the predictive efficacy of obesity assessment parameters for albuminuria in middle-aged and elderly T2DM patients. The results showed that the predictive efficacy of VFA was superior to that of SFA and traditional obesity indicators (BMI and WC), suggesting that VFA has high predictive value for DKD. Clinically, it is not only necessary to assess the severity of obesity in T2DM patients, but also to further evaluate the type of obesity, with particular focus on the population with visceral obesity.

This study is a cross-sectional, single-center, small-sample study with certain limitations, and its results need to be further confirmed by prospective, multi-center, and large-sample studies.

In conclusion, this study found that increased obesity assessment parameters (VFA, SFA, BMI, WC) are all risk factors for albuminuria in middle-aged and elderly T2DM patients, and the predictive efficacy of VFA for albuminuria is superior to that of SFA, BMI, and WC.

Conflict of interest None

Reference

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·论　著·

中老年2型糖尿病患者肥胖评估参数与尿白蛋白/肌酐比值的相关性

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摘要：目的　探讨以身体质量指数（BMI）、腰围、内脏脂肪面积（VFA）、皮下脂肪面积（SFA）为主的肥胖评估参数与中老年2型糖尿病（T2DM）患者尿白蛋白/肌酐比值（UACR）的相关性。**方法**　选取2022年8月至2025年6月在南京医科大学附属老年医院就诊的1 034例中老年T2DM患者进行回顾性分析。收集患者一般资料，测定肥胖评估参数指标、生化指标、UACR等，以UACR ≥30 mg/g定义为白蛋白尿，分为合并白蛋白尿组（n=293）和不合并白蛋白尿组（n=741），并分析肥胖评估参数与各项临床指标的相关性。绘制受试者工作特征（ROC）曲线评估各肥胖评估参数预测白蛋白尿的效能。**结果**　中老年T2DM患者合并白蛋白尿组的年龄、糖尿病病程、吸烟率、收缩压、BMI、腰围、血管紧张素转换酶抑制剂/血管紧张素受体拮抗剂（ACEI/ARB）使用率、空腹葡萄糖（FPG）、糖化血红蛋白（HbA_{1c}）、三酰甘油（TG）、低密度脂蛋白胆固醇（LDL-C）、尿素氮、血肌酐、UACR、VFA、SFA均显著高于不合并白蛋白尿组（P<0.05）。二元线性回归分析显示，校正混杂因素后，中老年T2DM患者发生白蛋白尿的危险因素包括高VFA（OR=1.010，95%CI：1.004~1.016，P=0.001）、高SFA（OR=1.005，95%CI：1.002~1.009，P=0.002）、高BMI（OR=1.107，95%CI：1.036~1.182，P=0.003）和腰围大（OR=1.048，95%CI：1.024~1.074，P<0.01）。VFA、SFA、BMI、腰围评估中老年T2DM患者出现白蛋白尿的曲线下面积（AUC）分别为0.620、0.584、0.592和0.613，截断值分别为79.2 cm^2、162.9 cm^2、24.3 kg/m^2和87.5 cm。**结论**　中老年T2DM患者VFA、SFA、BMI、腰围升高均为白蛋白尿的危险因素，VFA对白蛋白尿的预测效能优于SFA、BMI、腰围。

关键词：2型糖尿病；尿白蛋白/肌酐比值；内脏脂肪面积；皮下脂肪面积；身体质量指数；腰围；白蛋白尿
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Abstract：Objective　To explore the correlation between obesity evaluation parameters [including body mass index (BMI), waist circumference (WC), visceral fat area (VFA), and subcutaneous fat area (SFA)] and urinary albumin-to-creatinine ratio (UACR) in middle-aged and elderly patients with type 2 diabetes mellitus (T2DM). **Methods**　A retrospective analysis was conducted on 1 034 middle-aged and elderly T2DM patients who were admitted to the Geriatric Hospital of Nanjing Medical University from August 2022 to June 2025. General data, obesity evaluation parameters, biochemical indicators and UACR were measured. UACR ≥ 30 mg/g was defined as albuminuria. The patients were divided into two groups according to the presence or absence of albuminuria: albuminuria group (n=293) and non-albuminuria group (n=741), and the correlation between obesity evaluation parameters and various clinical indicators were analyzed. Receiver operating characteristic (ROC) curves were drawn to evaluate the efficacy of various obesity evaluation parameters in predicting albuminuria. **Results**　Age, duration of diabetes, the proportions of

