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Research Article

Section: Radiodiagnosis

Correlation between Carotid Artery Intima Media Thickness & Body Mass Index in Adult Hypertensive Patients using Bright Mode & Colour Doppler Ultrasonography

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HIGHLIGHTS

- Hypertension increased CIMT
- BMI showed weak correlation
- CIMT reflected hypertension severity
- Carotid plaques commonly detected
- Blood pressure predicts atherosclerosis

Key Words:
Carotid Intima-Media Thickness
Hypertension
Body Mass Index
Ultrasonography
Atherosclerosis
Doppler

ABSTRACT

Introduction: Atherosclerosis remains a leading contributor to global morbidity and mortality. Carotid intima-media thickness (CIMT), assessed using B-mode ultrasonography, is widely recognized as a reliable surrogate marker for subclinical atherosclerosis. Hypertension and elevated body mass index (BMI) are established risk factors implicated in vascular remodeling. This study aimed to evaluate the association between CIMT and BMI among hypertensive adults. **Aim & Objective:** To measure CIMT using B-mode and color Doppler ultrasonography and to calculate BMI in adult hypertensive individuals, and to determine the correlation between these parameters for early identification of vascular complications**. Materials & Methods:** A cross-sectional study was conducted on 150 participants (75 hypertensive and 75 normotensive) aged over 30 years. CIMT was measured at multiple segments of the common carotid artery using a 5–13 MHz linear transducer. BMI was calculated using Quetelet's formula. Statistical analysis was performed using Pearson's correlation coefficient and chi-square test. **Results:** The mean age of participants was 61.7 ± 12.3 years. Hypertensive individuals exhibited significantly higher CIMT values compared to normotensive controls. Obesity was observed in 42% of the study population. CIMT demonstrated a strong positive correlation with systolic blood pressure ($r = 0.843$, $p < 0.001$), diastolic blood pressure ($r = 0.814$, $p < 0.001$), and hypertension grade ($r = 0.75$, $p < 0.001$). In contrast, the correlation between CIMT and BMI was weak and not statistically significant ($r = 0.126$, $p = 0.069$). Carotid plaques were detected in 45.33% of participants. **Conclusion:** CIMT was strongly associated with the severity of hypertension, whereas BMI did not show a significant independent correlation. These findings suggest that effective blood pressure control may play a more pivotal role than BMI alone in mitigating subclinical atherosclerosis in this population.

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INTRODUCTION

Cardiovascular diseases (CVDs) remain the leading cause of morbidity and mortality worldwide, accounting for nearly one-third of all deaths annually, with a disproportionately higher burden in low- and middle-income countries [1]. Among the major risk factors, hypertension and obesity have emerged as highly prevalent and modifiable determinants contributing to the rising incidence of vascular complications [2].

Hypertension plays a central role in the development of target organ damage involving the heart, brain, kidneys, & vasculature. Chronic elevation of blood pressure induces vascular remodeling and intima-media thickening, thereby accelerating atherosclerosis and increasing the risk of myocardial infarction and stroke [3,4]. Obesity also contributes to cardiovascular morbidity and exhibits a synergistic relationship with hypertension, further promoting vascular injury [5-8].

Atherosclerosis is a progressive disease characterized by early structural changes within the arterial wall long before clinical manifestations become apparent [9]. In this context, carotid intima-media thickness (CIMT), measured by high-resolution B-mode ultrasonography, has gained widespread acceptance as a reliable, non-invasive marker of subclinical atherosclerosis [10,11]. Increased CIMT reflects cumulative vascular injury and has been shown to be associated with a significantly higher risk of future myocardial infarction and stroke, independent of conventional cardiovascular risk factors [13-16].

Several studies have reported a positive association between body mass index (BMI) and CIMT, suggesting that increasing adiposity contributes to early arterial wall thickening [17]. This relationship appears to be more pronounced among hypertensive individuals, indicating a possible additive effect of obesity on hypertension-induced vascular remodeling [18]. However, findings across studies remain inconsistent, necessitating further investigation [19,20].

