Section: General Medicine

Original Research Article

COLOR DOPPLER EVALUATION OF CAROTID AND VERTEBRAL ARTERIES IN ACUTE ISCHEMIC STROKE AND CORRELATION WITH SPECIFIC RISK FACTORS

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ABSTRACT

Background: Acute ischemic stroke is a major neurological emergency and is frequently associated with atherosclerotic disease of the extracranial carotid and vertebral arteries. Identification of carotid atherosclerosis and quantification of arterial stenosis are important components of stroke evaluation because large-vessel disease may contribute to cerebral ischemia through thrombotic, embolic, or hemodynamic mechanisms. Carotid duplex ultrasonography is a non-invasive, readily available and relatively inexpensive technique that permits assessment of carotid intima-media thickness (CIMT), atherosclerotic plaque, luminal narrowing and hemodynamic alterations. The objective was to evaluate the role of color Doppler ultrasonography of the carotid and vertebral arteries in patients with acute ischemic stroke and to assess the relationship between carotid artery stenosis and selected risk factors, particularly age, sex, diabetes mellitus and hypertension.

Materials and Methods: A descriptive study was conducted among 100 adult patients with acute ischemic stroke admitted to the medical and neurological wards of K.A.P.V. Government Medical College and M.G.M. Government Hospital, Tiruchirappalli, between February 2018 and January 2019. Patients older than 18 years with neurological deficits lasting more than 24 hours and who provided informed consent were included. Patients with transient neurological deficits lasting less than 24 hours, hemorrhagic stroke and those younger than 18 years were excluded. Clinical information, relevant risk factors, blood glucose, blood pressure and neuroimaging findings were recorded. Color Doppler evaluation of the extracranial carotid and vertebral arteries was performed, including assessment of CIMT, plaque, arterial calibre, stenosis and Doppler velocity parameters. Statistical analysis was performed using SPSS version 20. Qualitative variables were assessed using the chi-square test and quantitative variables using the unpaired t-test.

Results: Among the 100 patients, 66 (66%) were male and 34 (34%) were female. The largest age groups were 41–60 years (37%) and 61–70 years (36%). Twenty-six patients had diabetes mellitus and 56 had hypertension. Forty-four patients had left middle cerebral artery (MCA) infarction, 48 had right MCA infarction, 4 had left posterior cerebral artery (PCA) infarction and 4 had right PCA infarction, demonstrating a predominance of anterior circulation stroke. Increased CIMT(>0.8mm) was identified in 84 patients on the infarct side and 83 patients on the non-infarct side. Carotid plaque was more frequently identified in the internal carotid artery than in the common carotid artery. Carotid artery stenosis was reported in 39% of patients on the infarct side, stenosis was ≤50% in 12 patients, 51–60% in 6, 61–70% in 9 and >70% in 12 patients. The average Doppler velocity increased progressively from 56 cm/s in

patients without stenosis to 113 cm/s in patients with >70% stenosis. Patients with carotid stenosis had a significantly higher mean age than those without stenosis (71.33 ± 7.42 vs. 58.84 ± 10.57 years; p=0.047). Carotid artery stenosis was significantly associated with diabetes mellitus (p<0.001) and hypertension (p=0.011), whereas no statistically significant association was observed with sex (Pearson chi-square p=0.749, calculated from the displayed frequencies). **Conclusion:** Extracranial carotid atherosclerotic abnormalities were frequent among patients with acute ischemic stroke. Carotid stenosis was identified in 39% of the study population, with higher age associated with the presence of stenosis. Increasing stenosis was accompanied by increased Doppler velocity. The study supports the clinical usefulness of carotid duplex ultrasonography as a non-invasive investigation in acute ischemic stroke, particularly for identifying extracranial carotid atherosclerotic disease.
Keywords: Acute Ischemic Stroke, Carotid Artery Stenosis, Carotid Doppler, Color Doppler Ultrasonography, Atherosclerosis, Vertebral Artery, Diabetes Mellitus, Hypertension.