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smoking, systolic blood pressure, BMI, WC, utilization rate of angiotensin-converting enzyme inhibitors (ACEI)/angiotensin receptor blocker (ARB), fasting plasma glucose (FPG), glycated hemoglobin (HbA_{1C}), triglyceride (TG), low-density lipoprotein cholesterol (LDL-C), blood urea nitrogen (BUN), serum creatinine, UACR, VFA, and SFA in the albuminuria group were significantly higher than those in non-albuminuria group (P<0.05). After adjusting for confounding factors in binary line regression analysis, the risk factors for albuminuria in middle-aged and elderly patients with T2DM were high VFA (OR=1.010, 95%CI: 1.004-1.016, P=0.001), high SFA (OR=1.005, 95%CI: 1.002-1.009, P=0.002), high BMI (OR=1.107, 95%CI:1.036-1.182, P=0.003) and high WC (OR=1.048, 95%CI:1.024-1.074, P<0.01). The area under curve (AUC) of VFA, SFA, BMI and WC for predicting albuminuria was 0.620, 0.584, 0.592 and 0.613, with the cut-off value of 79.2 cm^2, 162.9 cm^2, 24.3 kg/m^2 and 87.5 cm, respectively. **Conclusion** Elevated VFA, SFA, BMI and WC are the risk factors for albuminuria in middle-aged and elderly patients with T2DM. The predictive efficacy of VFA for albuminuria is superior to SFA, BMI, and WC.

Keywords: Type 2 diabetes mellitus; Urinary albumin-to-creatinine ratio; Visceral fat area; Subcutaneous fat area; Body mass index; Waist circumference; Albuminuria

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近年来,我国2型糖尿病(type 2 diabetes mellitus, T2DM)患病率持续上升,成人患病率已高达12.8%,人数约1.25亿,是全球T2DM人数最多的国家[1]。糖尿病肾病(diabetic kidney disease, DKD)是指由糖尿病所致的慢性肾脏病(chronic kidney disease, CKD),也是糖尿病最常见的微血管并发症,我国T2DM患者的DKD患病率约40%[2]。临床上通常以尿白蛋白/肌酐比值(urinary albumin-to-creatinine ratio, UACR)≥30 mg/g作为DKD诊断标准之一。

早期识别及管理DKD的危险因素,是预防其发生和改善预后的重要措施。有研究显示,肥胖尤其是腹型肥胖,为DKD的危险因素之一[3]。传统的肥胖评估指标包括身体质量指数(body mass index, BMI)、腰围,而内脏脂肪面积(visceral fat area, VFA)及皮下脂肪面积(subcutaneous fat area, SFA)是近年来评估肥胖的新型指标,可更准确反映腹型肥胖程度[4]。本研究拟通过分析中老年T2DM患者中上述肥胖评估参数与UACR的相关性,为临床早期筛查及干预T2DM患者合并白蛋白尿形成提供参考。

1 对象与方法

1.1 *研究对象* 纳入2022年8月至2025年6月在南京医科大学附属老年医院门诊就诊或住院的中老年T2DM患者1 034例进行回顾性分析,年龄40~91周岁,男性634例,女性400例。以UACR≥30 mg/g定义为白蛋白尿,按照是否合并白蛋白尿进行分组,其中合并白蛋白尿组293例,不合并白蛋白尿组741例。纳入标准:(1)年龄≥40岁,性别不限;(2)符合2024年中华医学会糖尿病学分会T2DM诊断标准[5]。排除标准:(1)1型糖尿病、成人晚发自身免疫性糖尿病、继发性糖尿病、特殊类型糖尿病;(2)妊娠期糖尿病或糖尿病合并妊娠;(3)已明确为其他原因引起的肾脏损伤,如慢性肾小球肾炎、系统性红斑狼疮等;(4)存在尿路感染、高热等影响UACR水平的疾病或状态;(5)近3月使用非奈利酮、黄葵胶囊等降蛋白药物;(6)体内有金属物或心脏起搏器植入;(7)资料不完整。研究经南京医科大学附属老年医院伦理委员会批准[(2022)院伦审字第029号],并获得患者知情同意。

1.2 *研究方法* 收集患者的一般临床资料,包括年龄、性别、糖尿病病程、吸烟饮酒史、身高、体质量、腰围、收缩压、舒张压、降糖及降压方案等。降糖方案包括使用钠-葡萄糖协同转运蛋白2抑制剂(sodium-dependent glucose transporters 2 inhibitor, SGLT-2i)和胰高血糖素样肽-1受体激动剂(glucagon-like peptide-1 receptor agonist, GLP-1RA)。降压方案包括使用血管紧张素转化酶抑制剂(angiotensin-converting enzyme inhibitor, ACEI)或血管紧张素受体拮抗剂(angiotensin receptor blocker, ARB)。

