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Original Research Article

Association Between Carotid Intima-Media Thickness and Cardiovascular Risk Factors in Patients with Type 2 Diabetes Mellitus

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Abstract

Background: Type 2 Diabetes Mellitus (T2DM) is associated with accelerated atherosclerosis and increased cardiovascular morbidity and mortality. Carotid intima-media thickness (CIMT) is a recognized non-invasive marker of subclinical atherosclerosis and may help identify diabetic patients at increased cardiovascular risk.

Aim: To evaluate the association between carotid intima-media thickness (CIMT) and cardiovascular risk factors in patients with Type 2 Diabetes Mellitus and assess its usefulness as a marker of subclinical atherosclerosis.

Materials & Methods: This hospital-based cross-sectional observational study included 120 patients with T2DM. Demographic, clinical, anthropometric, and biochemical parameters were recorded. CIMT was measured using high-resolution B-mode ultrasonography. Associations between CIMT and cardiovascular risk factors were evaluated using independent t-tests, Pearson's correlation analysis, one-way ANOVA, and multiple linear regression. Statistical analysis was performed using IBM SPSS Statistics version 27.0, with $p < 0.05$ considered statistically significant.

Results: The mean age of the participants was 56.8 ± 9.4 years, and the mean duration of diabetes was 9.8 ± 5.7 years. The overall mean CIMT was 0.84 ± 0.16 mm. CIMT was significantly higher among males (0.87 ± 0.17 mm), hypertensive patients (0.91 ± 0.15 mm), patients with dyslipidemia (0.89 ± 0.16 mm), and smokers (0.92 ± 0.17 mm) compared to their counterparts ($p < 0.05$). CIMT showed significant positive correlations with age ($r=0.481$), duration of diabetes ($r=0.534$), BMI ($r=0.287$), systolic blood pressure ($r=0.446$), fasting blood glucose ($r=0.358$), HbA1c ($r=0.512$), total cholesterol ($r=0.376$), triglycerides ($r=0.343$), and LDL-C ($r=0.421$), while HDL-C demonstrated a significant negative correlation ($r=-0.268$) (all $p < 0.05$). CIMT increased progressively with worsening glycemic control and longer duration of diabetes ($p < 0.001$). Multiple linear regression identified duration of diabetes ($\beta=0.287$), HbA1c ($\beta=0.261$), age ($\beta=0.243$), hypertension ($\beta=0.205$), LDL-C ($\beta=0.182$), and smoking ($\beta=0.176$) as independent predictors of increased CIMT.

Conclusion: CIMT is significantly associated with both metabolic and traditional cardiovascular risk factors in patients with T2DM. Increased CIMT correlates with poor glycemic control, longer disease duration, hypertension, dyslipidemia, and smoking. CIMT may serve as a valuable, non-invasive tool for early detection of subclinical atherosclerosis and cardiovascular risk stratification in patients with Type 2 Diabetes Mellitus.

Keywords: Type 2 Diabetes Mellitus, Carotid Intima-Media Thickness, Cardiovascular Risk Factors, HbA1c, Dyslipidemia.

Introduction

Type 2 Diabetes Mellitus (T2DM) is one of the most prevalent chronic metabolic disorders worldwide and constitutes a major public health challenge. The disease is characterized by persistent hyperglycemia resulting from insulin resistance and progressive β-cell dysfunction, leading to microvascular and macrovascular complications. Cardiovascular disease (CVD) remains the leading cause of morbidity and mortality among patients with T2DM, accounting for a substantial proportion of diabetes-related deaths worldwide. According to the International Diabetes Federation, the global burden of diabetes continues to rise, with a significant increase in prevalence observed in both developed and developing countries, including India [1]. Atherosclerosis is the principal pathological process underlying most cardiovascular events in

patients with T2DM. Chronic hyperglycemia promotes endothelial dysfunction, oxidative stress, inflammation, vascular smooth muscle proliferation, and lipid abnormalities, all of which contribute to accelerated atherosclerotic changes [2]. These vascular alterations often begin long before the clinical manifestation of cardiovascular disease, emphasizing the need for reliable methods to detect subclinical atherosclerosis at an early stage.

