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Carotid Artery Intima-Media Thickness and Its Correlation with Body Mass Index and Cardiovascular Risk Factors in Asymptomatic Adults in Rural India: A Cross-Sectional Ultrasonographic Study

Yatika Pasricha[1], Nirmal Kumar Mittal[2], Bharti Verma[3]

[1]3rd year PG Resident, [2]Professor & Head,[3]Associate Professor,
Department of Radiodiagnosis, Amaltas Institute of Medical Sciences, Dewas, Madhya Pradesh, India.

Corresponding Author: Yatika Pasricha

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ABSTRACT

Background: Cardiovascular diseases are increasingly prevalent in rural India, and early identification of subclinical atherosclerosis is important for preventive intervention. Carotid intima-media thickness (CIMT) measured by B-mode ultrasonography is a validated surrogate marker for cardiovascular risk assessment. The present study evaluated carotid intima-media thickness and carotid luminal diameter in asymptomatic rural Indian adults and determined their association with body mass index (BMI) and established cardiovascular risk factors.

Materials and Methods: This cross-sectional observational study included 150 asymptomatic adults aged 20–80 years. Participants underwent demographic assessment, anthropometric measurements, blood pressure recording, and carotid ultrasonography using high-resolution B-mode imaging (7.5–12.0 MHz). Carotid intima-media thickness and luminal diameter were measured bilaterally at the common carotid artery (CCA), carotid bifurcation, and internal carotid artery (ICA). Statistical analysis was performed using SPSS version 16.0.

Results: The mean age of participants was 53.2 ± 16.6 years and the mean body mass index was 24.2 ± 4.6 kg/m². Significant positive associations were observed between carotid intima-media thickness and advancing age, obesity, hypertension, diabetes mellitus, smoking, and alcohol consumption. A moderate-to-strong correlation was identified between age and whole carotid intima-media thickness ($r = 0.612$, $p < 0.0001$). Plaque prevalence increased with increasing cardiovascular risk burden.

Conclusion: Carotid ultrasonography is a reliable non-invasive modality for detecting subclinical atherosclerosis and may be useful for cardiovascular risk stratification in asymptomatic rural Indian adults.

Keywords: Carotid intima-media thickness, cardiovascular disease, ultrasonography, obesity, atherosclerosis, rural India

INTRODUCTION

The leading cause of mortality worldwide and a major contributor to non-communicable disease burden in India are cardiovascular diseases (1). The increasing prevalence of cardiovascular disease in both urban and rural populations has been greatly influenced by rapid urbanization, lifestyle transitions, obesity, tobacco use, alcohol consumption, hypertension, and diabetes mellitus (2). While the traditional view was that rural populations were at a lower risk, recent evidence suggests that rural India has a significantly higher rate of cardiovascular morbidity due to changes in dietary patterns, sedentary lifestyles, and increased metabolic risk factors (3). Atherosclerosis is a chronic inflammatory process involving lipid buildup, endothelial dysfunction, smooth muscle growth, and progressive arterial wall thickening (4). Before developing into peripheral vascular disease, myocardial infarction, or stroke, early stages of atherosclerosis frequently go years without showing any clinical symptoms. Therefore, primary prevention and risk reduction depend heavily on early detection of subclinical vascular alterations (5). High-resolution B-mode ultrasonography can accurately measure carotid intima-media thickness (CIMT), a validated indicator of subclinical atherosclerosis (6). Future cardiovascular events, coronary artery disease, cerebrovascular accidents, and all-cause mortality have all been linked to increased carotid intima-media thickness (7). A safe, non-invasive, repeatable, and reasonably priced way to evaluate cardiovascular risk is through carotid artery ultrasonography (8).

A key sign of obesity, body mass index (BMI) has been connected to insulin resistance, dyslipidemia, endothelial dysfunction, and accelerated vascular aging (9). Numerous studies have shown links between increased carotid intima-media thickness and obesity. Atherosclerotic plaque formation and vascular remodeling have also been linked to smoking, alcohol consumption, diabetes mellitus, and hypertension. There is little information on carotid intima-media thickness and its correlation with cardiovascular risk factors in asymptomatic rural Indian adults, despite the country's rising cardiovascular disease burden. In order to assess carotid intima-media thickness and carotid luminal diameter in asymptomatic rural adults and ascertain their correlation with body mass index and other recognized cardiovascular risk factors, the current study was carried out.