Carotid ultrasonography offers a cost-effective, non-invasive, and widely available method for assessing CIMT and detecting early vascular changes [21,22]. **Figure 1.** Mechanistic pathway linking BMI, hypertension, and increased carotid intima-media thickness (CIMT), with B-mode and colour Doppler ultrasonography for CIMT and carotid blood flow assessment.

Despite the established roles of hypertension and obesity in cardiovascular disease, conventional risk assessment tools may fail to identify early structural vascular alterations. Moreover, limited and heterogeneous data exist regarding the relationship between BMI and CIMT in Indian hypertensive adults [27,28]. Therefore, the present study was undertaken to evaluate the correlation between body mass index and carotid intima-media thickness in hypertensive adults using B-mode and colour Doppler ultrasonography, to improve early detection of subclinical atherosclerosis and enhance cardiovascular risk stratification [23–25].

MATERIAL & METHODS

This cross-sectional study was conducted over a period of 1.5 years in the Department of Radio-Diagnosis at K. D. Medical College, Hospital and Research Centre, Mathura, Uttar Pradesh. A total of 150 participants aged >30 years undergoing bilateral carotid Doppler ultrasonography were enrolled using consecutive sampling and divided into hypertensive and normotensive groups. Hypertension was defined as blood pressure ≥140/90 mmHg on at least two occasions and further classified as per WHO grading. Data regarding demographic characteristics, clinical history, and cardiovascular risk factors were collected using a structured questionnaire. Body mass index (BMI) was