Carotid intima-media thickness (CIMT), measured by high-resolution B-mode ultrasonography, is a well-established, non-invasive marker of early atherosclerotic vascular disease. CIMT reflects structural changes in the arterial wall and has been shown to correlate with future cardiovascular events, including myocardial infarction and stroke [3]. Due to its simplicity, reproducibility, and cost-effectiveness, CIMT has been widely utilized as a surrogate marker for cardiovascular risk assessment in both research and clinical settings.

Several investigators have reported increased CIMT among patients with T2DM compared with non-diabetic individuals. Lorenz et al. (2007) demonstrated that increased CIMT is associated with an elevated risk of future myocardial infarction and stroke, supporting its role as a predictor of cardiovascular events [4]. Hyperglycemia-induced vascular injury results in increased arterial wall thickness through mechanisms involving advanced glycation end-products, oxidative stress, and chronic low-grade inflammation [5]. Furthermore, diabetic dyslipidemia, characterized by elevated triglycerides, increased low-density lipoprotein cholesterol (LDL-C), and reduced high-density lipoprotein cholesterol (HDL-C), further accelerates atherogenesis [6]. Recent studies have continued to emphasize the clinical significance of CIMT in diabetic populations. Sibal et al. reported that increased CIMT is associated with both microvascular and macrovascular complications in patients with T2DM and may serve as an early indicator of generalized vascular damage [7]. In addition, contemporary cardiovascular risk assessment guidelines acknowledge the value of vascular imaging markers, including CIMT, in identifying high-risk individuals who may benefit from aggressive preventive interventions [8].

Aim & Objectives

Aim: To evaluate the association between carotid intima-media thickness (CIMT) and cardiovascular risk factors in patients with Type 2 Diabetes Mellitus (T2DM) and assess its utility as a marker of subclinical atherosclerosis.

Objectives

- To measure CIMT in patients with T2DM using ultrasonography.
- To assess the relationship of CIMT with demographic characteristics, duration of diabetes, glycemic control, and cardiovascular risk factors.
- To evaluate the association between CIMT and lipid profile parameters, including total cholesterol, triglycerides, LDL-C, and HDL-C.
- To identify independent predictors of increased CIMT using multivariate regression analysis.
- To evaluate the usefulness of CIMT as a non-invasive marker of subclinical atherosclerosis in patients with Type 2 Diabetes Mellitus.

Materials & Methods

Study Design: This hospital-based cross-sectional observational study was conducted to evaluate the association between carotid intima-media thickness (CIMT) and cardiovascular risk factors among patients with Type 2 Diabetes Mellitus (T2DM).

Study Place: The study was conducted in the Department of General Medicine at Swamy Vivekanandha Medical College Hospital & Research Institute, Namakkal, Tamilnadu, India.

Study Period: The study was carried out over a period of 12 months from October 2024 to September 2025.

Study Population: The study population comprised adult patients diagnosed with Type 2 Diabetes Mellitus attending the outpatient and inpatient services of the Department of General Medicine during the study period.

Sample Size: A total of 120 patients with Type 2 Diabetes Mellitus fulfilling the eligibility criteria were consecutively enrolled in the study.

Ethical Considerations: The study protocol was reviewed and approved by the Institutional Ethics Committee prior to commencement of the study. Written informed consent was obtained from all participants after explaining the purpose and procedures of the study. Confidentiality and anonymity of patient information were maintained throughout the study in accordance with the ethical principles of the Declaration of Helsinki.

Inclusion Criteria

Patients meeting the following criteria were included:

- Age ≥18 years.
- Diagnosed cases of Type 2 Diabetes Mellitus according to American Diabetes Association (ADA) criteria.
- Patients willing to participate and provide written informed consent.

Exclusion Criteria

Patients with any of the following conditions were excluded:

- Type 1 Diabetes Mellitus.
- Gestational diabetes mellitus.
- History of ischemic heart disease, myocardial infarction, stroke, or peripheral arterial disease.
- Known carotid artery stenosis or previous carotid surgery.
- Chronic kidney disease stage IV or V.
- Chronic inflammatory or autoimmune disorders.
- Active infection, malignancy, or severe systemic illness.
- Patients unwilling to participate in the study.

Methodology

After obtaining informed consent, detailed demographic and clinical information was collected using a predesigned case record form. Information regarding age, gender, duration of diabetes, smoking status, history of hypertension, and dyslipidemia was recorded.

