

Comparison of Carotid Intima Media Thickness and Resistive Index by High Resolution Ultrasound and Color Doppler in Hypertensive Patients and Normotensive Subjects

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Abstract

Background: Hypertension causes progressive structural and haemodynamic changes in the arterial wall, contributing to subclinical atherosclerosis and increased cardiovascular risk. Carotid intima-media thickness (CMT) and carotid resistive index (RI), assessed using high-resolution ultrasonography and colour Doppler, may provide non-invasive markers of early vascular injury.

Methods: An observational comparative study was conducted in the Department of Radiodiagnosis at Dr. D. Y. Patil Medical College, Hospital and Research Institute, Kolhapur. Participants were divided into hypertensive and normotensive groups and underwent standardized bilateral common carotid artery B-mode ultrasonography and colour Doppler examination. CMT was measured at the distal common carotid artery, while RI was calculated from peak systolic and end-diastolic velocities. Associations with duration of hypertension and blood pressure were also evaluated.

Results: Hypertensive participants demonstrated significantly higher combined CMT than normotensive subjects (0.835 ± 0.119 vs. 0.620 ± 0.101 mm; $p < 0.001$). Combined RI was also significantly higher among hypertensive participants (0.7869 ± 0.045 vs. 0.6595 ± 0.033 ; $p < 0.001$). Abnormal CMT (> 0.70 mm) was observed in 90.8% of hypertensive subjects compared with 15.4% of normotensive subjects ($\chi^2 = 74.158$, $p < 0.001$). Duration of hypertension showed positive correlations with CMT ($r = 0.456$) and RI ($r = 0.663$), both $p < 0.001$. CMT was positively correlated with SBP ($r = 0.649$) and DBP ($r = 0.599$). Multivariate analysis identified hypertension as an independent predictor of increased CMT (AOR=47.6; 95% CI: 15.1–142.9; $p < 0.001$).

Conclusion: Hypertension is strongly associated with increased CMT and RI, indicating early structural and haemodynamic vascular changes. High-resolution ultrasonography and colour Doppler may therefore provide useful non-invasive tools for detecting subclinical vascular injury and facilitating cardiovascular risk assessment.

Keywords: Hypertension; Carotid intima-media thickness; Resistive index; Ultrasonography; Colour Doppler; Subclinical atherosclerosis.

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Introduction

Hypertension represents a significant component in the growth of atherosclerotic cardiovascular disease and an independent risk aspect for worldwide morbidity and death. A structural and functional remodeling of the arterial wall is involved in the gradual vascular alterations that are linked with persistent increase of arterial blood pressure. Among these shifts, measuring vascular stiffness and detecting subclinical atherosclerosis early have become hot topics because they provide useful prognostic information beyond what is derived from traditional blood pressure readings. alternatives to

invasive procedures in imaging, such as color Doppler. Recent years have seen a rise in the use of Doppler investigations on the carotid arteries as a means to quantify artery wall thickness and hemodynamic characteristics. Hypertension target organ damage surrogate indicators have been extensively studied, and two such measurements, carotid intima-media thickness (CMT) and resistive index (RI), are two examples' predictors of future cardiovascular events. [2]

Ultrasound measurements taken at the common carotid artery using high-resolution B-mode are used to determine the carotid intima-media thickness, which is the distance between the arterial wall's lumen-intima and media-adventitia interfaces. The artery wall undergoes structural changes due to atherosclerosis, endothelial dysfunction, and chronic hemodynamic stress [3]. An increased CIMT has a substantial correlation with the risk of myocardial infarction and stroke, and it is regularly linked to hypertension, dyslipidemia, diabetes mellitus, and smoking. Many researchers and clinicians now employ CIMT as a surrogate diagnostic for early atherosclerosis due to its reliability, lack of invasiveness, and low cost. The vascular thickening process which affects the media and intima layers develops as an adaptive mechanism to prolonged vascular disease. This condition establishes a connection between risk factor exposure and the development of cardiovascular disease. [4]

The resistive index estimates the difference between peak systolic velocity and end-diastolic speed as a percentage of maximum systolic force to indicate hemodynamic in Doppler waveforms. The system modulates microvascular resistance and compliance directly and indirectly, affecting the vascular system. Hypertensives have high systemic vascular resistance, which affects artery wall flexibility and blood flow patterns, raising their RI [5]. The presence of higher resistive index shows that blood vessels lose their ability to expand their capacity while becoming more rigid and their blood flow capacity decreases which results in organ harm. RI serves as a dynamic vascular function assessment tool which works together with CIMT as a structural marker to evaluate hypertensive vascular damage. [6]

Hypertension stimulates the renin-angiotensin-aldosterone system and several interrelated pathways to modify the vascular system by causing oxidative stress, low-grade vascular inflammation, and high mechanical stress. The arterial wall stiffens due to smooth muscle development and collagen buildup. Studies of vascular alterations employ the carotid artery as a model vessel due to its simple access and capacity to monitor superficial blood vessels. The CIMT test demonstrates early structural thickening, whereas the RI measurement shows how wall characteristics impact blood flow. Combining these measures improves vascular health assessment in hypertensive patients compared to clinical parameters. [8]

Normal blood pressure patients have lower CIMT and resistive index scores because their blood vessels and artery walls remain flexible. It compares hypertensive and normotensive individuals to determine whether artery wall characteristics are physiologically altered by hypertension. The study

shows how hypertension causes vascular damage over time and helps researchers identify high-risk individuals who need rapid treatment. For risk assessment and continuing monitoring of individuals without cardiovascular disease, vascular imaging is essential. [9]

