Original Article
DOI: https://doi.org/10.70749/ijbr.v3i4.2415

INDUS JOURNAL OF BIOSCIENCE RESEARCH
https://ijbr.com.pk
ISSN: 2960-2793/ 2960-2807

Frequency and Pattern of Carotid Artery Stenosis in Ischemic Stroke Patients

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ARTICLE INFO

Keywords: Ischemic stroke, Carotid artery stenosis, Doppler ultrasound.

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Declaration
Authors' Contribution: All authors equally contributed to the study and approved the final manuscript.

Conflict of Interest: No conflict of interest.

Funding: No funding received by the authors.

Article History
Received: 02-02-2025 Revised: 18-04-2025
Accepted: 22-04-2025 Published: 30-04-2025

ABSTRACT

Objective: Ischemic stroke is a major contributor of global morbidity and mortality and is often associated with carotid artery stenosis, which can impact the extent of cerebral infarction and clinical outcomes. Early detection of significant stenosis is essential for prompt intervention and effective risk stratification. This study was conducted to assess the frequency and patterns of carotid artery stenosis in patients with acute ischemic stroke. **Methods:** A cross-sectional study was conducted over six months at the Department of Neurology, Hayatabad Medical Complex, Peshawar, during July 2024 to December 2024, after ethical approval from the Institutional Review Board and CPSP. A total of 150 patients aged 20–75 years were recruited via consecutive sampling. Clinical evaluation, CT brain, and carotid Doppler ultrasound were performed to confirm ischemic stroke and to assess stenosis. Patients with prior carotid surgery, hemorrhagic stroke, brain injury, neck masses, cervical deformities, or inability to undergo Doppler were excluded. Demographic, clinical, and vascular risk factors were recorded, and data were analyzed using SPSS version 22, quantitative variables were expressed as mean ± SD, qualitative variables as frequencies and percentages, and associations assessed with chi-square tests ($p < 0.05$). **Results:** Among 150 patients, ischemic changes on CT brain were present in 87 (58.0%) patients. Right-sided ≥50% stenosis was observed in 33 (22%) and left-sided in 41 (27%), while complete occlusion was rare (6 [4.0%] right and 2 [1.3%] left). Hypertension 102 (68%) and diabetes 61 (40.7%). Higher systolic and diastolic blood pressures and confusion 25(28.7%) were significantly associated with ischemic changes ($p = 0.001$). **Conclusion:** It was predicted in our study that majority of the patients exhibited <50% of stenosis, while complete occlusion was infrequent. However, significant association existed between ischemic changes with left carotid artery stenosis which was insignificant in case of right side.

INTRODUCTION

Ischemic stroke, accounting for approximately 80–87% of all strokes, represents a major global public health concern and is a leading cause of morbidity and mortality. Among the various factors influencing its occurrence and outcomes, carotid artery stenosis constitutes a particularly significant contributor [1,2]. In Pakistan, the reported frequency of significant carotid artery stenosis among ischemic stroke patients is approximately 55% [3].

Ischemic stroke results from an abrupt interruption of cerebral blood flow, causing focal neurological deficits such as sudden weakness, sensory loss, or speech disturbance. Diagnosis is based on clinical assessment and confirmed by neuroimaging, particularly computed tomography (CT), which identifies ischemic changes [4]. As a leading cause of disability and death worldwide with a high risk of recurrence, ischemic stroke significantly impacts patients' quality of life. Identifying and addressing risk factors for recurrence is therefore critical for effective prevention and management [5].

Carotid artery stenosis refers to the narrowing of one or both carotid arteries, which supply blood to the brain, most commonly due to atherosclerotic plaque formation. It can present with a wide spectrum of clinical manifestations, ranging from transient visual disturbances to severe neurological deficits resulting from stroke. [6,7]. The severity of stenosis is typically quantified as a reduction in luminal diameter, with clinically significant stenosis generally considered to be within the range of 50–70% or greater. For this research, clinically significant carotid stenosis will be defined as a ≥50% reduction in luminal diameter, as determined by Doppler ultrasound [8].