Anthropometric measurements including height and weight were measured using standard techniques, and body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters (kg/m^2). Blood pressure was measured in the sitting position after adequate rest using a calibrated sphygmomanometer, and the average of two readings was recorded.

All enrolled participants underwent laboratory investigations and carotid ultrasonography for assessment of CIMT.

Carotid Ultrasonography Procedure: Carotid intima-media thickness was assessed using high-resolution B-mode ultrasonography with a linear-array transducer operating at 7–12 MHz. Participants were examined in the supine position with slight neck extension and head rotation opposite to the side being scanned. The far wall of the common carotid artery, approximately 1 cm proximal to the carotid bulb, was evaluated bilaterally. CIMT was measured as the distance between the leading edge of the lumen-intima interface and the leading edge of the media-adventitia interface. Three measurements were obtained from each side, and the average value was calculated and recorded as the mean CIMT.

All examinations were performed by an experienced radiologist blinded to the clinical and laboratory characteristics of the participants.

Laboratory Investigations: All participants underwent routine laboratory evaluation, including complete blood count (CBC), fasting blood glucose (FBG), glycated hemoglobin (HbA1c), serum urea, serum creatinine, serum electrolytes, urine routine microscopy, urinary albumin/protein estimation, and lipid profile assessment comprising total cholesterol, triglycerides, low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C).

Venous blood samples were collected after an overnight fast of at least 8–10 hours and analyzed in the central laboratory using standardized methods.

Outcome Measures

Primary Outcome: Mean carotid intima-media thickness (CIMT) measured by B-mode ultrasonography.

Secondary Outcomes

- Association of CIMT with age, gender, duration of diabetes, BMI, blood pressure, fasting blood glucose, and HbA1c.
- Association of CIMT with cardiovascular risk factors including hypertension, dyslipidemia, and smoking.
- Correlation of CIMT with lipid profile parameters.
- Identification of independent predictors of increased CIMT using multivariate regression analysis.

Statistical Analysis: Data were entered into Microsoft Excel 365 and analyzed using IBM SPSS Statistics for Windows, Version 27.0 (IBM Corp., Armonk, NY, USA).

Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages.

The normality of data distribution was assessed using the Shapiro–Wilk test. Comparisons between two groups were performed using the independent samples t-test for normally distributed continuous variables. Comparisons among more than two groups were conducted using one-way analysis of variance (ANOVA). Pearson's correlation coefficient (r) was used to evaluate the relationship between CIMT and continuous clinical and biochemical variables, including age, duration of diabetes, BMI, blood pressure, fasting blood glucose, HbA1c, and lipid profile parameters.

Variables demonstrating significant association with CIMT on univariate analysis were entered into a multiple linear regression model to identify independent predictors of increased CIMT. Standardized beta (β) coefficients, standard errors, t-values, and p-values were calculated.

A two-tailed p-value of less than 0.05 was considered statistically significant

Results

A total of 120 patients with Type 2 Diabetes Mellitus were enrolled.

Table 1: Demographic and Clinical Characteristics of Study Participants (n = 120)

Variable	Mean ± SD / n (%)
Age (years)	56.8 ± 9.4
Male	70 (58.3)
Female	50 (41.7)
Duration of Diabetes (years)	9.8 ± 5.7
BMI (kg/m²)	27.4 ± 3.8
Systolic BP (mmHg)	136.5 ± 15.8
Diastolic BP (mmHg)	84.2 ± 9.6
Fasting Blood Glucose (mg/dL)	156.4 ± 42.8
HbA1c (%)	8.4 ± 1.5
Total Cholesterol (mg/dL)	202.6 ± 38.7
Triglycerides (mg/dL)	184.3 ± 59.4
LDL-C (mg/dL)	126.7 ± 31.5
HDL-C (mg/dL)	42.8 ± 8.6
Mean CIMT (mm)	0.84 ± 0.16
Hypertension	68 (56.7)
Dyslipidemia	74 (61.7)
Smoking History	32 (26.7)

Table 1 show the mean age of the participants was 56.8 ± 9.4 years. Of the 120 patients, 70 (58.3%) were males and 50 (41.7%) were females. The mean duration of diabetes was 9.8 ± 5.7 years, while the mean body mass index (BMI) was 27.4 ± 3.8 kg/m².