The clinical importance of CIMT testing results from its ability to forecast future heart attack events. The meta-analyses of myocardial infarction and stroke show that increased CIMT values lead to higher risk levels which occur independently of established risk factors. The changes in resistive index have been associated with both decreased kidney function and increased risk of cerebrovascular disorders and cardiovascular diseases. The combination of CIMT and RI measurement provides two distinct methods to assess vascular damage which results from hypertension because the two methods measure different aspects of vascular disease. The assessment becomes essential because hypertension can cause target organ damage that progresses without symptoms until it leads to severe health emergencies like stroke or myocardial infarction. [10,11]

High-resolution ultrasound technology improves CIMT measuring accuracy and repeatability. Standardized techniques necessitate measurements far from the common carotid artery bifurcation to avoid plaque-induced measurement inaccuracies. Doppler-based resistive index measuring needs precision carotid artery lumen measurement by waveform analysis for appropriate computation. These non-invasive imaging modalities are safe and affordable, making them suited for clinical research and conventional medical treatments. Their usage helps clinicians analyses hypertensive patients' cardiovascular risk factors beyond blood pressure. [12,13]

Patho physiologically, carotid artery changes and hypertension are interconnected. Increasing blood pressure induces arterial remodeling because the body develops increased vascular stiffness and less vascular compliance, which raises central hemodynamic pressures. Continuous cycling strains the cardiovascular system. A quantifiable link between structural and functional changes at CIMT and RI shows their mutual reinforcing. These measures are examined in hypertensives and normotensives to identify the number of vascular alterations caused by chronic high blood pressure. [14]

The study aimed to compare hypertensive patients with normotensive control group members through high resolution ultrasonography and color Doppler system measurements of carotid intima media thickness and resistive index.

Methodology

An observational, comparative study was conducted at Dr. D. Y. Patil's Medical College, Hospital, and Research Institute's in Department of Radiodiagnosis, Kadamwadi, Kolhapur, on two distinct groups hypertensive patients and normotensive subjects based on the parameters of interest (CIMT and RI) without any intervention being administered by the investigator. The study was conducted for a duration of two years. All aspects of the study's design and execution were carried out in agreement with the ethical standards laid forth in the Declaration of Helsinki. Institutional Ethics Committee (IEC) review and approval was sought before the study began for the full research protocol, which included the informed consent form and participant information sheet, from Dr. D. Y. Patil Medical College, Hospital Research Institute, Kolhapur. All the participants were selected according to the exclusion and inclusion criteria. The sample size was 110 participants, 55 for each group.

Case group 1: contained fifty-five adults confirmed to have primary hypertension as per the explicit criteria for inclusion.

Group II (Control group): Forty-seven normotensive individuals were included who had no clinical evidence of hypertension or other major atherosclerotic risk factors.

Inclusion Criteria: For the Hypertensive Group: Patients must be adults (18–50 years old) and have a two-year medical history of essential hypertension to be considered. A systolic blood pressure of 140 mm Hg or higher and/or a diastolic blood pressure of 90 mm Hg or higher on more than one occasion, or the present use of antihypertensive medication, were the recognized clinical criteria that formed the basis of the diagnosis, For the Normotensive Group: Adult individuals aged between 18 and 50 years with no prior history of hypertension and not on any antihypertensive medication, with blood pressure readings consistently below 130/85 mmHg.

Exclusion Criteria: Individuals with secondary hypertension due to specific underlying conditions (e.g., renal disease, endocrine disorders), Individuals with past heart problems (such as a myocardial infarction or stroke) or serious vascular diseases (e.g., carotid artery stenosis).

Result

Table 1: Comparison of Combined (Right + Left) Mean CIMT Between Groups

Group	Combined Mean CIMT (mm) $\pm$ SD	95% CI	p-value
Hypertensive (n = 65)	0.835 $\pm$ 0.119	0.81 - 0.87	<0.001
Normotensive (n = 65)	0.620 $\pm$ 0.101	0.60 - 0.64	<0.001

The combined people with hypertension had significantly higher carotid intima-media thickness (CIMT) than those with normotension ($p < 0.001$).

Study Procedure: Data-acquisition process was standardized to obtain reliable and reproducible results across the users.

Participant Preparation: After obtaining written informed consent, each participant was made to stabilize hemodynamic parameters, lie down for ten minutes in a cool, dark place without noise.

Ultrasound Examination: All scans were conducted utilizing a LOGIQ F8 EXPERT ultrasound system (GE Healthcare, Milwaukee, WI, USA) that had a high-frequency linear array transducer ideally 12 MHz attached. The subject's head was angled away from the side under scrutiny and their neck was somewhat erect.