INTRODUCTION

Stroke is a major cause of death and long-term disability worldwide and represents an important public health problem. Ischemic stroke occurs as a consequence of interruption of cerebral blood flow, most commonly due to arterial occlusion from thromboembolism or atherosclerotic disease. In 2021, stroke accounted for an estimated 11.9 million new cases globally and remained one of the leading causes of death and disability worldwide. Hypertension, diabetes mellitus, dyslipidemia, smoking, obesity and physical inactivity are among the important modifiable risk factors contributing to stroke development and recurrence.[1] Atherosclerotic disease of the extracranial carotid arteries is an important cause of ischemic stroke. Carotid atherosclerosis represents a progressive process beginning with arterial wall thickening, followed by development of atherosclerotic plaque and, in some patients, progression to significant luminal stenosis.[2] Carotid plaque may cause cerebral ischemia either through progressive reduction in cerebral blood flow or through embolization of thrombotic or atherosclerotic material to the intracranial circulation. The presence and severity of carotid stenosis therefore have important implications for the evaluation and secondary prevention of ischemic stroke. Carotid intima-media thickness (CIMT) is a measurable marker of arterial wall remodeling and systemic atherosclerotic burden. Increased CIMT has been associated with cardiovascular and cerebrovascular disease and has been investigated as a surrogate marker of subclinical atherosclerosis.[3] In patients with ischemic stroke, increased CIMT and carotid plaque may provide additional information regarding the underlying vascular disease and may help identify patients with an increased burden of atherosclerotic risk. Color Doppler ultrasonography is a non-invasive, readily available imaging technique for evaluating the extracranial carotid and vertebral arteries. It permits assessment of arterial wall morphology, CIMT, plaque characteristics, luminal narrowing and blood-flow velocities. Duplex ultrasound is widely used for the detection and grading of extracranial internal carotid artery stenosis and for follow-up of patients with carotid disease.[4] Standardized ultrasound assessment incorporates both morphological and hemodynamic information and can assist in identifying clinically significant carotid stenosis.[5] The degree of carotid stenosis is clinically relevant because symptomatic severe carotid stenosis may represent a treatable cause of ischemic stroke. Randomized trials have demonstrated a benefit from carotid endarterectomy in appropriately selected patients with symptomatic high-grade carotid stenosis, while the magnitude of benefit varies according to the degree of stenosis and other clinical characteristics.[6,7] Consequently, accurate identification of carotid stenosis in patients presenting with ischemic stroke is important for determining the need for further vascular evaluation and appropriate secondary prevention. The extracranial vertebral arteries also contribute to cerebral circulation through the posterior circulation. Vertebral artery hypoplasia and other vertebral arterial abnormalities may be relevant in selected patients with posterior circulation ischemic stroke. Modern ultrasound assessment therefore includes evaluation of both carotid and vertebral arteries when clinically appropriate.[5] Vascular risk factors play an important role in the development and progression of carotid atherosclerosis. Advancing age is associated with cumulative vascular injury and increasing prevalence of atherosclerotic disease. Hypertension promotes endothelial dysfunction and arterial remodeling, while diabetes mellitus is associated with accelerated atherosclerosis through metabolic and inflammatory mechanisms. The assessment of these risk factors in relation to carotid abnormalities may therefore improve understanding of the vascular profile of patients presenting with acute ischemic stroke.[1,2] Although carotid Doppler ultrasonography is widely used in the evaluation of cerebrovascular disease, the prevalence and distribution of carotid and vertebral arterial abnormalities may vary between populations because of differences in age, vascular risk factors and demographic characteristics. Local data are therefore useful for understanding the burden

of extracranial arterial disease among patients presenting with acute ischemic stroke. The present study was undertaken to evaluate the carotid and vertebral arteries using color Doppler ultrasonography in patients with acute ischemic stroke and to assess the relationship of carotid vascular abnormalities, particularly CIMT and carotid artery stenosis, with selected risk factors including age, sex, diabetes mellitus and hypertension. The study also evaluated carotid plaque characteristics, degree of stenosis and Doppler flow parameters in relation to the side and territory of cerebral infarction.

MATERIALS AND METHODS

Study Design and Setting: This was a descriptive study conducted in the Medical and Neurological Wards of K.A.P. Viswanatham Government Medical College and M.G.M. Government Hospital, Tiruchirappalli, Tamil Nadu. The study was conducted over a period of 12 months, from February 2018 to January 2019. A total of 100 patients with acute ischemic stroke were included in the study.

Study Population: The study population comprised adult patients presenting with acute ischemic stroke. Stroke was clinically considered in patients with neurological deficits persisting for more than 24 hours, with neuroimaging used to support the diagnosis. Patients underwent clinical assessment and relevant investigations before evaluation of the extracranial carotid and vertebral arteries by Doppler ultrasonography.

Inclusion Criteria

Patients were eligible for inclusion if they:

1. were older than 18 years;
2. had neurological deficits persisting for more than 24 hours; and
3. were able to provide written informed consent, either personally or through an attendant where appropriate.

Exclusion Criteria

Patients were excluded if they:

1. were younger than 18 years;
2. had neurological deficits lasting less than 24 hours; or
3. had hemorrhagic stroke.

Sample Size: A total of 100 patients fulfilling the eligibility criteria were included in the study.

