

Assessment of Carotid Artery Stenosis Using Doppler Ultrasonography: A Cross-Sectional Study in High-Risk Patients

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Abstract: ***Background:** Carotid artery stenosis (CAS) is a significant cause of ischemic stroke and transient ischemic attacks (TIA). Early detection, especially in high-risk populations, allows timely intervention and can reduce morbidity and mortality. Doppler ultrasonography is a non-invasive, real-time imaging modality widely used for screening and assessment of CAS. **Objectives:** To determine the prevalence and severity of carotid artery stenosis in a high-risk patient population using Doppler ultrasonography. **Methods:** A descriptive, cross-sectional study conducted over 6 months at Dr. Vitthalrao Vikhe Patil Foundation Medical College and Hospital involving 20 high-risk patients (age ≥ 40 years) with risk factors such as hypertension, diabetes mellitus, smoking, dyslipidemia, and previous history of cerebrovascular events. Doppler ultrasonography measured intima-media thickness (IMT), peak systolic velocity (PSV), end-diastolic velocity (EDV), and plaque morphology to categorize the degree of stenosis. **Results:** Of the 20 patients, 15 (75%) were male and 5 (25%) female. The mean age was 62.3 ± 9.8 years. Doppler detected CAS in 10 patients (50%) with varying severity: mild ($n=6$), moderate ($n=3$), and severe ($n=1$). Increased carotid IMT correlated positively with severity of stenosis ($p<0.05$). Patients with diabetes and hypertension showed higher prevalence of significant stenosis. **Conclusions:** Doppler ultrasonography effectively identified and graded CAS in high-risk individuals. Routine screening in such populations may help early diagnosis and prevent ischemic cerebrovascular events.*

Keywords: Carotid artery stenosis, Doppler ultrasonography, high-risk patients, cerebrovascular disease, intima-media thickness.

1. Introduction

One of the main causes of death and long-term impairment, cerebrovascular disorders (CVDs) are a significant global public health concern. Globally, stroke is the second leading cause of death and a major contributor to disability-adjusted life years lost, with ischemic strokes accounting for nearly 80–85% of all cases.^[1] In India, the burden of stroke has been steadily increasing due to rapid urbanization, lifestyle changes, aging population, and rising prevalence of non-communicable diseases such as hypertension and diabetes mellitus.^[2]

One known and perhaps avoidable cause of ischaemic stroke and transient ischaemic attack (TIA) is atherosclerotic carotid artery stenosis (CAS).^[3] The arterial lumen gradually narrows as a result of carotid atherosclerosis, impairing cerebral blood flow and increasing the risk of artery-to-artery embolism. The carotid bifurcation and proximal internal carotid artery are particularly susceptible to the formation of atherosclerotic plaque due to their complex flow dynamics and low shear stress.^[4]

Numerous epidemiological studies have shown that patients with severe carotid artery stenosis have a much increased risk of experiencing ischaemic cerebrovascular events in the future. Therefore, early CAS diagnosis and grading are crucial to stroke prevention strategies, especially for high-risk people^[5]. High-risk individuals often include those with advanced age, hypertension, diabetes mellitus, dyslipidaemia, smoking or tobacco use, and a history of cardiovascular or cerebrovascular events.

Carotid Doppler ultrasonography is now the main imaging method for identifying and evaluating carotid artery disease. Spectral, colour Doppler, and B-mode imaging This non-invasive, radiation-free, real-time technique combines Doppler analysis to provide morphological and haemodynamic data.^[6] Accurate measures of intima-media thickness (IMT), plaque properties, and blood flow velocities, such as peak systolic velocity (PSV) and end-diastolic velocity (EDV), are made possible by Doppler ultrasonography and are essential for determining the degree of stenosis.^[7]

Compared to invasive techniques like digital subtraction angiography (DSA), Doppler ultrasonography is less expensive, safer, and suitable for routine follow-up scans. Although computed tomography angiography (CTA) and magnetic resonance angiography (MRA) provide good anatomical detail, their availability, greater cost, and contrast agent exposure limit their frequent use, particularly in low-resource settings.^[8] Doppler ultrasonography is the most effective technique for large-scale screening and risk assessment.