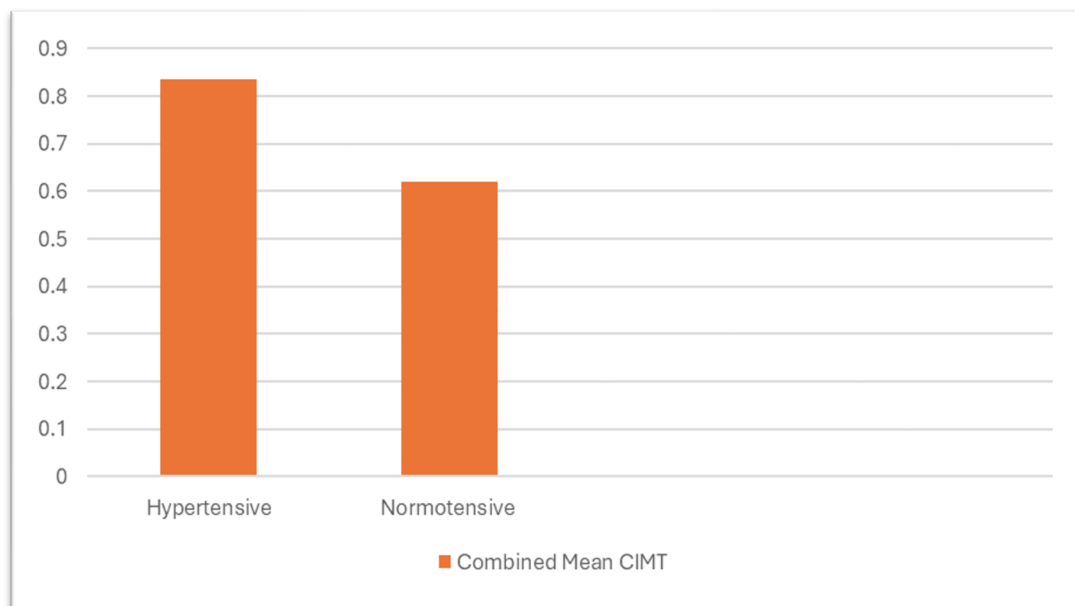
B-mode Imaging for CIMT: A longitudinal plane was first used to identify the common carotid artery (CCA). To enhance the visualization of the intima-media complex, the transducer was adjusted so that the ultrasound beam was perpendicular to the vessel wall. The lumen-intima interface to media-adventitia interface distance was used to define the CIMT. Two or three centimeters to the left and right of the carotid bulb, on each side of the far wall of the distal CCA, were the three measurements obtained. For the final analysis, we recorded the average of these three observations for each side.

Color Doppler and Spectral Analysis for RI: The vessel's flow may be seen by using the Colour Doppler mode. Keeping the angle of in sonation at or below 60°, the pulsed-wave Doppler sample volume was positioned in the centre of the C lumen, identical to where the CIMT was recorded. Peak systolic velocity (PSV) also end diastolic velocity (EDV) were measured after obtaining the Doppler waveform. Machine software automatically computed the Resistive Index (RI) as follows: $(PSV - EDV) / PSV$. The average RI value for every carotid artery was recorded after three successive cardiac cycles.

Data Recording: In the Picture Archiving and Communication System, we kept all the measurements, along with some sample pictures and animations (PACS) for subsequent review and analysis.

The finding demonstrates that subclinical atherosclerosis occurs more frequently in people who have hypertension. The two groups show a

statistically significant difference according to the high effect size measurement which has a value of Cohen's d 1.945.



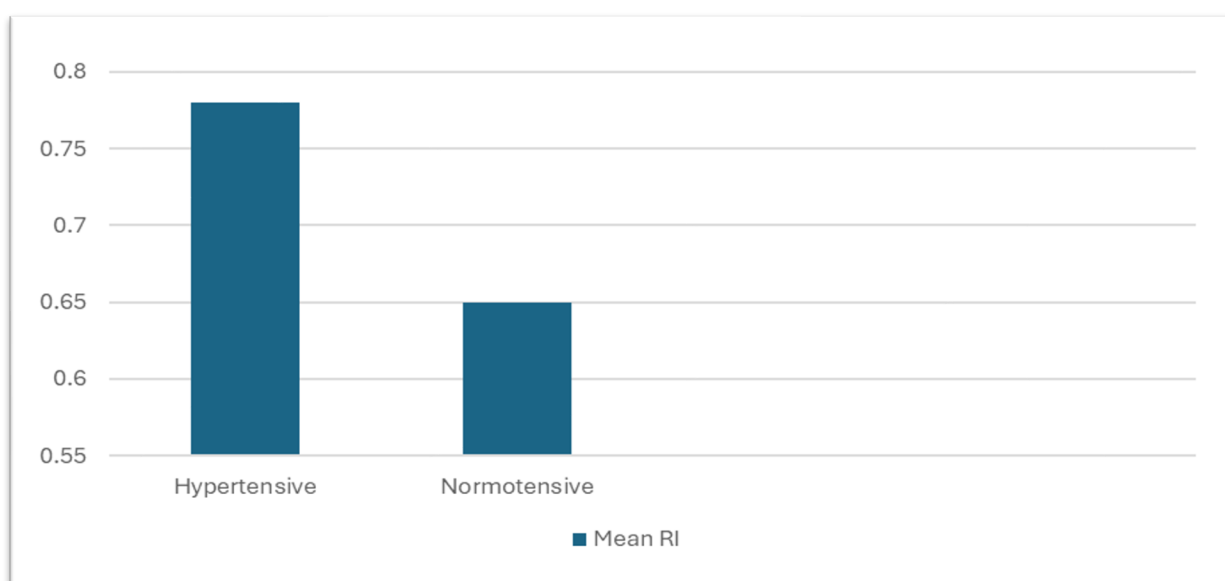
Graph 1: Comparison of Combined (Right + Left) Mean CIMT Between Groups

Table 2 : Combined (Right + Left) Mean RI Between Groups

Group	Mean RI $\pm$ SD	95% CI
Hypertensive (n = 65)	0.7869 $\pm$ 0.04527	0.776 - 0.798
Normotensive (n = 65)	0.6595 $\pm$ 0.03272	0.652 - 0.667
d = 3.226, p-value = <0.001		

The overall resistive index measurements showed a significant elevation in hypertension participants who scored 0.7869 compared to normotensive individuals who scored 0.6595. The results

demonstrate that hypertensive patients show increased vascular resistance which corresponds with their early vascular remodeling and elevated arterial stiffness.