Data Collection: A structured data collection proforma was used to record relevant demographic and clinical information. Detailed history regarding the presenting neurological symptoms and relevant cerebrovascular risk factors was obtained. Previous hospital records and available investigation reports were reviewed, with particular emphasis on the presence of diabetes mellitus and hypertension. In patients with confirmed acute ischemic stroke, relevant investigations included blood glucose assessment, blood-pressure monitoring, neuroimaging and carotid artery Doppler ultrasonography. The study proforma recorded demographic characteristics, diabetes mellitus, hypertension and CT/MRI findings.

Neuroimaging Assessment: Computed tomography or magnetic resonance imaging of the brain was used to support the diagnosis of ischemic stroke and to document the vascular territory and side of cerebral infarction. The recorded infarct locations included middle cerebral artery and posterior cerebral artery territories.

Color Doppler Ultrasonography: All patients with confirmed acute ischemic stroke underwent carotid artery Doppler evaluation. The examination included assessment of the extracranial carotid and vertebral arterial systems. The study evaluated arterial morphology and hemodynamic characteristics, including carotid intima-media thickness (CIMT), arterial calibre, presence and distribution of atherosclerotic plaque, plaque morphology, degree of carotid artery stenosis and Doppler flow velocities. Both the infarct and non-infarct sides were evaluated where applicable. The common carotid artery (CCA), internal carotid artery (ICA), external carotid artery (ECA) and vertebral arteries were assessed. The study also recorded the presence of vertebral artery hypoplasia in patients with posterior circulation infarction. CIMT was assessed ultrasonographically, and the study used a value of less than 0.8 mm as the reference for normal CIMT. Increased CIMT was subsequently categorized as an abnormal finding. The degree of carotid stenosis was recorded according to the categories used in the study, namely <50%, 51–60%, 61–70% and >70%.

Study Variables

The principal variables assessed were:

- Age;
- Sex;
- Diabetes mellitus;
- Hypertension;
- Cerebral infarction territory;
- Side of cerebral infarction;
- Carotid intima-media thickness;
- Common, internal and external carotid artery calibre;
- Vertebral artery calibre;
- Carotid plaque;
- Plaque morphology;
- Degree of carotid artery stenosis; and
- Doppler flow velocity.

The primary analytical outcome was the presence of carotid artery stenosis and its association with selected demographic and clinical risk factors, particularly age, sex, diabetes mellitus and hypertension.

Statistical Analysis: All collected data were tabulated and analyzed using Statistical Package for the Social Sciences (SPSS), version 20. Continuous variables were summarized using means and standard deviations. The chi-square test was used to assess associations between categorical variables, while the t-test was used to compare quantitative variables between qualitative groups. A p-value of <0.05 was considered statistically significant.

Ethical Considerations: The study was conducted after institutional ethical committee clearance. Written informed consent was obtained from participants or their attendants before inclusion. The patient information sheet stated that participation was voluntary and that participants could withdraw from the study without affecting their routine medical care. Confidentiality of medical records was maintained, and publication of study results was planned without disclosure of participant identity. The ethical committee clearance certificate documented approval of the project entitled "A Descriptive Study Using Color Doppler of Carotid and Vertebral Arteries in Acute Ischemic Stroke and Correlation with Specific Risk Factors" by the Institutional Ethics Committee of K.A.P. Viswanatham Government Medical College, Tiruchirappalli.

RESULTS

A total of 100 patients with acute ischemic stroke were included in the study. The demographic characteristics, vascular risk factors, neuroimaging findings, carotid and vertebral artery Doppler parameters, plaque characteristics, degree of carotid artery stenosis, and associations between stenosis and selected risk factors were analyzed.

Age Distribution: The age distribution of the study population is presented in [Figure 1]. The largest proportion of patients belonged to the 41–60-year age group (37%), followed by the 61–70-year age group (36%). Patients aged 71–80 years constituted 22% of the study population, whereas 3% were aged ≤40 years and 2% were older than 80 years. The minimum age was 28 years and the maximum age was 90 years.