Carotid intima-media thickness is a well-known surrogate biomarker of early atherosclerosis and cardiovascular risk. Elevated IMT, which has been shown to have a significant connection with the future risk of stroke and myocardial infarction, reflects subclinical arterial wall changes. Ultrasonographic evaluation of IMT provides an opportunity to detect vascular disease at a preclinical stage before haemodynamically substantial stenosis appears.^[9] Research demonstrating a favourable correlation between elevated

Volume 15 Issue 4, April 2026

Fully Refereed | Open Access | Double Blind Peer Reviewed Journal

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IMT and the degree of carotid artery stenosis has demonstrated the use of IMT as a screening tool in high-risk individuals.^[17] Monitoring the progression of IMT may also help evaluate the effectiveness of preventive treatments such as lifestyle modifications and lipid-lowering drugs.

There is a dearth of information from tertiary care facilities in semi-urban areas about the frequency and severity of carotid artery stenosis among high-risk patients, despite the rising incidence of stroke in India. The bulk of currently available Indian studies are either community-based or conducted in metropolitan regions with little imaging data, which may not accurately represent the disease burden in other settings. Because Doppler ultrasonography is widely available and simple to use, assessing its ability to detect CAS in high-risk patients in a tertiary care hospital setting has significant therapeutic implications. By allowing for timely medical therapy, risk factor modification, and, in some cases, surgical or endovascular intervention, early identification of carotid artery disease reduces the risk of stroke and transient ischaemic attack (TIA).^[10]

2. Objectives

Primary Objective

- To assess the prevalence and severity of carotid artery stenosis in high-risk patients using Doppler ultrasonography.

Secondary Objectives

- To correlate carotid intima-media thickness with degree of stenosis.
- To analyze the association between vascular risk factors and severity of carotid stenosis.

3. Materials and Methods

Study Design: The study was conducted as a descriptive, cross-sectional study.

Study Setting: The study was carried out in the Department of Radiology at Dr. Vithalrao Vikhe Patil Foundation Medical College and Hospital, Ahmednagar, Maharashtra, India.

Study Duration: The duration of the study was six months, from July 2024 to December 2024.

Sample Size: A total of 20 high-risk patients were enrolled using purposive sampling based on clinical risk profiles.

Study Population

Inclusion Criteria

- Adult patients aged ≥ 40 years.
- High-risk profile (presence of one or more risk factors: hypertension, diabetes mellitus, dyslipidemia, smoking/tobacco use, history of TIA or stroke).
- Patients who provided informed consent.

Exclusion Criteria

- Patients with previous carotid endarterectomy or stenting.

- Patients with severe comorbid conditions preventing participation.
- Unwilling or non-compliant patients.

Data Collection Procedure

Detailed history was recorded including age, gender, presence of hypertension, diabetes mellitus, smoking status, dyslipidemia, prior TIA/stroke, and medication usage.

All enrolled patients underwent carotid Doppler ultrasonography using a high-resolution linear array transducer (7.5–10 MHz). Scans were performed bilaterally to assess:

- Carotid intima-media thickness (IMT)
- Peak systolic velocity (PSV)
- End-diastolic velocity (EDV)
- Plaque morphology
- Degree of stenosis

Ultrasound Protocol

Patients were examined in a supine position with mild neck extension. Longitudinal and transverse views of the common carotid artery (CCA), carotid bulb, internal carotid artery (ICA), and external carotid artery (ECA) were acquired. Doppler waveforms were obtained to measure PSV and EDV at predefined segments. IMT was measured at the far wall of the distal CCA.

Definition of Stenosis Severity

Severity of stenosis was categorized based on established Doppler criteria:¹⁰

Stenosis Severity	PSV (ICA)	ICA/CCA PSV Ratio
Normal	<125 cm/s	<2
Mild (<50%)	<125 cm/s	<2
Moderate (50–69%)	125–230 cm/s	2–4
Severe ($\geq 70\%$)	>230 cm/s	>4

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS version 25. Descriptive statistics were expressed as mean \pm SD for continuous variables, and frequencies and percentages for categorical variables. Correlation analysis was performed between IMT and stenosis severity. A p-value <0.05 was considered statistically significant.

Ethical Considerations

This study was approved by the Institutional Ethics Committee of Dr. Vithalrao Vikhe Patil Foundation Medical College and Hospital (Approval No: IEC/DPVVPFMC/2024/07). Written informed consent was obtained from all participants.

4. Results

Demographic Characteristics

Out of 20 patients, **15 (75%) were male and 5 (25%) were female with a mean age of 62.3 ± 9.8 years.** Age distribution showed that majority (60%) were between 60 and 70 years (Table 1).