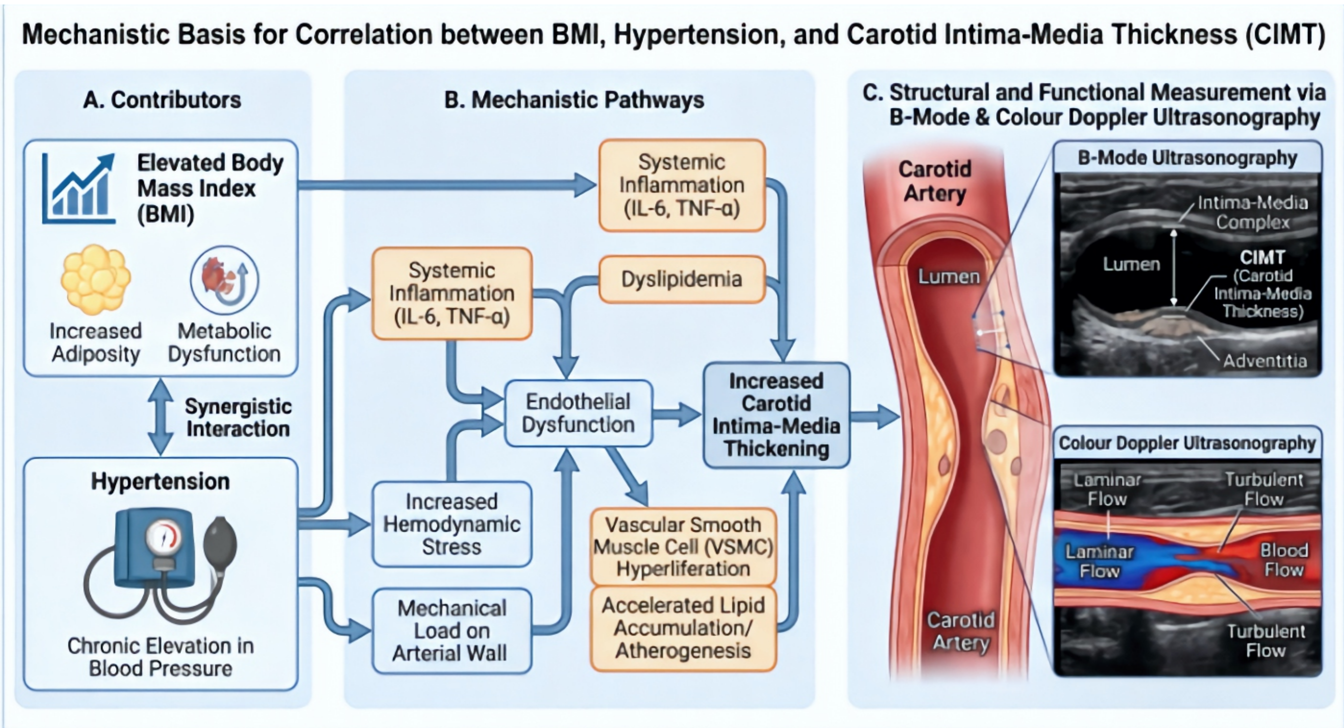

Figure 1: Mechanistic relationship between body mass index (BMI), hypertension, and carotid intima–media thickness (CIMT).

calculated using Quetelet's formula and categorized according to WHO criteria. Carotid intima-media thickness (CIMT) was measured bilaterally using a high-resolution ultrasound system (Logiq P9) with a 5–13 MHz linear probe, with participants in the supine position. Measurements were taken at standardized sites, including the mid common carotid artery, 1.5 cm proximal to the carotid bulb, the carotid bulb, and 1.5 cm distal to the internal carotid artery, and mean CIMT values were calculated, with >1 mm considered abnormal. Ethical approval was obtained from the institutional ethics committee, and informed consent was secured from all participants. Data was analyzed using SPSS version 26, employing descriptive statistics along with appropriate inferential tests such as Pearson's correlation and chi-square test, with $p < 0.05$ considered statistically significant.

RESULTS

- ***Age and gender-wise distribution of patients***

Among the 150 participants, males (58%) outnumbered females (42%). The proportion of participants increased with age, with only 15.33% in the 30–49 years group. Higher representation was seen in older age groups: 50–59 years (22.67%), 60–69 years (28.67%), and ≥70 years (33.33%), which had the largest share.

- ***Baseline clinical and anthropometric characteristics***

Figure 3 presents the baseline clinical and anthropometric characteristics, with a mean age of 61.7 ± 12.3 years indicating a predominantly older population. The mean BMI was 28.52 ± 4.45 kg/m², reflecting an overall overweight status. Mean systolic and diastolic blood pressures were 135.71 ± 19.57 mmHg and 85.81 ± 10.70 mmHg, respectively, likely influenced by inclusion of both treated hypertensive and normotensive individuals.

- ***Comorbidities among patients***

37.33% of patients had no comorbidities. Dyslipidemia was the most common comorbidity (28.67%), followed by hypothyroidism (15.33%), CKD (9.33%), combined dyslipidemia with hypothyroidism (6%), and COPD (3.33%).

- ***Evaluation of BMI among patients***

Table 1 shows BMI distribution among participants, with obesity being most common (42%), followed by overweight (37.33%), normal weight (20%), and only 0.7% underweight. Mean BMI increased progressively across categories, indicating a high burden of excess weight. This predominance of overweight and obesity is clinically significant, as increased adiposity contributes to hypertension, metabolic disturbances, and vascular changes that may influence CIMT.

- ***Hypertension grading among hypertensive patients***

Figure 4 shows the distribution of hypertensive patients by severity, with Grade 1 being most common (18.67%), followed by Grade 2 (9.33%) and Grade 3 (2.67%). The mean duration of hypertension was similar across grades, suggesting severity is influenced by factors beyond duration. A clear stepwise rise in systolic and diastolic blood pressure was observed with increasing hypertension grade.

- ***Evaluation of BMI among hypertensive patients***

Figure 5 demonstrates that most hypertensive patients (n = 75) were either overweight or obese, with obesity being the most common (35 patients; ~46.7%), followed by overweight (25; 33.3%), while normal BMI was seen in 14 (18.7%) and only one patient was underweight. The high mean BMI in obese individuals (32.65 ± 2.47 kg/m²) highlights excess adiposity as a key modifiable risk factor in hypertension. These findings support the link between increased body weight, metabolic disturbances, and vascular remodeling, contributing to elevated CIMT.

