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Frequency of Increased Intimal-Medial Thickness in Patients with Type 2 Diabetes and Ischemic Stroke

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ABSTRACT

Background: Type 2 diabetes mellitus is strongly associated with macrovascular complications including ischemic stroke and is a rapidly growing health concern globally. Carotid intimal media thickness has been recognized as a reliable, noninvasive marker of early vascular changes and subclinical atherosclerosis often introduces clinically apparent cerebrovascular events. There is a scarcity of region-specific data from South Asia, particularly Pakistan, where genetic predisposition, lifestyle factors, and healthcare disparities may affect vascular risk, while international studies have explored carotid intimal media thickness (C-IMT) in diabetic populations. **Objective:** To determine the frequency of increased C-IMT in patients with type 2 diabetes mellitus (T2DM) presenting with acute ischemic stroke was the aim of this study was in Pakistan and to explore the metabolic factors and clinical associated with this subclinical vascular marker. **Methods:** This cross-sectional study was conducted in the Department of Diagnostic Radiology at Lahore General Hospital, Lahore, over a 6-month period. After fulfilling inclusion and exclusion criteria, a total of 100 patients aged 30 to 70 years, diagnosed with T2DM and presenting with first ever, radiologically confirmed acute ischemic stroke were enrolled in this study. For recruitment non probability consecutive sampling was used. Clinical variables and sociodemographic like age, gender, body mass index (BMI), hypertension, smoking status, and duration of diabetes, were recorded. HbA1c, fasting lipid profile, and serum creatinine laboratory investigations that performed. In both common carotid arteries, avoiding plaque regions Carotid IMT was measured using a Philips EPIQ 7G ultrasound machine with a 12–3 MHz linear transducer, at three standardized points. Increased IMT was defined as a mean value >0.9 mm. Using SPSS v26, employing descriptive statistics, comparative tests (Chi-square), and correlation analyses (Pearson) with significance set at $p<0.05$ statistical analysis was conducted. **Results:** Among diabetic stroke patients, the study revealed that a significant majority of participants exhibited increased C-IMT, showing a high prevalence of subclinical carotid atherosclerosis. With increased IMT age, poor glycemic control (elevated HbA1c), dyslipidemia (high triglycerides and low HDL cholesterol), hypertension, and longer duration of diabetes were found to be significantly associated. In this cohort study, the observed frequency was higher than reports from other countries, potentially reflecting genetic susceptibility, suboptimal diabetes management, delayed healthcare access, and lifestyle factors unique to the Pakistani population. **Conclusions:** In this high-risk population, increased C-IMT is highly prevalent among Pakistani patients with T2DM presenting with acute ischemic stroke, emphasizing the silent yet progressive nature of subclinical atherosclerosis. For early vascular changes, the study supports the value of C-IMT as a non-invasive marker and underscores the importance of comprehensive risk assessment in diabetic patients.

INTRODUCTION

Across diverse regions and populations, Type 2 diabetes mellitus has evolved into a global health epidemic and is climbing steadily. It is well recognized for its main impact on the vascular system, contributing significantly to macrovascular complications beyond impaired glucose regulation. Diabetic individuals particularly are more vulnerable to structural arterial changes due to persistent hyperglycemia, insulin resistance, and metabolic disturbances, which accelerate endothelial dysfunction and promote the early development of atherosclerosis [1, 2]. Carotid intimal medial thickness (IMT) is one of the

most widely studied markers of these changes, a non-invasive indicator that reflects early atherosclerotic remodeling long before clinical symptoms occur. The risk of major cardiovascular events increases as IMT thickens, creating a crucial link between diabetes and future vascular disease [3].

Ischemic stroke stands out as one of the most serious and disabling outcomes among the macrovascular consequences of diabetes. Accelerated atherosclerotic plaque formation, altered coagulation profiles, increased arterial stiffness, and chronic inflammatory activity is found in diabetic individuals, all of which enhances the likelihood of cerebrovascular occlusion [4]. As compared to non-diabetic populations, this elevated risk means that individuals with T2DM often experience stroke at a younger age and with more severe complications. Increased IMT further enhances this vulnerability, serving as a valuable marker to identify diabetic patients at elevated risk of ischemic events [5, 6].

The public health implications of this association are particularly alarming in Pakistan. Urbanization, sedentary lifestyles, dietary patterns high in carbohydrates and fats, genetic susceptibility, and limited awareness regarding preventive care are the factors, which contribute to Type 2 diabetes in the region [7]. The incidence of ischemic stroke is rising, placing substantial strain on the healthcare system at the same time. Many individuals present late to healthcare facilities, so vascular risk delays due to limited access to advanced diagnostic tools. These factors create a population in which early identification of subclinical atherosclerosis such as increased IMT is both critically important and highly relevant. More effective screening strategies and inform targeted preventive measures tailored to the country's unique epidemiological and sociocultural landscape can be achieved by understanding how frequently IMT is elevated among diabetic stroke patients in Pakistan [8].

Over recent decades, the worldwide burden of type 2 diabetes mellitus has expanded substantially, transforming it from a metabolic disorder into a major public health emergency. Continuous rise in the number of individuals living with diabetes, driven by aging populations, rapid urbanization, and lifestyle patterns characterized by physical inactivity and unhealthy diets is indicated by current global trends [9]. This rise has resulted causes diabetes related complications, particularly those involving large blood vessels. Among diabetic populations, macrovascular complications, including coronary artery disease, peripheral arterial disease, and cerebrovascular events, account for a significant proportion of morbidity and mortality [10]. Progressive impact of diabetes on vascular health occur due to these outcomes, where early structural changes such as increased carotid intimal medial thickness often come before clinically evident events [11].

Ischemic stroke represents one of the most severe and debilitating consequences of type 2 diabetes among these complications. Individuals with diabetes faces higher risks of stroke compared to the general population. Within major cerebral and carotid arteries, chronic hyperglycemia impairs endothelial function, increases arterial stiffness, and accelerates the development of atherosclerotic lesions [12]. Among diabetic individuals, this pathological environment favors thrombus formation and vascular occlusion, contributing to higher stroke incidence and worse outcomes. These vascular changes begin long before stroke occurs, and measuring IMT provides a valuable window into recognizing such early arterial changes in many cases [13].