The common types of carotid stenosis (CS) are typically described in three clinical dimensions. First, symptomatic CS refers to patients who have experienced events like transient ischemic attack (TIA), amaurosis fugax, or ischemic stroke, whereas asymptomatic CS refers to a ≥ 50% narrowing detected incidentally without such

symptoms in the past six months [9]. Second, according to the NASCET criteria, stenosis is categorized anatomically as mild (< 30 %), moderate (30–69 %), severe (70–99 %), and complete occlusion (100 %) [10]. Third, plaque morphology on imaging can be classified broadly into calcified, non-calcified, or mixed plaques, differentiated by CT attenuation, which helps in assessing plaque stability and stroke risk [11].

Carotid stenosis (CS), driven by atherosclerotic plaque formation through endothelial dysfunction and foam cell accumulation, is associated with risk factors such as hypertension, diabetes, chronic kidney disease, smoking, and diet. Duplex ultrasound is the diagnostic standard, while carotid endarterectomy and stenting are preferred for symptomatic severe disease. In asymptomatic cases, intensive medical therapy is increasingly used, with lifestyle modification central to prevention [7].

Carotid stenosis is a major ischemic stroke risk factor, arising from endothelial dysfunction, inflammation, and oxidative stress that promote plaque progression into stable or unstable lesions. Carotid endarterectomy and stenting are effective for symptomatic high-grade stenosis, but management of asymptomatic disease remains debated. Advances in atherosclerosis research and evolving therapies are key to optimizing prevention and treatment [12].

Duplex ultrasound is the most widely used diagnostic modality for carotid artery stenosis, assessing severity by measuring blood flow velocity rather than direct luminal narrowing. Stenosis is commonly categorized as normal, <50%, 50–69%, ≥70% to near occlusion, or complete occlusion [13,14]. In this study, the pattern of carotid stenosis refers to both location (unilateral or bilateral) and degree of narrowing assessed by carotid Doppler ultrasound, classified as mild (<50%), moderate (50–69%), severe (≥70%), or complete occlusion (100%) [15].

Understanding the frequency and patterns of carotid artery stenosis in the setting of ischemic stroke is essential, not only due to its prevalence but also because of its implications for patient management and prognosis. Although carotid artery stenosis is a recognized contributor to ischemic stroke, there remains a considerable gap in the literature regarding its frequency and distribution, particularly among Pakistani patients. Reported rates in Pakistan appear significantly higher than global estimates, which range from 15% to 20% [14].

These marked variations highlight the need for further investigation. The present study aims to address this gap by evaluating the frequency and patterns of carotid artery stenosis in ischemic stroke patients through a noninvasive and widely accessible diagnostic modality. The findings are expected to advise therapeutic decision-making in clinical practice and provide a foundation for future research directed at optimizing the management of ischemic stroke.

METHODOLOGY

This cross-sectional study was conducted in the Department of Neurology at Hayatabad Medical Complex (HMC), Peshawar, over period of six months, from July 2024 to December 2024. A total of 150 participants were be recruited using consecutive non-probability sampling. The sample size was calculated using the Open-Epi calculator, based on an anticipated prevalence of 52.9% carotid artery stenosis among ischemic stroke patients, with a 95% confidence interval and an 8% margin of error. Ethical approval was obtained from the Institutional Review Board of HMC and the College of Physicians and Surgeons Pakistan (CPSP), and written informed consent was taken from all patients or their legal guardians.

The study population comprised of male and female patients aged 20–75 years, diagnosed with acute ischemic stroke within seven days of onset, confirmed by clinical assessment and brain computed tomography (CT), and subsequently evaluated with carotid Doppler ultrasound. Patients with a history of carotid surgery or cervical radiotherapy, hemorrhagic stroke, traumatic or non-traumatic brain injury, large neck masses, gross cervical spine deformities, or any condition limiting carotid Doppler assessment, as well as those unwilling to undergo Doppler ultrasound, were be excluded from the study.

