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ORIGINAL RESEARCH

A Cross-Sectional Study of the Association Between Uric Acid-to-High-Density Lipoprotein Cholesterol Ratio and Carotid Atherosclerosis in Patients with Type 2 Diabetes Mellitus

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Background: Carotid atherosclerosis (CAS) is a key diabetic complication needing predictive biomarkers. The serum uric acid-to-high-density lipoprotein cholesterol ratio (UHR), linked to metabolic dysfunction, may serve this role. Therefore, this cross-sectional study examines UHR-CAS association in type 2 diabetes.

Methods: This study included 615 type 2 diabetes patients, collecting demographic, biochemical, and carotid ultrasound data. Spearman correlation analyzed UHR's relationship with cardiovascular risk factors. Multivariate logistic regression combined with stratified regression modeling assessed UHR's independent link with CAS, while receiver operating characteristic (ROC) analysis evaluated its predictive value.

Results: CAS patients showed elevated UHR and cardiovascular risk markers (age, body mass index [BMI], homeostatic model assessment of insulin resistance [HOMA-IR], systolic blood pressure, low-density lipoprotein cholesterol [LDL-c], triglycerides, smoking) compared to controls ($P < 0.05$). UHR tertiles demonstrated dose–response associations with carotid intima-media thickness (cIMT) ≥1.0 mm, plaque formation, and CAS ($P < 0.05$). UHR exhibited positively with BMI, HOMA-IR, systolic blood pressure, triglycerides, uric acid (UA), and cIMT ($P < 0.05$), but inversely with total cholesterol, high-density lipoprotein cholesterol (HDL-c), and LDL-c ($P < 0.05$). UHR independently predicted carotid plaques (OR: 1.086, 95% CI: 1.033–1.142, $P = 0.001$) and CAS (OR: 1.097, 95% CI: 1.035–1.162, $P = 0.002$). Stronger associations occurred in BMI ≥25 kg/m² (OR: 1.210, 95% CI: 1.089–1.345, $P < 0.001$) and hypertension subgroups (OR: 1.136, 95% CI: 1.033–1.248, $P = 0.008$). ROC analysis demonstrated UHR's superior CAS prediction (AUC = 0.656, 95% CI: 0.611–0.701, $P < 0.01$) over triglyceride-to-HDL-c ratio, triglyceride-glucose index, HDL-c, and UA ($P < 0.05$).

Conclusion: UHR is an independent CAS risk factor in type 2 diabetes, outperforming traditional biomarkers for cardiovascular risk assessment.

Keywords: carotid atherosclerosis, type 2 diabetes mellitus, uric acid-to-high-density lipoprotein cholesterol ratio

Introduction

Cardiovascular disease (CVD) represented a significant burden in diabetic populations. Epidemiological studies demonstrated that CVD was the leading cause of mortality among individuals with diabetes, accounting for approximately 50% of deaths.[1] Atherosclerosis, characterized by arterial wall thickening and plaque formation, served as the primary pathological basis for CVD due to its association with vascular stenosis and impaired blood flow.[2] Previous research indicated that carotid atherosclerosis (CAS) in patients with type 2 diabetes mellitus strongly correlated with the occurrence of cardiovascular events, including myocardial infarction and stroke.[3,4] These findings highlighted the importance of investigating CAS risk factors to improve CVD prevention and management in diabetic patients.

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Uric acid (UA) and high-density lipoprotein cholesterol (HDL-c) were well-established biomarkers of cardiovascular health.[5–8] Elevated UA levels were associated with lipid metabolism disorders, inflammation, and endothelial dysfunction, all of which contributed to atherosclerosis pathogenesis.[9] In contrast, HDL-c played a protective role by improving lipid metabolism, exerting anti-inflammatory effects, and maintaining vascular endothelial function.[10] Patients with type 2 diabetes mellitus commonly exhibited elevated UA levels and reduced HDL-c levels, both of which were associated with increased CVD risk.[11,12] Recently, the serum uric acid-to-high-density lipoprotein cholesterol ratio (UHR) emerged as a novel composite biomarker for cardiovascular risk assessment, integrating both UA and HDL-c measurements. Studies demonstrated that UHR was strongly correlated with the occurrence of metabolic syndrome and adverse cardiovascular prognosis.[13–16] Emerging clinical evidence has further substantiated the strong correlations between UHR and extra-cardiac complications in type 2 diabetes mellitus cohorts, with particularly compelling links observed for kidney injury and non-alcoholic fatty liver disease progression.[17,18] However, research investigating the potential correlation between UHR and CAS in this specific population remained notably scarce, warranting further comprehensive investigation.