The mean systolic and diastolic blood pressures were 136.5 ± 15.8 mmHg and 84.2 ± 9.6 mmHg, respectively. The mean fasting blood glucose level was 156.4 ± 42.8 mg/dL, and the mean HbA1c was 8.4 ± 1.5%. Regarding lipid parameters, the mean total cholesterol, triglycerides, LDL-C, and HDL-C levels were 202.6 ± 38.7 mg/dL, 184.3 ± 59.4 mg/dL, 126.7 ± 31.5 mg/dL, and 42.8 ± 8.6 mg/dL, respectively.

The overall mean carotid intima-media thickness (CIMT) was 0.84 ± 0.16 mm. Hypertension was present in 68 (56.7%) patients, dyslipidemia in 74 (61.7%) patients, and a history of smoking was reported by 32 (26.7%) patients.

Table 2: Comparison of CIMT According to Demographic and Cardiovascular Risk Factors

Characteristics	Variable	n	CIMT (mm) Mean ± SD	p-value
Gender	Male	70	0.87 ± 0.17	0.041*
	Female	50	0.80 ± 0.14	
Hypertension	Present	68	0.91 ± 0.15	<0.001*
	Absent	52	0.75 ± 0.12	
Dyslipidemia	Present	74	0.89 ± 0.16	<0.001*
	Absent	46	0.76 ± 0.13	
Smoking Status	Smokers	32	0.92 ± 0.17	<0.001*
	Non-Smokers	88	0.81 ± 0.14	

*Independent t-test

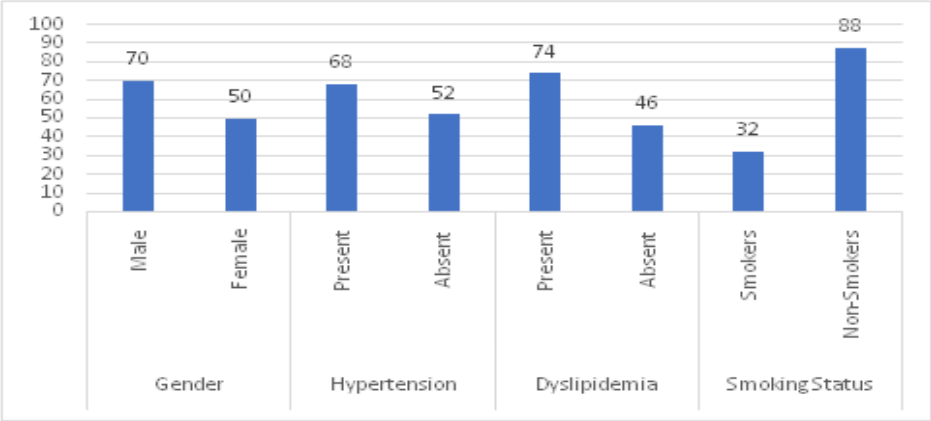

Figure 1: Comparison of CIMT According to Demographic

Table 2 show male patients exhibited significantly higher CIMT values compared to female patients (0.87 ± 0.17 mm vs. 0.80 ± 0.14 mm, p = 0.041). Patients with hypertension had significantly greater CIMT than those without hypertension (0.91 ± 0.15 mm vs. 0.75 ± 0.12 mm, p < 0.001). Similarly, patients with dyslipidemia demonstrated significantly higher CIMT values compared to those without dyslipidemia (0.89 ± 0.16 mm vs. 0.76 ± 0.13 mm, p < 0.001).

Smokers also showed significantly increased CIMT compared to non-smokers (0.92 ± 0.17 mm vs. 0.81 ± 0.14 mm, p < 0.001), indicating a strong association between traditional cardiovascular risk factors and subclinical atherosclerosis.

Table 3: Correlation of CIMT with Continuous Variables

Variable	Pearson Correlation (r)	p-value
Age	0.481	<0.001*
Duration of Diabetes	0.534	<0.001*
BMI	0.287	0.002*
Systolic BP	0.446	<0.001*
Diastolic BP	0.291	0.001*
Fasting Blood Glucose	0.358	<0.001*
HbA1c	0.512	<0.001*
Total Cholesterol	0.376	<0.001*
Triglycerides	0.343	<0.001*
LDL-C	0.421	<0.001*
HDL-C	-0.268	0.003*