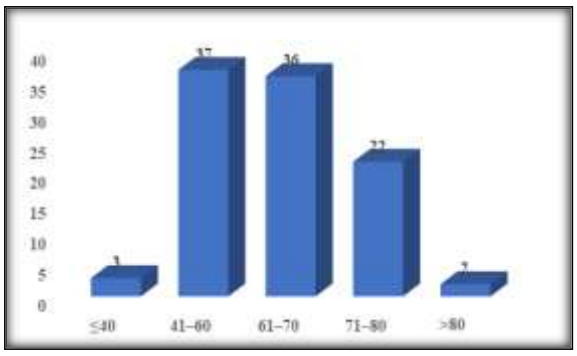


Figure 1: Age distribution of the study population

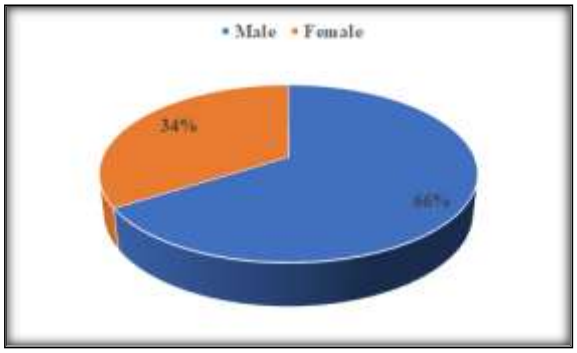


Figure 2: Sex distribution of the study population

Sex Distribution: The sex distribution of the study population is shown in [Figure 2]. Of the 100 patients, 66 (66%) were male and 34 (34%) were female, indicating a higher proportion of males in the study population.

Distribution of Diabetes Mellitus: The distribution of diabetes mellitus is presented in [Figure 3] Diabetes mellitus was present in 26 (26%) patients, while 74 (74%) patients did not have diabetes mellitus.

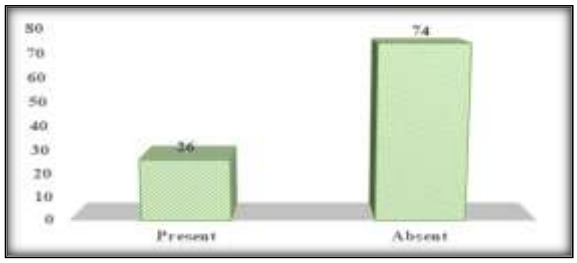


Figure 3: Distribution of diabetes mellitus

Distribution of Hypertension: The distribution of hypertension is shown in [Figure 4]. Hypertension was present in 56 (56%) patients, whereas 44 (44%) patients were not hypertensive. Thus, hypertension was the more frequently reported vascular risk factor in the study population.

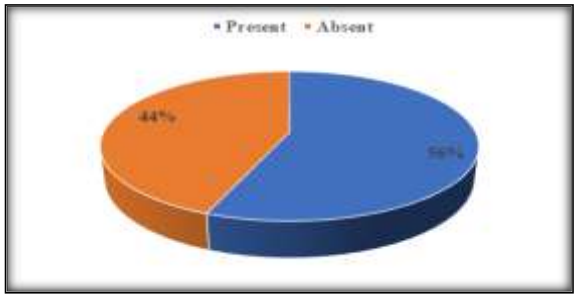


Figure 4. Distribution of hypertension

CT/MRI Diagnosis and Cerebral Infarction Territory: The distribution of cerebral infarction according to CT/MRI findings is presented in [Figure 5]. Right MCA infarction was the most common finding, occurring in 48 (48%) patients, followed by left MCA infarction in 44 (44%). Left PCA and right PCA infarctions were each identified in 4 (4%) patients. Overall, MCA infarction accounted for 92% of cases, whereas PCA infarction accounted for 8%.

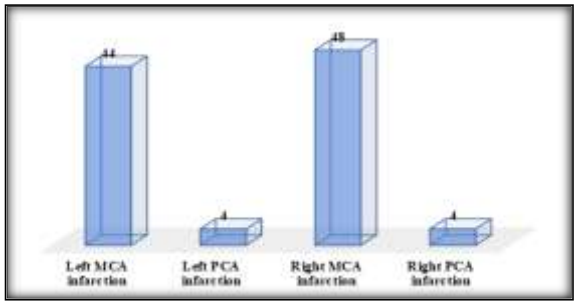


Figure 5: Distribution of cerebral infarction according to CT/MRI findings

Carotid Intima-Media Thickness: Carotid intima-media thickness (CIMT) findings on the infarct and opposite sides are shown in [Table 1]. CIMT ≤0.8 mm was observed in 16 patients on the infarct side and 17 patients on the opposite side. Increased CIMT (>0.8 mm) was observed in 84 patients on the infarct side and 83 patients on the opposite side.

Table 1: Distribution of carotid intima-media thickness

CIMT	Infarct side, n	Opposite side, n
≤0.8 mm	16	17
>0.8 mm	84	83
Total	100	100

Carotid and Vertebral Artery Calibre: The mean calibre of the common carotid artery (CCA), internal carotid artery (ICA), external carotid artery (ECA), and vertebral artery (VA), according to sex and side, is presented in [Table 2]. The mean right CCA calibre was 7.01 ± 0.35 mm in males and 7.07 ± 0.47 mm in females, while the corresponding left CCA measurements were 7.01 ± 0.39 mm and 7.12 ± 0.38 mm, respectively. The mean ICA calibre ranged from 4.89 to 4.93 mm. The ECA calibre ranged from 4.02 to 4.11 mm, while vertebral artery calibre ranged from 2.19 to 2.35 mm.