Therefore, this study attempted to investigate the association between UHR and CAS in patients with type 2 diabetes mellitus through a cross-sectional analysis. By identifying UHR as a potential biomarker, this research provided evidence for developing precise CVD prevention strategies in type 2 diabetes mellitus cohorts.

Materials and Methods

Study Population

This study consecutively enrolled adults with type 2 diabetes mellitus admitted to the metabolic management center at Longyan First Affiliated Hospital of Fujian Medical University from June 2023 to March 2024. Inclusion criteria were: (1) age ≥18 years; and (2) T2DM diagnosis confirmed per American Diabetes Association (ADA) guidelines.[19] Exclusion criteria included: (1) acute diabetic complications (eg, diabetic ketoacidosis or hyperosmolar hyperglycemic syndrome); (2) severe renal/hepatic impairment (eg, end-stage renal disease or hepatic cirrhosis); (3) active infections, malignancies, or autoimmune disorders; (4) incomplete carotid ultrasound data; and (5) current use of UA modifying agents (eg, febuxostat, thiazide diuretics). After screening, 615 eligible participants were included in the final analysis.

General Condition and Biochemical Index Collection

Demographic characteristics (gender, age), clinical parameters (duration of diabetes mellitus, height, weight, blood pressure), and behavioral factors (smoking history defined as ≥1 cigarette/day or ≥7 cigarettes/week for six consecutive months) were documented using standardized questionnaires. Anthropometric measurements (height and weight) were obtained with calibrated instruments; blood pressure measurements were performed in triplicate following standardized protocols. Fasting venous blood samples were analyzed using a Cobas 8000 automated biochemical analyzer (Roche Diagnostics), with hemoglobin A1c (HbA1c) quantified via high-performance liquid chromatography (Bio-Rad D10 system). Biochemical parameters included: Fasting blood glucose (FBG), total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-c), HDL-c, UA, creatinine (Cr), blood urea nitrogen (BUN), alanine aminotransferase (ALT), and albumin.

Derived indices comprised: (1) body mass index (BMI) = weight (kg)/height² (m²); (2) homeostatic model assessment of insulin resistance (HOMA-IR) = [fasting glucose (mmol/L) × fasting insulin (μU/mL)]/22.5; (3) uric acid-to-HDL-C ratio (UHR) = [UA (mg/dL)/HDL-C (mg/dL)] ×100; (4) triglyceride-to-HDL-C ratio (THR) = [TG (mg/dL)/HDL-C (mg/dL)]; and (5) triglyceride-glucose index (TyG) = ln[fasting TG (mg/dL) × fasting glucose (mg/dL)/2].

CAS Definition

Carotid ultrasound examinations were performed using a high-resolution B-mode ultrasound system (Philips EPIQ 5, L12-5 MHz linear array transducer). All scans were conducted by a certified vascular sonographer following standardized positioning protocols with participants positioned supine and the neck slightly extended. Carotid intima-media thickness (cIMT) was measured at 1 cm proximal to the carotid bifurcation, and the mean value of bilateral

measurements was recorded as the final cIMT (unit: mm). Carotid intimal thickening was defined as cIMT ≥1.0 mm, while carotid plaque was identified as either focal protrusion exceeding 50% of adjacent vessel wall thickness or cIMT ≥1.5 mm. CAS required documented carotid intimal thickening or plaque presence.[20]

Statistical Analysis

SPSS 24.0 statistical software was utilized for data analysis in this study. Based on distribution characteristics, measurement data with normal distribution were expressed as mean ± standard deviation (x±s), while non-normally distributed data were presented as median (interquartile range) [M (IQR)]. Categorical data were described as number of cases (percentage) [n (%)]. For inter-group comparisons, normally distributed continuous variables were analyzed using independent-samples *t*-test or one-way analysis of variance, while non-normally distributed variables were compared via Mann–Whitney *U*-test or Kruskal–Wallis test; categorical variables were assessed by chi-square test or Fisher's exact test. Spearman correlation analysis evaluated correlations between UHR and indicators including BMI, blood pressure, blood lipids, and insulin resistance. Multivariate logistic regression analyzed the independent association between UHR and CAS, while hierarchical logistic regression explored influencing factors. Receiver operating characteristic (ROC) curves evaluated the predictive performance of metabolic indicators (UHR, THR, TyG, HDL, UA) for CAS. A two-tailed test was conducted with $\alpha=0.05$, and $P<0.05$ was deemed statistically significant.

