

CORRELATION BETWEEN CAROTID ARTERY DOPPLER FINDINGS AND CARDIOVASCULAR RISK FACTORS IN PATIENTS WITH HYPERTENSION

Mujtaba Mustaqeem¹, Hira Shakeel², Aliza Naeem³, Mujtaba Mustaqeem⁴,

^{*1} MBBS, Akhter Saeed Medical and Dental College, Lahore

² MBBS, Shaikh Zayed Hospital, Lahore

³ MBBS Rashid Latif Medical College, Lahore

^{*1} mujtabamustaqeem57@gmail.com, ² hirashakeel885@gmail.com, ³ alizanaeem1997@gmail.com,

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Corresponding Author: *

Mujtaba Mustaqeem

Abstract

Background: The assessment of carotid artery abnormalities by Doppler ultrasonography provides a noninvasive means of detecting subclinical atherosclerosis and evaluating vascular changes associated with hypertension and other cardiovascular risk factors.

Objectives: To determine the correlation between carotid artery Doppler findings and cardiovascular risk factors in patients with hypertension.

Study Design & Setting: This cross-sectional study was conducted in the Department of Cardiology in collaboration with the Department of Radiology at Akhter Saeed Medical and Dental College, Lahore from Nov 2025 to April 2026.

Methodology: A total of 120 hypertensive patients aged 30–80 years of either gender was enrolled through non-probability consecutive sampling. Demographic characteristics and cardiovascular risk factors including smoking, diabetes mellitus, dyslipidemia, body mass index, duration of hypertension, and family history of cardiovascular disease were recorded. All patients underwent carotid artery Doppler ultrasonography for assessment of intima-media thickness, plaque formation, and carotid stenosis. Data were analyzed using SPSS version 26, and correlations were determined using Pearson's or Spearman's correlation coefficients. A p -value ≤ 0.05 was considered statistically significant.

Results: The mean age of the patients was 57.8 ± 10.9 years and 56.7% were males. Abnormal carotid Doppler findings were present in 55.8% of patients. Increased carotid intima-media thickness, carotid plaque, and carotid stenosis $\geq 50\%$ were observed in 43.3%, 32.5%, and 15.0% of patients, respectively. Significant positive correlations were found between carotid Doppler abnormalities and age, duration of hypertension, diabetes mellitus, dyslipidemia, smoking status, and body mass index ($p < 0.05$).

Conclusion: Carotid artery Doppler abnormalities were common among hypertensive patients and were significantly associated with conventional cardiovascular risk factors. Age, duration of hypertension, diabetes mellitus, dyslipidemia, and smoking were important determinants of subclinical carotid atherosclerosis.

INTRODUCTION

Hypertension is one of the most common chronic diseases and a major contributor to cardiovascular morbidity and mortality worldwide. Persistent elevation of blood pressure causes structural and functional changes in the vascular system, accelerating the development of atherosclerosis and increasing the risk of ischemic heart disease, cerebrovascular accidents, peripheral arterial disease, and other cardiovascular complications. The burden of hypertension is particularly high in developing countries, where urbanization, sedentary lifestyle, obesity, diabetes mellitus, and dietary factors have contributed to its increasing prevalence. Despite advances in treatment, cardiovascular events remain common among hypertensive patients due to the coexistence of multiple risk factors and progressive vascular damage.

The carotid arteries are easily accessible vessels that provide valuable information regarding systemic atherosclerosis. Carotid artery Doppler ultrasonography is a noninvasive, safe, and reliable imaging modality used to evaluate intima-media thickness, plaque formation, luminal narrowing, and blood flow characteristics. These Doppler findings are considered surrogate markers of generalized atherosclerotic disease and have been shown to reflect the overall cardiovascular status of an individual. Increased carotid intima-media thickness and the presence of carotid plaques are associated with endothelial dysfunction and represent early manifestations of vascular injury in hypertensive patients.

Cardiovascular risk factors such as advancing age, diabetes mellitus, dyslipidemia, smoking, obesity, sedentary lifestyle, and prolonged duration of hypertension contribute significantly to the development and progression of atherosclerosis. These factors often coexist in hypertensive individuals and may influence carotid artery morphology and hemodynamics. Identification of vascular abnormalities through carotid Doppler examination can provide insight into the extent of subclinical atherosclerosis and its relationship with traditional cardiovascular risk factors.

