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Evaluation of Extracranial Carotid Arteries by Duplex Ultrasound in Computed Tomography confirmed Ischemic Stroke and its correlation with brain parenchymal involvement

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Abstract

This study aimed to evaluate the relationship between carotid artery disease, infarct characteristics, and associated risk factors in patients with CT-confirmed ischemic stroke. The study included 50 participants, primarily aged 61-70 years (42%) with a mean age of 60.7 years, and a male predominance (78%). Hypertension, diabetes mellitus, and dyslipidemia were each prevalent in 68% of the sample. Most infarcts were located in the middle cerebral artery (MCA) territory (86%), with the combined cortical and sub-cortical regions being the most frequently affected (58%). A significant association was found between the severity of carotid stenosis and infarct size, with larger infarcts (>2 cm) predominantly occurring in patients with stenosis ≥70% ($p = 0.001$). The analysis of stenosis by age revealed that the 61-80 age group had the highest frequency of stenosis, primarily in the <50% category on both sides ($p = 0.01$ for the right side, $p = 0.04$ for the left side). Higher intima-media thickness (IMT >1) and the presence of plaques were significantly associated with infarcts in the MCA territory and sub-cortical areas. Calcified plaques were particularly prevalent in these regions. Strong associations were also found between carotid lesions and risk factors such as hypertension, diabetes, dyslipidemia, smoking, coronary artery disease, and history of stroke. The <50% stenosis category was more commonly associated with older age, female gender, hypertension, and diabetes, whereas the ≥70% stenosis category was more prevalent among males and linked to dyslipidemia and coronary artery disease. The findings underscore the importance of comprehensive evaluation using duplex ultrasound and the management of modifiable risk factors in ischemic stroke patients.

Keywords: Atherosclerosis, Stenosis, Diabetes, Smoking, Inflammation, Ultrasound, Stroke

Introduction

An ischemic stroke occurs when a portion of the brain is deprived of its vital blood supply, typically due to a blockage or significant reduction in circulation. This interruption hampers the delivery of oxygen and essential nutrients to the affected brain tissue, leading to the rapid death of brain cells and triggering a cascade of neurological consequences[1]. In contrast, a hemorrhagic stroke results from the rupture or leakage of a blood vessel within the brain, causing internal bleeding. The accumulated blood increases pressure within the cranial cavity, exerting damaging forces on delicate brain cells[2].

Recognized as a medical emergency, timely intervention is crucial in minimizing the harmful effects of a stroke. Swift access to medical care can significantly reduce brain damage and decrease the likelihood of long-term complications[3]. Fortunately, advancements in medical treatment and increased public awareness have contributed to a decline in stroke-related fatalities. Effective treatments now offer the potential to prevent or mitigate disability resulting from strokes, highlighting the importance of early detection and prompt action[4].

Ischemic stroke, the most common type of stroke, occurs when blood vessels in the brain become constricted or obstructed, leading to reduced blood flow or ischemia. This condition often arises due to the accumulation of fatty deposits within the vessel walls, known as atherosclerosis[5]. Additionally, blood clots or other debris, which may originate from the heart or other parts of the circulatory system, can travel to the brain and obstruct cerebral blood vessels, further contributing to the onset of ischemic stroke. The resulting lack of oxygen and nutrients to the brain tissue triggers a cascade of neurological dysfunction and cellular damage[6]. Understanding the pathogenesis of ischemic stroke highlights the importance of preventative

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measures aimed at reducing risk factors associated with vascular disease. Managing conditions such as hypertension and hyperlipidemia, alongside lifestyle modifications, plays a crucial role in decreasing the incidence of ischemic stroke[7]. Furthermore, advancements in diagnostic techniques, particularly in the use of ultrasound technology, have significantly enhanced the ability to assess cerebrovascular hemodynamics and anatomy[8]. Doppler ultrasonography, combined with B-mode imaging in duplex sonography, provides clinicians with valuable insights into both the structural and functional aspects of carotid artery disease, a key contributor to ischemic stroke.