Data collection involved a comprehensive medical history and detailed clinical examination of all eligible patients to rule out alternative diagnoses. All patients had undergone a CT scan of the brain on presentation, to exclude intracerebral hemorrhage and confirm ischemic changes. Once the diagnosis of ischemic stroke is established, carotid Doppler ultrasound was carried out to assess the presence and severity of carotid artery stenosis. Doppler ultrasound was selected as the diagnostic modality due to its noninvasive nature, wide availability, cost-effectiveness, and established reliability in estimating the degree of stenosis based on blood flow velocity. It is widely regarded as the first-line tool for screening and follow-up of carotid stenosis, making it suitable for large-scale studies in resource-constrained settings. Information regarding demographic characteristics, past medical history, vascular risk factors, presenting symptoms, and carotid Doppler findings will be documented on a structured proforma. All data was entered into a secure electronic database, regularly cross-checked to ensure accuracy, completeness, and confidentiality, and restricted to research purposes only.

Statistical analysis was performed using SPSS version 22. Descriptive statistics was applied to summarize the data, with mean ± standard deviation was used for normally distributed quantitative variables such as age, BMI, blood pressure, and symptom duration. Qualitative variables including gender, vascular comorbidities, clinical presentation, and degree of stenosis were presented as frequencies and percentages. The prevalence and severity of carotid artery stenosis was stratified by age, gender, weight, smoking status, hypertension, diabetes, and hyperlipidemia. Post-stratification chi-square tests was applied to determine associations, with a p-value <0.05 considered statistically significant.

RESULTS

Table 1 shows that among 150 patients, the mean age was 61.6 ± 13.1 years, with systolic and diastolic blood pressures of 150.3 ± 27.6 mmHg and 86.1 ± 11.7 mmHg. Most were aged 51–70 years, 87 (58.0%), and 100 (66.7%) males. Socioeconomic status was medium in 93 (62.0%) and low in 55 (36.7%). BMI was normal in 102 (68.0%),

overweight in 47 (31.3%), and underweight in 1 (0.7%). Hypertension history was present in 47 (31.3%) and diabetes in 31 (20.7%). Risk factors included hypertension 102 (68.0%), diabetes 61 (40.7%), ischemic heart disease 23 (15.3%), smoking 43 (28.7%), hyperlipidemia 7 (4.7%), and abnormal heart rhythm 7 (4.7%).

Table 1

Baseline Characteristics, Medical History, and Risk Factors of the Study Population (n=150)

Variable		Mean ± SD/n (%)
Age (Years)		61.58±13.12
Blood Pressure	Systolic	150.28±27.59
	Diastolic	86.12±11.73
Age Groups	30 to 50	35(23.3%)
	51 to 70	87(58.0%)
	71 and above	28(18.7%)
Gender	Male	100(66.7%)
	Female	50(33.3%)
Socioeconomic Status	Low	55(36.7%)
	Medium	93(62.0%)
	High	2(1.3%)
BMI (kg/m^2)	Normal (18.5 - 24.9)	102(68.0%)
	Overweight (> 25)	47(31.3%)
	Underweight (< 18.5)	1(0.7%)
Previous Medical History	Hypertension	47(31.3%)
	Diabetes Mellitus	31(20.7%)
	Ischemic Heart Disease	21(14.0%)
	Stroke	8(5.3%)
Risk Factor	Hypertension	102(68.0%)
	Diabetes Mellitus	61(40.7%)
	Hyperlipidemia	7(4.7%)
	Ischemic Heart Disease	23(15.3%)
	Smoking	43(28.7%)
	Abnormal Heart Rhythm	7(4.7%)

Table 2 shows that among 150 patients, right-sided symptoms were present in 78 (52.0%) and left-sided in 72 (48.0%). Upper and lower limb weakness occurred in 134 (89.3%) and 121 (80.7%), facial weakness in 72 (48.0%), speech problems in 78 (52.0%), and confusion in 29 (19.3%). Ischemic changes on CT were seen in 87 (58.0%). Right-sided carotid Doppler showed <50% stenosis in 23 (15.3%), 50–69% in 15 (10.0%), ≥70% in 11 (7.3%), normal in 95 (63.3%), and complete occlusion in 6 (4.0%), while left-sided stenosis <50% was in 34 (22.7%), 50–69% in 18 (12.0%), ≥70% in 8 (5.3%), normal in 88 (58.7%), and complete occlusion in 2 (1.3%).