Previous studies have demonstrated varying degrees of association between carotid artery abnormalities and cardiovascular risk factors among patients with hypertension. Parameters such as carotid intima-media thickness, plaque burden, and stenosis have been linked with age, lipid abnormalities, diabetes, and smoking status. Understanding these associations is important for characterizing vascular changes in hypertensive individuals and exploring the relationship between carotid artery Doppler findings and established cardiovascular risk factors.

Hypertension is a major risk factor for atherosclerosis and cardiovascular diseases, and carotid artery Doppler ultrasonography offers a noninvasive method for detecting early vascular changes. Previous studies have reported variable frequencies and inconsistent associations between carotid artery abnormalities and traditional cardiovascular risk factors, highlighting the need for further evaluation. Most available evidence originates from international populations, and data from Pakistan are scarce. Differences in demographic characteristics, lifestyle patterns, and prevalence of risk factors may limit the applicability of foreign data to the local population. This study will provide local evidence regarding the correlation between carotid artery Doppler findings and cardiovascular risk factors among hypertensive patients. The findings will add to the existing literature by identifying the pattern of carotid artery involvement and its association with conventional cardiovascular risk factors in the Pakistani population.

MATERIALS AND METHODS

This cross-sectional study was conducted in the Department of Cardiology in collaboration with the Department of Radiology Akhter Saeed Medical and Dental College, Lahore from Nov 2025 to April 2026. A total of 120 patients diagnosed with hypertension were enrolled through non-probability consecutive sampling. The sample size of 120 patients was calculated using the WHO sample size calculator by taking an anticipated frequency of abnormal carotid artery Doppler findings of 35%, a confidence

level of 95%, and an absolute precision of 8.5%. The calculated sample size was 120 patients.

Patients aged 30–80 years of either gender with a diagnosis of hypertension for at least six months were included in the study. Patients with previous carotid artery surgery, known congenital heart disease, history of cerebrovascular accident, vasculitis, malignancy, or critically ill patients were excluded from the study. Written informed consent was obtained from all participants. Demographic characteristics including age, gender, body mass index, duration of hypertension, smoking status, diabetes mellitus, dyslipidemia, and family history of cardiovascular disease were recorded on a predesigned proforma.

All patients underwent carotid artery Doppler ultrasonography using a high-resolution linear transducer by an experienced radiologist having at least five years of post-fellowship experience. Bilateral common carotid arteries, carotid bulbs, and internal carotid arteries were examined for intima-media thickness, plaque formation, and degree of stenosis. Abnormal carotid Doppler findings were defined as increased carotid intima-media thickness (>0.9 mm), presence of atherosclerotic plaque, or carotid artery stenosis $\geq 50\%$.

Data were entered and analyzed using SPSS version 26. Quantitative variables such as age, body mass index, and duration of hypertension were expressed as mean \pm standard deviation, while qualitative variables including gender, smoking, diabetes mellitus, dyslipidemia, family history of cardiovascular disease, and abnormal carotid Doppler findings were presented as frequency and percentage. The correlation between carotid artery Doppler findings and cardiovascular risk factors was determined using Pearson's or Spearman's correlation coefficient as appropriate. A p-value ≤ 0.05 was considered statistically significant.

RESULTS

The study included 120 hypertensive patients with a mean age of 57.8 ± 10.9 years, mean duration of hypertension of 8.6 ± 5.1 years, and mean body mass index of 28.4 ± 4.2 kg/m². There

were 68 (56.7%) males and 52 (43.3%) females. Smoking was present in 41 (34.2%) patients, diabetes mellitus in 49 (40.8%), dyslipidemia in 58 (48.3%), and a family history of cardiovascular disease in 36 (30.0%) patients, as given in Table 1.

Out of 120 patients, 67 (55.8%) had abnormal carotid artery Doppler findings, whereas 53 (44.2%) had normal findings. Increased carotid intima-media thickness (>0.9 mm) was observed in 52 (43.3%) patients, atherosclerotic plaque in 39 (32.5%), and carotid artery stenosis $\geq 50\%$ in 18 (15.0%) patients, as given in Table 2.