Clinical trials such as the North American Symptomatic Carotid Endarterectomy Trial (NASCET) and the European Carotid Surgery Trialists (ECST) have established the efficacy of carotid endarterectomy in patients with significant carotid artery stenosis. These studies underscore the clinical utility of diagnostic ultrasound in guiding therapeutic interventions, especially in patients with recently symptomatic carotid artery narrowing. As a noninvasive, accurate, and cost-effective diagnostic tool, duplex sonography has become central to the evaluation and management of carotid artery disease, offering a comprehensive assessment of both the severity and the potential impact of vascular obstructions on cerebral blood flow[9].

The correlation between duplex ultrasound findings of the extracranial carotid arteries and cerebral parenchymal involvement in CT-confirmed ischemic stroke is critical for understanding the contribution of carotid artery pathology to stroke outcomes. Duplex ultrasound, a non-invasive imaging technique, combines traditional ultrasound with Doppler ultrasound to visualize blood flow and detect abnormalities such as plaque buildup or stenosis in the carotid arteries. These findings are essential for assessing how blockages or narrowing in the carotid arteries may lead to reduced blood flow to the brain, resulting in cerebral parenchymal damage[10].

Research exploring this correlation seeks to determine whether specific characteristics of carotid artery disease, like the degree of stenosis or the presence of plaques, are linked to more severe cerebral involvement in stroke patients. Understanding these associations can help clinicians better assess stroke risk and make informed decisions about interventions, such as carotid endarterectomy or stenting, to reduce the likelihood of recurrent strokes. The insights gained from these studies also contribute to the development of more effective treatment guidelines, ultimately improving patient outcomes in ischemic stroke care[11].

The correlation between atherosclerotic risk factors and carotid artery disease is well-documented in medical research. Atherosclerosis, a chronic inflammatory condition, involves the buildup of plaque within arterial walls, leading to narrowing (stenosis) and impaired blood flow. The carotid arteries, which are critical in supplying blood to the brain, are particularly susceptible to atherosclerosis. Several traditional risk factors have been identified as significant contributors to the development and progression of carotid artery disease[12].

Hypertension, or high blood pressure, is a major risk factor for carotid artery disease. It damages the inner lining of the arteries, making them more vulnerable to plaque accumulation and increasing the heart's workload, which further harms the arterial walls. Hyperlipidemia, characterized by elevated cholesterol and triglyceride levels, also plays a pivotal role in plaque formation within the arterial walls. Specifically, low-density lipoprotein (LDL) cholesterol is highly atherogenic, promoting inflammation and the buildup of plaque in the carotid arteries, thereby restricting blood flow to the brain[13]. Diabetes mellitus and smoking are significant contributors to carotid artery disease, with diabetes causing systemic inflammation and endothelial dysfunction, leading to atherosclerosis, and high blood sugar levels increasing the risk of severe stenosis. Smoking exacerbates this by introducing chemicals that promote inflammation and oxidative stress, accelerating atherosclerosis in the carotid arteries. Obesity and inactivity further heighten these risks by promoting insulin resistance, dyslipidemia, and chronic inflammation. Regular physical activity can mitigate these effects by improving cardiovascular health. The complex interaction of these risk factors underscores the need for comprehensive strategies, including lifestyle changes and pharmacological interventions, to prevent and manage carotid artery disease. This study aims to evaluate extracranial carotid arteries using duplex ultrasound, correlating findings with cerebral involvement in ischemic stroke patients and examining the link between atherosclerotic risk factors and carotid artery disease[14].

MATERIAL AND METHODS

This cross-sectional study was conducted over 18 months in the Department of Radiodiagnosis at Jubilee Mission Medical College and Research Center, Thrissur.