In Pakistan, the situation is even more concerning where both diabetes and stroke are rising at alarming rates. Pakistan ranks among the countries with the highest number of adults living with Type 2 diabetes. T2DM is now a trend fueled by a combination of genetic predisposition, widespread consumption of calorie dense diets, low physical activity levels, and limited preventative healthcare practices [14]. The individuals at younger ages are affected by the incidence of ischemic stroke as it continues to grow, and imposing a heavy socioeconomic burden. These issues are further compounded by limited access to healthcare and underdiagnosis of early vascular disease, and limited availability of routine screening tools such as carotid IMT assessment. Until major events occur, these factors create a setting where vascular complications frequently go unnoticed. In Pakistan, understanding the burden of increased IMT among diabetic stroke patients becomes highly relevant, offering essential insights for early detection, risk stratification, and development of targeted public health programs [15].

Complex vascular changes which are induced by chronic metabolic disturbances are the roots of pathophysiological connection between type 2 diabetes mellitus and ischemic stroke. In accelerating atherosclerosis persistent hyperglycemia and insulin resistance play a major role. Fatty streaks and fibrous plaques are formed within arterial walls by elevated glucose levels promote endothelial dysfunction, increased oxidative stress, and trigger inflammatory pathways [16]. By altering lipid metabolism, increasing circulating triglycerides, reduced high density lipoprotein cholesterol and insulin resistance further compounds these effects, thereby enhancing the deposition of lipids within the vascular intimal. Eventually, diabetic individuals become susceptible to occlusive cerebrovascular disease by these processes which accelerate structural remodeling of arteries [10].

Clinically, ischemic stroke often appears as the earliest recognizable sign of this silent vascular disease. It often goes undetected until a major cerebrovascular event occurs, and many patients remain asymptomatic despite of significant subclinical atherosclerosis. How to identify high risk individuals before catastrophic outcomes, this presents a critical challenge for healthcare providers. For timely intervention and risk reduction early recognition of vascular changes in diabetic patients is therefore essential [17].

For subclinical atherosclerosis, Carotid intimal media thickness (C-IMT) has emerged as a well-established, non-invasive, and reliable ultrasonographic marker. C-IMT provides a direct assessment of early structural arterial changes that precede clinically apparent plaque formation, by measuring the combined thickness of the intimal and medial layers of the carotid artery. Thickening of the carotid intimal media indicates lipid accumulation, smooth muscle growth, and fibrosis, giving an early view of

atherosclerosis. For identifying diabetic individuals at increased risk of ischemic stroke, long before symptoms develops its reproducibility, ease of measurement, and ability to detect subtle changes in vascular architecture make C-IMT a valuable tool [18].

There still remains a notable scarcity of data from South Asian countries, particularly from Pakistan, although carotid intimal media thickness (C-IMT) has been extensively studied in Western and other global populations. Most of the existing literature focuses on genetic backgrounds, lifestyle factors, and healthcare environments of European, North American, or East Asian cohorts, which differs significantly from those in South Asia. Our understanding of how diabetes related vascular changes present in Pakistani patients limits by this lack of region-specific evidence, who may present with distinct risk profiles [19].

Because of ethnic variations and population specific risk factors, which can influence both the progression of atherosclerosis and the prevalence of ischemic stroke among diabetic individuals' data from Pakistan is especially crucial. Cardiovascular risk increases due to factors such as dietary patterns rich in carbohydrates and fats, higher rates of central obesity, genetic predispositions, and limited access to preventive healthcare [20]. Additionally, the South Asian context becomes different from other regions due to differences in screening practices, delayed diagnosis, and variations in clinical management. Interpreting these subtle variations is essential for developing targeted strategies for early detection and treatment [21].

The frequency and extent of increased IMT in high-risk cohorts of diabetic stroke patients in Pakistan remain poorly documented, despite the recognized utility of C-IMT as a non-invasive marker of subclinical atherosclerosis. This shows a major gap in knowledge, because detecting vascular changes early can greatly improve how patients are managed, how risks are assessed, and how preventive measures are applied. By evaluating the prevalence of increased carotid intimal media thickness in patients with type 2 diabetes who have experienced ischemic stroke, providing valuable insights into subclinical atherosclerosis within this high-risk population, the present study seeks to address this gap [22, 23].

The present study was designed to fill this critical knowledge gap by building the established link between type 2 diabetes, atherosclerosis, ischemic stroke, and considering the lack of region-specific data from Pakistan. At a tertiary care hospital in Pakistan, the primary objective of this study was to determine the frequency of increased carotid intimal media thickness in patients with type 2 diabetes mellitus presenting with acute ischemic stroke. The study also aims to highlight the potential role of C-IMT in early risk stratification and preventive strategies within this high-risk population by assessing this subclinical marker [24].

METHODOLOGY

Study Design

This research is conducted as a cross-sectional study, designed to evaluate the frequency of increased carotid intimal media thickness (C-IMT) among patients with type 2 diabetes mellitus (T2DM) presenting with acute ischemic stroke. A cross-sectional design was chosen because at a single point in time, it allows for the simultaneous assessment of structural vascular changes and metabolic risk factors in a defined patient cohort. Without the distorting influence of long-term therapeutic interventions, this approach provides a snapshot of the prevalence of subclinical atherosclerosis and enables the identification of potential associations between diabetes, vascular remodeling, and cerebrovascular outcomes.

For risk stratification, the cross-sectional design is particularly suitable for populations, where rapid assessment is critical factor. This study intends to offer meaningful insights into the burden of early atherosclerotic changes in diabetic patients by capturing data during the acute phase of stroke and to provide evidence for future preventive and interventional strategies.

Setting and Duration

The study was carried out in the Department of Diagnostic Radiology, Lahore General Hospital, Lahore (a tertiary care center recognized for providing comprehensive neurological and radiological services) from the period of 22nd November 2024 to 25th April 2025. For patients with cerebrovascular diseases and diabetes, this hospital serves as a major referral hub. It was an ideal location to examine the coexistence of metabolic and vascular pathology. Using standardized ultrasonographic protocols, the availability of advanced imaging facilities and experienced radiologists ensures accurate assessment of carotid intimal media thickness.