- ***CIMT status among patients***

Abnormal CIMT (>1 mm) was observed in 43 (28.67%) participants, whereas 107 (71.33%) had normal CIMT values. The abnormal group demonstrated higher mean CIMT values bilaterally (right: 1.038 ± 0.054 mm; left: 1.027 ± 0.046 mm), indicating a considerable burden of subclinical atherosclerosis. The bilateral elevation suggests generalized rather than localized vascular involvement.

- ***Segment-wise mean CIMT***

Table 2 shows segment-wise CIMT measurements with comparable values on both right and left carotid arteries, indicating symmetrical vascular involvement. The highest CIMT values were observed at the carotid bulb, consistent with its susceptibility to atherosclerosis due to disturbed flow. This segmental analysis strengthens the reliability of CIMT assessment and highlights the bulb as the most affected region.

- ***Correlation of mean CIMT with clinical and biochemical parameters***

Table 3 shows that CIMT had a moderate positive correlation with age ($r = 0.371$, $p < 0.001$), indicating increased arterial thickness with aging. BMI showed a weak, non-significant correlation ($r = 0.126$, $p = 0.069$). Blood pressure parameters demonstrated the strongest associations, with systolic BP ($r = 0.843$), diastolic BP ($r = 0.814$), and hypertension grade ($r = 0.75$) all highly significant ($p < 0.001$). Lipid parameters showed weaker but significant correlations, including total cholesterol ($r = 0.276$, $p = 0.001$) and triglycerides ($r = 0.245$, $p = 0.002$), indicating their contributory role in atherosclerosis.

- ***Cases of carotid plaques among patients***

Table 4 shows that carotid plaques were present in 68 patients (45.33%) and absent in 82 (54.67%), indicating that nearly half of the population had atherosclerotic changes. Plaque presence reflects a more advanced stage of disease than increased CIMT alone and is associated with higher cardiovascular risk, underscoring the clinical value of carotid ultrasonography in hypertensive patients.

- ***Use of anti-hypertensive drugs among patients***

Fifty percent of participants were on anti-hypertensive therapy. Persistent elevated blood pressure in many treated patients suggested suboptimal control and ongoing vascular remodeling (**Figure 6**).

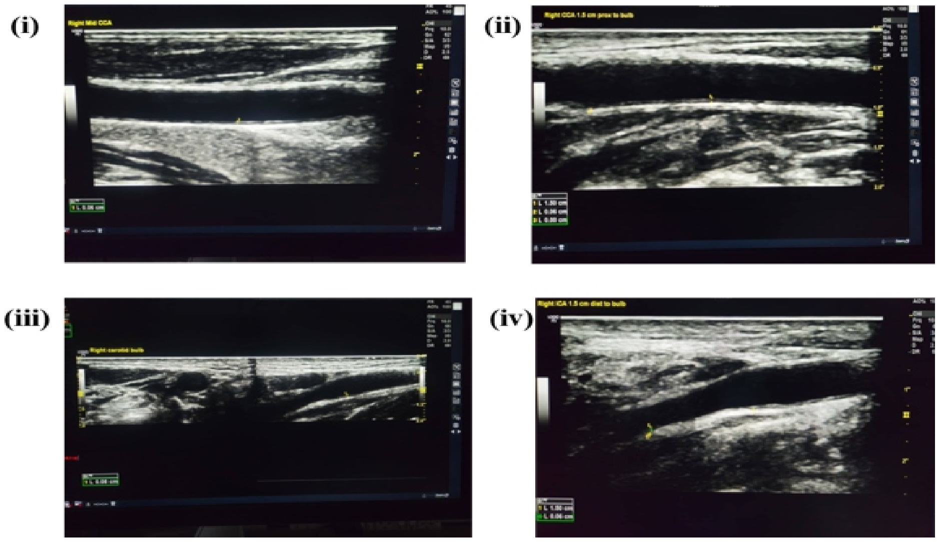

Figure 2. Standardized sites for carotid intima–media thickness (CIMT) measurement on B-mode ultrasonography: (i) Mid common carotid artery (CCA), (ii) CCA approximately 1.5 cm proximal to the carotid bulb, (iii) Carotid bulb, (iv) Internal carotid artery (ICA) approximately 1.5 cm distal to the carotid bulb.