Study Population

The study involves patients from the Neurology Department of Jubilee Mission Hospital, Thrissur. A total of 50 patients referred for carotid Doppler examination, who meet the inclusion criteria, will be included in the study. The association between carotid artery disease and various risk factors, such as diabetes mellitus, hypertension, hyperlipidemia, and smoking, will be assessed through a detailed clinical history, laboratory investigations, and patient examination.

Data Analysis

Data for patients undergoing Doppler ultrasound will be collected using the SAMSUNG HS 60 ultrasound equipment, which features B-mode, color flow monitoring, and power Doppler imaging, with a linear array transducer operating at 10-12 MHz. Following the Doppler examination, the data obtained from the common carotid artery (CCA) and internal carotid artery (ICA) will include peak systolic velocity (PSV), end diastolic velocity, ICA/CCA PSV ratio, percentage stenosis, and intima-media thickness. These measurements will be used to assess and analyze changes in the extracranial carotid arteries, including atherosclerotic plaque formation and stenosis, and their correlation with cerebral parenchymal involvement in patients presenting with ischemic stroke. The data will be analyzed using IBM SPSS version 25.

RESULTS

The study sample of 50 participants was primarily composed of individuals aged 61-70 years (42%), followed by those aged 51-60 years (26%), with a mean age of 60.7 years. The gender distribution showed a predominance of male subjects (78%) compared to female subjects (22%).

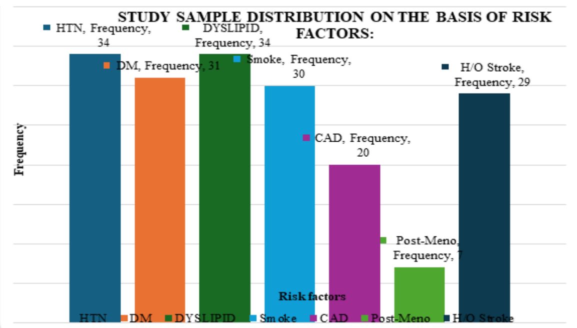

Figure 1: This bar chart illustrates the distribution of patient's risk factors. Hypertension, diabetes mellitus, and dyslipidemia were all notably prevalent, each affecting 68% of the study sample.

CT FINDINGS AND DOPPLER CHARCTERISTICS.

Table 1: Infarct territory and Infarct Area distributions.

Infarct Territory	Frequency (n=50)	Percent(%)
MCA	43	86%
ACA	7	14%
	Infarct Area	
CORTICAL	7	14%
SUB CORTICAL	14	28%
COMBINED	29	58%

Table 1: The study found that the majority of subjects had infarcts in the MCA territory, with 43 out of 50 subjects (86%) affected. In contrast, infarcts in the ACA territory were observed in only 7 subjects (14%). When analyzing the specific infarct areas, the combined and sub-cortical regions were most frequently involved, with 29 subjects (58%) showing infarcts in the combined region. Sub-cortical infarcts alone were observed in 14 subjects (28%), while cortical infarcts alone were present in 7 subjects (14%).

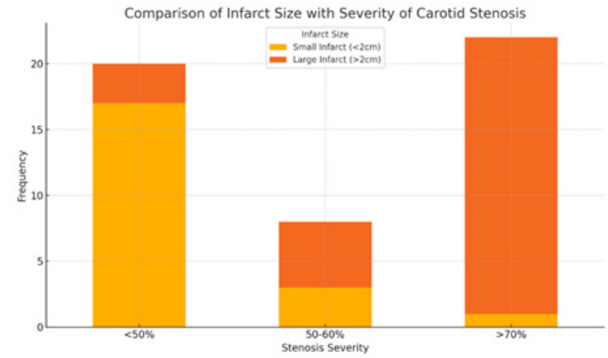

Figure 2- This bar chart illustrates the relationship between carotid stenosis severity and infarct size Patients with higher degrees of stenosis (≥70%) predominantly presented with large infarcts (>2 cm), with a statistically significant p-value of 0.001.