After approval of the study synopsis, the study was planned to run for five months providing adequate time to recruit a representative sample while ensuring the practicality of data collection. Conducting the study across this period captures patients from different seasons, helping to reduce systematic error from seasonal fluctuations in hospital admissions.

Sample Size and Sampling

For this study, the sample size was calculated using statistical software, considering a 95% confidence level, a 5% margin of error, and an expected frequency of increased intimal medial thickness of 92.5% among diabetic patients with acute ischemic stroke, based on previous literature. This calculation ensured a sufficient number of participants to detect meaningful associations and provide statistically strong results.

Participants were recruited consecutively from the neurology and radiology departments, including all eligible patients until the intended sample size is reached. This approach guarantees systematic enrollment of patients, which accurately reflects the hospital population and minimize the selection bias. Where patient flow was variable and rapid enrolment was needed to capture routine clinical practice, this approach is well suited to acute stroke settings.

Participants (Inclusion/Exclusion Criteria)

Inclusion Criteria:

- Patients aged 30–70 years.

- Both male and female patients.
- Diagnosed with type 2 diabetes mellitus according to established criteria.
- Patients presenting with ischemic stroke, as defined by the operational criteria for acute cerebrovascular events, confirmed by clinical assessment and neuroimaging.

Exclusion Criteria:

- Patients with known carotid artery disease, including those with prior significant stenosis diagnosed by imaging.
- Patients who have undergone carotid endarterectomy or other surgical interventions affecting the carotid arteries.
- Any patient in whom accurate assessment of carotid intima-media thickness (C-IMT) is not feasible due to technical limitations or poor imaging windows.

The study ensures the inclusion of a homogeneous cohort of high-risk individuals by applying these criteria, while minimizing potential confounding factors related to pre-existing carotid pathology. Among diabetic patients, this allows for a more accurate evaluation of the prevalence and characteristics of increased intimal medial thickness experiencing their first ischemic stroke.

Data Collection

Sociodemographic and Clinical Variables

Data on demographic and clinical characteristics of participants is systematically collected. This includes:

- Age (years)
- Gender (male/female)
- Body Mass Index (BMI)
- Smoking history (current, former, never)
- Hypertension status (yes/no, controlled / uncontrolled)
- Duration of diabetes (years since diagnosis)

These variables helped characterize the study population and allow for analysis of potential correlations between demographic/clinical factors and carotid intimal media thickness.

Laboratory Investigations

Baseline laboratory investigations include:

- Glycated hemoglobin (HbA1c), measured using high-performance liquid chromatography (HPLC) to assess long-term glycemic control.
- Fasting lipid profile, including total cholesterol, low-density lipoprotein (LDL), high-density lipoprotein (HDL), and triglycerides.
- Serum creatinine and other relevant biochemical parameters to assess renal function and metabolic status.

These investigations provided insight into the metabolic and vascular risk profile of each participant, which may influence the extent of subclinical atherosclerosis.

Data Collection Procedure

100 patients meeting the inclusion and exclusion criteria were enrolled in the study following approval from the Hospital Ethical Committee. Prior to data collection Written informed consent is obtained from each participant.

Demographic and clinical information, including name, age, BMI, address, smoking status, hypertension, and duration of diabetes, is recorded on a pre designed proforma.

Ultrasound assessment of carotid intimal media thickness was performed in the Department of Diagnostic Radiology, Lahore General Hospital, Lahore, under the supervision of residents with at least four years of FCPS radiology training. The IMT of both common carotid arteries (CCAs) is measured at three specific sites:

1. The thickest point of the artery.
2. One centimeter upstream from the thickest point.
3. One centimeter downstream from the thickest point.

All measurements were taken in the longitudinal view using Digimatic calipers, ensuring precision and reproducibility. Areas containing plaque is avoided to accurately reflect the intimal medial thickness.

For this study, the frequency of increased intimal medial thickness is labeled according to the operational definition established. All data, including sociodemographic information, clinical characteristics, laboratory results, and ultrasound findings, is systematically recorded on the pre designed proforma for analysis.

Carotid IMT Measurement

Equipment: Philips EPIQ 7G ultrasound machine equipped with a 12–3 MHz linear array transducer was used to measure Carotid intimal media thickness (C-IMT), which provides high resolution imaging of superficial arteries. Precise visualization of the intimal and medial layers of the carotid artery, which ensures accurate and reproducible measurements is obtained by this machine. To optimize image quality all scans were conducted in a dedicated radiology suite with controlled lighting and minimal external interference

Procedure: For clear access to the carotid arteries, participants were positioned in a supine position with the neck slightly extended and turned away from the side being examined. The left and right both common carotid arteries (CCAs) were scanned. C-IMT was measured in the far wall of the distal CCA a standardized site, approximately 1 cm proximal to the carotid bulb, that minimizes variability and has been validated in prior studies as representative of early atherosclerotic changes. Care was taken to avoid regions containing plaques, tortuous segments, or artifacts that could interfere with measurement accuracy during the procedure. To visualize the intimal media interface clearly the longitudinal view of the artery was used, and the measurements were recorded using Digimatic calipers integrated into the ultrasound system.

All scans were performed under the supervision of radiology residents with a minimum of four years of training in FCPS radiology, ensuring consistency and adherence to standardized protocols.

Measurement Protocol

For each CCA, three measurements were taken at defined points:

1. The thickest point of the distal CCA.
2. One centimeter proximal to the thickest point.
3. One centimeter distal to the thickest point.

The mean of these three measurements per side was calculated, providing a representative value for the left and right carotid arteries. From both sides, the final C-IMT value for each participant was then determined as the mean of the maximum values ensuring that regional differences did not distort the overall evaluation. This method provides a reliable and reproducible estimate of subclinical atherosclerosis.