Table 1: Demographic Profile of Study Participants

Variable	Frequency (n=20)	Percentage (%)
Mean age (years)	62.3 ± 9.8	—
Gender		
Male	15	75
Female	5	25
Age group		
40–49 years	2	10
50–59 years	6	30
60–69 years	12	60

Table 1 illustrates the demographic characteristics of the study population. Among the 20 participants, males constituted the majority with 15 patients (75%), while females accounted for 5 patients (25%). The mean age of the study population was 62.3 ± 9.8 years. Age-wise distribution revealed that the largest proportion of patients (60%) belonged to the 60–69 years age group, followed by 30% in the 50–59 years group and 10% in the 40–49 years group, indicating a predominance of elderly individuals in this high-risk cohort.

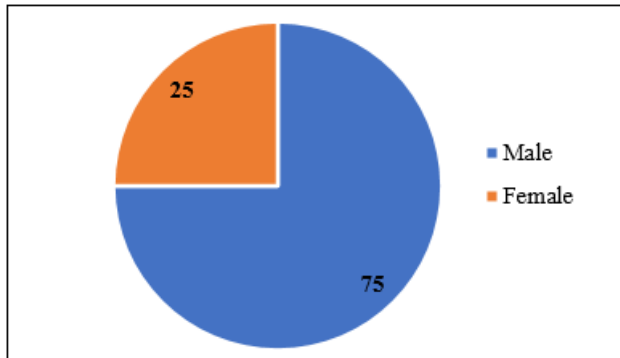


Figure 1A: Gender Distribution

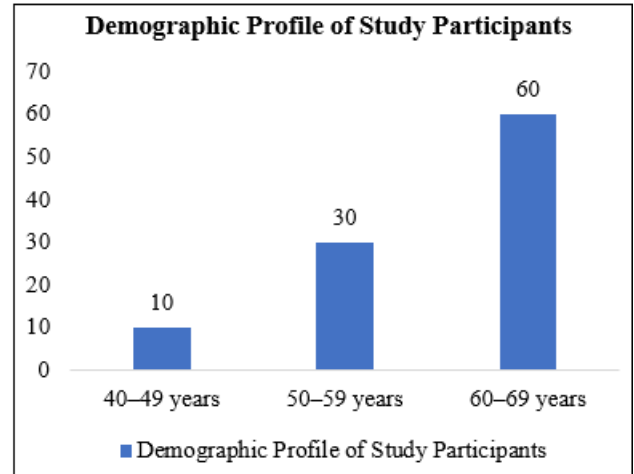


Figure 1B: Age distribution

Prevalence of Vascular Risk Factors

Most patients had multiple risk factors (Table 2). Hypertension was the most prevalent (85%), followed by diabetes mellitus (70%), dyslipidemia (55%), and smoking/tobacco use (50%).

Table 2: Distribution of Vascular Risk Factors

Risk Factor	Frequency (n=20)	Percentage (%)
Hypertension	17	85
Diabetes Mellitus	14	70
Dyslipidemia	11	55
Smoking/Tobacco use	10	50
History of TIA/Stroke	4	20

Table 2 presents the prevalence of vascular risk factors among the study participants. Hypertension was the most common risk factor, observed in 17 patients (85%), followed by diabetes mellitus in 14 patients (70%). Dyslipidemia was present in 11 patients (55%), while smoking or tobacco use was reported by 10 patients (50%). A prior history of transient ischemic attack or stroke was noted in 4 patients (20%). Most patients exhibited more than one vascular risk factor, emphasizing the high-risk nature of the study population.