Table 2: Mean calibre of extracranial carotid and vertebral arteries according to sex

Artery	Sex	Right mean ± SD (mm)	Left mean ± SD (mm)
CCA	Male	7.01 ± 0.35	7.01 ± 0.39
CCA	Female	7.07 ± 0.47	7.12 ± 0.38
ICA	Male	4.90 ± 0.48	4.89 ± 0.57
ICA	Female	4.93 ± 0.31	4.93 ± 0.44
ECA	Male	4.11 ± 0.36	4.04 ± 0.49
ECA	Female	4.11 ± 0.36	4.02 ± 0.34
VA	Male	2.19 ± 0.28	2.20 ± 0.24
VA	Female	2.24 ± 0.30	2.35 ± 0.42

CCA: common carotid artery; ICA: internal carotid artery; ECA: external carotid artery; VA: vertebral artery.

Vertebral Artery Abnormalities: The distribution of vertebral artery hypoplasia is presented in [Figure 6]. Hypoplastic vertebral arteries were identified in four patients with PCA infarction, with two involving the right vertebral artery and two involving the left vertebral artery. Overall, vertebral artery hypoplasia was identified in 2% of patients on each side.

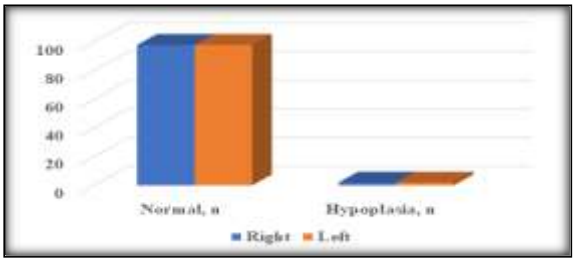


Figure 6: Distribution of vertebral artery hypoplasia

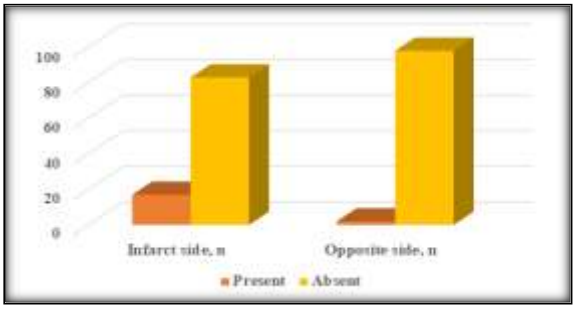


Figure 7: Distribution of plaque in the common carotid artery

Plaque Distribution in the Common Carotid Artery: The distribution of plaque in the CCA is presented in [Figure 7]. Plaque was detected in 17 patients on the infarct side and in 2 patients on the opposite side. No plaque was identified in 83 patients on the infarct side and 98 patients on the opposite side.

Plaque Distribution in the Internal Carotid Artery: The distribution of plaque in the ICA is shown in [Figure 8]. Plaque was present in 38 patients on the infarct side and in 6 patients on the opposite side. Plaque was absent in 62 and 94 patients on the respective sides.

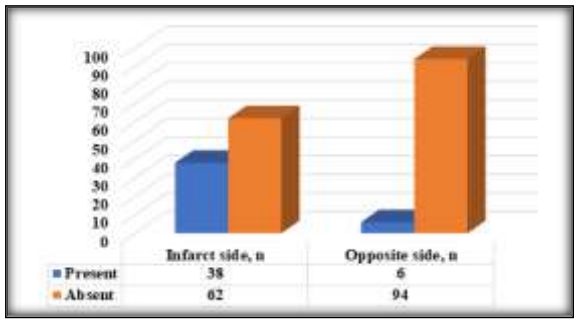


Figure 8: Distribution of plaque in the internal carotid artery

Plaque Type in the Common Carotid Artery: The distribution of plaque types in the CCA is presented in [Table 3]. On the infarct side, type 3 and type 4 plaques were each identified in six patients, while type 5 plaque was identified in three patients. Type 1 and type 2 plaques were each identified in one patient. On the opposite side, type 4 plaque was identified in two patients.

Table 3: Plaque type distribution in the common carotid artery

Plaque type in CCA	Infarct side, n	Opposite side, n
No plaque	83	98
Type 1	1	0
Type 2	1	0
Type 3	6	0
Type 4	6	2
Type 5	3	0
Total	100	100

Plaque Type in the Internal Carotid Artery: The distribution of plaque types in the ICA is presented in [Table 4]. On the infarct side, type 4 plaque was the most frequently observed plaque type (14 patients), followed by type 3 (10 patients), type 5 (6 patients), type 1 (4 patients), and type 2 (4 patients). On the opposite side, type 3 and type 4 plaques were each identified in three patients.