Graph 2: Combined (Right + Left) Mean RI Between Groups

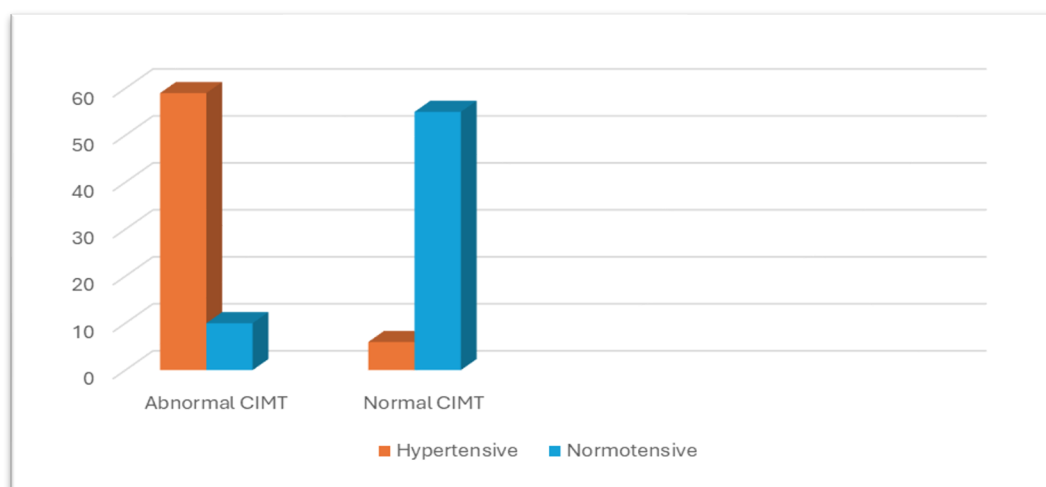
Table3 : Association Between Hypertension Status and Abnormal CIMT (>0.70 mm)

CIMT Status	Hypertensive (n = 65)	Percentage (%)	Normotensive (n = 65)	Percentage (%)
Abnormal CIMT (>0.70 mm)	59	90.8%	10	15.4%
Normal CIMT (≤0.70 mm)	6	9.2%	55	84.6%
Total	65	100%	65	100%

$\chi^2 = 74.158, p < 0.001$

An individual's hypertension condition was substantially correlated with abnormal CIMT findings. Among hypertension people, 90.8% had aberrant CIMT (>0.70 mm), compared to only 15.4% of normotensive individuals. Conversely, normal CIMT values were largely reported in

normotensives (84.6%) compared to hypertensives (9.2%). According to the chi-square test, this link is statistically significant ($\chi^2 = 74.158, p < 0.001$), meaning that those with hypertension are much more likely to have elevated CIMT levels, which may indicate a higher prevalence of subclinical atherosclerosis in this population.

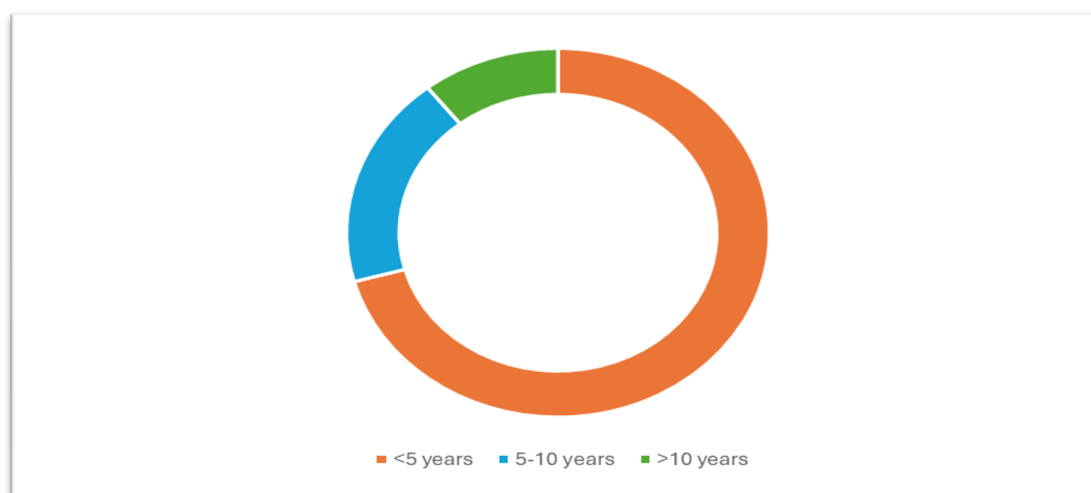
**Graph 3: Association Between Hypertension Status and Abnormal CIMT (>0.70 mm)****Table 4: Correlation Between Duration of Hypertension & CIMT**

Duration of Hypertension	Frequency (n)	Mean CIMT (mm)
<5 years	87	0.76
5-10 years	23	0.80
>10 years	13	0.86

$r = 0.456, p < 0.001$

The study showed that longer durations of hypertension lead to greater increases in carotid intima-media thickness (CIMT). The mean right CIMT of individuals with less than five years of hypertension was 0.76 mm, which increased to 0.80 mm for those who experienced 5-10 years of hypertension and reached 0.86 mm for individuals with hypertension that lasted more than 10 years. The research established that there exists a

statistically significant relationship between the duration of hypertension and CIMT, which showed a moderately positive correlation ($r = 0.456, p < 0.001$). The research outcomes demonstrate that CIMT increases with extended periods of hypertension, which indicates that persistent high blood pressure causes ongoing damage to blood vessels.