Definition of 'Increased IMT': For the purposes of this study, increased carotid intimal media thickness was defined as a mean C-IMT value greater than 0.9 mm, based on internationally recognized guidelines for subclinical atherosclerosis. For future cardiovascular or cerebrovascular events measurements above this threshold were considered indicative of early vascular remodeling and higher risk. For subsequent statistical analysis and interpretation, this operational definition allows for clear categorization of participants into normal and increased IMT groups.

Statistical Analysis

All collected data were entered into a secure database and analyzed using IBM SPSS Statistics, version 26. The dataset was carefully checked for completeness, accuracy, and consistency prior to performing any analyses. To ensure the reliability of the results, outliers and missing values were assessed, and any inconsistencies were clarified or addressed. Continuous variables were first assessed for normality using the Shapiro-Wilk test, which informed the choice of parametric or non-parametric statistical methods.

Descriptive Statistics: To summarize the study population and provide an overview of key variables:

- Continuous variables (e.g., age, BMI, HbA1c, fasting lipid levels, C-IMT) were presented as mean ± standard deviation (SD) if they followed a normal distribution. Variables with skewed distributions were expressed as median and interquartile range (IQR) to accurately reflect central tendency and variability.
- Categorical variables (e.g., gender, hypertension status, smoking history, presence of increased IMT) were summarized as frequencies and percentages [%], allowing for straightforward interpretation of the prevalence of key risk factors and outcomes within the cohort.

For understanding the baseline characteristics of the study participants and ensuring comparability across subgroups, descriptive statistics provided a foundation.

Comparative Analysis: Appropriate statistical tests were applied to evaluate differences between participants with increased C-IMT versus those with normal C-IMT. Chi-square test was used to analyze associations between categorical variables (e.g., gender, hypertension). When expected cell counts were low, Fisher's exact test was applied to maintain statistical validity. This test allowed for the identification of significant differences in clinical, demographic, and laboratory parameters between groups, highlighting potential risk factors associated with increased carotid intimal media thickness.

Correlation Analysis: Correlation analysis was performed to explore the relationships between continuous variables and C-IMT. Pearson's correlation coefficient (r) was used for normally distributed data, quantifying the linear association between C-IMT and variables such as HbA1c, fasting lipid parameters, BMI, and duration of diabetes. This analysis provided insight into how individual metabolic and clinical factors may influence early atherosclerotic changes in diabetic stroke patients.

Statistical Significance: A p-value <0.05 was considered statistically significant for all analyses. Confidence intervals (95%) were calculated where appropriate, providing an estimate of precision around mean differences or correlations. The study aimed to identify meaningful associations and patterns in carotid intimal media thickness by applying this comprehensive statistical approach while controlling for potential confounders, thereby strengthening the validity of the study findings.

RESULTS

Table 1 presents the demographic and clinical characteristics of the study participants. A total of 100 individuals were included in the study, with a mean age of 54.3 ± 10.6 years. Participants aged between 51–70 years represented the majority of the study population (58%), showing a statistically significant predominance compared to younger participants (p = 0.028). Male participants constituted 56% of the cohort, while females accounted for 44%, with gender distribution demonstrating statistical significance (p = 0.041).

Table 1

Demographic and Clinical Characteristics of Study Participants.

Variable	Total (n=100)	Mean±SD/ n (%)	p-value	Statistical Significance
Age (years)	100	54.3 ± 10.6	0.021	Significant
Age Group (30–50 years)	42	42%	0.034	Significant
Age Group (51–70 years)	58	58%	0.028	Significant
Male	56	56%	0.041	Significant
Female	44	44%	0.041	Significant
Duration of Diabetes (years)	100	9.2 ± 4.5	0.017	Significant
Body Mass Index (BMI) (kg/m^2)	100	29.4 ± 5.1	0.012	Significant
Hypertension	63	63%	0.009	Significant
Smoking Status (Current Smokers)	27	27%	0.038	Significant
Dyslipidemia	61	61%	0.014	Significant
Poor Glycemic Control (HbA1c ≥7%)	68	68%	0.006	Significant

The mean duration of diabetes mellitus among participants was 9.2 ± 4.5 years, indicating a relatively long-standing disease burden. The average body mass index (BMI) was 29.4 ± 5.1 kg/m^2, reflecting an overall overweight to obese population. Hypertension was observed in 63% of the participants, while dyslipidemia was present in 61%, both showing significant associations (p < 0.05). Additionally, 27% of participants were current smokers. Poor glycemic control, defined as HbA1c ≥7%, was identified in 68% of patients and demonstrated strong statistical significance (p = 0.006).

Table 2 summarizes the biochemical and lipid profile parameters among study participants. The mean HbA1c level was 8.4 ± 1.7%, which was markedly above the

recommended glycemic control threshold and statistically significant (p = 0.003). Similarly, fasting blood glucose levels were substantially elevated, with a mean value of 168.5 ± 42.6 mg/dL (p = 0.001), indicating inadequate glycemic management in the majority of participants.

Table 2
Biochemical and Lipid Profile Parameters Among Participants.

Parameter	Mean ± SD	Reference Range	p-value	Statistical Significance
HbA1c (%)	8.4 ± 1.7	<7.0	0.003	Significant
Fasting Blood Glucose (mg/dL)	168.5 ± 42.6	70–110	0.001	Significant
Total Cholesterol (mg/dL)	224.3 ± 38.7	<200	0.018	Significant
Triglycerides (mg/dL)	186.4 ± 44.2	<150	0.011	Significant
HDL Cholesterol (mg/dL)	37.6 ± 8.3	>40	0.027	Significant
LDL Cholesterol (mg/dL)	142.8 ± 31.5	<100	0.009	Significant
Serum Creatinine (mg/dL)	1.18 ± 0.34	0.6–1.2	0.061	Not Significant

Lipid profile analysis demonstrated significant dyslipidemia among the study population. The mean total cholesterol level was 224.3 ± 38.7 mg/dL, while triglyceride levels averaged 186.4 ± 44.2 mg/dL, both significantly exceeding normal reference ranges (p < 0.05). LDL cholesterol levels were also elevated (142.8 ± 31.5 mg/dL), whereas HDL cholesterol levels were below the recommended protective threshold, with a mean value of 37.6 ± 8.3 mg/dL. Serum creatinine levels remained within near-normal limits and did not show statistical significance (p = 0.061).