MATERIALS & METHODS

Study Design and Sample Size Calculation

This hospital-based cross-sectional observational study was conducted in the Department of Radiodiagnosis at Amaltas Institute of Medical Sciences, Dewas, Madhya Pradesh, over a one-year period following approval from the Institutional Human Ethics Committee (Reg. No: EC/NEW/INST/2022/2692). Based on an anticipated correlation coefficient (r) of 0.25 between BMI and CIMT from pilot regional metrics, an alpha error of 5% (a = 0.05), and a statistical power of 85% (1 - b = 0.85), the minimum calculated target sample size was 141 participants. To maximize statistical validity, a total cohort of 150 asymptomatic adults aged 20–80 years was enrolled.

Participant Recruitment Strategy

Participants were selected via consecutive opportunistic sampling from individuals presenting to the general outpatient health screening units or accompanying patients. Asymptomatic status was defined as the total absence of clinical signs or history suggestive of cerebrovascular accidents, transient ischemic attacks, or peripheral vascular diseases. Exclusion criteria consisted of a confirmed history of coronary artery disease, previous stroke, prior carotid endarterectomy or stenting, critical illness, pregnancy, or an unwillingness to provide written informed consent. Detailed demographic and clinical histories were recorded for all participants, tracking age,

sex, smoking status, alcohol consumption, hypertension, diabetes mellitus, and family history of cardiovascular disease.

Anthropometric and Clinical Measurements

Height and weight were measured using standardized techniques, and body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m²). BMI was categorized according to Asian-specific World Health Organization criteria: Normal weight (<23.0 kg/m²), Overweight (23.0–24.9 kg/m²), Obese Class I (25.0–29.9 kg/m²), and Obese Class II (≥30.0 kg/m²). Blood pressure measurements were obtained using standard sphygmomanometric methods after 10 minutes of rest. Hypertension was defined based on a previous formal diagnosis, current usage of antihypertensive therapy, or blood pressure ≥140/90 mmHg. Diabetes mellitus was identified based on prior diagnosis or ongoing antidiabetic treatment.

Ultrasound Imaging and Measurement Protocol

Carotid ultrasonography was performed utilizing a high-resolution Mindray DC-70 system equipped with a linear array transducer (L12-3E) operating at an optimized operational frequency of 7.5–12.0 MHz. All examinations were executed by a single certified radiologist with the patient resting in a relaxed supine position, neck mildly extended, and the head rotated 45° contralateral to the side being imaged.

B-mode scanning was systematically carried out along the bilateral common carotid artery (CCA), carotid bifurcation, and origin of the internal carotid artery (ICA). Carotid Intima-Media Thickness (CIMT) was measured on the far wall of the CCA along a plaque-free segment 1 cm proximal to the carotid bulb. Carotid luminal diameter was measured from the leading edge of the near-wall intima to the leading edge of the far-wall intima during end-diastole. Carotid plaque was defined according to the Mannheim Consensus criteria as a distinct focal protrusion into the vascular lumen measuring ≥1.5 mm, or representing an encroachment of ≥0.5 mm or ≥50% of the adjacent background CIMT wall thickness. Acoustic parameters including gain, dynamic range, and focal zone were standardized during all examinations to minimize measurement variability.

Observer Variability Assessment

To eliminate intra-observer measurement variability, a subset of 20 randomly selected participants underwent a repeated blinded evaluation by the same radiologist two weeks post-initial exam. The calculated Intra-class Correlation Coefficient (ICC) for the mean CIMT measurements was 0.91 (95% CI: 0.84–0.96), demonstrating excellent internal consistency and reproducibility.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics version 16.0. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were expressed as frequencies and percentages. Group differences for continuous variables across stratified categories were analyzed using the Independent Sample t-test and One-Way Analysis of Variance (ANOVA). Bivariate associations between continuous parameters were assessed via the Pearson correlation coefficient (r). To isolate independent predictors of increased CIMT and control for confounding variables, a multivariable linear regression analysis was executed using mean CCA-CIMT as the dependent variable. A two-tailed p-value less than 0.05 was considered statistically significant.