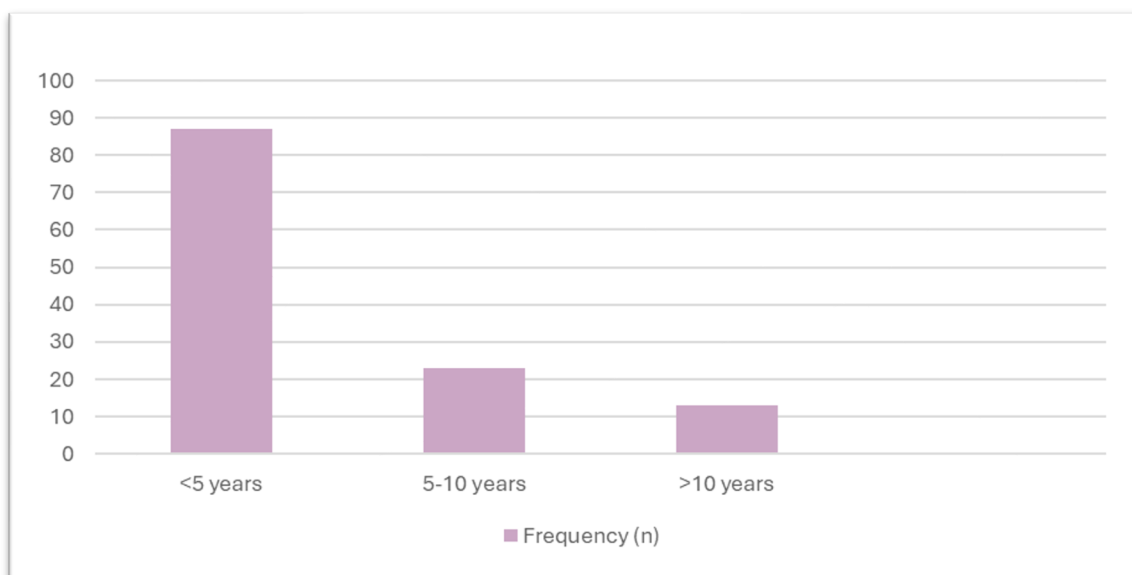
Graph 4: Correlation Between Duration of Hypertension & CIMT

Table 5: Correlation Between Duration of Hypertension and Resistive Index (Right CCA)

Duration of Hypertension	Frequency (n)	Mean RI
<5 years	87	0.75
5-10 years	23	0.80
>10 years	13	0.86
$r = 0.663, p < 0.001$		

As the period of hypertension increased, there was a steady increase in the right common carotid artery's resistive index (RI). Patients with a duration of hypertension of less than five years had a mean RI of 0.75, which increased to 0.80 in those with hypertension for 5–10 years, and further elevated to 0.86 among persons with a period beyond 10 years.

Correlation analysis demonstrated a considerable positive connection RI is significantly correlated with the duration of hypertension ($r = 0.663, p < 0.001$), showing that extended exposure to raised blood pressure contributes considerably to increased vascular resistance.



Graph 5: Correlation Between Duration of Hypertension and Resistive Index (Right CCA)

Table 6: Correlation Matrix Between Age, SBP, DBP, Overall CIMT & Overall RI

Variable	Age	SBP	DBP	CIMT	RI
Age	1	0.163	0.116	0.200	0.068
SBP	0.163	1	0.830	0.649	0.735
DBP	0.116	0.830	1	0.599	0.751
CIMT	0.200	0.649	0.599	1	0.631
RI	0.068	0.735	0.751	0.631	1

The correlation matrix shows that Higher blood pressure is linked to greater arterial thickness and vascular resistance, as seen by the substantial positive relationships between systolic and diastolic

blood pressure and CIMT and RI ($p < 0.001$). Above and beyond that, CIMT and RI are highly correlated. Age has just a weak but significant link with CIMT, and no significant correlation with BP or RI.

Table 7: Multivariate Logistic Regression Predicting Increased CIMT

Predictor	Adjusted Odds Ratio (AOR)	95% CI for AOR	p-value
Hypertension (1 = Hypertensive, 2 = Normotensive)	47.6	15.1 - 142.9	<0.001
Age > 40 years	1.50	0.82 - 2.75	0.186
Smoking	0.71	0.20 - 2.48	0.591
Diabetes Mellitus	0.84	0.21 - 3.36	0.806

In multivariate logistic regression, hypertension was the only self-governing predictor of abnormal CIMT (AOR = 47.6, $p < 0.001$). A much higher prevalence of carotid intima-media thickening was seen in

hypertensive persons after controlling for age, smoking, and diabetes. Age >40 years, smoking, and diabetes were not statistically significant predictors in the adjusted model.

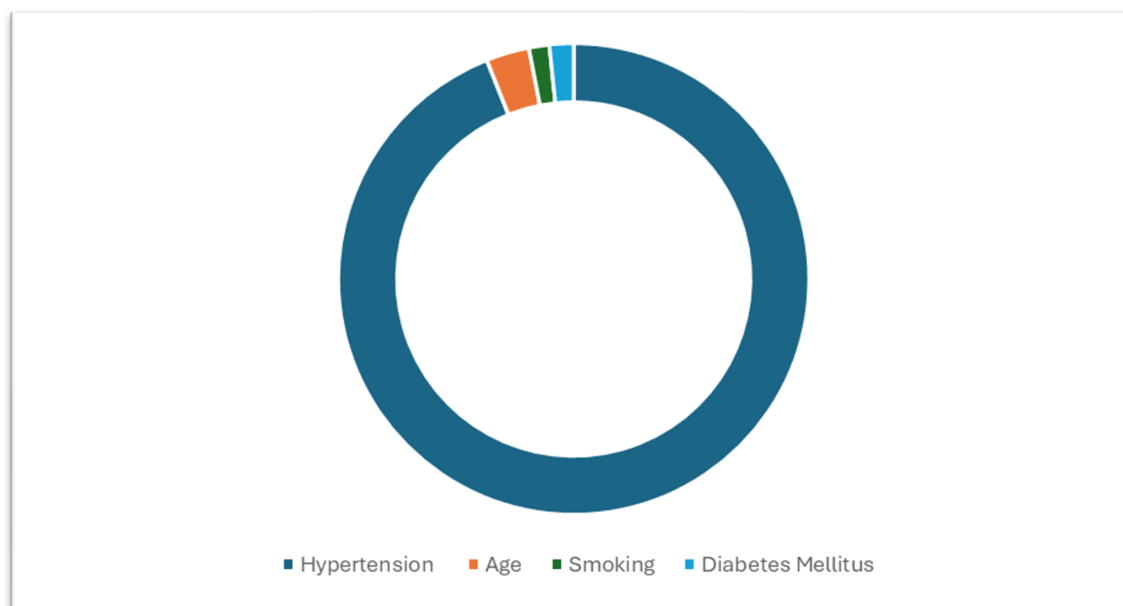
**Graph 6: Multivariate Logistic Regression Predicting Increased CIMT**