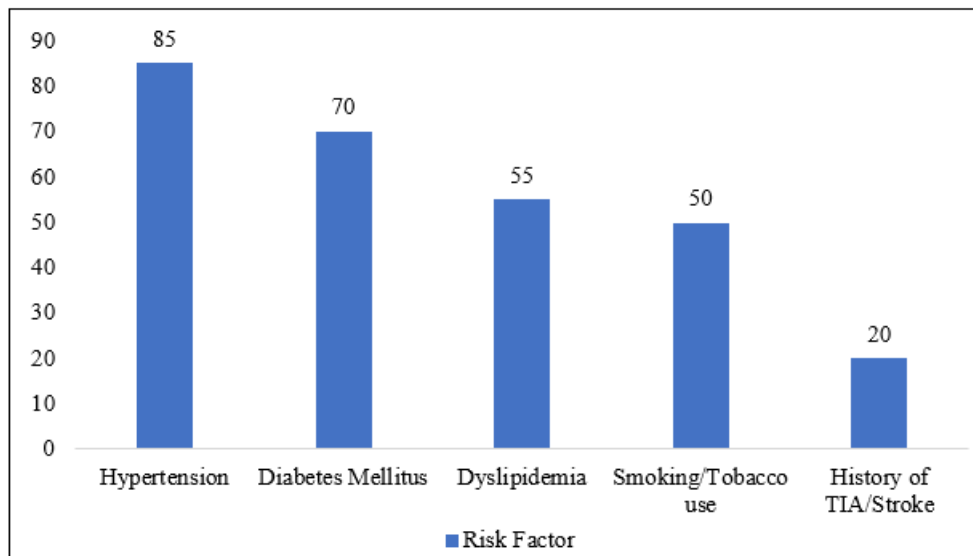


Figure 2: Risk Factor

Carotid Doppler Findings

Carotid Doppler detected stenosis in **10 patients (50%)** (Table 3). Among those, 6 had *mild stenosis*, 3 had *moderate stenosis*, and 1 patient had *severe stenosis* (>70%).

Table 3: Severity of Carotid Artery Stenosis

Stenosis Category	Frequency (n=20)	Percentage (%)
No stenosis	10	50
Mild (<50%)	6	30
Moderate (50–69%)	3	15
Severe (≥70%)	1	5

Table 3 summarizes the severity of carotid artery stenosis as detected by Doppler ultrasonography. Half of the patients (50%) showed no evidence of carotid artery stenosis. Among the remaining 50% with stenosis, mild stenosis (<50%) was the most common, seen in 6 patients (30%), followed by moderate stenosis (50–69%) in 3 patients (15%). Severe stenosis (≥70%) was identified in 1 patient (5%), indicating a smaller proportion with advanced disease.

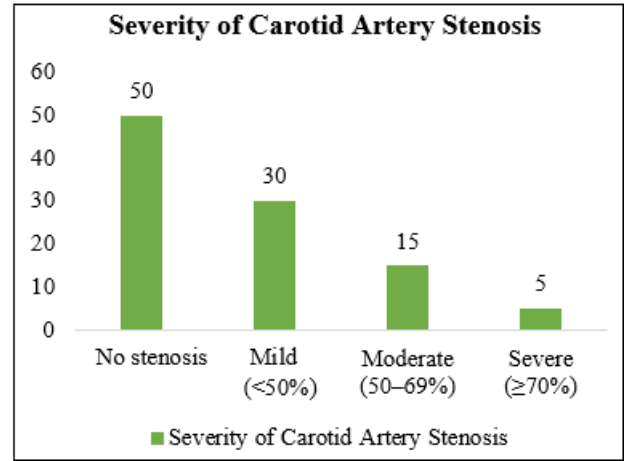
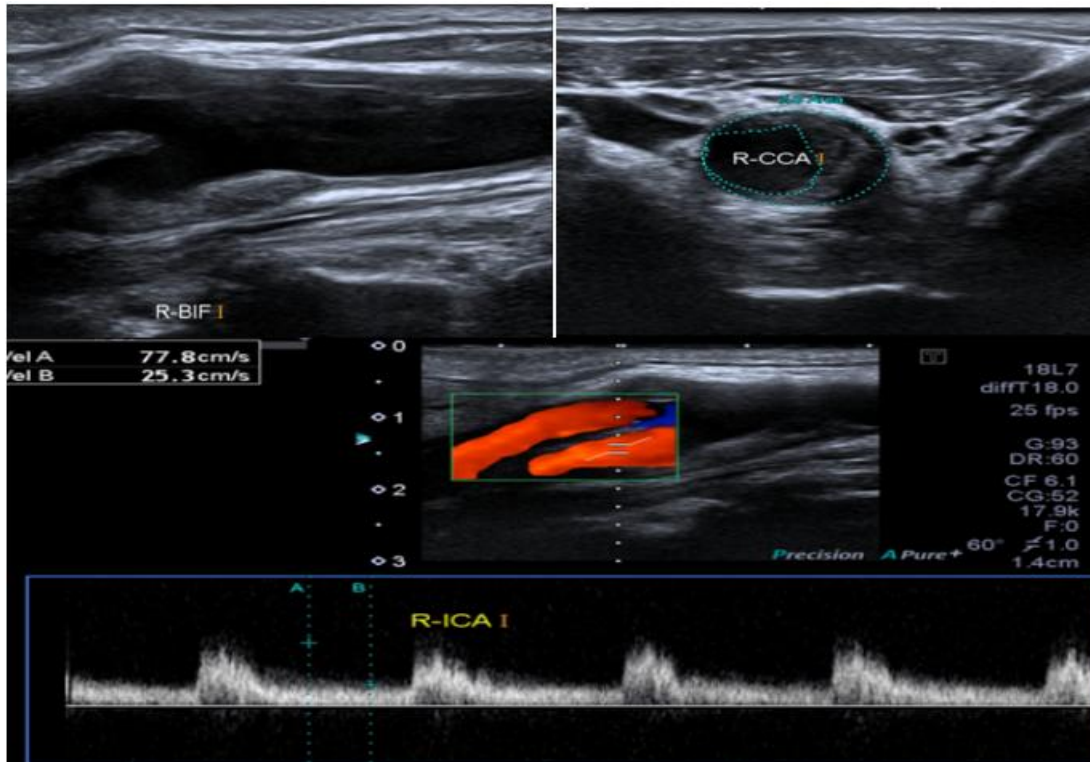