Table 2

Distribution of Neurological Symptoms, CT-scan Changes, and Carotid Doppler Findings (n = 150)

Variable			Mean±SD/ n(%)
Presenting Symptoms		Right Side	78(52.0%)
		Left Side	72(48.0%)
		Upper Limb Weakness	134(89.3%)
		Lower Limb Weakness	121(80.7%)
		Facial Weakness	72(48.0%)
		Speech Problem	78(52.0%)
		Confusion	29(19.3%)
Ischemic Changes on CT Brain		Yes	87(58.0%)
		No	63(42.0%)
Carotid Doppler Ultrasound Finding	Right	< 50 %	23(15.3%)
		50 % to 69 %	15(10.0%)
		≥ 70 %	11(7.3%)
		Normal	95(63.3%)
		Complete Occlusion	6(4.0%)
	Left	< 50 %	34(22.7%)
		50 % to 69 %	18(12.0%)
		≥ 70 %	8(5.3%)
		Normal	88(58.7%)
		Complete Occlusion	2(1.3%)

Table 3 shows that patients with ischemic changes, 16 were aged 30–50 years (18.4%), 55 were 51–70 (63.2%), and 16 were ≥71 (18.4%) (p = 0.207); 57 were male (65.5%) and 30 female (34.5%) (p = 0.726). Systolic and diastolic blood pressures were significantly higher, 156.75 ± 30.12 mmHg (p = 0.001) and 88.11 ± 11.50 mmHg (p = 0.014), respectively. Hypertension history was present in 33 patients (37.9%, p = 0.041). Other variables, including diabetes mellitus, ischemic heart disease, prior stroke, BMI, socioeconomic status, and additional risk factors, showed insignificant associations.

Table 3

Association of Demographic, Clinical, and Risk Factor Characteristics with Ischemic Changes on CT Brain Among Study Patients (n = 150)

Variable		Ischemic Changes on CT Brain		p-value
		Yes Mean±SD/n(%)	No Mean±SD/n(%)	
Age (Years)		61.79±11.93	61.30±14.69	0.822
Blood Pressure	Systolic	156.75±30.12	141.34±20.75	0.001
	Diastolic	88.11±11.50	83.36±11.57	0.014
Age Groups	30 to 50	16(18.4%)	19(30.2%)	0.207
	51 to 70	55(63.2%)	32(50.8%)	
	71 and above	16(18.4%)	12(19.0%)	
Gender	Male	57(65.5%)	43(68.3%)	0.726
	Female	30(34.5%)	20(31.7%)	
Socioeconomic Status	Low	32(36.8%)	23(36.5%)	0.475
	Medium	53(60.9%)	40(63.5%)	
	High	2(2.3%)	0(0.0%)	
BMI (kg/m^2)	Normal (18.5 - 24.9)	58(66.7%)	44(69.8%)	0.662
	Overweight (> 25)	28(32.2%)	19(30.2%)	
	Underweight (< 18.5)	1(1.1%)	0(0.0%)	
Previous Medical History	Hypertension	33(37.9%)	14(22.2%)	0.041
	Diabetes Mellitus	21(24.1%)	10(15.9%)	0.217
	Ischemic Heart Disease	10(11.5%)	11(17.5%)	0.299
	Stroke	5(5.7%)	3(4.8%)	0.791
Risk Factor	Hypertension	61(70.1%)	41(65.1%)	0.514
	Diabetes Mellitus	37(42.5%)	24(38.1%)	0.585
	Hyperlipidemia	5(5.7%)	2(3.2%)	0.461
	Ischemic Heart Disease	11(12.6%)	12(19.0%)	0.283
	Smoking	26(29.9%)	17(27.0%)	0.698
	Abnormal Heart Rhythm	4(4.6%)	3(4.8%)	0.962