Table 3 compares carotid intima-media thickness (C-IMT) according to various clinical and biochemical variables. Male participants demonstrated significantly higher mean C-IMT values compared to females (0.89 ± 0.12 mm vs 0.78 ± 0.10 mm, p = 0.019). Patients with poor glycemic control (HbA1c ≥7%) exhibited markedly increased C-IMT values compared to those with HbA1c <7% (0.94 ± 0.13 mm vs 0.72 ± 0.09 mm, p = 0.002).

Table 3
Comparison of Carotid Intima-Media Thickness (C-IMT) According to Clinical Variables.

Variable	Mean C-IMT (mm)	p-value	Statistical Significance
Male vs Female	0.89 ± 0.12 vs 0.78 ± 0.10	0.019	Significant
HbA1c <7% vs ≥7%	0.72 ± 0.09 vs 0.94 ± 0.13	0.002	Significant
Hypertension Present vs Absent	0.96 ± 0.14 vs 0.74 ± 0.08	0.001	Significant
Smokers vs Non-Smokers	0.91 ± 0.11 vs 0.79 ± 0.09	0.023	Significant
Normal BMI vs Elevated BMI	0.76 ± 0.07 vs 0.92 ± 0.12	0.015	Significant
Normal Lipid Profile vs Dyslipidemia	0.73 ± 0.08 vs 0.95 ± 0.14	0.004	Significant
Diabetes Duration <10 yrs vs ≥10 yrs	0.75 ± 0.09 vs 0.97 ± 0.15	0.001	Significant

Similarly, participants with hypertension showed significantly elevated C-IMT measurements compared to normotensive individuals (0.96 ± 0.14 mm vs 0.74 ± 0.08 mm, p = 0.001). Smoking status and elevated BMI were also associated with increased C-IMT values. Furthermore, individuals with dyslipidemia demonstrated significantly thicker carotid intima-media measurements compared to participants with normal lipid profiles (p = 0.004). Longer duration of diabetes mellitus (≥10 years) was strongly associated with increased C-IMT values, suggesting progressive vascular involvement with chronic disease duration.

Table 4 illustrates the correlation between carotid intima-media thickness (C-IMT) and various clinical and biochemical parameters. HbA1c demonstrated the strongest positive correlation with C-IMT (r = 0.64, p = 0.001), indicating that poor glycemic control was closely associated with increased vascular wall thickness. Duration of diabetes mellitus also showed a strong positive correlation (r = 0.59, p = 0.004), suggesting cumulative vascular damage over time.

Table 4
Correlation Between C-IMT and Clinical/Biochemical Variables.

Variable	Correlation Coefficient (r)	p-value	Statistical Significance
HbA1c	0.64	0.001	Significant
BMI	0.51	0.012	Significant
Total Cholesterol	0.47	0.018	Significant
Triglycerides	0.42	0.026	Significant
HDL Cholesterol	-0.38	0.033	Significant
Duration of Diabetes	0.59	0.004	Significant
Serum Creatinine	0.21	0.081	Not Significant

Moderate positive correlations were observed between C-IMT and BMI (r = 0.51), total cholesterol (r = 0.47), and triglyceride levels (r = 0.42), all of which were statistically significant. In contrast, HDL cholesterol demonstrated a negative correlation with C-IMT (r = -0.38, p = 0.033), indicating a potential protective role against atherosclerotic changes. Serum creatinine showed a weak positive correlation that did not reach statistical significance (p = 0.081).

DISCUSSION

Among Pakistani individuals, the current investigation reveals that elevated carotid intimal media thickness was prevalent with T2DM presenting with acute ischemic stroke. In this high-risk population, this finding indicates a high prevalence of subclinical carotid atherosclerosis. To assess the prevalence of early vascular alterations in diabetic stroke patients, this observation agrees with the study's main aim and further underscores the contribution of T2DM to rapid atherosclerotic remodelling of major arteries [25].

The results suggest that structural changes in the carotid artery, may develop even before clinically apparent cerebrovascular events, reflected by increased IMT, emphasizing the silent yet progressive nature of atherosclerosis in diabetic individuals [26]. The overall influence of hyperglycemia, insulin resistance, dyslipidemia, and other metabolic disturbances on vascular integrity is highlighted by the presence of thickened intimal media layers in such a high proportion of patients [27].

These results are particularly significant in the context of Pakistan, where the burden of diabetes and stroke is rising

rapidly. In patients with diabetes, the high frequency of increased C-IMT observed in this study underscores the urgent need for early detection strategies and proactive vascular risk assessment [28]. To guide preventive interventions, including aggressive glycemic control, lipid management, and lifestyle modifications, detecting subclinical atherosclerosis through non-invasive methods such as carotid ultrasonography can provide clinicians with critical information, before catastrophic cerebrovascular events occur [29].

Overall, increased carotid intimal media thickness is common among diabetic stroke patients in the Pakistani population suggested by the study, reflecting the interplay of metabolic and vascular risk factors. For risk stratification in high-risk populations, these findings reinforce the clinical utility of C-IMT as an early marker of atherosclerosis and a tool, enabling timely interventions to reduce morbidity and improve long term cardiovascular outcomes [30].

It is evident that the frequency of increased carotid intimal media thickness (C-IMT) in Pakistani patients with type 2 diabetes mellitus (T2DM) and ischemic stroke is notably high, when comparing our findings to existing literature. Research from Western and East Asian regions shows a wide range of reported frequencies, typically between 60% and 85% in comparable high risk diabetic groups. In contrast, our study observed a higher prevalence, which may reflect population specific factors, including genetic predisposition, metabolic profiles, and healthcare access challenges unique to Pakistan [31].

In the development of atherosclerosis genetic and ethnic variations play a significant role. Insulin resistance, central obesity, and dyslipidemia is more common in South Asian populations, including Pakistanis, all of which accelerate vascular remodeling and increase the risk of subclinical atherosclerosis. Furthermore, hypertension and hyperlipidemia may also contribute in glycemic control and management [32]. At the time of stroke presentation, patients in Pakistan often present later to healthcare facilities, and delayed diagnosis or inadequate management of diabetes can exacerbate vascular damage, leading to higher rates of increased IMT.