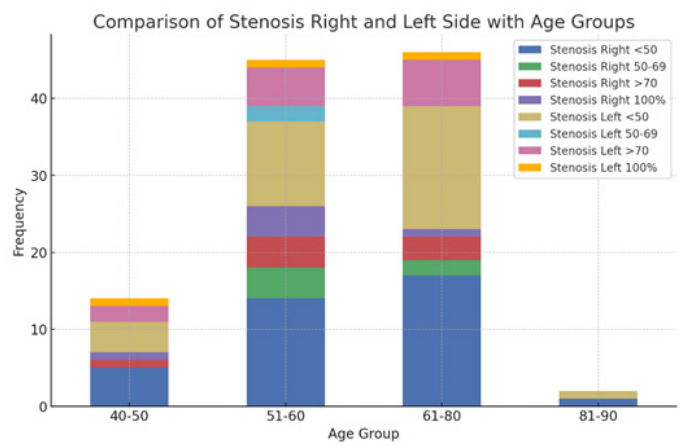

Figure 3: Comparison of stenosis right and left side with the age groups.

Figure 3- This stacked bar chart compares the stenosis categories on the right and left sides across different age groups.The 61-80 age group showed the highest frequency of stenosis, primarily in the <50% category on both sides. Significant p-values were observed, with 0.01 for the right side and 0.04 for the left side, according to the Kruskal-Wallis Test.

Figure 3: Comparison of stenosis right and left side with the age groups.

	Infarct Territory		Infarct Area		
Stenosis	**MCA**	**ACA**	**CORTICAL**	**SUB CORTICAL**	**COMBINED**
<50%	18	3	3	10	8
50-69%	4	1	1	0	4
≥70%	13	3	3	3	10
100%	8	0	0	1	7
p-value	0.004	0.05	0.05	0.0003	0.01

	Infarct Territory		Infarct Area		
IMT	**MCA**	**ACA**	**CORTICAL**	**SUB CORTICAL**	**COMBINED**
< 0.8	9	0	0	2	7
0.8-1	14	3	3	5	9
> 1	20	4	4	7	13
p-value	0.004	0.26	0.26	0.0003	0.01

Table 2: The comparison of stenosis with infarct territory and location in stroke patients revealed that subjects with stenosis <50% predominantly had infarcts in the MCA territory (18 subjects) and sub-cortical areas (10 subjects). In contrast, those with higher degrees of stenosis (≥70% and 100%) also showed significant involvement in these same territories, with p-values indicating strong associations. Similarly, the comparison of IMT with infarct territory and location showed that the MCA territory had the highest infarct frequency across all IMT categories, especially in subjects with IMT >1. Significant p-values were observed for the MCA territory (0.004), sub-cortical areas (0.0003), and combined areas (0.01) according to the Chi-square test.

Table 3: Comparison of PLA ICA and Plaque typewith Infarct Territory and Location/Area in the Patient of Stroke.

	Infarct Territory		Infarct Area		
PLA ICA	**MCA**	**ACA**	**CORTICAL**	**SUB CORTICAL**	**COMBINED**
PLA YES	28	3	4	10	17
PLA NO	15	4	3	4	12
p-value	0.025	0.85	0.85	0.002	0.05
	Infarct Territory				Infarct Area
Plaque type	**MCA**	**ACA**	**CORTICAL**	**SUB CORTICAL**	**COMBINED**
LUCENT	9	2	3	3	5
ECHOGENIC	10	0	2	1	7
CALCIFIED	15	3	3	8	7
p-value	0.5	0.02	0.88	0.01	0.79

Table 3: The comparison of PLA ICA with infarct territory and location in stroke patients showed that subjects with plaques (PLA YES) had a higher frequency of infarcts in the MCA (28 subjects), sub-cortical (10 subjects), and combined areas (17 subjects), with statistically significant p-values for the MCA (0.025) and sub-cortical areas (0.002) according to the Chi-square test. Additionally, when comparing plaque types, calcified plaques were more prevalent in the MCA territory (15 subjects) and sub-cortical areas (8 subjects).