所有患者禁食8~12 h,次日清晨采集外周静脉血检测空腹葡萄糖(fasting plasma glucose, FPG)、糖化血红蛋白(glycated hemoglobin, HbA_{1C})、血脂四项[总胆固醇(total cholesterol, TC)、三酰甘油(triglycerides, TG)、低密度脂蛋白胆固醇(low density lipoprotein cholesterol, LDL-C)、高密度脂蛋白胆固醇(high density lipoprotein cholesterol, HDL-C)]、肝功能[丙氨酸转氨酶(alanine aminotransferase, ALT)、天冬氨酸转氨酶(aspartate aminotransferase, AST)]、肾

功能(尿素氮、血肌酐),并留取次日晨尿检测UACR。检测FPG、血脂、肝肾功能等指标采用全自动生化仪(Roche cobas8000),检测HbA_{1C}采用高效液相色谱法,检测晨尿样本中的尿白蛋白和肌酐浓度分别采用蛋白散射比浊法和酶法,并以尿白蛋白除以尿肌酐来计算UACR,测量VFA和SFA采用生物电阻抗技术(Omron HDS-2000)。

1.3 统计学方法 统计分析使用SPSS 25.0软件。符合正态分布的计量资料用$\bar{x}\pm s$表示,组间比较采用独立样本t检验;非正态分布计量资料用$M(P_{25}, P_{75})$表示,组间比较采用Mann-Whitney U检验;计数资料用例(%)表示,比较采用χ^2检验。采用Pearson相关性分析评估肥胖评估参数与各项临床指标的相关性。二元logistic回归分析评估校正了年龄、性别、糖尿病病程、吸烟史、收缩压、HbA_{1C}、TG、LDL-C、血肌酐、降糖方案(是否使用SGLT-2i、GLP-1RA)、降压方案(是否使用ACEI/ARB)等混杂因素后,肥胖评估参数与白蛋白尿的相关性。绘制肥胖评估参数预测白蛋白尿的受试者工作特征(receiver operating characteristic, ROC)曲线,并计算各指标的截断值。以$P<0.05$为差异有统计学意义。

2 结果

2.1 两组一般临床资料比较 合并白蛋白尿组的年龄、糖尿病病程、吸烟率、收缩压、BMI、腰围、ACEI/ARB使用率、FPG、HbA_{1C}、TG、LDL-C、尿素氮、血肌酐、UACR、VFA、SFA均显著高于不合并白蛋白尿组($P<0.05$)。见表1。

2.2 肥胖评估参数与临床指标的相关性分析 VFA、BMI或腰围均分别与收缩压、舒张压、FPG、TG及UACR呈显著正相关($P<0.05$),SFA分别与收缩压、舒张压、TC、TG、LDL-C及UACR呈显著正相关($P<0.05$),VFA、SFA、BMI及腰围分别与HDL-C呈显著负相关($P<0.05$)。见表2。

2.3 以白蛋白尿为因变量的二元logistic回归分析 二元线性回归分析显示,校正年龄、性别、糖尿病病程、吸烟史、收缩压、HbA_{1C}、TG、LDL-C、血肌酐、降糖方案、降压方案等混杂因素后,VFA、SFA、BMI、腰围升高均为中老年T2DM患者发生白蛋白尿的危险因素($P<0.01$)。见表3。