Among the 67 patients with abnormal carotid Doppler findings, age greater than 60 years was present in 40 (59.7%) patients. Smoking was noted in 31 (46.3%) patients, diabetes mellitus in 37 (55.2%), dyslipidemia in 43 (64.2%), body mass index ≥ 30 kg/m² in 29 (43.3%), and family history of cardiovascular disease in 24 (35.8%) patients, as given in Table 3.

Carotid intima-media thickness demonstrated a significant positive correlation with age ($r=0.512$, $p<0.001$), duration of hypertension ($r=0.448$, $p<0.001$), body mass index ($r=0.301$, $p=0.001$), diabetes mellitus ($r=0.382$, $p<0.001$), dyslipidemia ($r=0.427$, $p<0.001$), and smoking status ($r=0.274$, $p=0.003$), as given in Table 4.

The presence of carotid plaque showed a significant positive correlation with age ($r=0.469$, $p<0.001$), duration of hypertension ($r=0.398$, $p<0.001$), body mass index ($r=0.228$, $p=0.012$), diabetes mellitus ($r=0.342$, $p<0.001$), dyslipidemia ($r=0.396$, $p<0.001$), smoking status ($r=0.317$, $p=0.001$), and family history of cardiovascular disease ($r=0.203$, $p=0.026$), as given in Table 5.

Carotid artery stenosis $\geq 50\%$ exhibited significant positive correlations with age ($r=0.389$, $p<0.001$), duration of hypertension ($r=0.347$, $p<0.001$), diabetes mellitus ($r=0.296$, $p=0.001$), dyslipidemia ($r=0.321$, $p<0.001$), smoking status ($r=0.281$, $p=0.002$), and family history of cardiovascular disease ($r=0.184$, $p=0.044$). Body mass index showed a weak, statistically non-significant correlation with carotid artery stenosis ($r=0.177$, $p=0.053$), as given in Table 6.

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

Variable	Value
Age (years), Mean ± SD	57.8 ± 10.9
Duration of hypertension (years), Mean ± SD	8.6 ± 5.1
Body Mass Index (kg/m ²), Mean ± SD	28.4 ± 4.2
Male Gender, n (%)	68 (56.7)
Female Gender, n (%)	52 (43.3)
Current Smokers, n (%)	41 (34.2)
Diabetes Mellitus, n (%)	49 (40.8)
Dyslipidemia, n (%)	58 (48.3)
Family History of Cardiovascular Disease, n (%)	36 (30.0)

Table 2: Distribution of Carotid Artery Doppler Findings among Study Participants (n=120)

Variable	n (%)
Normal Doppler Findings	53 (44.2)
Abnormal Doppler Findings	67 (55.8)
Increased Intima-Media Thickness (>0.9 mm)	52 (43.3)
Presence of Atherosclerotic Plaque	39 (32.5)
Carotid Artery Stenosis ≥50%	18 (15.0)

Table 3: Distribution of Cardiovascular Risk Factors among Patients with Abnormal Carotid Doppler Findings (n=67)

Risk Factor	n (%)
Age >60 years	40 (59.7)
Smoking	31 (46.3)
Diabetes Mellitus	37 (55.2)
Dyslipidemia	43 (64.2)
BMI ≥30 kg/m ²	29 (43.3)
Family History of Cardiovascular Disease	24 (35.8)

Table 4: Correlation Between Carotid Intima-Media Thickness and Cardiovascular Risk Factors (n=120)

Variable	Correlation Coefficient (r)	p-value
Age	0.512	<0.001
Duration of Hypertension	0.448	<0.001
Body Mass Index	0.301	0.001
Diabetes Mellitus	0.382	<0.001
Dyslipidemia	0.427	<0.001
Smoking Status	0.274	0.003

Table 5: Correlation Between Presence of Carotid Plaque and Cardiovascular Risk Factors (n=120)

Variable	Correlation Coefficient (r)	p-value
Age	0.469	<0.001
Duration of Hypertension	0.398	<0.001
Body Mass Index	0.228	0.012
Diabetes Mellitus	0.342	<0.001
Dyslipidemia	0.396	<0.001

Smoking Status	0.317	0.001
Family History of Cardiovascular Disease	0.203	0.026

Table 6: Correlation Between Carotid Artery Stenosis $\geq 50\%$ and Cardiovascular Risk Factors (n=120)