Table 4: Plaque type distribution in the internal carotid artery

Plaque type in ICA	Infarct side, n	Opposite side, n
No plaque	62	94
Type 1	4	0
Type 2	4	0
Type 3	10	3
Type 4	14	3
Type 5	6	0
Total	100	100

Distribution of Carotid Artery Stenosis: The degree of carotid artery stenosis on the infarct and opposite sides is shown in [Table 5]. On the infarct side, 12 patients had ≤50% stenosis, 6 had 51–60% stenosis, 9 had 61–70% stenosis, and 12 had >70% stenosis. No stenosis was identified in 61 patients on the infarct side. On the opposite side, 5 patients had ≤50% stenosis, while no patients had stenosis exceeding 50%.

Thus, carotid stenosis was identified in 39 patients on the infarct side, corresponding to 39% of the study population.

Table 5: Distribution of carotid artery stenosis

Degree of stenosis	Infarct side, n	Opposite side, n
Normal	61	95
≤50%	12	5
51–60%	6	0
61–70%	9	0
>70%	12	0
Total	100	100

Doppler Velocity According to Degree of Stenosis: The relationship between degree of carotid stenosis and average Doppler velocity is presented in [Table 6]. The average velocity increased progressively with increasing degree of stenosis, from 56 cm/s in patients without stenosis to 113 cm/s in patients with >70% stenosis.

Table 6: Average Doppler velocity according to degree of carotid stenosis

Degree of stenosis	Frequency (n)	Average velocity (cm/s)
Normal	61	56
≤50%	12	61
51–60%	6	78
61–70%	9	95
>70%	12	113

CIMT and Doppler Velocity According to Degree of Stenosis: The average CIMT and Doppler velocity according to the degree of carotid stenosis are presented in [Table 7]. The mean CIMT was 1.01 mm among patients without stenosis and ranged from 1.07 to 1.30 mm among patients with stenosis. The highest mean CIMT was observed in patients with >70% stenosis. Average Doppler velocity increased from 56 cm/s in patients without stenosis to 113 cm/s in patients with >70% stenosis.

Table 7: Mean CIMT and Doppler velocity according to degree of carotid stenosis

Degree of stenosis	Frequency (n)	Mean CIMT (mm)	Average velocity (cm/s)
Normal	61	1.01	56
≤50%	12	1.23	61
51–60%	6	1.07	78
61–70%	9	1.27	95
>70%	12	1.30	113

Association Between Carotid Artery Stenosis and Age: The association between carotid artery stenosis and age is presented in [Table 8]. Patients with carotid stenosis had a mean age of 71.33 ± 7.42 years, whereas patients without stenosis had a mean age of 58.84 ± 10.57 years. The difference was statistically significant according to the unpaired t-test (p=0.047).

Table 8: Association between carotid artery stenosis and age

Carotid stenosis	Frequency (n)	Mean age (years)	SD	SE
Present	39	71.33	7.42	1.19
Absent	61	58.84	10.57	1.35
Statistical test		Unpaired t-test		
p-value		0.047		
Inference		Significant		

Association Between Carotid Artery Stenosis and Sex: The association between carotid artery stenosis and sex is shown in [Table 9]. After aligning the row labels with the cohort totals, stenosis was recorded in 25 males and 14 females, while stenosis was absent in 41 males and 20 females. The reported p-value (0.742) should be checked against the original SPSS output because it cannot be independently confirmed from the displayed frequencies.

Table 9: Association between carotid artery stenosis and sex

Carotid artery stenosis	Male, n	Female, n
Present	25	14
Absent	41	20
p-value	0.742	
Inference	Not significant	

Association Between Carotid Artery Stenosis and Diabetes Mellitus: The association between carotid artery stenosis and diabetes mellitus is presented in [Table 10]. After aligning the row labels with the cohort totals, 19 patients with stenosis had diabetes mellitus and 20 did not among patients without stenosis, 7 had diabetes mellitus and 54 did not. The reported p-value should be verified against the original SPSS output; if SPSS displays 0.000, it should be reported as p<0.001.

Table 10: Association between carotid artery stenosis and diabetes mellitus

Carotid artery stenosis	Diabetes: Yes, n	Diabetes: No, n
Present	19	20
Absent	7	54
Chi-square test	p=<0.001	
Inference	Significant	

Association Between Carotid Artery Stenosis and Hypertension: The association between carotid artery stenosis and hypertension is presented in [Table 11]. The displayed frequencies require verification: the row totals are 38 and 61, accounting for only 99 patients. The missing observation must be checked against the original dataset before the group-specific association and p-value are interpreted.