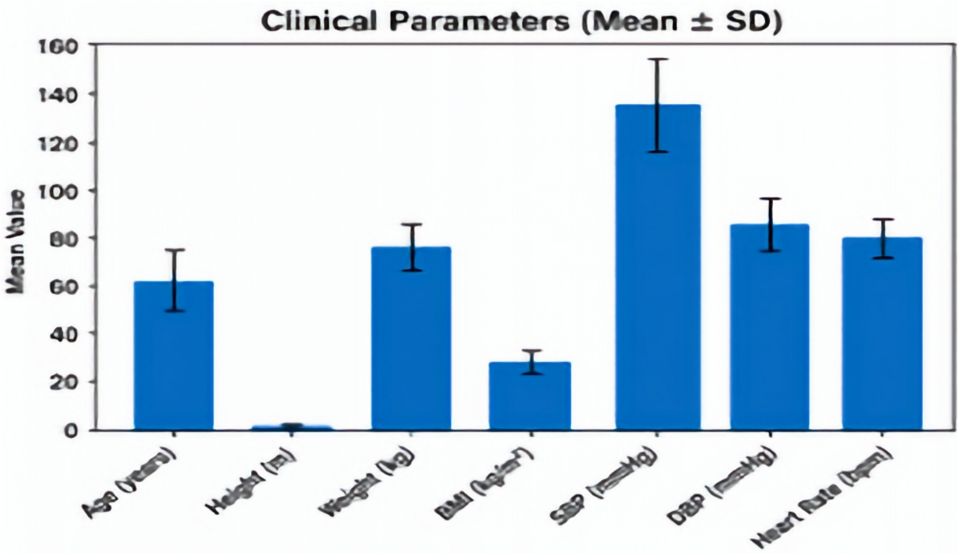

Figure 3: Baseline Clinical & Anthropometric evaluation of patients

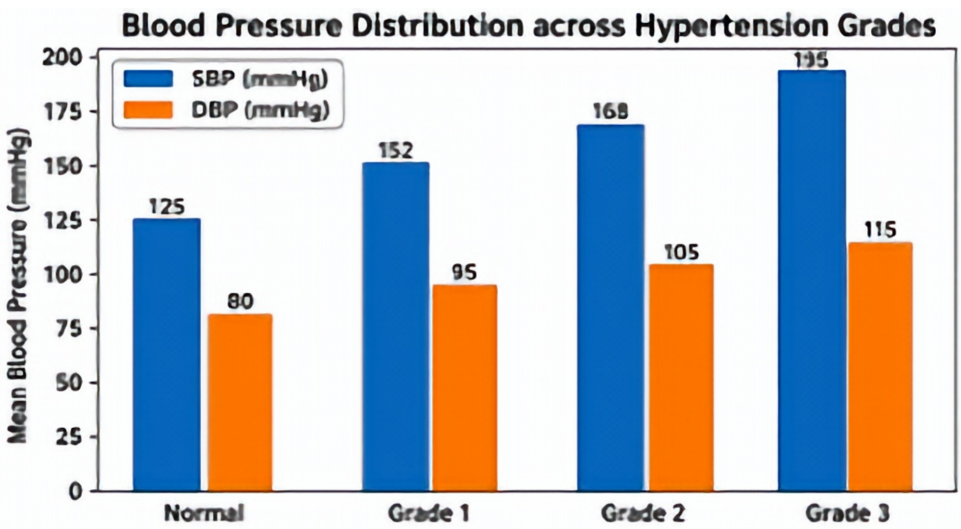

Figure 4: Hypertension grading among hypertensive patients (n = 75)