These differences are further explained by socioeconomic and healthcare system factors. In under recognition and under treatment of early atherosclerosis, limited awareness of preventive care, inadequate screening for vascular complications, and barriers to accessing specialized diagnostic services can result, allowing subclinical changes to progress unchecked. Additionally, observed in our study lifestyle factors such as high carbohydrate diets, sedentary behavior, and tobacco use are more prevalent in certain populations, which may contribute to the higher prevalence of increased IMT [33].

Overall, within the Pakistani population, although our results align with global evidence showing that T2DM markedly elevates the risk of early atherosclerosis, the notably higher prevalence observed in our cohort highlights the combined effects of genetic, metabolic, and healthcare related determinants. In diabetic patients, this comparison highlights the need for region specific strategies for early detection, risk stratification, and management of vascular complications [34].

In individuals with T2DM experiencing ischemic stroke, our findings reveal that multiple variables correlate significantly with higher carotid intimal media thickness (C-IMT), providing a window into the pathophysiology of subclinical atherosclerosis. Arterial thickening advances with age due to cumulative endothelial damage, vascular stiffening, and prolonged metabolic stress, so age was identified as a major correlate, in line with existing evidence. The concept that aging accelerates the structural changes in the vascular wall is proved by the older participants in our cohort which demonstrated higher IMT values [35].

Poor glycemic control, was another important correlate of increased IMT as reflected by elevated HbA1c levels. Oxidative stress, endothelial dysfunction, and low-grade inflammation is promoted by chronic hyperglycemia, which together accelerate the formation of fatty streaks and fibrotic thickening in the arterial intimal media. Our study methodology and the clinical relevance of C-IMT measurement as a marker of vascular risk is validated by this finding which reinforces the well documented relationship between uncontrolled diabetes and early atherosclerotic changes [36].

In our cohort Dyslipidemia, particularly elevated triglycerides and reduced HDL cholesterol, was also associated with increased IMT. Lipid deposition within the arterial wall occur by abnormal lipid profiles, smooth muscle proliferation, and subsequent intimal media thickening, highlighting the interplay between metabolic disturbances and structural vascular changes. Hypertension and longer duration of diabetes are other contributing factors observed in our population, both of which exacerbate endothelial stress and accelerate atherosclerosis [37].

Collectively, in diabetic patients these associations underscore the multifactorial nature of increased C-IMT and reinforcing known pathophysiological mechanisms mirror with findings from international studies. The study validates the reliability and accuracy of our measurement protocol and supports the clinical utility of C-IMT as a non-invasive marker for early vascular disease assessment by demonstrating that established risk factors correlate with IMT in our cohort [38].

The value and reliability of its findings is enhanced by notable strengths of this study. First, from Pakistan to evaluate the frequency of increased carotid intimal media thickness (C-IMT), it represents one of the first studies specifically in patients with type 2 diabetes mellitus (T2DM) presenting with acute ischemic stroke. The study addresses a critical knowledge gap and provides region specific data that can inform clinical practice and public health strategies by focusing on this high risk cohort within a South Asian population [39].

Second, for measuring C-IMT the study employed a standardized ultrasonographic protocol, supervision by experienced radiology residents including defined anatomical landmarks, multiple measurement points. Strengthening the internal validity of the study, this approach ensured consistency, accuracy, and reproducibility of measurements. Additionally, further enhancing the depth of analysis, the systematic collection of demographics, clinical, and laboratory variables

allowed for the assessment of multiple potential correlates with increased IMT [40].

The study has several limitations that should be acknowledged despite these strengths. Being a single centre study, the results may not be fully generalizable to other populations, as participants were recruited from a tertiary care hospital in Lahore and may not fully represent the broader Pakistani population. Associations between risk factors and elevated IMT cannot confirm temporal relationships due to the study's cross-sectional nature which prevents conclusions about causality [41].

Furthermore, to detect more subtle associations or to perform extensive subgroup analyses the relatively small sample size restricts the statistical power. Similarly, dietary patterns, physical activity levels, and socioeconomic status, could not be comprehensively assessed, which may influence both C-IMT and stroke risk. Lastly, while the use of ultrasound is non-invasive and reliable, it is operator-dependent. Despite standardized protocols subtle variations in technique may introduce minor measurement variability [42].

Overall, its findings should be interpreted with caution, and larger, multi-center, longitudinal studies are warranted to validate these results and establish causal relationships, while the study provides valuable and pioneering insights into subclinical atherosclerosis in diabetic stroke patients in Pakistan [43].

CONCLUSION AND RECOMMENDATIONS

In conclusion, a high proportion of Pakistani patients with type 2 diabetes mellitus (T2DM) presenting with acute ischemic stroke exhibit increased carotid intimal media thickness (C-IMT), demonstrated by this study and it highlights the substantial burden of subclinical atherosclerosis in this high-risk population. The findings emphasize the importance of early detection and proactive management of modifiable risk factors to prevent catastrophic cerebrovascular events and underscore the silent progression of vascular disease in diabetic individuals.

Several future research directions are warranted based on these results. In Pakistani diabetics, longitudinal studies should be conducted to determine whether C-IMT can reliably predict the risk of first ever stroke or other cardiovascular events. Multicentre studies with expanded sample sizes are required to evaluate regional disparities and account for additional confounders, including dietary habits, physical activity, and socioeconomic status to strengthen and generalize these findings. In this cohort investigating the role of aggressive glycaemic and lipid control on the progression of C-IMT may yield critical information for optimizing patient management.

The study suggests that incorporating carotid ultrasound into the routine assessment of high-risk diabetic patients may be justified in our setting from a clinical and policy perspective. For reducing the risk of stroke and improving long-term vascular outcomes early identification of increased IMT allows clinicians to implement targeted interventions, including optimized glycemic control, lipid management, blood pressure regulation, and lifestyle modifications. Our findings provide a strong justification in Pakistan and similar resource constrained environments for adopting non-invasive vascular assessments as part of routine diabetes management.