表1 两组一般临床资料比较

Tab.1 Comparison of clinical characteristics between two groups

指标	合并白蛋白尿组(n=293)	不合并白蛋白尿组(n=741)	$\chi^2/t/Z$值	P值
性别(男/女,例)	193/100	441/300	3.576	0.059
年龄(岁)[a]	65.94±10.88	64.29±10.61	2.229	0.026
糖尿病病程(月)[b]	130.00(46.00,238.00)	90.00(16.00,159.50)	4.326	<0.001
吸烟史[例(%)]	78(26.62)	147(19.83)	5.211	0.022
饮酒史[例(%)]	59(20.14)	161(21.73)	0.317	0.573
收缩压(mmHg)[a]	138.29±16.59	133.49±15.71	4.352	<0.001
舒张压(mmHg)[a]	78.82±10.74	78.90±10.69	0.112	0.911
BMI(kg/m^2)[a]	25.61±3.20	24.61±3.25	4.463	<0.001
腰围(cm)[a]	93.22±9.06	89.76±8.76	5.625	<0.001
降糖方案[例(%)]				
SGLT-2i	107(36.52)	283(38.19)	0.250	0.617
GLP-1RA	51(17.41)	103(13.90)	2.036	0.154
降压方案[例(%)]				
ACEI/ARB	138(47.10)	226(30.50)	25.365	<0.001
FPG(mmol/L)[a]	7.82±2.20	7.28±2.15	3.542	<0.001
HbA_{1C}(%)[a]	8.83±1.99	8.46±1.92	2.702	0.007
TC(mmol/L)[a]	4.14±1.12	4.14±1.08	0.025	0.980
TG(mmol/L)[b]	1.46(1.04,2.22)	1.28(0.94,1.85)	3.746	<0.001
LDL-C(mmol/L)[a]	2.46±0.89	2.38±0.88	2.016	0.044
HDL-C(mmol/L)[a]	1.03±0.27	1.06±0.27	1.511	0.131
ALT(u/L)[a]	23.39±5.32	23.33±6.68	0.056	0.956
AST(u/L)[a]	20.37±8.51	19.07±8.75	1.962	0.050
尿素氮(mmol/L)[b]	6.00(4.75,7.60)	5.60(4.70,6.70)	3.496	<0.001
血肌酐(μmol/L)[b]	71.00(58.00,89.75)	65.00(55.00,77.00)	4.550	<0.001
UACR(mg/g)[b]	82.07(45.00,211.35)	8.55(4.58,14.83)	25.086	<0.001
VFA(cm^2)[a]	101.53±40.19	86.66±37.79	5.598	<0.001
SFA(cm^2)[a]	196.14±63.98	178.24±58.97	4.292	<0.001

注:[a]表示数据以$\bar{x}\pm s$表示;[b]表示数据以$M(P_{25}, P_{75})$表示。

表2　肥胖评估参数与各项临床指标的相关性分析

Tab.2　Correlation analysis of the obesity evaluation parameters and other clinical characteristics

指标	VFA		SFA		BMI		腰围	
	r值	P值	r值	P值	r值	P值	r值	P值
年龄	0.001	0.985	0.020	0.527	0.033	0.293	0.022	0.478
收缩压	0.153	<0.001	0.090	0.004	0.100	0.001	0.082	0.009
舒张压	0.182	<0.001	0.122	<0.001	0.200	<0.001	0.136	<0.001
FPG	0.111	<0.001	0.034	0.283	0.086	0.007	0.085	0.008
HbA_{1C}	−0.007	0.818	−0.052	0.051	−0.055	0.080	−0.055	0.079
TC	0.028	0.363	0.092	0.003	0.033	0.289	−0.023	0.469
TG	0.230	<0.001	0.198	<0.001	0.235	<0.001	0.193	<0.001
LDL-C	0.036	0.250	0.087	0.006	0.017	0.591	−0.025	0.419
HDL-C	−0.240	<0.001	−0.125	<0.001	−0.215	<0.001	−0.265	<0.001
UACR	0.158	<0.001	0.114	<0.001	0.131	<0.001	0.143	<0.001

2.4　肥胖评估参数对中老年T2DM患者出现白蛋白尿的预测分析　ROC曲线分析结果显示，VFA、SFA、BMI、腰围评估中老年T2DM患者出现白蛋白尿的曲线下面积（area under the curve，AUC）分别为0.620、0.584、0.592、0.613，截断值分别为79.2 cm^2、162.9 cm^2、24.3 kg/m^2、87.5 cm。见表4、图1。

表3　二元logistic回归分析白蛋白尿的影响因素

Tab.3　Binary logistic regression analysis of the influencing factors for albuminuria

指标	β	SE	P值	Wald值	OR（95%CI）
VFA	0.010	0.003	0.001	12.077	1.010（1.004~1.016）
SFA	0.005	0.002	0.002	9.476	1.005（1.002~1.009）
BMI	0.101	0.034	0.003	9.100	1.107（1.036~1.182）
腰围	0.047	0.012	<0.001	15.082	1.048（1.024~1.074）