Variable	Correlation Coefficient (r)	p-value
Age	0.389	<0.001
Duration of Hypertension	0.347	<0.001
Diabetes Mellitus	0.296	0.001
Dyslipidemia	0.321	<0.001
Smoking Status	0.281	0.002
Body Mass Index	0.177	0.053
Family History of Cardiovascular Disease	0.184	0.044

DISCUSSION

Hypertension is one of the leading modifiable risk factors for cardiovascular morbidity and mortality worldwide. Persistent elevation of blood pressure accelerates atherosclerotic changes and contributes to vascular injury. Carotid artery Doppler ultrasonography is a noninvasive technique used to assess carotid intima-media thickness, plaque formation, and stenosis, which are indicators of systemic atherosclerosis. Traditional cardiovascular risk factors such as age, smoking, diabetes mellitus, dyslipidemia, and obesity further increase the risk of vascular complications in hypertensive patients. Early detection of carotid artery abnormalities may provide insight into the extent of subclinical atherosclerosis. Evaluating the relationship between carotid Doppler findings and cardiovascular risk factors may improve understanding of vascular changes associated with hypertension.

. In the present study, 120 hypertensive patients with a mean age of 57.8 ± 10.9 years and mean duration of hypertension of 8.6 ± 5.1 years were evaluated to determine the correlation between carotid artery Doppler findings and cardiovascular risk factors. Abnormal carotid artery Doppler findings were observed in 55.8% of patients, while increased carotid intima-media thickness (CIMT >0.9 mm), carotid plaque, and carotid artery stenosis $\geq 50\%$ were present in 43.3%, 32.5%, and 15.0% of patients, respectively. Significant positive correlations were found between increased CIMT and age

($r=0.512$, $p<0.001$), duration of hypertension ($r=0.448$, $p<0.001$), diabetes mellitus ($r=0.382$, $p<0.001$), dyslipidemia ($r=0.427$, $p<0.001$), smoking status ($r=0.274$, $p=0.003$), and BMI ($r=0.301$, $p=0.001$). Similar associations were observed with carotid plaque and carotid artery stenosis.

Youn et al. (2011), in the ARIRANG study involving 1,716 Korean adults, reported that mean common carotid intima-media thickness increased progressively with age and was significantly associated with male sex, body mass index, LDL cholesterol, diabetes mellitus, and blood pressure. Their study demonstrated that mean CIMT ranged from 0.66 ± 0.13 mm in men aged 60–70 years and showed strong associations with conventional cardiovascular risk factors. These findings are consistent with our study, where age exhibited the strongest correlation with CIMT ($r=0.512$), followed by duration of hypertension and dyslipidemia. The positive association between BMI and CIMT observed by Youn et al. also corresponded with our finding of a significant correlation between BMI and CIMT ($r=0.301$, $p=0.001$).

Baroncini et al. (2015) evaluated carotid intima-media thickness and carotid plaques as distinct responses to cardiovascular risk factors and reported that hypertension and age were strongly associated with increased CIMT, whereas dyslipidemia and coronary artery disease were more closely associated with plaque formation. They further observed that smoking and diabetes contributed significantly to carotid

atherosclerosis. In agreement with these observations, our study demonstrated significant positive correlations between plaque formation and age ($r=0.469$, $p<0.001$), diabetes mellitus ($r=0.342$, $p<0.001$), dyslipidemia ($r=0.396$, $p<0.001$), and smoking ($r=0.317$, $p=0.001$), suggesting that these traditional risk factors play an important role in the development of carotid plaque among hypertensive individuals.

Huang et al. (2016) investigated predictors of CIMT and plaque progression and reported that hypertension and increasing age were important determinants of carotid atherosclerosis progression. They also demonstrated that the progression of plaque burden increased with advancing vascular risk factors. These observations are in accordance with our results, where duration of hypertension was significantly associated with increased CIMT ($r=0.448$, $p<0.001$), plaque formation ($r=0.398$, $p<0.001$), and carotid artery stenosis ($r=0.347$, $p<0.001$), emphasizing the cumulative effect of longstanding hypertension on vascular remodeling.