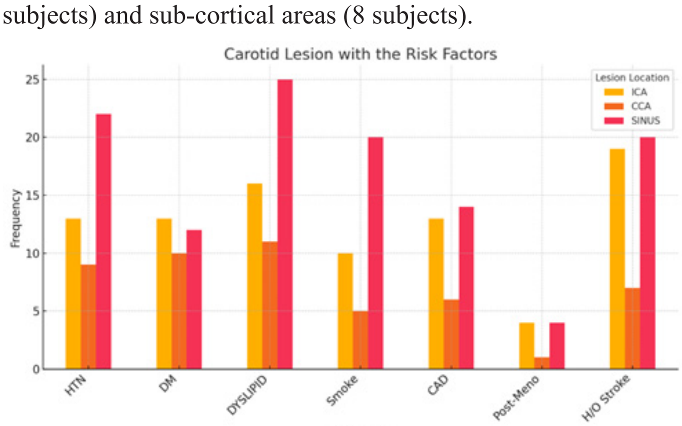

Figure 4- This chart evaluates the relationship between carotid lesions and various risk factor. Significant p-values for hypertension (0.01), diabetes mellitus (0.001), dyslipidemia (0.0001), smoking (0.001), coronary artery disease (0.01), and history of stroke (0.01) indicate strong associations between these risk factors and the presence of carotid lesions.

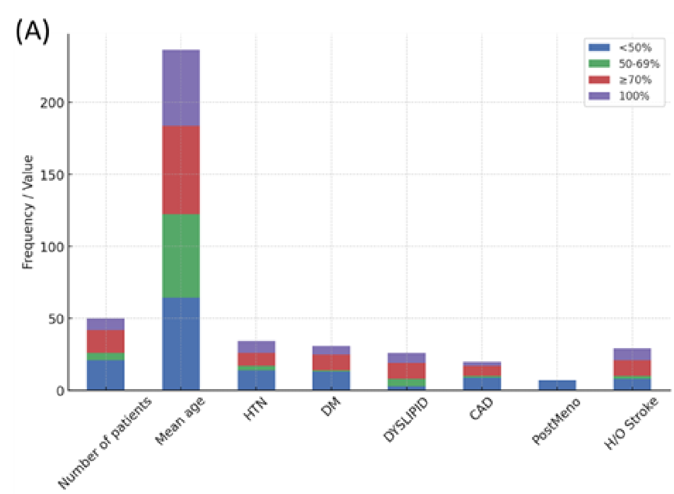

Figure 5: Severity of Stenosis with the risk factors. The <50% stenosis category was associated with the highest mean age, a greater proportion of females, and a higher prevalence of hypertension and diabetes. In contrast, the ≥70% stenosis category was more commonly linked to males, dyslipidemia, and coronary artery disease (CAD).

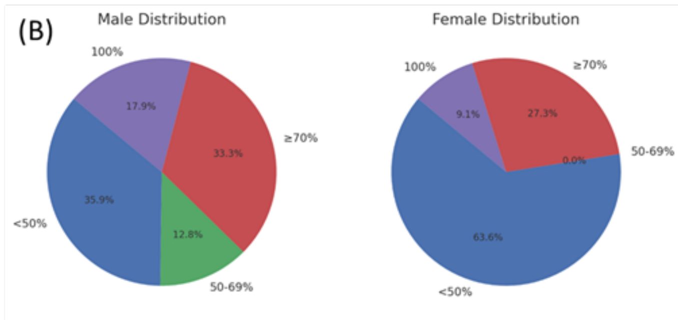

Figure 6: The pie charts illustrate the distribution of male and female subjects across various stenosis categories (<50%, 50-69%, ≥70%, 100%). The gender ratio reveals a higher proportion of males in each stenosis category.