Table 4 represents patients with ischemic changes, right-sided symptoms were 44 (50.6%) and left-sided 43 (49.4%), with upper limb weakness 76 (87.4%), lower limb weakness 73 (83.9%), facial weakness 45 (51.7%), speech problems 45 (51.7%), and confusion 25 (28.7%) (p = 0.001). Right carotid Doppler showed <50% stenosis 14 (16.1%), 50–69% stenosis 12 (13.8%), ≥70% stenosis 3 (3.4%), normal 53 (60.9%), and complete occlusion 5 (5.7%) (p = 0.059). Left carotid findings included <50% stenosis 28 (32.2%), 50–69% stenosis 12 (13.8%), ≥70% stenosis 0 (0%), normal 45 (51.7%), and complete occlusion 2 (2.3%) (p < 0.001).

Table 4

Distribution of Presenting Symptoms and Carotid Doppler Ultrasound Findings According to Ischemic Changes on CT Brain.

Variable			Ischemic Changes on CT Brain		p-value
			Yes Mean±SD n(%)	No Mean±SD n(%)	
Presenting Symptoms		Right Side	44(50.6%)	34(54.0%)	0.681
		Left Side	43(49.4%)	29(46.0%)	
		Upper Limb Weakness	76(87.4%)	58(92.1%)	0.357
		Lower Limb Weakness	73(83.9%)	48(76.2%)	0.237
		Facial Weakness	45(51.7%)	27(42.9%)	0.283
		Speech Problem	45(51.7%)	33(52.4%)	0.937
		Confusion	25(28.7%)	4(6.3%)	0.001
Carotid Doppler Ultrasound Finding	Right	< 50 %	14(16.1%)	9(14.3%)	0.059
		50 % to 69 %	12(13.8%)	3(4.8%)	
		≥ 70 %	3(3.4%)	8(12.7%)	
		Normal	53(60.9%)	42(66.7%)	
		Complete Occlusion	5(5.7%)	1(1.6%)	
	Left	< 50 %	28(32.2%)	6(9.5%)	<0.001
		50 % to 69 %	12(13.8%)	6(9.5%)	
		≥ 70 %	0(0.0%)	8(12.7%)	
		Normal	45(51.7%)	43(68.3%)	
		Complete Occlusion	2(2.3%)	0(0.0%)	

DISCUSSION

This study assessed carotid artery stenosis patterns in ischemic stroke patients (mean age 61.6 years, male predominance), with hypertension (68%) and diabetes (40.7%) as leading risk factors. Most had <50% stenosis, while occlusion was uncommon. Ischemic changes on CT brain (58%) correlated with higher blood pressure and confusion, highlighting Doppler ultrasound's value in predicting ischemic outcomes.

The large cohort showed higher complications in symptomatic patients symptomatic ICH (0.9% vs 0.2%), any ICH (1.4% vs 0.3%), in-stent occlusion (0.8% vs 0.4%), and hyper-perfusion (1.9% vs 0.8%) [16]. In our 150-patient study, ≥50% carotid stenosis occurred in 22% of right and 27% of left arteries, reinforcing that greater stenosis or symptomatic status increases adverse outcomes and highlighting the value of noninvasive Doppler ultrasound for risk assessment and management.

A review on non-stenosing carotid plaques noted that plaques with vulnerable features, even with <50% narrowing, can independently trigger ischemic stroke [17]. In our study of 150 patients, 36% had carotid stenosis, with ≥50% narrowing in 22% of right and 27% of left carotid arteries, highlighting that both stenotic and non-stenotic vulnerable plaques contribute to stroke risk. While the review emphasizes the risk from non-stenosing but vulnerable plaques, our results quantify the prevalence of significant stenosis, demonstrating that both stenotic and non-stenotic vulnerable plaques are clinically relevant in stroke pathogenesis.

The study of 81 patients reported hypertension (68%), diabetes (34.5%), cardiac disease (41%), dyslipidemia (59.3%), and smoking (52%) [18]. In our 150-patient cohort (mean age 61.6 y), hypertension was 68%, diabetes 40.7%, ischemic heart disease 15.3%, dyslipidemia 4.7%, and smoking 28.7%, highlighting the high burden of vascular risk factors.