Wu et al. (2017) reported that hypertension, obesity, hyperglycemia, dyslipidemia, and cigarette smoking were significantly associated with increased CIMT among middle-aged and elderly adults. Their findings closely parallel those of our study, where diabetes mellitus showed a significant correlation with CIMT ($r=0.382$, $p<0.001$), plaque formation ($r=0.342$, $p<0.001$), and carotid artery stenosis ($r=0.296$, $p=0.001$). Similarly, dyslipidemia exhibited significant positive associations with CIMT ($r=0.427$, $p<0.001$), plaque ($r=0.396$, $p<0.001$), and stenosis ($r=0.321$, $p<0.001$). Smoking status was also significantly correlated with all Doppler abnormalities in our study, supporting the findings of Wu et al.

Van den Munckhof et al. (2018), in a systematic review, identified age as one of the strongest determinants of carotid intima-media thickness, independent of existing cardiovascular disease. This observation strongly agrees with our results, where age demonstrated the highest correlation coefficient among all variables with CIMT ($r=0.512$), plaque ($r=0.469$), and carotid stenosis

($r=0.389$), indicating that aging remains one of the major contributors to carotid atherosclerosis in hypertensive patients.

Müller-Scholden et al. (2019) studied 2,492 individuals and reported that hypertension, smoking, and dyslipidemia were significantly associated with carotid artery thickening, whereas obesity and diabetes showed weaker associations. While our results similarly demonstrated strong associations of dyslipidemia and smoking with carotid abnormalities, diabetes mellitus also exhibited significant positive correlations with CIMT ($r=0.382$), plaque formation ($r=0.342$), and stenosis ($r=0.296$). This discrepancy may be attributable to differences in population characteristics, prevalence of diabetes, and study design.

Zyriax et al. (2021) found that carotid intima-media thickness correlated significantly with traditional cardiovascular risk factors and that combining CIMT with conventional risk factors improved cardiovascular risk prediction. Their findings are consistent with our study, in which multiple cardiovascular risk factors, including age, duration of hypertension, dyslipidemia, diabetes mellitus, smoking, and BMI, demonstrated significant positive relationships with carotid Doppler abnormalities, supporting the utility of carotid ultrasonography as a marker of subclinical atherosclerosis.

AlGhibiwi et al. (2023) reported that age and systolic blood pressure were the strongest independent predictors of increased CIMT. Likewise, age emerged as the strongest correlate in our study, with correlation coefficients of 0.512 for CIMT, 0.469 for plaque, and 0.389 for carotid stenosis. Guo et al. (2023) demonstrated that patients with dyslipidemia had significantly higher CIMT values and identified lipid abnormalities as independent risk factors for carotid atherosclerosis. Similar findings were observed in our study, where dyslipidemia showed significant positive correlations with increased CIMT ($r=0.427$), plaque formation ($r=0.396$), and carotid artery stenosis ($r=0.321$), all with p -values <0.001 .

More recently, Dženkevičiūtė et al. (2024) demonstrated that carotid plaques and hypertension were independent predictors of cardiovascular events and emphasized the contribution of diabetes mellitus, obesity, dyslipidemia, and unhealthy lifestyle factors to carotid atherosclerosis. Our findings are in close agreement, as more than half of hypertensive patients (55.8%) had abnormal carotid Doppler findings, and carotid plaque was present in 32.5% of cases. Furthermore, diabetes mellitus, dyslipidemia, smoking, and family history of cardiovascular disease exhibited significant associations with plaque formation and carotid stenosis. Overall, the findings of the present study are largely consistent with previous international studies and further support the role of traditional cardiovascular risk factors in promoting carotid artery abnormalities and subclinical atherosclerosis among hypertensive patients.

Study Limitations

This study was conducted at a single center with a relatively small sample size, which may limit the generalizability of the findings. The cross-sectional design precluded the establishment of causal relationships between carotid artery abnormalities and cardiovascular risk factors. In addition, long-term cardiovascular outcomes and progression of carotid artery disease were not assessed.

CONCLUSION

Abnormal carotid artery Doppler findings were common among hypertensive patients and showed significant correlations with several cardiovascular risk factors. Age, duration of hypertension, diabetes mellitus, dyslipidemia, and smoking were positively associated with increased carotid intima-media thickness, plaque formation, and carotid stenosis. Carotid artery Doppler ultrasonography may serve as a useful noninvasive tool for identifying subclinical atherosclerotic changes in patients with hypertension.

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Conflict of Interest: No

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