DISCUSSION

Ischemic stroke, the most common type of stroke, occurs when a blood vessel supplying the brain becomes obstructed, leading to restricted oxygen and nutrient flow and subsequent brain cell death[1, 2]. This condition accounts for about 87% of all stroke cases and is a leading cause of morbidity and mortality worldwide, with around 795,000 cases annually in the United States alone. Major risk factors include hypertension, diabetes, hyperlipidemia, smoking, and atrial fibrillation, with additional influences from age, sex, and genetics[12, 13]. The pathophysiology involves mechanisms like embolic and thrombotic strokes, where blood clots block brain-supplying arteries, often due to atherosclerosis. The extracranial carotid arteries, particularly the common and internal carotid arteries, play a vital role in cerebrovascular circulation. Pathologies such as atherosclerosis, carotid artery dissection, and fibromuscular dysplasia can lead to conditions like stenosis, increasing the risk of stroke[10].

The majority of subjects in the study were aged 61–70 years, accounting for 42% of the total sample, followed by those aged 51–60 years at 26%, with a mean participant age of 60.7 years. These findings align with similar research by Fernandes et al. (2016), Pathak et al. (2019), and Walubembe et al. (2023), which reported a mean age of around 61 years with a standard deviation of 13 years[15, 17]. Additionally, the gender distribution revealed a predominance of male subjects, comprising 78% of the sample, consistent with the findings of Fernandes et al. (2016), Walubembe et al. (2023), and Das et al. (2021), who also observed a higher proportion of male participants. These trends suggest a common demographic pattern, with individuals in their sixth and seventh decades, particularly males, being more frequently represented in such research studies[15, 17, 18].

The prevalence rates of hypertension, diabetes mellitus, and dyslipidemia were notably high, each affecting 68% of the sample, consistent with findings from Pathak MR et al. (2019) and Fernandes M et al. (2016). These studies also reported similarly high rates of these risk factors, highlighting their significant role in the development of stenosis, particularly in cases with stenosis greater than 60%. Additionally, Das PJ et al. (2021) found no significant difference in risk factor prevalence between patient groups with <50% and ≥50% stenosis[16, 18].

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The prevalence rates of hypertension, diabetes mellitus, and dyslipidemia were notably high, each affecting 68% of the sample, consistent with findings from Pathak MR et al. (2019) and Fernandes M et al. (2016). These studies also reported similarly high rates of these risk factors, highlighting their significant role in the development of stenosis, particularly in cases with stenosis greater than 60%. Additionally, Das PJ et al. (2021) found no significant difference in risk factor prevalence between patient groups with <50% and ≥50% stenosis[16, 18]. The study subjects predominantly had infarcts in the MCA territory, with 86% (43 out of 50 subjects) affected, while the ACA territory accounted for only 14% (7 subjects) of the infarcts. This pattern is consistent with findings from previous studies by Fernandes M et al. (2016), Al-Huthi MA et al. (2023), and Walubembe J et al. (2023), which also reported a higher prevalence of infarcts in the MCA territory compared to the ACA territory[15, 17, 19]. Regarding infarct areas, the combined and sub-cortical regions were most frequently affected, with 58% (29 subjects) exhibiting infarcts in the combined region. Sub-cortical infarcts alone were observed in 28% (14 subjects), while cortical infarcts alone were seen in 14% (7 subjects). This distribution aligns with the studies by Walubembe J et al. (2023), Das PJ et al. (2021), and Fernandes M et al. (2016), which similarly reported a higher prevalence of infarcts in combined and sub-cortical regions compared to cortical regions alone[15, 17, 18].