Table 11: Association between carotid artery stenosis and hypertension

Carotid artery stenosis	Hypertension: Yes, n	Hypertension: No, n
Present	28	11
Absent	28	33
Chi-square test	p=0.011	
Inference	Significant	

DISCUSSION

The present study evaluated extracranial carotid and vertebral artery abnormalities using color Doppler ultrasonography in 100 patients with acute ischemic stroke and examined their relationship with selected vascular risk factors. The principal findings were a predominance of male patients, a high frequency of increased carotid intima-media thickness (CIMT), frequent carotid plaque formation, carotid artery stenosis in 39% of patients, a progressive increase in Doppler velocity with increasing stenosis, and a significant association between increasing age and carotid stenosis. In the present study, males constituted 66% of the study population, while females constituted 34%. Similar male predominance has been reported in previous studies of carotid atherosclerosis and ischemic stroke. In a case-control study of patients with acute ischemic stroke, Sengupta et al. reported that 63.3% of their stroke patients were male and found significantly greater CIMT among stroke patients than controls.[8] The predominance of males in the present study may reflect the greater burden of conventional vascular risk factors and atherosclerotic disease among men,

although sex itself was not significantly associated with carotid stenosis in the present analysis.

The age distribution in the current study demonstrated that most patients were between 41 and 70 years of age. Importantly, patients with carotid stenosis had a significantly higher mean age than those without stenosis (71.33 ± 7.42 years versus 58.84 ± 10.57 years; p=0.047). This finding supports the well-established relationship between advancing age and carotid atherosclerosis. Sengupta et al. similarly demonstrated that CIMT was independently associated with increasing age in patients with acute ischemic stroke.[8] In another long-term study of patients who had experienced ischemic stroke at a young age, increasing CIMT was associated with increasing age as well as hypertension and diabetes mellitus.[9] These observations are consistent with the present study and indicate that progressive arterial wall thickening and plaque formation are manifestations of cumulative vascular injury. Increased CIMT was a prominent finding in the present study. CIMT greater than 0.8 mm was observed in 84% of patients on the infarct side and 83% on the opposite side. The bilateral occurrence of increased CIMT suggests that carotid wall thickening represents a generalized atherosclerotic process rather than a lesion confined to the artery supplying the infarcted cerebral territory. This finding is supported by a systematic review and meta-analysis involving 19 studies, which demonstrated a significant association between increased common carotid IMT and ischemic stroke and also found a stronger association with large-vessel disease compared with small-vessel disease.[10] Sengupta et al. reported a mean CIMT of 0.798 mm in acute ischemic stroke patients compared with 0.6 mm in controls, with significantly greater CIMT among patients with carotid plaques.[8] Thus, the high prevalence of increased CIMT in the present study further supports the role of carotid ultrasonography as a marker of systemic atherosclerotic burden.

Carotid plaque was more frequently identified in the internal carotid artery (ICA) than in the common carotid artery (CCA) in the present study. Plaque was observed in 38% of patients on the infarct side in the ICA compared with 17% in the CCA. Type 4 plaque was the most frequently reported plaque morphology in the ICA. The predominance of ICA plaque is clinically relevant because atherosclerotic disease at the carotid bifurcation and proximal ICA can act as a source of artery-to-artery embolization. The presence of plaque in addition to increased CIMT may therefore provide additional information regarding the vascular mechanism underlying ischemic stroke. Carotid artery stenosis was detected in 39% of the patients in the present study. On the infarct side, 12 patients had stenosis of ≤50%, 6 had 51–60% stenosis, 9 had 61–70% stenosis and 12 had >70% stenosis. The identification of severe stenosis in 12% of the total study population is clinically important because symptomatic severe ICA stenosis is a potentially treatable cause of recurrent ischemic stroke. Evidence from the North American Symptomatic Carotid Endarterectomy Trial (NASCET) demonstrated substantial benefit from carotid endarterectomy in appropriately selected patients with symptomatic high-grade carotid stenosis.[6] Subsequent pooled analyses of NASCET, the European Carotid Surgery Trial and the Veterans Affairs trial confirmed that carotid endarterectomy provides the greatest benefit in symptomatic stenosis of ≥70%, while benefit in 50–69% stenosis is more modest.[7,11] Current European Stroke Organisation guidance similarly recommends carotid endarterectomy for appropriate patients with symptomatic 70–99% stenosis and suggests consideration in selected patients with 50–69% stenosis.[12]