RESULT

The study population consisted of 150 asymptomatic adults with a mean age of 53.2±16.6 years. Male participants constituted 55.3% (n=83) of the study population while females accounted for 44.7% (n=67). The mean body mass index was 24.2 ± 4.6 kg/m². According to Asian

body mass index classification, 32.7% (n=49) of participants were overweight, 20.7% (n=31) were classified as obese class I, and 11.3% (n=17) belonged to obese class II. Hypertension was observed in 34.0% (n=51) of participants and was the most common cardiovascular risk factor. Diabetes mellitus was present in 20.0% (n=30) of participants, while 24.7% (n=37) had a history of smoking and 20.7% (n=31) reported alcohol consumption.

Table 1: Baseline Demographic and Clinical Characteristics of the Study Population (N=150)

Variable	Category	Frequency (n)	Percentage (%)
Age (years)	Mean ± SD	53.2 ± 16.6	—
Age Group	<40 years	42	28.0%
	40–60 years	58	38.7%
	>60 years	50	33.3%
Sex	Male	83	55.3%
	Female	67	44.7%
BMI (kg/m²)	Mean ± SD	24.2 ± 4.6	—
BMI Status	Normal (<23)	53	35.3%
BMI Status	Overweight	49	32.7%
	Obese Class I	31	20.7%
	Obese Class II	17	11.3%
Hypertension	Yes	51	34.0%
Diabetes Mellitus	Yes	30	20.0%
Smoking Status	Yes	37	24.7%
Alcohol Intake	Yes	31	20.7%

Significant variations in carotid intima-media thickness were observed when evaluated across stratified age groups, hypertensive states, glycemic profiles, and BMI metrics. As detailed in Table 2, a One-Way ANOVA confirmed highly significant differences in mean CCA-CIMT across the age tranches ($p < 0.001$) and BMI classifications ($p = 0.014$). Independent Sample t-tests established significant differences based on history of hypertension ($p < 0.001$) and diabetes mellitus ($p < 0.001$).

Table 2: Carotid Parameters and Plaque Prevalence Stratified by Risk Factors

Variable	Sub-category	Mean CCA-CIMT (mm)	Mean Luminal Diam. (mm)	Plaque Prev. (n, %)	p-value*
Age Group	<40 years (n=42)	0.54 ± 0.06	5.8 ± 0.4	1 (2.4%)	<0.001
	40–60 years (n=58)	0.72 ± 0.09	6.1 ± 0.5	9 (15.5%)	
	>60 years (n=50)	0.94 ± 0.12	6.4 ± 0.6	22 (44.0%)	
Hypertension	Yes (n=51)	0.85 ± 0.14	6.3 ± 0.5	18 (35.3%)	<0.001
	No (n=99)	0.66 ± 0.11	5.9 ± 0.4	14 (14.1%)	
Diabetes	Yes (n=30)	0.88 ± 0.15	6.4 ± 0.6	13 (43.3%)	<0.001
	No (n=120)	0.69 ± 0.11	5.9 ± 0.4	19 (15.8%)	
BMI Status	Normal (<23, n=53)	0.65 ± 0.10	5.9 ± 0.4	6 (11.3%)	0.014
	Overweight (23–24.9)	0.74 ± 0.12	6.1 ± 0.5	11 (22.4%)	
	Obese (≥25, n=48)	0.81 ± 0.15	6.3 ± 0.5	15 (31.3%)	

Bivariate Pearson correlation established a strong, statistically significant linear association between continuous age and whole common carotid intima-media thickness ($r = 0.612$, $p < 0.0001$), as presented in Table 3.