Figure 3



Intima-media thickness is increased diffusely with variable thickness predominantly hypoechoic plaques (type-1) causing 78% of area stenosis in the right proximal ICA. there is no color aliasing at the site of maximum stenosis in right ICA.

Intima-Media Thickness and Stenosis

Mean carotid IMT was significantly higher among patients with carotid artery stenosis compared to those without stenosis (1.12 ± 0.20 mm vs 0.78 ± 0.10 mm). The difference was statistically significant, indicating a positive correlation between IMT and severity of stenosis (p < 0.05).

Table 4: Comparison of Carotid IMT in Patients with and Without Stenosis

Parameter	Stenosis Present (n=10)	No Stenosis (n=10)	p-value
Mean IMT (mm)	1.12 ± 0.20	0.78 ± 0.10	<0.05*

*Statistically significant

Table 4 compares the mean carotid intima-media thickness (IMT) between patients with and without carotid artery stenosis. The mean IMT of patients with stenosis was substantially greater (1.12 ± 0.20 mm) than that of patients without stenosis (0.78 ± 0.10 mm). This difference was statistically significant (p < 0.05), indicating that carotid artery stenosis and elevated IMT are positively correlated.

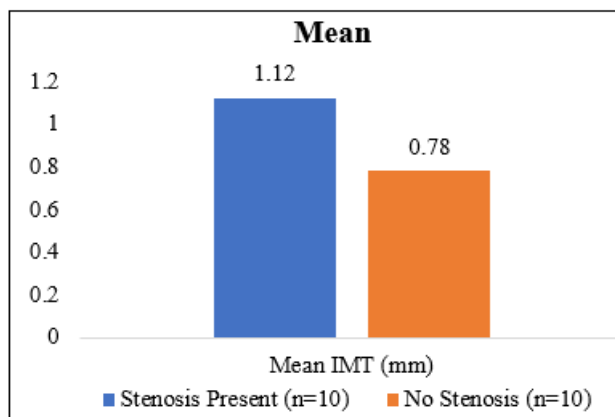


Figure 4A

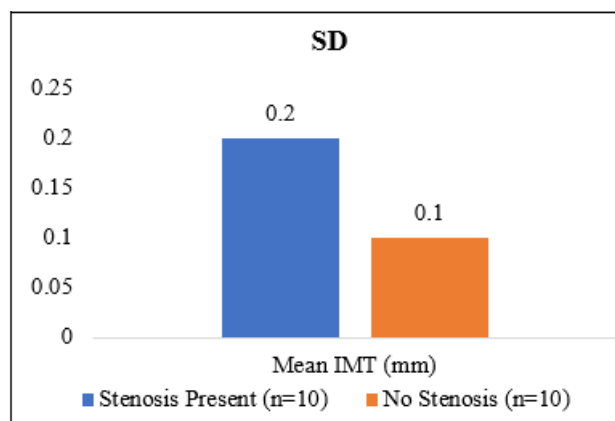


Figure 4B

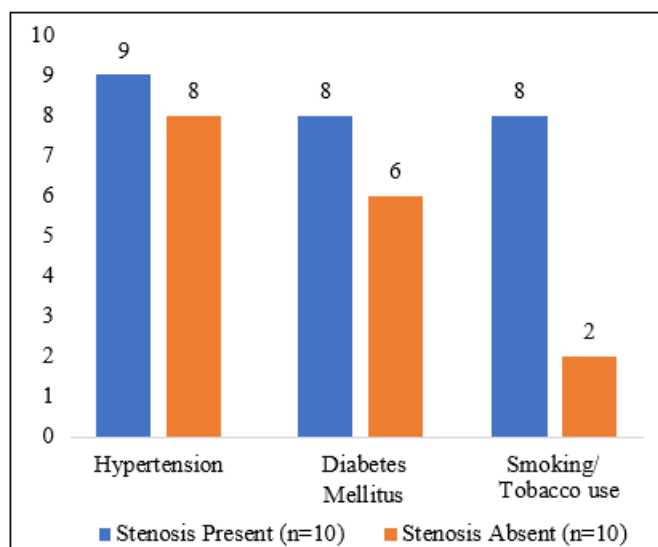


Figure 3

Association between Risk Factors and Carotid Stenosis

Patients with combined risk factors demonstrated a higher prevalence and severity of carotid artery stenosis. Those with both hypertension and diabetes mellitus showed a 70% prevalence of stenosis. Smoking or tobacco use was associated with increased severity of stenosis.

Table 5: Association Between Major Risk Factors and Carotid Artery Stenosis

Risk Factor	Stenosis Present (n=10)	Stenosis Absent (n=10)	p-value
Hypertension	9	8	0.04*
Diabetes Mellitus	8	6	0.03*
Smoking/Tobacco use	8	2	0.02*

*Statistically significant

Table 5 depicts the association between major vascular risk factors and the presence of carotid artery stenosis. Nine patients with stenosis and eight patients without stenosis had hypertension, which was substantially correlated with stenosis (p = 0.04). With eight individuals in the stenosis group compared to six in the non-stenosis group, diabetes mellitus also shown a significant correlation (p = 0.03). Eight individuals with carotid artery stenosis had smoking or tobacco use, compared to just two patients without stenosis (p = 0.02), indicating a high correlation between the two conditions. These results suggest that the development and severity of carotid artery stenosis are significantly influenced by conventional vascular risk factors.

5. Discussion