Table 8: Summary of Key Findings of the Study

Key Parameter	Finding	Statistical Result	Interpretation
1. Mean CIMT (Right & Left) Difference Between Groups	Hypertensive: 0.835 mm, Normotensive: 0.619 mm	$t(130)=11.08, p < 0.001$	Hypertensive patients have significantly thicker carotid intima, indicating increased subclinical atherosclerosis.
2. Mean Resistive Index (RI) Difference Between Groups	Hypertensive: 0.7869, Normotensive: 0.6595	$t(130)=18.39, p < 0.001$	Hypertensives have markedly higher vascular resistance.
3. Prevalence of Abnormal CIMT (>0.70 mm)	Hypertensive: 85.5%, Normotensive: 14.5%	$\chi^2(1)=74.15, p < 0.001$	Abnormal CIMT is drastically more common in hypertensives.
4. Correlation of CIMT with Blood Pressure	CIMT vs SBP: $r = 0.649$, CIMT vs DBP: $r = 0.599$	Both $p < 0.001$	CIMT strongly increases with higher systolic and diastolic BP.
5. Effect of Duration of Hypertension	Duration vs CIMT: $r = 0.456$, Duration vs RI: $r = 0.663$	Both $p < 0.001$	Longer disease duration strongly predicts vascular wall thickening and higher resistance.
6. Multivariate Predictors of Abnormal CIMT	Hypertension (OR = 47.6) Age (NS), Smoking (NS), Diabetes (NS)	Logistic Regression Model $\chi^2 = 85.83, p < 0.001$	Hypertension is the strongest independent factor predicting abnormal CIMT.

Resistance index (RI) and carotid intima-media thickness (CIMT) were significantly greater in hypertension individuals compared to normotensive individuals, according to the research. Almost 85% of hypertensives had abnormal CIMT (>0.70 mm), indicating a strong association between hypertension and subclinical atherosclerosis. The duration of hypertension, systolic and diastolic blood pressure, also CIMT all showed strong positive correlations. When controlling for age, smoking, and diabetes, hypertension was still the strongest independent predictor of aberrant CIMT according to multivariate logistic regression. The study accomplishes its complete objectives through these findings which demonstrate the medical value of CIMT and RI as diagnostic tools for detecting arterial damage in hypertensive patients.

Discussion

The present study evaluated carotid intima-media thickness (CIMT) and carotid resistive index (RI) in hypertensive and normotensive individuals to assess early vascular changes associated with hypertension. The findings demonstrated significantly greater carotid wall thickness and vascular resistance among hypertensive participants, supporting the presence of subclinical vascular injury detectable by high-resolution ultrasonography and colour Doppler.

Carotid Intima-Media Thickness: Hypertensive participants showed significantly increased CIMT in both the right and left common carotid arteries. The mean right CCA CIMT was 0.820 ± 0.141 mm in hypertensive subjects compared with 0.610 ± 0.112

mm in normotensive subjects ($p < 0.001$), while the corresponding left CCA values were 0.850 ± 0.122 mm and 0.630 ± 0.107 mm, respectively ($p < 0.001$). The combined mean CIMT was also significantly higher in hypertensive individuals (0.835 ± 0.119 mm) than in normotensive individuals (0.620 ± 0.101 mm; $p < 0.001$). These findings indicate substantial structural arterial wall thickening associated with hypertension and are consistent with previous studies reporting increased CIMT among hypertensive patients [15,16].

The categorical distribution further supported this association. CIMT >0.8 mm was observed in 58.5% of hypertensive subjects on the right side compared with only 4.7% of normotensive subjects. On the left side, 70.5% of hypertensive subjects had CIMT >0.8 mm compared with 6.2% of normotensive subjects. Similarly, abnormal CIMT (>0.70 mm) was present in 90.8% of hypertensive subjects compared with 15.4% of normotensive subjects ($\chi^2=74.158, p < 0.001$). These findings support CIMT as a useful non-invasive marker of hypertension-related subclinical vascular damage. Touboul et al. emphasized the prognostic value of carotid IMT and plaque assessment in cardiovascular risk evaluation [17].

Carotid Resistive Index: Hypertension was also associated with significantly increased carotid vascular resistance. The mean right CCA RI was 0.79 ± 0.06 in hypertensive subjects compared with 0.65 ± 0.05 in normotensive subjects ($p < 0.001$), while the left CCA RI was 0.79 ± 0.08 and $0.67 \pm$

0.04, respectively ($p < 0.001$). The combined RI was significantly higher in hypertensive participants (0.7869 ± 0.04527) than in normotensive participants (0.6595 ± 0.03272 ; $p < 0.001$). The increased RI indicates greater vascular resistance and reduced arterial compliance in hypertension. Uthoff et al. reported a baseline RI of approximately 0.66 and demonstrated its association with future cardiovascular morbidity, supporting the clinical significance of elevated RI [18].