表4　肥胖评估参数对白蛋白尿的预测效能

Tab.4　Predictive efficacy of obesity assessment parameters for albuminuria

指标	AUC（95%CI）	截断值	敏感度（%）	特异度（%）	约登指数
VFA	0.620（0.585~0.655）	79.2 cm^2	72.5	54.8	0.273
SFA	0.584（0.546~0.623）	162.9 cm^2	68.6	42.3	0.109
BMI	0.592（0.553~0.630）	24.3 kg/m^2	64.8	51.4	0.162
腰围	0.613（0.575~0.651）	87.5 cm	77.7	39.5	0.172

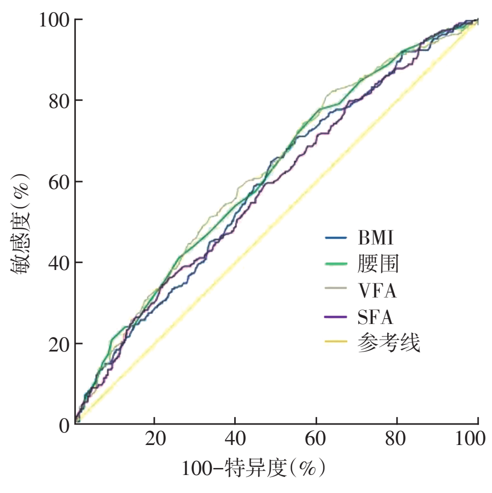

图1　肥胖评估参数预测白蛋白尿的ROC曲线

Fig.1　ROC curve of obesity evaluation parameters for predicting of albuminuria

3　讨　论

DKD是T2DM最常见的微血管并发症，也是终末期肾病（end-stage renal disease，ESRD）的首要原因。UACR是DKD早期诊断关键标志物之一，寻找能预测UACR进展且简单有效的标志物对DKD的筛查和预防至关重要。

肥胖是DKD的独立危险因素之一[6]，但肥胖导致DKD的机制尚未完全明确，可能的机制如下：肥胖导致肾小球高滤过以满足代谢需求，从而造成局灶节段性肾小球硬化并降低肾功能[7]；肥胖使肾脏脂肪过度沉积，导致脂肪酸代谢产生的有害物质积聚，造成线粒体损伤、细胞凋亡，最终造成肾脏损伤[8]；在肾脏积聚的脂质可诱导氧化应激，导致肾小球损伤和系膜纤维化[8]；脂质代谢功能障碍可直接损伤足细胞，从而加速DKD的进展[9]。

BMI是目前评估肥胖应用最广泛的指标，但不能区分脂肪、肌肉、骨骼。腰围是最常用评估腹型肥胖的指标，但不能表示腹部脂肪分布情况。腹部脂肪可分为两种类型：内脏脂肪和皮下脂肪[10]。近年来VFA和SFA作为可区分腹部脂肪分布的指标受到广泛关注[11]。本研究发现，中老年T2DM合并白蛋白尿组的年龄、糖尿病病程、吸烟率、收缩压、FPG、HbA_{1C}、TG、LDL-C、肥胖评估参数（BMI、腰围、VFA、SFA）均显著高于中老年T2DM不合并白蛋白尿组，提示高龄、长糖尿病病程、吸烟、高血压、高血糖、血脂紊乱及肥胖均是T2DM患者发生白蛋白尿的危险因素，与既往研究结果一致[12-15]，说明T2DM患者需要进行控制血糖、血压、血脂、体重及戒烟等综合管理，延缓DKD的发生发展。

既往国内外研究关于肥胖评估参数与UACR的相关性研究结论不一。本研究发现，中老年T2DM患者肥胖评估参数（VFA、SFA、BMI、腰围）均与UACR

呈显著正相关,并且校正混杂因素后,上述肥胖评估参数升高均为中老年T2DM患者发生白蛋白尿的危险因素。有研究表明,脂肪组织分布比脂肪总量对发生糖尿病并发症的影响更为关键[16]。本研究进一步采用ROC曲线分析中老年T2DM患者肥胖评估参数对白蛋白尿的预测效能,结果发现VFA的预测效能优于SFA及传统肥胖指标BMI和腰围,提示VFA对DKD的预测价值大,临床上不仅需要评估T2DM患者的肥胖严重程度,还需要进一步评估肥胖类型,尤其应重点关注内脏型肥胖人群。

本研究为横断面、单中心、小样本研究,存在一定的局限性,其结果需要前瞻性、多中心、大样本研究进一步证实。

综上所述,本研究发现肥胖评估参数(VFA、SFA、BMI、腰围)升高均为中老年T2DM发生白蛋白尿的危险因素,且VFA对白蛋白尿的预测效能优于SFA、BMI、腰围。

利益冲突 无

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