Results

Basic Characteristics of the Study Population

The study included 615 patients with type 2 diabetes mellitus after excluding 45 patients based on predefined criteria (as shown in Figure 1), with 220 patients in the non-CAS group and 395 patients in the CAS group. Baseline characteristics are summarized in Table 1. The table clearly illustrated whether the study groups were well-balanced in baseline characteristics or exhibited clinically relevant differences in demographic and clinical parameters. The mean age of patients was 60.02 ± 11.54 years, with 55.45% being male. The CAS group exhibited significantly higher age, greater male proportion, longer diabetes duration, and increased cIMT compared with the non-CAS group ($P < 0.05$) . In addition, the CAS group demonstrated higher cardiovascular risk markers including BMI, HOMR-IR, SBP, TC, LDL-c, TG, UA, UHR, THR, and TyG levels, alongside reduced HDL-c ($P < 0.05$) . Additionally, creatinine, BUN, smoking prevalence, hypertension rates, and use of anti-arteriosclerotic medications were significantly higher in the CAS group ($P < 0.05$).

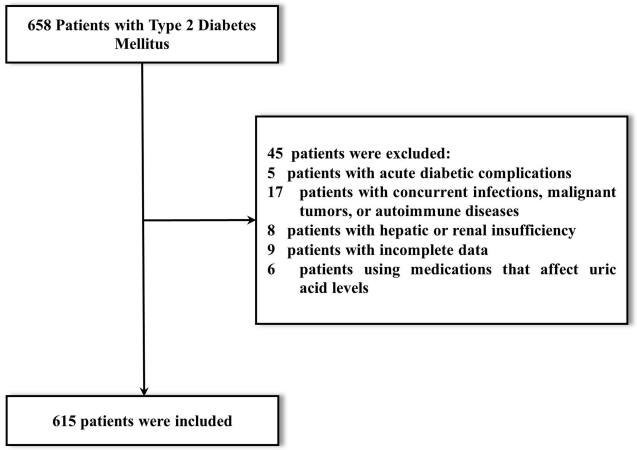

Figure 1 Participant flow diagram: inclusion and exclusion process.

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Table 1 Comparison of Baseline Data Between Non-CAS and Comorbid CAS Patients

Variable	Total (n=615)	Non-CAS (n=220)	CAS (n=395)	P value
Age (years)	60.02±11.54	54.07±10.89	63.33±10.53	<0.001
Men, n (%)	341 (55.45%)	104 (47.27%)	237 (60.00%)	0.002
Duration (years)	8.00 [3.00, 12.00]	6.00 [2.00, 10.00]	10.00 [4.00, 13.00]	<0.001
cIMT (mm)	0.91±0.19	0.75±0.10	0.99±0.17	<0.001
BMI (kg/m^2)	24.37±3.34	23.89±3.41	24.64±3.27	0.007
HbAlc (%)	8.91±2.27	8.83±2.20	8.96±2.31	0.496
HOMA-IR	3.03±1.71	2.84±1.71	4.20±1.84	<0.001
SBP (mmHg)	135.06±17.40	129.63±16.40	138.09±17.22	<0.001
DBP (mmHg)	78.85±9.86	79.28±9.91	78.62±9.84	0.422
TC (mmol/L)	4.43±1.02	4.13±0.94	4.51±1.07	0.037
LDL-c (mmol/L)	2.77±0.86	2.62±0.75	2.95±0.92	0.018
HDL-c (mmol/L)	1.07±0.26	1.13±0.26	1.03±0.25	<0.001
TG (mmol/L)	1.62±0.96	1.49±0.96	1.69±0.95	0.014
UA (μmol/L)	322.35±82.51	297.43±75.04	336.23±83.31	<0.001
Cr (μmol/L)	60.54±18.06	55.55±16.18	63.32±18.46	<0.001
BUN(mmol/L)	5.52±1.56	5.28±1.41	5.65±1.63	0.004
Albumin (g/L)	40.12±3.62	40.30±3.46	40.02±3.70	0.360
ALT (IU/L)	20.00 [15.00, 28.00]	21.00 [15.00, 27.75]	20.00 [15.00, 28.00]	0.487
UHR (%)	13.97±5.09	12.15±4.48	14.98±5.14	<0.001
THR	3.07 [1.99, 4.92]	2.57 [1.64, 4.13]	3.49 [2.17, 5.10]	0.001
TyG	9.13±0.69	9.05±0.68	9.17±0.69	0.030
Smoking, n (%)	183 (29.76%)	50 (22.73%)	133 (33.67%)	0.004
Hypertention, n (%)	333 (54.15%)	71 (32.27%)	262 (66.33%)	<0.001
Anti-arteriosclerotic drugs, n (%)	92 (14.96%)	22 (10.00%)	70 (17.72%)	0.010