Carotid artery stenosis is a major contributor to ischemic stroke and transient ischemic attack, particularly among individuals with established vascular risk factors. A dependable, non-invasive, and reasonably priced method for the early identification and grading of carotid artery disease is Doppler ultrasonography. The current cross-sectional investigation evaluated the link between carotid intima-media thickness (IMT) and the prevalence, severity, and risk factors of carotid artery stenosis in high-risk individuals. Kasliwal RR *et al.* [9]

With a mean age of 62.3 ± 9.8 years, the majority of participants in this research were male (75%), and the majority of patients were in the 60–69 age range (Table 1). Due to cumulative exposure to atherosclerotic risk factors and hormonal influences that provide relative vascular protection in premenopausal women, this demographic pattern is consistent with previous studies that reported a higher prevalence of carotid artery disease among older males. Ling Y *et al.* [11] The prevalence of older people in this research emphasises the need of focused screening in this age range, as ageing is a well-established independent risk factor for atherosclerosis.

This cohort's distribution of vascular risk variables highlights the complexity of carotid artery disease. The most common risk factor was hypertension (85%), which was followed by dyslipidaemia (55%), diabetes mellitus (70%), and smoking or tobacco use (50%) (Table 2). These results are consistent with earlier epidemiological research showing that diabetes and hypertension are the best indicators of carotid atherosclerosis because of their involvement in endothelial dysfunction, arterial wall remodelling, and accelerated plaque formation Zyriax BC *et al.* [12]. The majority of patients have numerous risk factors, which highlights how these problems work together to accelerate the development of vascular disease.

Fifty percent of the study group had some degree of carotid artery stenosis, according to carotid Doppler test (Table 3). The most frequent result was mild stenosis (<50%), which was seen in 30% of patients. Moderate and severe stenosis

were seen in 15% and 5% of patients, respectively. The usefulness of Doppler ultrasonography as a screening technique in asymptomatic or slightly symptomatic persons has been reinforced by similar prevalence rates found in high-risk groups in both Indian and international research Goffi A *et al.* [10]. Even if severe stenosis was less prevalent, it is clinically important to identify it since it has a significantly higher risk of cerebrovascular events and may require endovascular or surgical intervention.