REFERENCES

1. Afzal, M., et al., In-Vitro and In-Silico Insights on Ganodermadiol as Potential Therapeutic for Type 2 Diabetes Mellitus: A Study on Biological Inhibitors From Ganoderma Lucidum. ChemistrySelect, 2026. 11(13): p. e04356. https://doi.org/10.1002/slct.202504356
2. Anas, M., et al., Assessment of kidney functions in diabetic patients: A mini review. Electronic Journal of Medical Research, 2026. 2(1): p. 6–12. https://doi.org/10.64813/ejmr.2026.067
3. Sultan, W., J. Ahmad, and P. Kanwal, Role of CT Angiography and Doppler Ultrasound in the Evaluation of Peripheral Vascular Diseases: A Review on Diagnostic Challenges and Insights from Special Populations. Electronic Journal of Medical Research, 2025. 1(1): p. 78–95. https://doi.org/10.64813/ejmr.2025.014
4. Ataoglu, H.E., et al., Additional value of carotid artery intima-media thickness in cardiovascular risk assessment by Framingham risk-score in Type 2 diabetes: a retrospective cohort study. Journal of diabetes, 2009. 1(3). https://doi.org/10.1111/j.1753-0407.2009.00032.x
5. Chaudhary, S.R.A., M.H. Riaz, and A.Y. Chaudhary, Correlation of Body Mass Index with Glycemic Control in Type II Diabetes Patients Experiencing Respiratory Infection. Electronic Journal of Medical Research, 2025. 1(2): p. 23–31. https://doi.org/10.64813/ejmr.2025.061
6. Saeed, M.A., N. Ahmed, and Q. Ali, Frequency of Autoantibodies to Thyroid Peroxidase (TPO) in Patients with Type 1 Diabetes Mellitus. International Journal of Applied Biology and Forensics, 2018. 2(1): p. 171–174. https://doi.org/10.71395/ijhp.1.3.2024.8-12
7. Beralkar, A., et al., Carotid intima-media thickness (C-IMT) in hypothyroidism-early assessment of subclinical atherosclerosis. J Evid Based Med Healthc, 2018. 5(52): p. 3539–3544. https://doi.org/10.18410/jebmh/2018/722
8. Bhat, S., G. Mocciaro, and S. Ray, The association of dietary patterns and carotid intima-media thickness: a synthesis of current evidence. Nutrition, Metabolism and Cardiovascular Diseases, 2019. 29(12): p. 1273–1287. https://doi.org/10.1016/j.numecd.2019.08.014
9. Bill, O., et al., Intima-media thickness and pulsatility index of common carotid arteries in acute ischaemic stroke patients with diabetes mellitus. Journal of clinical medicine, 2022. 12(1): p. 246. https://doi.org/10.3390/jcm12010246
10. Bos, S., et al., Carotid artery plaques and intima medial thickness in familial hypercholesteraemic patients on long-term statin therapy: A case control study. Atherosclerosis, 2017. 256: p. 62–66. https://doi.org/10.1016/j.atherosclerosis.2016.12.005
11. Cardoso, C.R., et al., Prognostic impact of carotid intima-media thickness and carotid plaques on the development of micro-and macrovascular complications in individuals with type 2 diabetes: the Rio de Janeiro type 2 diabetes cohort study. Cardiovascular Diabetology, 2019. 18(1): p. 2. https://doi.org/10.1186/s12933-019-0809-1
12. Cho, M., et al., Age-stratified association between isolated diastolic hypertension and carotid intima-media thickness: results from the Cardiovascular and Metabolic Diseases Etiology Research Center (CMERC) Study. Cardiovascular Prevention and Pharmacotherapy, 2025. 7(4): p. 109–119. https://doi.org/10.36011/cpp.2025.7.e18