Duration of Hypertension: The severity of vascular changes increased with longer duration of hypertension. Mean CIMT increased from 0.76 mm among participants with hypertension for less than five years to 0.80 mm in those with 5–10 years of hypertension and 0.86 mm among those with hypertension for more than 10 years. This association was statistically significant ($r = 0.456$, $p < 0.001$). Similarly, RI increased from 0.75 to 0.80 and 0.86 across the same duration categories, with a strong positive correlation ($r = 0.663$, $p < 0.001$). These findings indicate that prolonged exposure to elevated blood pressure may contribute progressively to arterial wall thickening, vascular stiffness and increased vascular resistance. Previous studies have similarly demonstrated associations between duration or cumulative blood pressure exposure and arterial stiffness [19,16].

Relationship of Blood Pressure with CIMT and RI: The correlation analysis demonstrated strong positive relationships between blood pressure and both CIMT and RI. Systolic blood pressure correlated positively with CIMT and RI ($r = 0.649$ and 0.735 , respectively), while diastolic blood pressure also showed positive correlations with CIMT and RI ($r = 0.599$ and 0.751 , respectively). CIMT and RI themselves were strongly correlated ($r = 0.631$), suggesting that structural arterial wall thickening and increased vascular resistance occur together in hypertensive vascular injury. In contrast, correlations of age with CIMT and RI were weak, indicating that blood pressure burden was more closely related to these vascular parameters than age alone [19,15].

Independent Effect of Hypertension: Multivariate logistic regression further established hypertension as the dominant independent factor associated with increased CIMT. After adjustment for age >40 years, smoking and diabetes mellitus, hypertension had an adjusted odds ratio of 47.6 (95% CI: 15.1–142.9; $p < 0.001$). Age, smoking and diabetes were not statistically significant independent predictors in the adjusted model. These findings strengthen the evidence that hypertension itself plays a major role in carotid arterial wall thickening, consistent with previous observations of increased CIMT among hypertensive individuals [15,16].

Clinical Significance of Ultrasonography and Colour Doppler: The combined findings demonstrate that high-resolution ultrasonography and colour Doppler can identify both structural and haemodynamic manifestations of early vascular injury. CIMT provides information regarding arterial wall thickening, while RI reflects vascular resistance and arterial compliance. The marked differences between hypertensive and normotensive individuals, the association with duration of hypertension, and the strong relationship with blood pressure support their potential value in identifying subclinical vascular changes before overt cardiovascular or cerebrovascular complications occur. Nambi et al. also demonstrated that CCA-IMT with plaque information can improve cardiovascular risk prediction [20].

Overall, the present findings support the use of CIMT and RI as complementary non-invasive markers for assessing vascular effects of hypertension. Early detection of these abnormalities may help identify individuals at increased cardiovascular risk and reinforce the importance of strict blood pressure control, regular monitoring and management of associated risk factors.

Conclusion

The study establishes hypertension as the dominant factor. Among this group of people, there is an increase in the thickness of the carotid intima-media. Based on the results, it seems that the use of high-resolution ultrasonography and color Doppler as valuable, non-invasive methods for assessing early carotid vascular damage in hypertensive patients. Measurement of CIMT helps identify structural arterial wall thickening, while RI provides additional information regarding vascular resistance and compliance. These parameters, particularly in those with uncontrolled or long-term hypertension, could be helpful for early classification of cardiovascular risk. The research highlights the significance of identifying subclinical atherosclerosis early on, monitoring patients regularly, controlling blood pressure strictly, and evaluating risk factors in order to avoid future cardiovascular and cerebrovascular morbidity and prevent its development.

References

1. Poznyak AV, Sadykhov NK, Kartuesov AG, Borisov EE, Melnichenko AA, Grechko AV, Orekhov AN. Hypertension as a risk factor for atherosclerosis: Cardiovascular risk assessment. *Front Cardiovasc Med.* 2022 Aug 22;9:959285. doi: 10.3389/fcvm.2022.959285. PMID: 36072873; PMCID: PMC9441708.
2. Liu FJ, Chen Q, Cheng Y. Noninvasive carotid ultrasound for predicting vulnerable plaques of the coronary artery based on optical coherence tomography images. *Quant Imaging Med Surg.*