Note: Anti-arteriosclerotic drugs: including statins (eg, atorvastatin, rosuvastatin) and antiplatelet agents (eg, aspirin, clopidogrel).
Abbreviactions: CAS, carotid atherosclerosis; cIMT, carotid intima-media thickness; BMI, body mass index; HOMA-IR, homeostatic model assessment of insulin resistance; SBP/DBP, systolic/diastolic blood pressure; TC, total cholesterol; LDL-c/HDL-c, low-/high-density lipoprotein cholesterol; TG, triglycerides; UA, uric acid; Cr, creatinine; BUN, blood urea nitrogen; ALT, alanine aminotransferase; UHR, uric acid-to-HDL-c ratio; THR, triglyceride-to-HDL-C ratio; TyG, triglyceride-glucose Index.

Differences in the Incidence of cIMT ≥ 1mm, Carotid Plaque Formation, and CAS According to UHR Tertiles

When patients were stratified into tertiles based on UHR, the incidence of cIMT ≥1.0 mm, carotid plaque formation, and CAS showed a significant increase across ascending UHR tertiles, indicating a dose–response relationship between elevated UHR and these CAS outcomes (as shown in Figure 2, P <0.05).

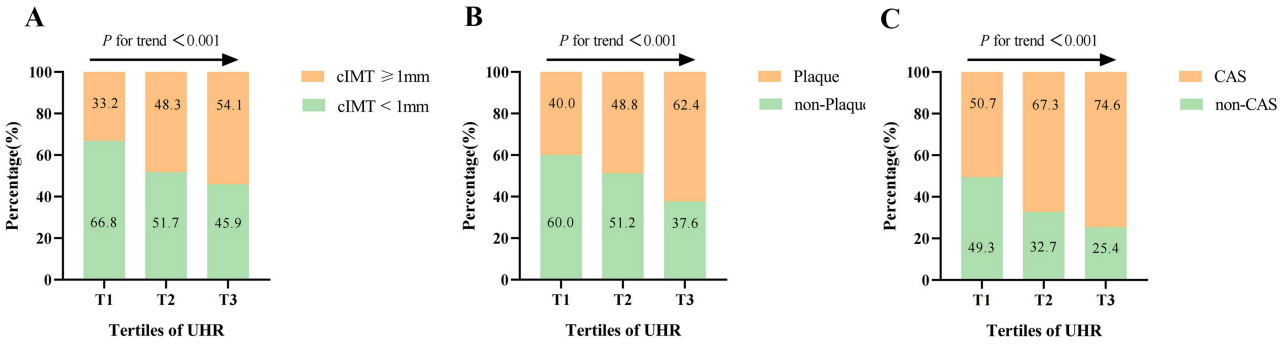

Figure 2 Comparison of incidence rates of cIMT≥1 mm (**A**), carotid plaque formation (**B**), and CAS (**C**) across UHR tertiles.
Abbreviactions: cIMT, carotid intima-media thickness; CAS, carotid atherosclerosis; UHR, uric acid-to-HDL-c ratio.

Table 2 Correlation Analysis Between UHR and Other Metabolic Indicators

Variable	Correlation Coefficient	P value
BMI (kg/m^2)	0.305	<0.001
HOMA-IR	0.115	0.004
SBP (mmHg)	0.084	0.037
DBP (mmHg)	0.046	0.253
TC (mmol/L)	−0.212	<0.001
LDL-c (mmol/L)	−0.167	<0.001
HDL-c (mmol/L)	−0.677	<0.001
TG (mmol/L)	0.307	<0.001
UA(μmol/L)	0.776	<0.001

Abbreviations: BMI, body mass index; HOMA-IR, homeostatic model assessment of insulin resistance; SBP/DBP, systolic/diastolic blood pressure; TC, total cholesterol; LDL-c/HDL-c, low-/high-density lipoprotein cholesterol; TG, triglycerides; UA, uric acid.

Correlation Analysis Between UHR and Cardiovascular Risk Factors as Well as cIMT

Correlation analysis in Table 2 demonstrated significant associations between UHR and key cardiometabolic parameters. Specifically, UHR demonstrated positive correlations with BMI, HOMA-IR, SBP, TG, and UA; negative correlations with TC, LDL-c, and HDL-c (all $P < 0.05$). These results suggest that UHR is associated with multiple cardiovascular risk factors. Notably, as shown in Figure 3, UHR displayed a particularly strong positive correlation with cIMT ($r = 0.181$, $P < 0.001$), suggesting its potential clinical relevance in CAS assessment.