Table 3: Bivariate Pearson Correlation Matrix of Continuous Variables

Parameters	Age (r)	BMI (r)	Systolic BP (r)	Mean CCA-CIMT (r)
Age	1.000	0.112 (p=0.17)	0.415 (p<0.001)	0.612 (p<0.001)
BMI	0.112	1.000	0.284 (p<0.001)	0.362 (p<0.001)
Systolic BP	0.415	0.284	1.000	0.518 (p<0.001)

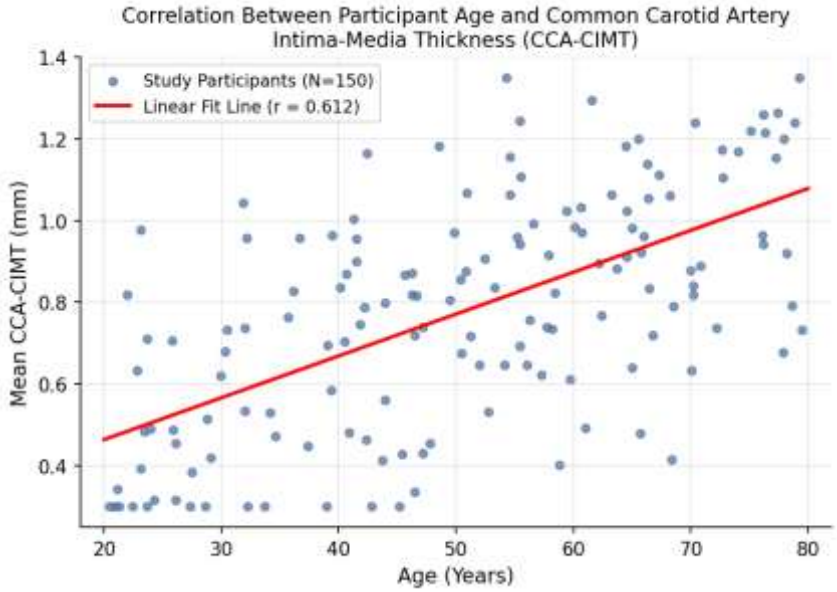

Figure 1: *Bivariate scatter plot demonstrating the strong linear correlation between advancing chronological age and mean Common Carotid Artery Intima-Media Thickness (CCA-CIMT) across the study population (N=150). The solid red line represents the linear regression fit (r=0.612, p<0.0001), illustrating progressive structural vascular remodeling across the age spectrum*

To isolate independent effects and control for confounding pathways, a Multivariable Linear Regression analysis was conducted with mean CCA-CIMT as the dependent outcome parameter (Table 4). The model demonstrates that Age, Hypertension, and Diabetes Mellitus act as independent predictors of elevated CIMT.

Table 4: Multivariable Linear Regression Assessing Independent Predictors of Mean CIMT

Predictor Variable	Unstandardized β	95% Confidence Interval	Standardized Coeff. (β)	t-stat	p-value
Intercept	0.214	[0.145, 0.283]	—	6.14	<0.001
Age (per year)	0.007	[0.006, 0.008]	0.548	8.14	<0.001
BMI (kg/m²)	0.003	[-0.001, 0.007]	0.054	1.12	0.264
Hypertension (Yes/No)	0.068	[0.024, 0.112]	0.182	3.05	0.003
Diabetes (Yes/No)	0.074	[0.028, 0.120]	0.198	3.18	0.002

DISCUSSION

The present study evaluated carotid intima-media thickness and carotid luminal diameter in asymptomatic rural Indian adults and examined their association with body mass index and established cardiovascular risk factors. The mean age of the study population was 53.2 ± 16.6 years with a slight male predominance. A large proportion of participants were overweight or obese, indicating a rising burden of obesity and metabolic risk factors even in rural communities. These findings are consistent with recent Indian epidemiological studies that have reported an increasing prevalence of obesity and cardiovascular disease in rural populations (2).