The present study also showed a progressive increase in the reported average Doppler velocity with increasing stenosis. The average velocity increased from 56 cm/s in patients without stenosis to 61 cm/s in those with ≤50% stenosis, 78 cm/s in those with 51–60% stenosis, 95 cm/s in those with 61–70% stenosis and 113 cm/s in those with >70% stenosis. This progressive haemodynamic elevation reflects luminal narrowing and supports the diagnostic value of duplex ultrasonography in grading, extracranial, carotid disease. [13,14] Consistent with the previous reports, sex was not significantly associated with carotid stenosis([p=0.742]). Diabetes mellitus was present in 26% of the study population, while hypertension was present in 56%. Both conditions are biologically plausible contributors to carotid atherosclerosis because chronic metabolic and hemodynamic vascular injury can promote endothelial dysfunction, arterial wall thickening and plaque formation. Previous studies have reported associations between these risk factors and carotid atherosclerotic changes.[9,15] In the present study, the frequencies displayed in Tables 10 and 11 require verification against the original SPSS dataset before the direction or statistical significance of the associations between carotid stenosis and diabetes mellitus or hypertension can be stated. Accordingly, no directional or causal inference is made from these unverified comparisons.

Diabetes mellitus was present in 26% of the study population, while hypertension was present in 56%. Both conditions are biologically plausible contributors to carotid atherosclerosis because chronic metabolic and hemodynamic vascular injury can promote endothelial dysfunction, arterial wall thickening and plaque formation. In the present study, carotid artery stenosis was significantly associated with both diabetes Mellitus (p<0.001) and hypertension(p=0.011). These findings align with the recent clinical investigations, demonstrating that hypertension and diabetes mellitus significantly accelerate carotid intima- media thickening and Atherosclerotic stenosis in patients with acute ischemic stroke.[15] Similarly, the Norwegian study of young stroke survivors found increasing CIMT to be associated with hypertension and diabetes mellitus.[9]

The dissertation reported statistically significant associations between carotid stenosis and diabetes mellitus (p=0.000) and between carotid stenosis and hypertension (p=0.009). However, the raw frequencies displayed in the corresponding dissertation tables do not consistently support the direction of the stated associations. Therefore, these results should be interpreted cautiously and the original SPSS dataset and variable coding should be reviewed before final journal submission. The present manuscript should not infer a causal or directional relationship until the original statistical analysis has been verified.

The majority of patients in the current study had middle cerebral artery (MCA) infarction, accounting for 92% of the study population, while posterior cerebral artery (PCA) infarction accounted for 8%. This predominance of anterior circulation stroke is relevant because the extracranial ICA is a major arterial pathway supplying the anterior cerebral circulation. The relatively small number of PCA infarctions also limits the strength of conclusions regarding vertebral artery abnormalities. Four patients with PCA infarction had vertebral artery hypoplasia, but the sample was too small to establish a statistically reliable relationship. Overall, the findings support the usefulness of carotid color Doppler ultrasonography in the evaluation of patients with acute ischemic stroke. The examination provides information about arterial wall thickening, plaque morphology, luminal narrowing and hemodynamic alterations without exposure to ionizing radiation. Identification of significant carotid stenosis is particularly important because it may influence secondary stroke-prevention strategies and the need for further vascular assessment. At the same time, Doppler findings should be interpreted in conjunction with clinical presentation and brain imaging rather than considered in isolation.

Limitations: This study had several limitations. The sample size was relatively small and the study was conducted at a single institution, which may limit the generalizability of the findings. The descriptive observational design also limits the ability to establish causal relationships between vascular risk factors and carotid artery stenosis. Only selected risk factors, namely age, sex, diabetes mellitus and hypertension, were evaluated, while other potentially relevant risk factors such as smoking, dyslipidemia, obesity and other cardiovascular comorbidities were not comprehensively assessed. In addition, the study did not include longitudinal follow-up to determine the association of carotid Doppler findings with recurrent stroke, mortality or functional outcomes. Assessment of carotid stenosis was based on Doppler ultrasonography, and technical factors such as High carotid bifurcation or patient neck Anatomy may occasionally limit ultrasonographic visualisation.

CONCLUSION

This study demonstrates that extracranial carotid and vertebral arterial abnormalities are common among patients with acute ischemic stroke. Increased carotid intima-media thickness and carotid atherosclerotic plaques were frequently observed, with the internal carotid artery being the predominant site of plaque formation. Carotid artery stenosis was identified in 39% of the study population, including a considerable proportion with severe stenosis. Increasing carotid stenosis was associated with progressively higher Doppler flow velocity, demonstrating the utility of color Doppler ultrasonography in assessing carotid vascular disease. Patients with carotid stenosis were significantly older than those without stenosis, whereas no significant association was observed between sex and carotid stenosis. The findings support the role of carotid color Doppler ultrasonography as a non-invasive and useful investigation for detecting extracranial carotid atherosclerotic disease in patients with acute ischemic stroke and for identifying patients who may require further vascular evaluation and secondary stroke-prevention measures. Larger prospective studies with comprehensive assessment of vascular risk factors and clinical outcomes are warranted to validate these findings.

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