Multivariate Logistic Regression Analysis of UHR with cIMT≥1mm, Carotid Plaque, and CAS

As shown in Figure 4, multivariate logistic regression analysis showed that after adjusting for potential confounding factors, UHR did not significantly increase the risk of cIMT ≥1 mm (OR: 1.048, 95% CI: 0.999–1.100, $P = 0.056$). However, UHR was independently associated with an increased risk of carotid plaque formation (OR: 1.086, 95% CI: 1.033–1.142, $P = 0.001$) and CAS (OR: 1.097, 95% CI: 1.035–1.162, $P = 0.002$).

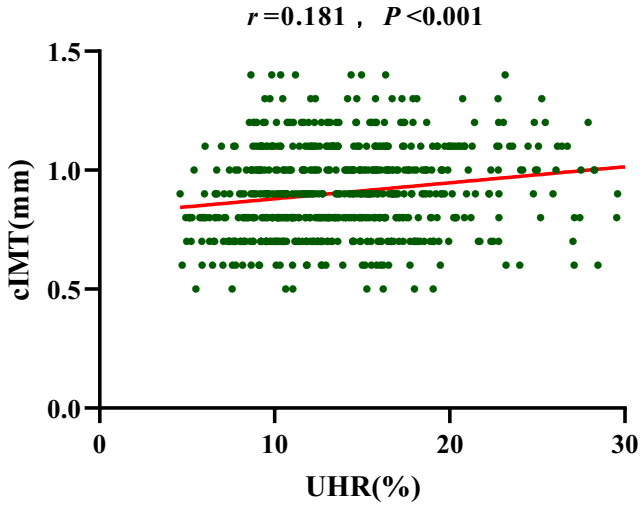

Figure 3 Correlation analysis between UHR and cIMT.
Abbreviactions: cIMT, carotid intima-media thickness; UHR, uric acid-to-HDL-c ratio.

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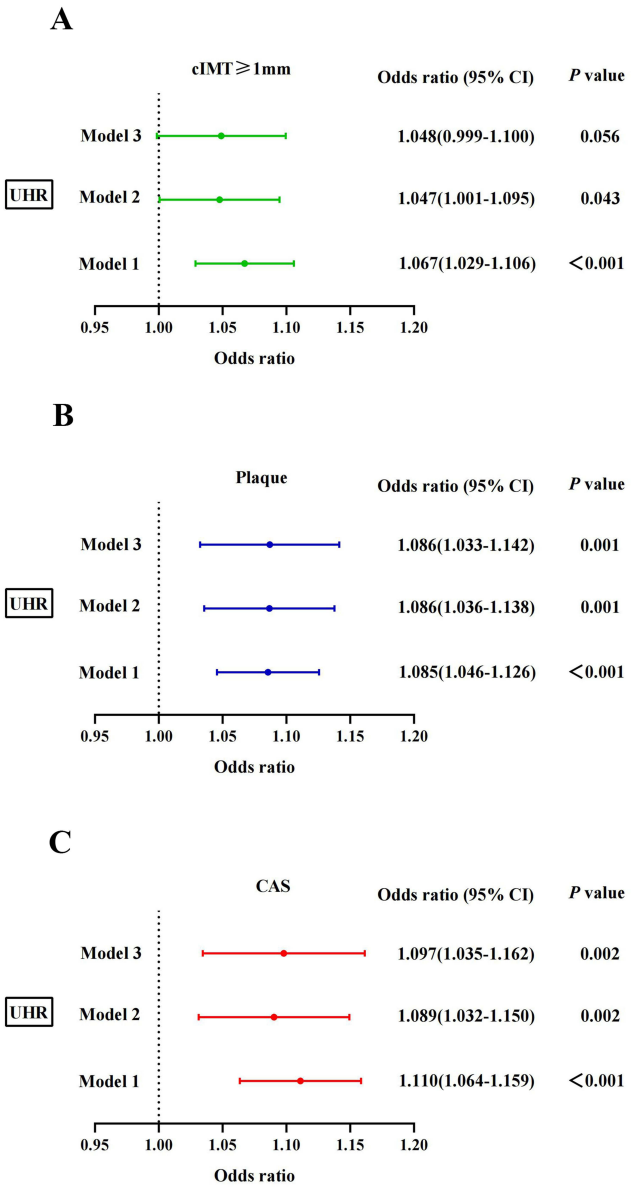