Patients with higher degrees of stenosis (≥70%) predominantly exhibited large infarcts (>2 cm), with a significant p-value of 0.001, consistent with findings from Demchuk AM et al. (2016), Fernandes M et al. (2016), and Walubembe J et al. (2023), which also reported a significant correlation between severe stenosis and the occurrence of large infarcts[15, 17, 20]. The 61–80 age group showed the highest frequency of stenosis, particularly in the <50% category for both sides, with significant p-values of 0.01 for the right side and 0.04 for the left side, as observed using the Kruskal-Wallis Test. This trend aligns with studies by Al-Huthi MA et al. (2023), Fernandes M et al. (2016), and Walubembe J et al. (2023), which also reported a higher prevalence of stenosis in this age group[15, 17, 19]. Additionally, subjects with stenosis <50% were more likely to have infarcts in the MCA territory (18 subjects) and sub-cortical areas (10 subjects), while higher degrees of stenosis (≥70% and 100%) were significantly associated with involvement in these same territories, reflecting patterns reported by Pandey T et al. (2024), Das PJ et al. (2021), and Fernandes M et al. (2016)[17, 18, 21]. The MCA territory showed the highest infarct frequency across all IMT categories, particularly in subjects with IMT >1, with significant p-values noted for the MCA (0.004), sub-cortical (0.0003), and combined areas (0.01) using the Chi-square Test. This pattern is consistent with studies by Pandey T et al. (2024), Fernandes M et al. (2016), and Chitrah R et al. (2019), which also reported a high frequency of infarcts in the MCA territory and significant associations with increased IMT[17, 21, 22]. Additionally, subjects with plaques had a higher frequency of infarcts in the MCA (28 subjects), sub-cortical (10 subjects), and combined areas (17 subjects), with statistically significant p-values for the MCA (0.025) and sub-cortical areas (0.002). This finding aligns with the studies by Chitrah R et al. (2019), Pandey T et al. (2024), and Saba L et al. (2014), which similarly reported higher infarct frequencies in these regions among subjects with plaques[21,23].

Significant p-values were observed for hypertension (0.01), diabetes mellitus (0.001), dyslipidemia (0.0001), smoking (0.001), coronary artery disease (0.01), and history of stroke (0.01), indicating strong associations between these risk factors and the presence of carotid lesions. These findings are consistent with studies by Pandey T et al. (2024), Chitrah R et al. (2019), and Saba L et al. (2014), which also reported significant correlations between these risk factors and carotid artery pathology[21,23]. Saba L et al. (2014) specifically measured carotid artery diameter, determining that a diameter of 1.3 mm corresponds to 70% NASCET stenosis, with a reported sensitivity of 88% and specificity of 92%[23].

The <50% stenosis category was associated with the highest mean age, a greater prevalence of female gender, and a higher incidence of hypertension and diabetes. In contrast, the ≥70% stenosis category was more common among males and had higher rates of dyslipidemia and coronary artery disease (CAD). These findings are consistent with studies by Pandey T et al. (2024), Fernandes M et al. (2016), and Saba L et al. (2014), which also reported similar distributions of demographic factors and comorbidities across different stenosis severity categories[17, 21, 23]. The analysis of various parameters, including patient count, mean age, and the prevalence of hypertension, diabetes, dyslipidemia, CAD, postmenopausal status, and history of stroke across stenosis categories, revealed distinct trends, with gender differences highlighted in separate columns. These trends align with findings from Saba L et al. (2014), Fernandes M et al. (2016), and Das PJ et al. (2021), which also demonstrated significant associations between these parameters and stenosis severity[17, 18, 23].

CONCLUSION

In conclusion, this study highlights the significant correlations between carotid artery disease, particularly the severity of stenosis and intima-media thickness, and the occurrence of infarcts in ischemic stroke patients. The findings emphasize the higher prevalence of severe carotid stenosis in males, which is strongly associated with larger infarcts, particularly in the middle cerebral artery territory. Additionally, the study underscores the critical role of modifiable risk factors, such as hypertension, diabetes, dyslipidemia, and smoking, in the development and progression of carotid artery disease. These results support the need for routine duplex ultrasound screening in at-risk populations and the importance of targeted interventions to manage these risk factors, ultimately aiming to reduce the incidence and severity of ischemic strokes.

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