Table 1: Evaluation of BMI among patients

BMI Category	Number of Patients	Total %	Mean ± SD of BMI (kg/m²)
Underweight	1	0.7	17.30 ± NA
Normal	30	20	22.71 ± 1.50
Overweight	56	37.33	27.10 ± 1.53
Obese	63	42	32.73 ± 2.51
Chi(χ^2)=45.57, **p**=<0.001			

Table 2: Segment-wise Mean ± Standard Deviation of Right and Left Carotid Artery Intima–Media Thickness

Segment	Right (Mean ± SD, mm)	Left (Mean ± SD, mm)
Mid CCA	0.957 ± 0.125	0.953 ± 0.115
CCA 1.5 cm Proximal Bulb	0.979 ± 0.128	0.982 ± 0.130
Carotid Bulb	1.031 ± 0.149	0.994 ± 0.140
ICA 1.5 cm Distal	0.974 ± 0.125	0.969 ± 0.120

Table 3: Correlation of Mean CIMT with Clinical and Biochemical Parameters

Variable	Pearson correlation (r)	p-value
Age (years)	0.371	<0.001
BMI	0.126	0.069
SBP (mmHg)	0.843	<0.001
DBP (mmHg)	0.814	<0.001
Hypertension Grade	0.75	<0.001
Total Cholesterol (mg/dL)	0.276	0.001
Triglycerides (mg/dL)	0.245	0.002

Table 4: Cases of Carotid plaques present among

Carotid Plaque Status	Number of Patients	Total %
Absent	82	54.67
Present	68	45.33
Total	150	100

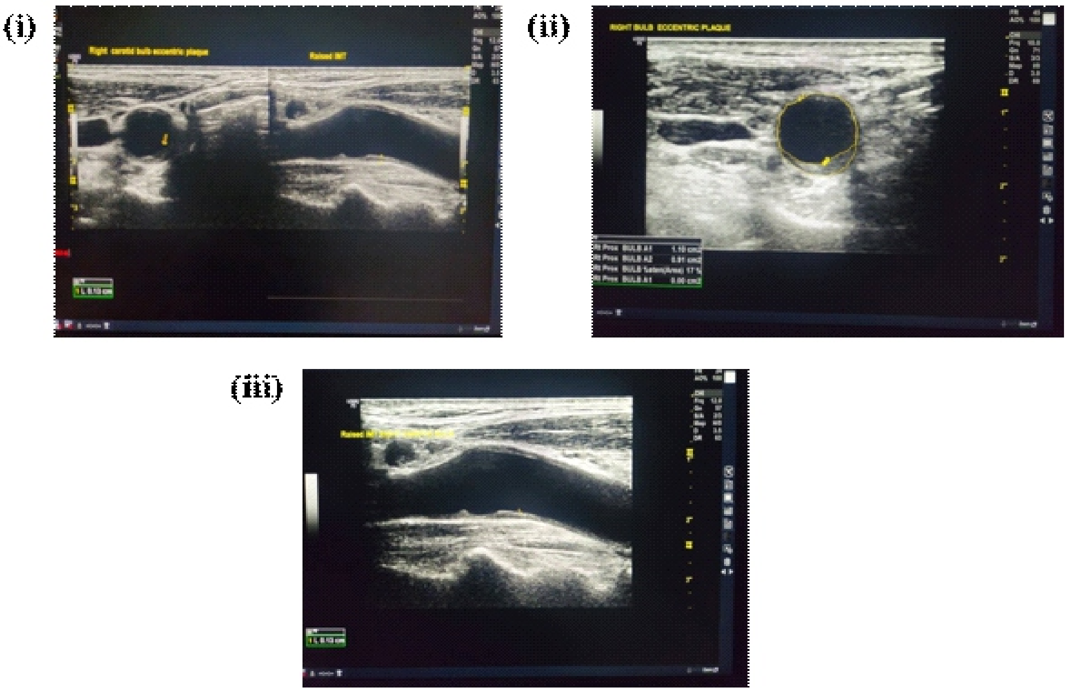

Figure 6. (i) B-mode ultrasound images demonstrating carotid atherosclerotic changes at the right carotid bulb, (ii) Eccentric predominantly echolucent (Grey–Weale type II) atherosclerotic plaque with mild luminal narrowing (~17% area stenosis), (iii) Increased CIMT measuring approximately 1.3 mm.