- 2024 Jan 3;14(1):316-324. doi: 10.21037/qims-23-621. Epub 2023 Nov 13. PMID: 38223065; PMCID: PMC10784012.
3. Tschiderer L, Klingenschmid G, Seekircher L, Willeit P. Carotid intima-media thickness predicts carotid plaque development: Meta-analysis of seven studies involving 9341 participants. *Eur J Clin Invest*. 2020 Apr;50(4):e13217. doi: 10.1111/eci.13217. Epub 2020 Mar 17. PMID: 32112400; PMCID: PMC7187327.
 4. Rundek T, Blanton SH, Bartels S, Dong C, Raval A, Demmer RT, Cabral D, Elkind MS, Sacco RL, Desvarieux M. Traditional risk factors are not major contributors to the variance in carotid intima-media thickness. *Stroke*. 2013 Aug;44(8):2101-8. doi: 10.1161/STROKEAHA.111.000745. Epub 2013 May 23. PMID: 23704105; PMCID: PMC3738011.
 5. Cauwenberghs N, Kuznetsova T. Determinants and Prognostic Significance of the Renal Resistive Index. *Pulse (Basel)*. 2016 Apr;3(3-4):172-8. doi: 10.1159/000442445. Epub 2016 Jan 9. PMID: 27195237; PMCID: PMC4865069.
 6. Geraci G, Ferrara P, La Via L, Sorce A, Calabrese V, Cuttone G, Paternò V, Pallotti F, Sambataro G, Zanolì L, George J, Polosa R, Mulè G, Carollo C. Renal Resistive Index from Renal Hemodynamics to Cardiovascular Risk: Diagnostic, Prognostic, and Therapeutic Implications. *Diseases*. 2025 Jun 9;13(6):178. doi: 10.3390/diseases13060178. PMID: 40558590; PMCID: PMC12191597.
 7. Zeng X, Yang Y. Molecular Mechanisms Underlying Vascular Remodeling in Hypertension. *Rev Cardiovasc Med*. 2024 Feb 20;25(2):72. doi: 10.31083/j.rcm2502072. PMID: 39077331; PMCID: PMC11263180.
 8. Kasliwal RR, Bansal M, Desai D, Sharma M. Carotid intima-media thickness: Current evidence, practices, and Indian experience. *Indian J Endocrinol Metab*. 2014 Jan;18(1):13-22. doi: 10.4103/2230-8210.126522. PMID: 24701425; PMCID: PMC3968727.
 9. Triantafyllou A, Anyfanti P, Koletsos N, Malliora A, Lamprou S, Dipla K, Gkaliagkousi E. Clinical Significance of Altered Vascular Morphology and Function in Normotension. *Curr Hypertens Rep*. 2023 Oct;25(10):287-297. doi: 10.1007/s11906-023-01251-7. Epub 2023 Jul 1. PMID: 37392357; PMCID: PMC10505095.
 10. Kablak-Ziembicka A, Przewlocki T. Clinical Significance of Carotid Intima-Media Complex and Carotid Plaque Assessment by Ultrasound for the Prediction of Adverse Cardiovascular Events in Primary and Secondary Care Patients. *J Clin Med*. 2021 Oct 9;10(20):4628. doi: 10.3390/jcm10204628. PMID: 34682751; PMCID: PMC8538659.
 11. Willeit, Peter et al. "Carotid Intima-Media Thickness Progression as Surrogate Marker for Cardiovascular Risk: Meta-Analysis of 119 Clinical Trials Involving 100 667 Patients." *Circulation* vol. 142,7 (2020): 621-642. doi:10.1161/CIRCULATIONAHA.120.046361
 12. Bots, Michiel L et al. "Carotid Intima-media Thickness Measurements: Relations with Atherosclerosis, Risk of Cardiovascular Disease and Application in Randomized Controlled Trials." *Chinese medical journal* vol. 129,2 (2016): 215-26. doi:10.4103/0366-6999.173500
 13. Peters, Sanne A E, and Michiel L Bots. "Carotid intima-media thickness studies: study design and data analysis." *Journal of stroke* vol. 15,1 (2013): 38-48. doi:10.5853/jos.2013.15.1.38
 14. Kim, Hack-Lyoung. "Arterial stiffness and hypertension." *Clinical hypertension* vol. 29,1 31. 1 Dec. 2023, doi:10.1186/s40885-023-00258-1
 15. Kablak-Ziembicka A, Przewlocki T, Tracz W, Pieniazek P, Musialek P, Sokolowski A. Gender differences in carotid intima-media thickness in patients with suspected coronary artery disease. *Am J Cardiol*. 2005 Nov 1;96(9):1217-22. doi: 10.1016/j.amjcard.2005.06.059. Epub 2005 Sep 2. PMID: 16253585.
 16. Naseh G, Fard MM, Kazemi T, Mirgholami A, Hashemi N, Saburi A. Comparison of Carotid Intima-media Thickness in Hypertensive Patients and Control Group. *J Cardiovasc Echogr*. 2016 Apr-Jun;26(2):48-51. doi: 10.4103/2211-4122.183749. PMID: 28465960; PMCID: PMC5224654.
 17. Touboul PJ, Hennerici MG, Meairs S, Adams H, Amarenco P, Bornstein N, Csiba L, Desvarieux M, Ebrahim S, Hernandez Hernandez R, Jaff M, Kownator S, Naqvi T, Prati P, Rundek T, Sitzer M, Schminke U, Tardif JC, Taylor A, Vicaute E, Woo KS. Mannheim carotid intima-media thickness and plaque consensus (2004-2006-2011). An update on behalf of the advisory board of the 3rd, 4th and 5th watching the risk symposia, at the 13th, 15th and 20th European Stroke Conferences, Mannheim, Germany, 2004, Brussels, Belgium, 2006, and Hamburg, Germany, 2011. *Cerebrovasc Dis*. 2012;34(4):290-6. doi: 10.1159/000343145. Epub 2012 Nov 1. PMID: 23128470; PMCID: PMC3760791.
 18. Uthoff H, Staub D, Meyerhans A, Hochuli M, Bendi B, Schmid HP, Frauchiger B. Intima-media thickness and carotid resistive index: progression over 6 years and predictive value for cardiovascular events. *Ultraschall Med*.

- 2008 Dec;29(6):604-10. doi: 10.1055/s-2008-1027470. Epub 2008 Jun 5. PMID: 18528807.
19. Li, Shengxu et al. "Childhood blood pressure as a predictor of arterial stiffness in young adults: the bogalusa heart study." *Hypertension (Dallas, Tex. : 1979)* vol. 43,3 (2004): 541-6. doi:10.1161/01.HYP.0000115922.98155.23
20. Nambi V, Chambless L, He M, Folsom AR, Mosley T, Boerwinkle E, Ballantyne CM. Common carotid artery intima-media thickness is as good as carotid intima-media thickness of all carotid artery segments in improving prediction of coronary heart disease risk in the Atherosclerosis Risk in Communities (ARIC) study. *Eur Heart J*. 2012 Jan;33(2):183-90. doi: 10.1093/eurheartj/ehr192. Epub 2011 Jun 11. PMID: 21666250; PMCID: PMC3258447.