*Pearson correlation test

Table 3 present, CIMT demonstrated a significant positive correlation with age (r = 0.481, p < 0.001), duration of diabetes (r = 0.534, p < 0.001), BMI (r = 0.287, p = 0.002), systolic blood pressure (r = 0.446, p < 0.001), and diastolic blood pressure (r = 0.291, p = 0.001). Significant positive correlations were also observed between CIMT and fasting blood glucose (r = 0.358, p < 0.001) as well as HbA1c levels (r = 0.512, p < 0.001), suggesting that poor glycemic control is associated with increased arterial wall thickness. Furthermore, CIMT showed significant positive correlations with total cholesterol (r = 0.376, p < 0.001), triglycerides (r = 0.343, p < 0.001), and LDL-C (r = 0.421, p < 0.001). In contrast, HDL-C exhibited a significant negative correlation with CIMT (r = -0.268, p = 0.003), indicating a protective effect of higher HDL-C levels against atherosclerotic changes.

Table 4: CIMT According to Glycemic Control Categories

HbA1c Category	n	CIMT (mm) Mean ± SD	p-value
<7.0%	28	0.69 ± 0.11	<0.001*
7.0–8.9%	54	0.83 ± 0.12	
≥9.0%	38	0.98 ± 0.15	

*One-way ANOVA

Table 4 presents the patients with HbA1c values below 7.0% had the lowest mean CIMT (0.69 ± 0.11 mm), whereas those with HbA1c levels between 7.0% and 8.9% had a mean CIMT of 0.83 ± 0.12 mm. Patients with poor glycemic control (HbA1c ≥9.0%) exhibited the highest CIMT values (0.98 ± 0.15 mm). The difference among the three groups was statistically significant (p < 0.001), demonstrating a progressive increase in CIMT with worsening glycemic control.

Table 5: CIMT According to Duration of Diabetes

Duration (Years)	n	CIMT (mm) Mean ± SD	p-value
<5 Years	30	0.71 ± 0.11	<0.001*
5–10 Years	46	0.83 ± 0.12	
>10 Years	44	0.96 ± 0.15	

*One-way ANOVA

Table 5 show that patients with diabetes duration of less than 5 years had a mean CIMT of 0.71 ± 0.11 mm, while those with a duration of 5–10 years had a mean CIMT of 0.83 ± 0.12 mm. The highest CIMT values were observed among patients with diabetes duration exceeding 10 years (0.96 ± 0.15 mm). The difference was statistically significant (p < 0.001), indicating that longer duration of diabetes is associated with greater carotid arterial wall thickening and increased atherosclerotic burden.

Table 6: Multiple Linear Regression Analysis for Predictors of Increased CIMT

Variable	β Coefficient	Standard Error	t-value	p-value
Age	0.243	0.004	3.28	0.001*
Duration of Diabetes	0.287	0.006	4.11	<0.001*
HbA1c	0.261	0.012	3.74	<0.001*
LDL-C	0.182	0.001	2.68	0.008*
Hypertension	0.205	0.029	3.01	0.003*
Smoking	0.176	0.032	2.52	0.013*

Table 6 demonstrate that duration of diabetes emerged as the strongest independent predictor of CIMT (β = 0.287, p < 0.001), followed by HbA1c (β = 0.261, p < 0.001) and age (β = 0.243, p = 0.001). Hypertension (β = 0.205, p = 0.003), LDL-C (β = 0.182, p = 0.008), and smoking status (β = 0.176, p = 0.013) were also found to be significant independent determinants of increased CIMT. These findings suggest that both metabolic and traditional cardiovascular risk factors contribute significantly to carotid atherosclerosis in patients with Type 2 Diabetes Mellitus.

Discussion

The present study included 120 patients with Type 2 Diabetes Mellitus (T2DM), with a mean age of 56.8 ± 9.4 years and a predominance of male participants (58.3%). The mean duration of diabetes was 9.8 ± 5.7 years, while the mean HbA1c level was 8.4 ± 1.5%, indicating suboptimal glycemic control in a substantial proportion of patients. The mean CIMT was 0.84 ± 0.16 mm, suggesting the presence of subclinical atherosclerotic changes in this diabetic population.These findings are consistent with those reported by Wu et al. (2023), who observed that patients with T2DM and increased cardiovascular risk factors frequently exhibited abnormal CIMT measurements, indicating early vascular damage before the onset of overt cardiovascular disease [9].