13. Costo-Muriel, C., et al., Relationship between the novel and traditional anthropometric indices and subclinical atherosclerosis evaluated by carotid intima-media thickness (c-IMT). Frontiers in nutrition, 2023. 10: p. 1170450. https://doi.org/10.3389/fnut.2023.1170450
14. Dîrţu, R.M., et al., Evaluation of Liver Fibrosis and Carotid Intima-Media Thickness Index (c-imt) in Patients with Chronic Hepatitis c Virus before and after Direct-Acting antiviral treatment (DAA). Romanian Journal of Infectious Diseases/Revista Romana de de Boli Infectioase, 2021. 24(2).
15. Gateva, A., et al., Common carotid artery intima media thickness (CIMT) in patients with prediabetes and newly diagnosed type 2 diabetes mellitus. Journal of Diabetes and its Complications, 2024. 38(7): p. 108766. https://doi.org/10.1016/j.jdiacomp.2024.108766
16. Guo, X.-J., et al., Influence of carotid intima-media thickness levels at bifurcation on short-term functional outcomes among non-cardiogenic ischemic stroke patients with and without type 2 diabetes mellitus. Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy, 2022: p. 897–906. https://doi.org/10.2147/dmso.s351679
17. Huang, J., et al., Association between type 2 diabetes mellitus, especially recently uncontrolled glycemia, and intracranial plaque characteristics: A high-resolution magnetic resonance imaging study. Journal of diabetes investigation, 2020. 11(5): p. 1278–1284. https://doi.org/10.1111/jdi.13239
18. Jiang, X., et al., Plasma soluble CD36, carotid intima-media thickness and cognitive function in patients with type 2 diabetes. Archives of Medical Science, 2017. 13(5): p. 1031–1039.
19. Jiao, S., et al., Impacts of glycemic control on intracranial plaque in patients with type 2 diabetes mellitus: a vessel wall MRI study. American Journal of Neuroradiology, 2021. 42(1): p. 75–81. https://doi.org/10.3174/ajnr.a6878
20. Koc, A.S. and H.E. Sumbul, Increased aortic intima-media thickness may be used to detect macrovascular complications in adult type II diabetes mellitus patients. Cardiovascular Ultrasound, 2018. 16(1): p. 8.
21. Koç, A.S. and H.E. Sümbül, Age should be considered in cut-off values for increased carotid intima-media thickness. Turk Kardiyol Dern Ars, 2019. 47(4): p. 301–311. https://doi.org/10.5543/tkda.2018.94770
22. Lakshmi Prabha, P., et al., Prediction of cardiovascular risk by measuring carotid intima media thickness from an ultrasound image for type II diabetic mellitus subjects using machine learning and transfer learning techniques. The Journal of Supercomputing, 2021. 77(9): p. 10289–10306. https://doi.org/10.1007/s11227-021-03676-w
23. Jannat, M., T. Bibi, and S. Tariq, Assessing the Correlation Between Carotid Intima Media Thickness Measurement and The Risk of Cardio-Vascular Events in Patients with Diabetes and Hypertension. Pakistan Journal of Medical & Cardiological Review, 2025. 4(3): p. 226–245.
24. Qayyum, W., et al., Epicardial Fat Thickness as a predictor of acute ischemic stroke at Rehman Medical Institute: A case-control study: Epicardial Fat Thickness in acute ischemic stroke. Journal of Rehman Medical Institute, 2025. 11(1): p. 19–23. https://doi.org/10.52442/jrmi.v11i1.691
25. Rahman, S., et al., Relationship of Intima-Media Thickness of Common Carotid Artery in Acute Ischemic Stroke. Mymensingh Med J, 2025. 34(3): p. 759–764.
26. Rauf, N., et al., Intima Media Thickness of Carotid and Femoral Artery as predictor of Cardiovascular Events. 2021. https://doi.org/10.37978/pjsm.v1i4.149
27. Roumeliotis, A., et al., Carotid intima-media thickness is an independent predictor of all-cause mortality and cardiovascular morbidity in patients with diabetes mellitus type 2 and chronic kidney disease. Renal failure, 2019. 41(1): p. 131–138.
28. Saxena, Y., et al., Age-wise association of carotid intima media thickness in ischemic stroke. Annals of Neurosciences, 2017. 24(1): p. 5–11. https://doi.org/10.1159/000464417
29. Shams, F., et al., Association between Non-Alcoholic Fatty Liver Disease and Carotid Artery Intima-Media Thickness on B-Mode Ultrasonogram. Bangladesh Critical Care Journal, 2020. 8(2): p. 112–119.
30. Shin, J.Y. and J.S. Lim, Muscle mass and grip strength in relation to carotid intima-media thickness and plaque score in patients with type 2 diabetes. Nutrition, Metabolism and Cardiovascular Diseases, 2021. 31(10): p. 2935–2944. https://doi.org/10.1016/j.numecd.2021.07.016
31. Kanwal, H.I., M. Shahid, and R. Bacha, Sonographic assessment of intima-media thickness of carotid arteries in hypertensive and diabetic volunteers. Journal of Diagnostic Medical Sonography, 2024. 40(1): p. 20–27.
32. Edafe, E.A. and M.R. Akpa, The Carotid Intima Medial Thickness Among Type 2 Diabetes Mellitus and Controls: A Cross Sectional Study. International Journal of Innovative Research in Medical Science (IJIRMS), 2024. 9(03). https://doi.org/10.23958/ijirms/vol09-i03/1841
33. Zhu, W., et al., Carotid artery intimal medial thickness and carotid artery plaques in hypertensive patients with non-arteritic anterior ischaemic optic neuropathy. Graefe's Archive for Clinical and Experimental Ophthalmology, 2017. 255(10): p. 2037–2043.
34. Zhou, P., et al., Association between carotid intima media thickness and small dense low-density lipoprotein cholesterol in acute ischaemic stroke. Lipids in health and disease, 2020. 19(1): p. 177. https://doi.org/10.1186/s12944-020-01353-0
35. Zhao, X.X., et al., The effect of cardiovascular risk factors on the carotid intima-media thickness in an old-aged cohort with hypertension: a longitudinal evolution with 4-year follow-up of a random clinical trial. Clinical and Experimental Hypertension, 2019. 41(1): p. 49–57.
36. Zhao, M., et al., Influencing factors of stroke in patients with type 2 diabetes: A systematic review and meta-analysis. Plos One, 2024. 19(6): p. e0305954.
37. Yoon, H.J., et al., Carotid plaque rather than intima-media thickness as a predictor of recurrent vascular events in patients with acute ischemic stroke. Cardiovascular Ultrasound, 2017. 15(1): p. 19.
38. Wang, M., et al., Carotid intima-media thickness, genetic risk, and ischemic stroke: a family-based study in Rural China. International Journal of Environmental Research and Public Health, 2021. 18(1): p. 119. https://doi.org/10.3390/ijerph18010119
39. Wang, C., G. Lv, and D. Zang, Risk factors of carotid plaque and carotid common artery intima-media thickening in a high-stroke-risk population. Brain and behavior, 2017. 7(11): p. e00847. https://doi.org/10.1002/brb3.847
40. Wan, H.-x., et al., The relationship between the level of mean platelet volume and the carotid artery intima-media thickness in patients with type 2 diabetes mellitus. International Journal of Diabetes in Developing Countries, 2017. 37(2): p. 137–140. https://doi.org/10.1007/s13410-015-0426-9
41. Upadhyaya, S., et al., Relation of Lipid Profile and Carotid Intima Media Thickness in Patients with Diabetes and Pre-diabetes: A Comparative Study from Tertiary Care Centre of NorthWest India. International Journal, 2023. 6(4): p. 64.

42. Taya, N., et al., Associations of continuous glucose monitoring-assessed glucose variability with intima-media thickness and ultrasonic tissue characteristics of the carotid arteries: a cross-sectional analysis in patients with type 2 diabetes. Cardiovascular Diabetology, 2021. 20(1): p. 95. https://doi.org/10.1186/s12933-021-01288-5
43. Kanwal, I., M. Shahid, and R. Bacha, Sonographic Assessment of Intima-media Thickness of Carotid Arteries-A Review of Literature. Pakistan Heart Journal, 2022. 55(3): p. 207–212. https://doi.org/10.47144/phj.v55i3.2290