Figure 4 Logistic regression analysis of the association between UHR and cIMT ≥1 mm (**A**), carotid plaque formation (**B**), and CAS (**C**). Model 1: adjusted for sex and age. Model 2: further adjusted for duration of diabetes mellitus, body mass index, homeostatic model assessment of insulin resistance, systolic blood pressure, diastolic blood pressure, total cholesterol, triglycerides, and low-density lipoprotein cholesterol based on Model 1. Model 3: additionally adjusted for creatinine, blood urea nitrogen, alanine aminotransferase, smoking status, and anti-arteriosclerotic medications based on Model 2.
Abbreviactions: cIMT, carotid intima-media thickness; CAS, carotid atherosclerosis; UHR, uric acid-to-HDL-c ratio.

Hierarchical Logistic Regression Analysis of the Association Between UHR and CAS

The relationship between UHR and CAS was further assessed in as shown in Figure 5 after stratification by sex, age, BMI, and hypertension status. The results demonstrated that this relationship was modified by BMI and hypertension, with the independent association primarily observed in individuals with BMI ≥ 25 kg/m² (OR: 1.210, 95% CI: 1.089–1.345, $P < 0.001$), and hypertension (OR: 1.136, 95% CI: 1.033–1.248, $P = 0.008$), regardless of age or gender (P for interaction>0.05).

ROC Curve Analysis for Evaluating the Predictive Performance of UHR

As shown in Figure 6 and Table 3, ROC curve analysis was performed to evaluate the predictive performance of UHR for CAS. The area under the curve (AUC) for UHR was 0.656 (95% CI: 0.611–0.701, $P < 0.001$), with an optimal cutoff value of

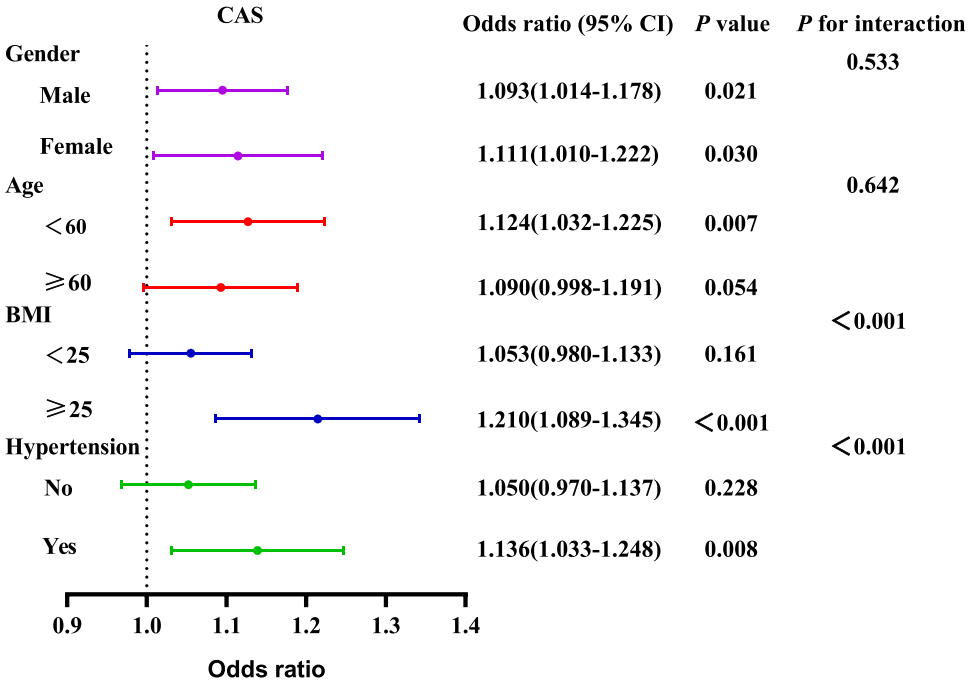

Figure 5 Stratified regression analysis of UHR and carotid atherosclerosis stratified by sex, age, BMI, and hypertension.
Abbreviations: BMI, body mass index; CAS, carotid atherosclerosis.