The substantial correlation between carotid IMT and the existence of carotid artery stenosis was one of the study's main conclusions. The mean IMT of patients with stenosis was substantially greater than that of patients without stenosis (1.12 ± 0.20 mm vs. 0.78 ± 0.10 mm), and the difference was statistically significant ($p < 0.05$) (Table 4). Kasliwal RR *et al.* [9] This finding confirms previous findings that elevated carotid IMT is a good indicator of the existence and severity of carotid artery stenosis and is an early indicator of subclinical atherosclerosis Polak JF *et al.* [13]. Even before luminal constriction becomes noticeable, IMT testing is very useful in detecting people with elevated cardiovascular risk.

This study further investigated the relationship between carotid artery stenosis and major vascular risk variables (Table 5). There were statistically significant correlations between the occurrence of stenosis and diabetes mellitus, hypertension, and tobacco use. Stenosis was much more common in patients with both diabetes and hypertension, underscoring the combined impact of both risk factors on arterial wall pathology. Due to its pro-inflammatory and pro-thrombotic effects, as well as its function in generating oxidative stress and plaque instability, smoking was also strongly linked to higher severity of stenosis Vranic H *et al.* [14]. These results are consistent with earlier research that shown smoking to be a significant but modifiable risk factor for stroke and carotid atherosclerosis.

The study's findings have significant clinical ramifications. The necessity of frequent carotid Doppler screening in individuals with numerous vascular risk factors is supported by the high incidence of carotid artery stenosis. Early detection of mild to moderate stenosis enables prompt beginning of aggressive medical care, including lipid-lowering medicine, glycaemic control, optimum blood pressure control, and lifestyle changes. Mortimer R *et al.* [15] Additionally, IMT evaluation might be a useful supplementary indicator for cardiovascular risk assessment, especially in environments with limited resources where sophisticated imaging techniques might not be easily accessible.

The study has certain shortcomings despite its advantages. The results may not be as broadly applicable as they may be due to the limited sample size and single-center methodology. Furthermore, the study's cross-sectional design makes it impossible to evaluate the causes and long-term course of carotid artery disease. To confirm these results and investigate the prognostic importance of IMT and carotid stenosis in predicting cerebrovascular outcomes, more research with bigger sample numbers, multicenter involvement, and long-term follow-up is necessary.

The current study concludes that high-risk individuals have a significant burden of carotid artery stenosis, and that conventional vascular risk factors, elevated carotid IMT, and stenosis severity are strongly correlated. An efficient and trustworthy method for the early identification and grading of carotid artery disease is Doppler ultrasonography. Through early intervention and thorough risk factor management, frequent carotid screen and IMT evaluation in high-risk groups may be crucial in lowering the incidence of stroke.

6. Limitations of the Study

When evaluating the results, it is important to take into account the limitations of the current study. First, the results may not be as generalisable to a larger population due to the limited sample size ($n = 20$). Second, it is difficult to determine the temporal or causative links between vascular risk factors and the onset or advancement of carotid artery stenosis due to the cross-sectional research design. Third, only Doppler ultrasonography was used for carotid artery assessment; the lack of confirmatory imaging modalities like computed tomography angiography (CTA) or magnetic resonance angiography (MRA) may have decreased diagnostic accuracy, especially in complex or borderline cases of stenosis. Notwithstanding these drawbacks, the study offers insightful first information about the prevalence of carotid artery disease in high-risk individuals.

7. Conclusion

This study demonstrates a substantial prevalence of carotid artery stenosis among high-risk individuals, with a higher burden observed in older males and in patients with multiple vascular risk factors such as hypertension, diabetes mellitus, and smoking. Carotid Doppler ultrasonography has been shown to be a useful non-invasive method for determining the thickness of the carotid intima-media and for identifying and grading carotid artery stenosis. Its usefulness as an early indicator of atherosclerosis is shown by the strong correlation between elevated IMT and the existence of carotid artery stenosis. Regular carotid Doppler screening may help with early identification and prompt care, thereby lowering the incidence of further cerebrovascular episodes, especially in people with multiple risk factors. To confirm these results and clarify the function of carotid Doppler ultrasonography in stroke preventive tactics, more extensive, long-term investigations using cutting-edge imaging methods are advised.

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