In 550 stroke patients (mean age 58.9 y, 59.3% male), Doppler showed low-grade stenosis in 96%, ≥50% in 2.2%, and occlusion in 0.5%, with age predicting higher stenosis [19]. In our 150-patient cohort, ≥50% stenosis occurred in 22% (right) and 27% (left), occlusion in 4% (right) and 1.3% (left), significantly linked to hypertension and diabetes. Both studies underscore Doppler ultrasound as a vital tool, though our findings reflect a higher burden of stenosis and additional risk factor links.

In 1,480 stroke patients, CAS occurred in 18.7%, with age, hypertension, smoking, and male gender as predictors, and ≥50% stenosis linked to worse 90-day outcomes [14]. In our 150-patient cohort, ischemic changes were significantly associated with higher systolic (p = 0.001) and diastolic BP (p = 0.014) and hypertension (37.9% vs 22.2%; p = 0.041), Both studies highlight the strong role of hypertension and vascular burden in carotid stenosis–related ischemic stroke risk, though our findings emphasize blood pressure parameters more directly.

A prior study found stenosis severity, not plaque morphology, predicted infarct volume (r = 0.446, p = 0.035), with age and stenosis explaining 48% of variation [20]. In our cohort, ischemic changes were linked to confusion (28.7% vs 6.3%, p = 0.001) and left-sided <50% stenosis (32.2% vs 9.5%), while ≥70% stenosis was higher in those without ischemic changes (12.7% vs 0%; p < 0.001). Both studies highlight the importance of stenosis severity and distribution as key predictors of ischemic outcomes.

A Southern Pakistan study (mean age 65.8 y; 64.7% male) reported hypertension 78%, diabetes 44.7%, hyperlipidemia 36.7%, and carotid stenosis 32%, linked to age, BMI, and smoking [21]. In our cohort (mean age 61.6 y; 66.7% male), hypertension was 68%, diabetes 40.7%, smoking 28.7%, hyperlipidemia 4.7%, and ≥50% stenosis 22% (right) and 27% (left), highlighting similar vascular risk patterns but lower hyperlipidemia.

In 221 stroke patients, 41.6% had significant carotid stenosis (≥50%), strongly linked to age, male sex, and vascular risk factors, with severe stenosis predicting higher stroke incidence [22]. In our study, ≥50% stenosis was 17.3% bilaterally, with ischemic changes (58.0%) significantly associated with confusion (p = 0.001) and more frequent <50% left-sided stenosis. Both studies underscore Doppler ultrasound's diagnostic value, highlighting stenosis severity as a key determinant, while our findings also stress the role of stenosis distribution.

The referenced study found ICAC in 67.8% of ischemic stroke patients, mediating hypertension's link to white matter lesions and lacunes, particularly via IEL calcification [23]. In contrast, our study showed higher systolic (156.8 vs. 141.3 mmHg, p = 0.001) and diastolic pressures (88.1 vs. 83.4 mmHg, p = 0.014) and more frequent hypertension (37.9% vs. 22.2%, p = 0.041) in patients with ischemic changes. Both studies highlight hypertension as a key determinant, though one implicates ICAC as a mediator while ours emphasizes direct blood pressure elevation and clinical prevalence.

This study was limited by its single-center design and

relatively small sample size. Advanced imaging modalities for plaque characterization were not utilized, and long-term follow-up for recurrent stroke was not assessed. Despite these limitations, the findings emphasize the clinical utility of carotid Doppler ultrasound in detecting significant stenosis, guiding early intervention, and informing risk stratification. Future multicenter studies with larger cohorts and longitudinal follow-up are warranted to validate these findings and assess the impact of targeted management on stroke recurrence and functional outcomes.

CONCLUSION

It was predicted in our study that majority of the patients exhibited <50% of stenosis, while complete occlusion was infrequent. However, significant association existed between ischemic changes with left carotid artery stenosis which was insignificant in case of right side. Carotid Doppler ultrasound serves as a reliable noninvasive modality for the detection of stenosis, facilitating timely intervention and supporting risk stratification, thereby underscoring the importance of focused assessment in high-risk ischemic stroke patients.

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