DISCUSSION

Hypertension remains one of the most important modifiable risk factors for cardiovascular morbidity and mortality worldwide, significantly contributing to ischemic heart disease, stroke, and peripheral vascular disease [30]. Chronic elevation of blood pressure induces structural and functional alterations in the arterial wall, collectively known as vascular remodeling, which accelerates the development of atherosclerosis. Early identification of these subclinical vascular changes is essential for preventing adverse cardiovascular outcomes. Carotid intima-media thickness (CIMT) has emerged as a reliable, non-invasive marker of early atherosclerosis, reflecting arterial wall changes before the onset of overt clinical disease [31].

High-resolution B-mode ultrasonography, supplemented by colour Doppler imaging, is widely used for CIMT assessment because of its safety, accessibility, reproducibility, and cost-effectiveness. Increased CIMT has been consistently associated with established cardiovascular risk factors including age, hypertension, dyslipidemia, diabetes mellitus, smoking, and obesity [32]. The present study evaluated the relationship between BMI and CIMT in hypertensive adults and explored the influence of hemodynamic and metabolic factors on vascular remodeling.

Our findings demonstrated that CIMT was strongly associated with blood pressure parameters and age, whereas its correlation with BMI was weak and statistically non-significant. The study population comprised predominantly older individuals, with most participants aged ≥60 years and a slight male preponderance (58%). These findings are comparable to those reported by Rashid et al., who also identified age as a significant determinant of CIMT [29]. The high prevalence of overweight and obesity (79.33%) observed in the present study reflects the substantial burden of excess adiposity in the study population. Previous studies by Eric et al. and Asaleye et al. reported a positive association between BMI and CIMT [36,37]. However, contrary to these findings, our study demonstrated only a weak and statistically non-significant correlation between BMI and CIMT ($r = 0.126$, $p = 0.069$). This discrepancy may be explained by differences in study populations, particularly the higher mean age of our cohort, in which age and hypertension may exert a greater influence on vascular remodeling than BMI alone.

Hypertension severity showed a significant relationship with CIMT. Progressive increases in systolic and diastolic blood pressure across hypertension grades were associated with corresponding increases in CIMT. These findings are consistent with previous studies demonstrating that both the severity of hypertension and blood pressure levels are major determinants of vascular remodeling and arterial wall thickening [28]. Furthermore, only half of the hypertensive participants were receiving antihypertensive treatment, suggesting that inadequate blood pressure control may contribute substantially to ongoing vascular damage. Abnormal CIMT values (>1 mm) were observed in 28.67% of participants, indicating a considerable burden of subclinical atherosclerosis. Segment-wise analysis demonstrated the highest CIMT values at the carotid bulb, consistent with its greater susceptibility to atherosclerotic changes due to disturbed flow patterns. Correlation analysis demonstrated strong positive associations between CIMT and systolic blood pressure ($r = 0.843$), diastolic blood pressure ($r = 0.814$), and hypertension grade ($r = 0.750$), along with moderate correlations with age and lipid parameters. These findings are in agreement with previous studies identifying blood pressure as one of the strongest determinants of carotid wall thickness [28,29,38]. Carotid plaque was detected in 45.33% of participants, indicating that a substantial proportion of the study population had established atherosclerotic disease. This prevalence is comparable to that reported in other hypertensive populations [39,40]. Plaque presence reflects a more advanced stage of atherosclerosis than increased CIMT alone and supports the complementary role of plaque assessment during carotid ultrasonography. These findings further emphasize the value of B-mode & colour Doppler ultrasonography in identifying both early & advanced vascular changes in hypertensive individuals [41].