The high prevalence of hypertension (56.7%) and dyslipidemia (61.7%) observed in the present study further reflects the clustering of cardiovascular risk factors commonly encountered in T2DM. Martins et al. (2023) reported that diabetic patients frequently exhibit multiple coexisting cardiovascular risk factors that contribute synergistically to vascular remodeling and atherosclerotic progression [10].

The present study demonstrated significantly higher CIMT values among male patients compared to female patients (p = 0.041). Gender-related differences in vascular remodeling have been reported previously, with males often exhibiting greater exposure to cardiovascular risk factors and lower vascular protection associated with estrogen deficiency. Lu et al. (2024) demonstrated gender-specific associations between metabolic dysfunction and CIMT in patients with T2DM, reporting significantly greater carotid arterial thickening among men [11].

Hypertension was strongly associated with increased CIMT in the current study. Patients with hypertension exhibited significantly greater CIMT values than normotensive individuals (0.91 ± 0.15 mm versus 0.75 ± 0.12 mm; p < 0.001). Elevated blood pressure contributes to endothelial injury, increased arterial stiffness, and smooth muscle proliferation, resulting in progressive arterial wall thickening. Similar observations were reported by Wu et al. (2023), who identified hypertension as a major determinant of abnormal CIMT in diabetic populations [9].

Dyslipidemia also demonstrated a significant association with CIMT. Patients with dyslipidemia had significantly greater carotid wall thickness compared with those without dyslipidemia (p < 0.001). Mashaba et al. (2024) reported that abnormalities in lipid metabolism are consistently associated with increased CIMT and accelerated atherosclerotic changes in T2DM patients [12]. Elevated concentrations of atherogenic lipoproteins promote lipid deposition within the vascular wall and stimulate inflammatory pathways involved in plaque formation.

Smoking emerged as another important determinant of CIMT in the present study. Smokers exhibited significantly greater CIMT values than non-smokers (0.92 ± 0.17 mm versus 0.81 ± 0.14 mm; p < 0.001). Smoking induces oxidative stress, endothelial dysfunction, inflammation, and enhanced thrombogenicity, all of which accelerate atherosclerotic progression. These findings are consistent with previous contemporary investigations demonstrating significantly higher carotid arterial thickness among diabetic smokers compared with non-smokers [10].

The present study demonstrated significant positive correlations between CIMT and age, duration of diabetes, BMI, blood pressure parameters, fasting blood glucose, HbA1c, total cholesterol, triglycerides, and LDL-C, while HDL-C showed a significant negative correlation.

Age demonstrated a moderate positive correlation with CIMT (r = 0.481, p < 0.001). Increasing age is associated with cumulative vascular injury, endothelial dysfunction, and progressive arterial

stiffening. Similar findings were reported by Martins et al. (2023), who observed a significant age-dependent increase in carotid vascular abnormalities among patients with T2DM [10].

Duration of diabetes showed the strongest correlation with CIMT ($r = 0.534$, $p < 0.001$). Chronic exposure to hyperglycemia promotes the formation of advanced glycation end-products, oxidative stress, and inflammation, leading to progressive arterial wall thickening. Chen et al. (2023) similarly reported a significant relationship between long-term glycemic exposure and carotid atherosclerosis [13].

The positive correlation between BMI and CIMT ($r = 0.287$, $p = 0.002$) highlights the role of obesity-related metabolic disturbances in vascular disease. Excess adiposity contributes to insulin resistance, systemic inflammation, and endothelial dysfunction, thereby accelerating atherosclerotic processes. Blood pressure parameters also demonstrated significant correlations with CIMT. Systolic blood pressure showed a stronger association ($r = 0.446$) than diastolic blood pressure ($r = 0.291$), suggesting that increased arterial pressure contributes substantially to vascular remodeling. These findings are consistent with those reported by Wu et al. (2023) [9].

Poor glycemic control emerged as an important determinant of CIMT. Both fasting blood glucose and HbA1c demonstrated significant positive correlations with CIMT, with HbA1c exhibiting one of the strongest associations ($r = 0.512$, $p < 0.001$). Chen et al. (2023) demonstrated that HbA1c variability and chronic hyperglycemia are independently associated with increased CIMT and carotid plaque formation in patients with T2DM [13]. Their findings strongly support the relationship observed in the present study.