The study demonstrated a significant positive association between body mass

index and carotid intima-media thickness in bivariate analyses, though this effect was attenuated when adjusted for age, blood pressure, and glycemic status in multivariable modeling. Obesity contributes to endothelial dysfunction, chronic low-grade inflammation, oxidative stress, insulin resistance, and vascular remodeling, which together accelerate subclinical atherosclerosis. Increased carotid intima-media thickness among obese individuals observed in the present study supports previous studies conducted in Indian and international populations (5).

Hypertension demonstrated a significant independent association with increased carotid intima-media thickness. Chronic elevation of arterial pressure results in endothelial shear injury, medial hypertrophy, and increased arterial stiffness, which accelerates atherosclerotic progression (1). Diabetes mellitus was also independently associated with significantly increased carotid intima-media thickness. Hyperglycemia induces endothelial dysfunction, oxidative stress, advanced glycation end-product (AGE) formation, and inflammatory pathways, contributing to accelerated vascular aging and elevated cardiovascular risk burden (4).

Smoking participants demonstrated significantly higher carotid intima-media thickness compared to non-smokers. Tobacco exposure causes direct endothelial injury, oxidative stress, reduced nitric oxide bioavailability, and increased vascular inflammation. Smoking remains one of the strongest modifiable cardiovascular risk factors (6). Alcohol consumption was also associated with increased carotid intima-media thickness and carotid luminal diameter. Chronic alcohol intake may contribute to secondary hypertension, vascular remodeling, and adverse hemodynamic effects (7).

The strongest correlation identified in the present study was between age and carotid intima-media thickness (r = 0.612). The progressive increase in carotid intima-media thickness with age reflects cumulative arterial wall remodeling and progressive atherosclerotic changes over time. Similar findings have been reported in major epidemiological studies including the ARIC study and SCORE-India study (6, 9).

Our cross-sectional study showed that as the cardiovascular risk factor burden clustered, the prevalence of distinct carotid plaques increased significantly, reaching 44.0% in individuals over 60 years of age. The detection of advanced subclinical plaques in completely asymptomatic individuals underscores the potential public health utility of early cardiovascular screening pathways. High-resolution B-mode ultrasonography provides a safe, non-invasive, repeatable, and economical method appropriate for targeted risk screening in resource-limited rural environments. Early identification of high-risk individuals via carotid evaluations may facilitate timely lifestyle modifications and primary preventive medical interventions.

Limitations

This study has several limitations that must be acknowledged. First, the cross-sectional design captures data at a single point in time, which strictly precludes any causal interpretations or prospective tracking of incident clinical cardiovascular events. Second, this was a single-center study conducted with a relatively small sample size (N=150) at a rural tertiary hospital using consecutive opportunistic sampling, which may introduce selection bias and limit the immediate generalizability of the findings to the wider, highly heterogeneous Indian population. Third, our clinical risk profiling lacked comprehensive biochemical parameters, such as full serum lipid panels (LDL, HDL, total cholesterol, triglycerides) and glycosylated hemoglobin (HbA1c) values, which are critical elements of established cardiovascular risk scores. Future multi-centric, prospective longitudinal cohorts with comprehensive metabolic profiling are required to validate regional normative CIMT standards and quantify long-term predictive accuracy..

CONCLUSION

Carotid intima-media thickness demonstrates a significant cross-sectional association with advancing age, hypertension, diabetes mellitus, smoking, alcohol consumption, and elevated body mass index in asymptomatic rural Indian adults. The study highlights a substantial unaddressed burden of subclinical atherosclerosis and clustering cardiovascular risk factors in rural populations undergoing lifestyle transitions. High-resolution carotid ultrasonography represents a reliable, non-invasive, and practical tool for the early identification of subclinical vascular alterations. Early detection of high-risk individuals may facilitate timely primary preventive interventions and mitigate long-term cardiovascular morbidity and mortality. Further multi-centric studies with larger sample sizes are recommended to validate routine cardiovascular risk screening strategies.

Declaration by Authors

Ethical Approval: Approved by the Institutional Human Ethics Committee (Amaltas Institute of Medical Sciences, Reg. No: EC/NEW/INST/2022/2692).

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Conflict of Interest: The authors declare no conflict of interest.

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