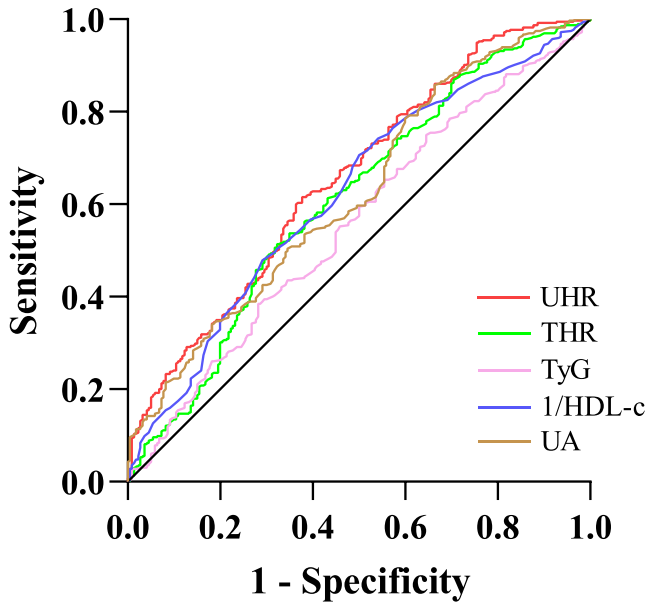

Figure 6 ROC analysis of UHR, THR, TyG, HDL-c, and UA for predicting CAS.
Abbreviations: TyG, triglyceride-glucose Index; HDL-c, high-density lipoprotein cholesterol; UA, uric acid; UHR, uric acid-to-HDL-c ratio; THR, triglyceride-to-HDL-C ratio.

13.070. At this threshold, UHR exhibited a sensitivity of 60.3% and a specificity of 63.6% for predicting CAS. Additionally, the AUCs of THR, TyG, 1/HDL-c, and UA were calculated for comparison. UHR demonstrated a significantly higher AUC value compared with THR ($P = 0.035$), TyG ($P = 0.001$), 1/HDL-c ($P = 0.047$), and UA ($P = 0.041$).

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Table 3 ROC Analysis of UHR, THR, TyG, HDL-c, and UA in Identifying CAS

Variables	AUC (95% CI)	Cutoff Value	Sensitivity (%)	Specificity (%)
UHR	0.656 (0.611–0.701)	13.070	0.603	0.636
THR	0.610 (0.563–0.657)	3.430	0.514	0.677
TyG	0.556 (0.508–0.603)	8.693	0.752	0.355
1/HDL-c	0.621 (0.575–0.667)	0.881	0.737	0.473
UA	0.622 (0.576–0.668)	254.500	0.858	0.336

Abbreviations: AUC, area under the curve; UHR, uric acid-to-HDL-c ratio; THR, triglyceride-to-HDL-C ratio; TyG, triglyceride-glucose Index; HDL-c, high-density lipoprotein cholesterol; UA, uric acid.

Discussion

Diabetic patients bear a heavy burden of cardiovascular diseases, with cardiovascular and cerebrovascular events constituting the leading causes of mortality.[21] CAS, a validated early marker of systemic atherosclerosis, is strongly associated with cardiovascular risk in this population.[22] Therefore, this study investigated the relationship between UHR and CAS in diabetic patients, thereby providing novel insights for early cardiovascular risk stratification. Consistent with our hypothesis, we observed elevated UHR levels in the CAS group compared to the non-CAS cohort ($P < 0.05$). Correlation analysis revealed significant positive associations between UHR and cardiovascular risk factors, including BMI, HOMA-IR, SBP, and TG. After adjusting for confounders, UHR independently correlated with plaque formation and CAS in diabetic patients. Furthermore, stratified analysis demonstrated that the association between UHR and CAS was primarily manifested in overweight individuals (BMI $\geq$ 25 kg/m²) and hypertensive subgroups, whereas no significant gender- or age-related differences were observed. Clinically, UHR outperformed traditional markers (THR, TyG, HDL-c, and UA) in predicting CAS risk, as evidenced by ROC curve analysis (AUC: 0.656 vs 0.556–0.622, $P < 0.05$).

Mounting clinical evidence has firmly established hyperuricemia as an independent risk factor for CAS.[23–25] In this context, the UHR has gained prominence as a novel integrated biomarker that simultaneously reflects purine metabolism and lipid homeostasis in cardiovascular pathophysiology.[26,27] A cohort study involving 48,054 participants showed 16% and 20% increased risks for all-cause and cardiovascular mortality, respectively, in the highest UHR quintile.[28] Relevant investigations further demonstrated UHR's predictive value for coronary hemodynamic abnormalities[29] and its association with vulnerable plaque characteristics including rupture, erosion, and thrombosis formation.[30] Critically, accumulating clinical evidence had established that the UHR independently predicted multiple diabetes-associated complications in patients with type 2 diabetes mellitus, particularly lower extremity arterial disease, chronic kidney disease, and steatotic liver disease.[31–33] Our findings corroborated and extended these observations through multivariate analysis that showed each 1% UHR increment conferred 8.6% and 9.7% increased risks for carotid plaque and CAS, respectively, in type 2 diabetes patients. This risk amplification was particularly pronounced in subjects with BMI ≥25 kg/m² or hypertension, suggesting synergistic vascular injury from metabolic derangements. Notably, in head-to-head comparisons with established metabolic markers (THR, TyG, UA, and HDL-c),[34,35] UHR demonstrated superior predictive performance for CAS risk assessment.