Regarding lipid parameters, total cholesterol, triglycerides, and LDL-C showed significant positive correlations with CIMT, whereas HDL-C demonstrated a significant inverse relationship. Similar findings were reported by Liu et al. (2024), who observed that adverse lipid parameters contribute significantly to carotid arterial thickening in T2DM patients [14]. The negative association between HDL-C and CIMT may reflect the anti-inflammatory, antioxidant, and reverse cholesterol transport properties of HDL particles.

The present study demonstrated a progressive increase in CIMT across worsening HbA1c categories. Patients with HbA1c <7% had the lowest CIMT values (0.69 ± 0.11 mm), whereas those with HbA1c ≥9% exhibited the highest CIMT values (0.98 ± 0.15 mm), with a highly significant difference among groups ($p < 0.001$).These findings suggest that poor glycemic control contributes directly to the progression of subclinical atherosclerosis. Persistent hyperglycemia promotes oxidative stress, endothelial dysfunction, inflammation, and advanced glycation end-product accumulation, resulting in arterial wall thickening. Chen et al. (2023) demonstrated that elevated HbA1c levels and increased HbA1c variability were independently associated with greater CIMT and carotid plaque burden in patients with T2DM [13]. Similar conclusions have been reported in recent diabetic vascular studies, highlighting the importance of maintaining optimal glycemic control to reduce cardiovascular risk.

A significant increase in CIMT was observed with increasing duration of diabetes. Patients with disease duration greater than 10 years exhibited the highest CIMT values (0.96 ± 0.15 mm), whereas those with duration less than 5 years had significantly lower CIMT values (0.71 ± 0.11 mm).This finding emphasizes the cumulative vascular impact of chronic diabetes. Long-standing hyperglycemia leads to progressive endothelial injury, vascular inflammation, and arterial remodeling. Martins et al. (2023) reported that prolonged diabetes duration was strongly associated with greater carotid vascular abnormalities and coronary calcification [10].

Multivariate regression analysis identified duration of diabetes, HbA1c, age, hypertension, LDL-C, and smoking status as independent predictors of increased CIMT. Among all variables, duration of diabetes emerged as the strongest predictor ($\beta = 0.287$, $p < 0.001$), indicating that prolonged exposure to diabetic metabolic abnormalities plays a central role in atherosclerotic progression. HbA1c was the second strongest predictor, further emphasizing the importance of glycemic control in preventing vascular complications. Age remained an independent determinant of CIMT, reflecting cumulative vascular aging.

Hypertension and smoking also retained statistical significance after adjustment, confirming their independent contribution to carotid arterial remodeling. LDL-C remained a significant predictor, highlighting the critical role of dyslipidemia in atherosclerotic progression. These findings are consistent with the observations of Liu et al. (2024), who reported that glycemic status, lipid abnormalities, blood pressure, and smoking independently influence carotid vascular structure in diabetic populations [14].

Limitations of the Study

- The sample size of 120 patients, although adequate for statistical analysis, may not fully represent the heterogeneity of patients with Type 2 Diabetes Mellitus.
- CIMT measurements were obtained at a single point in time, preventing assessment of

progression of atherosclerotic changes over time.

- Potential confounding factors such as physical activity, dietary habits, socioeconomic status, medication adherence, and family history of cardiovascular disease were not comprehensively evaluated.
- The study did not include a non-diabetic control group for comparison of CIMT values.
- Other markers of subclinical atherosclerosis, such as coronary artery calcium score, pulse wave velocity, or endothelial function assessment, were not evaluated.
- Long-term cardiovascular outcomes were not assessed; therefore, the predictive value of increased CIMT for future cardiovascular events could not be determined.

Conclusion

The present study demonstrated carotid intima-media thickness (CIMT) was significantly associated with multiple cardiovascular risk factors in patients with Type 2 Diabetes Mellitus, including age, duration of diabetes, poor glycemic control, hypertension, dyslipidemia, smoking, and adverse lipid parameters. CIMT increased progressively with worsening HbA1c levels and longer disease duration. Multivariate analysis identified duration of diabetes, HbA1c, age, hypertension, LDL-C, and smoking as independent predictors of increased CIMT. These findings support the use of CIMT as a simple, non-invasive marker for the early detection of subclinical atherosclerosis and cardiovascular risk stratification in patients with Type 2 Diabetes Mellitus.

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