Overall, the present study highlights the complex interaction between hemodynamic and metabolic factors in the development of subclinical atherosclerosis. Although obesity is a recognized cardiovascular risk factor, BMI did not demonstrate a significant independent association with CIMT in this cohort. In contrast, age and blood pressure emerged as the predominant determinants of vascular remodeling. CIMT assessment using carotid ultrasonography provides a direct, reliable, and non-invasive measure of arterial wall changes and may improve cardiovascular risk stratification in high-risk populations. The cross-sectional design, use of BMI as the sole measure of adiposity, and single-centre setting remain important limitations. Nevertheless, the study supports the incorporation of CIMT assessment into routine cardiovascular risk evaluation among hypertensive individuals [39-41].

CONCLUSIONS

This study demonstrated that carotid intima-media thickness (CIMT) was significantly associated with age, blood pressure parameters, hypertension severity, and lipid profile, indicating the dominant role of hemodynamic and metabolic factors in vascular remodeling. Although a high prevalence of overweight and obesity was observed, body mass index (BMI) showed only a weak and statistically nonsignificant correlation with CIMT, suggesting that its influence may be indirect rather than independent. A considerable proportion of participants exhibited increased CIMT and carotid plaques, indicating a substantial burden of subclinical atherosclerosis, particularly among hypertensive individuals. These findings emphasize that effective blood pressure control remains an important determinant in preventing atherosclerotic progression, while lifestyle modification and weight management continue to play supportive roles. Furthermore, B-mode and colour Doppler ultrasonography serve as reliable, non-invasive tools for early detection and risk stratification, supporting their role as valuable imaging tools for early detection and cardiovascular risk stratification in high-risk populations.

LIMITATIONS & FUTURE PERSPECTIVES

The study's limitations include a single-centre setting, a relatively small sample size, and a short study duration, which may limit the broader applicability of the results. Future studies should incorporate multicentre designs with larger populations to enhance validity, assess long-term outcomes, and investigate advanced diagnostic & management approaches. Such efforts will improve overall patient care & help minimize complications.

CLINICAL SIGNIFICANCE

The clinical significance of this study lies in its potential to bridge the gap between research findings and practical health-.care, diagnosis, and treatment outcomes. By highlighting real-care applications. It emphasizes the importance of translating scientific observations into meaningful improvements in patientworld relevance, the study contributes to evidence based medical practice and supports informed clinical decision making. Ultimately, the findings aim to enhance patient quality of life, optimize therapeutic strategies, and promote better disease management in clinical settings.

ABBREVIATIONS

BMI: Body Mass Index
CIMT: Carotid Intima–Media Thickness
B-mode: Brightness Mode Ultrasonography
r: Pearson's Correlation Coefficient

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AUTHOR CONTRIBUTIONS

All authors significantly contributed to the study conception and design, data acquisition, or data analysis and interpretation. They participated in drafting the manuscript or critically revising it for important intellectual content, consented to its submission to the current journal, provided final approval for the version to be published, and accepted responsibility for all aspects of the work. Additionally, all authors meet the authorship criteria outlined by the International Committee of Medical Journal Editors (ICMJE) guidelines.

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CONFLICT OF INTEREST

Authors declared that there is no conflict of interest.

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None

ETHICAL APPROVAL & CONSENT TO PARTICIPATE

All necessary consent & approval was obtained by authors.

CONSENT FOR PUBLICATION

All necessary consent for publication was obtained by authors.

DATA AVAILABILITY

All data generated and analyzed are included within this research article. The datasets utilized and/or analyzed in this study can be obtained from the corresponding author upon a reasonable request.

USE OF ARTIFICIAL INTELLIGENCE (AI) & LARGE LANGUAGE MODEL (LLM)

The authors confirm that no AI & LLM tools were used in the writing or editing of the manuscript, and no images were altered or manipulated using AI & LLM.

AUTHOR'S NOTE

This article serves as an important educational tool for the scientific community, offering insights that may inspire future research diretions. However, they should not be relied upon independently when making treatment decisions or developing public health policies.

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