Our study provided mechanistic insights into UHR's role in cardiovascular risk among type 2 diabetes patients. Blood pressure, insulin resistance, and dyslipidemia were established as major cardiovascular risk factors that significantly elevated risks of both atherosclerosis development and subsequent cardiovascular events.[36–38] The positive correlation between UHR and SBP observed in this study aligns with prior research findings.[39] However, no significant association was observed between UHR and DBP in the current cohort. This discrepancy may reflect hyperuricemia's specific effects on vascular tension and hemodynamics, which predominantly influencing SBP rather than DBP.[40] Recent large-scale clinical evidence has established that elevated UHR levels independently predict worsened insulin resistance and impaired glycemic control.[41] Our investigation in a type 2 diabetes cohort further substantiated these findings, demonstrating a significant positive association between UHR and HOMA-IR. At the molecular level, we propose that hyperuricemia-induced oxidative stress in adipocytes may serve as a key pathological mechanism, driving both ectopic

lipid deposition and the development of insulin resistance.[42] Lipid profile analysis further demonstrated a significant positive association between UHR and TG levels, implying that elevated UHR might contribute to atherogenesis through dysregulated lipid metabolism. Interestingly, UHR demonstrated a consistent inverse association with TC, LDL-c, and HDL-c. Although HDL-c was conventionally considered cardioprotective, its levels might be modulated by TC and LDL-c concentrations. These apparently contradictory associations could be explained by common underlying metabolic mechanisms, with cholesterol ester transfer protein activity representing a plausible mediator of these complex interactions.[43]

The pathophysiological mechanism between UHR and CAS in type 2 diabetes remains unclear, but it may involve synergistic interactions among inflammation, oxidative stress, endothelial dysfunction, and metabolic disorders. Previous investigation demonstrated that hyperuricemia activated the NLRP3 inflammasome pathway, which promoted inflammatory cytokine release (eg, interleukin-1β and interleukin-18) and triggered chronic vascular inflammation, ultimately accelerating atherogenesis.[44] Concurrently, hyperuricemia exacerbated oxidative stress through increased production of reactive oxygen species, which damaged vascular endothelial cells and facilitated LDL-c oxidation.[45] Notably, multiple clinical studies consistently reported that reduced HDL-c levels impaired its anti-inflammatory and antioxidant functions, including impaired inhibition of inflammatory factor release, reduced free radical scavenging and defective reverse cholesterol transport mechanisms.[7,46] These findings confirmed that such dysfunctions directly contributed to amplified lipid deposition in arterial walls. Furthermore, the imbalance between UA and HDL-c synergistically induced endothelial dysfunction, characterized by reduced nitric oxide (NO) production, impaired vasodilation, and increased release of vasoconstrictors such as endothelin-1, collectively exacerbating vascular damage.[47–49]

In conclusion, our multivariate regression analysis demonstrates that UHR serves as a significant independent predictor of CAS in patients with type 2 diabetes mellitus, exhibiting superior discriminative capability compared to traditional biomarkers. These findings underscore UHR's potential clinical value for CAS risk assessment in patients with type 2 diabetes mellitus. While this study provides the first evidence of an association between UHR and CAS in type 2 diabetes populations, several methodological limitations warrant careful interpretation. First, the predominantly cross-sectional design precluded definitive conclusions regarding causal relationships between the UHR and CAS. Second, substantial heterogeneity in genetic profiles, lifestyle factors, and metabolic characteristics across populations constrained the generalizability of the findings. Additionally, while the study included patients from real-world clinical settings where comorbidities were common, this aspect introduced potential confounding effects. Consequently, large-scale, multicenter studies are imperative to validate the clinical significance of UHR and its potential for guiding CAS management in type 2 diabetes mellitus patients.

Data Sharing Statement

The datasets will be made available from the corresponding author upon reasonable request.

Ethical Statement

The study protocol adhered to the Declaration of Helsinki and received ethical approval from the Institutional Ethics Committee of Longyan First Affiliated Hospital of Fujian Medical University (Approval No. IC-2022-009). All participants provided written informed consent forms prior to enrollment.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that there are no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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