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Comparative Study of Carotid Artery Disease in Hypertensive Versus Non-Hypertensive Patients Using Color Doppler Flow Imaging

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Disclaimers

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ABSTRACT

Background: Carotid artery disease is common in patients with hypertension, leading to thickened intima-media layers and narrowed arteries, increasing the risk of stroke and myocardial infarction.

Objective: This study compared Color Doppler findings in hypertensive and non-hypertensive patients, focusing on intima-media thickness (IMT) and Doppler indices.

Methods: A cross-sectional study was conducted on 120 patients at the University of Lahore, including 72 hypertensive and 48 non-hypertensive individuals. Doppler ultrasonography was performed using a Toshiba XARIO XG machine with a 5-7.5 MHz linear probe. Data on age, hypertension, diabetes status, gender, and IMT were collected. Doppler indices including Resistive Index (RI), Pulsatility Index (PI), End Diastolic Velocity (EDV), and Peak Systolic Velocity (PSV) were analyzed using SPSS version 25.0. An independent t-test compared Doppler indices between groups, with $p < 0.05$ considered significant.

Results: IMT was significantly higher in hypertensive patients (0.63 ± 0.16 mm right, 0.62 ± 0.14 mm left) compared to non-hypertensive patients (0.56 ± 0.14 mm right, 0.57 ± 0.14 mm left) with p-values of 0.013 and 0.048, respectively. No significant differences were found in other Doppler indices.

Conclusion: Hypertension is linked to increased carotid IMT, indicating a higher risk for plaque formation. Doppler ultrasound can help in early detection and prevention of cardiovascular diseases.

INTRODUCTION

Carotid artery stenosis is a prevalent medical condition and a well-known risk factor for stroke, caused by the presence of atherosclerotic plaque. Various indicators such as age, smoking, male sex, hypertension, hyperlipidemia, diabetes, and genetic factors are recognized as contributors to the development of atherosclerosis (1). Among these, hypertension is particularly significant as it has been found to play a critical role in carotid atherosclerosis. Research indicates that lifelong hypertension is related to fatty streaks and raised atherosclerotic lesions in the coronary, carotid, and aortic arteries, as well as the prevalence of both (2). The early stages of atherosclerosis manifest as structural alterations in the arterial wall, which are not easily detectable through macroscopic pathological examination or arteriography. Consequently, the contribution of hypertension to the progression of early-stage atherosclerosis in humans has remained somewhat unclear due to the limitations of conventional imaging techniques (3).

In hypertensive individuals, cerebrovascular accidents may be attributed to cerebral hemorrhage or infarction, with raised arterial blood pressure almost invariably resulting in cerebral hemorrhage, except in individuals with inherent hematological problems. Hypertensive individuals are also at a higher risk of experiencing cerebral infarctions, with high blood pressure identified as a major risk factor for atherothrombotic cerebral infarction (4). In particular, low diastolic blood pressure in individuals with isolated systolic hypertension serves as a marker for carotid stenosis, which is closely linked with this form of hypertension (5). High systolic blood pressure is associated with an elevated risk for developing atherosclerotic diseases, including carotid artery disease, and may lead to arterial rigidity and increased systolic blood pressure due to early atherosclerosis development (6).

Doppler ultrasound is a simple, safe, and reproducible method for evaluating adaptive vascular changes, such as arterial wall thickening and atherosclerotic progression (7). This imaging technique enables precise measurement of the intima-media thickness (IMT), which represents the thickness of the artery walls. Numerous studies have demonstrated a strong correlation between hypertension and carotid intima-media thickness (CIMT), with CIMT serving as a prognostic marker for organ damage and facilitating the detection of carotid atherosclerosis (8, 9). Hypertension, a potent biomarker associated with cerebrovascular and cardiovascular disease development, causes hypertrophy of the arterial wall, contributing to carotid IMT thickening. Moreover, it exacerbates plaque formation by exerting pressure on artery walls, potentially

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leading to further plaque accumulation over time (10). In a population of 1.3 million adults, hypertension was found to significantly increase the risk of adverse cardiovascular events, including hemorrhagic stroke, ischemic stroke, and myocardial infarction (11). Stroke remains the third leading cause of disability and mortality globally, with ischemic strokes accounting for 80 to 85% of all strokes caused by stenosis, clots, and embolism (12). Extracranial carotid artery stenosis contributes to 20 to 30% of all strokes, whereas intracranial CAS accounts for 5–10% (13, 14).

Prospective data from the Framingham Survey identifies hypertension as a primary risk factor for "atherothrombotic cerebral infarction," often resulting from tiny deep lacunar infarcts in small perforating arteries exposed to chronically high blood pressure in hypertensive patients. Large infarcts, prevalent in most non-hemorrhagic strokes, are also linked to hypertension, typically explained by increased atheroma prevalence or severity in the presence of high blood pressure (15). This study emphasizes the significant correlation between carotid IMT in both hypertensive and non-hypertensive individuals, addressing the role of hypertension in carotid artery disease. Unlike previous studies primarily focusing on hypertension, our research aims to evaluate carotid IMT and plaque presence in both hypertensive and non-hypertensive groups. This research seeks to improve early identification of stenosis or plaque in the carotid artery, enhancing prevention strategies and improving prognosis for individuals with varying blood pressure condition.

MATERIAL AND METHODS

The study was conducted over four months at the ultrasound clinic of the University of Lahore in Green Town. A total of 120 patients, comprising 72 hypertensive and 48 non-hypertensive individuals, were recruited for the research. The participants were selected based on their clinical indications of carotid artery disease, and a convenient sampling technique was used to recruit participants. Both male and female patients were eligible for inclusion, provided they were cooperative and willing to participate. Exclusion criteria included patients who were uncooperative or unwilling to participate in the study.

Ethical approval for the study was obtained from the Institutional Review Board of the University of Lahore, and all procedures were conducted in accordance with the ethical standards of the Helsinki Declaration. Informed consent was obtained from all participants prior to their inclusion in the study. Participants were assured of the confidentiality of their data and were informed of their right to withdraw from the study at any time without any consequences.

Data collection involved a comprehensive assessment of each participant's medical history, including previous occurrences of hypertension, diabetes, smoking, and other risk factors contributing to carotid artery disease. Participants underwent Doppler ultrasound imaging using a Toshiba XARIO XG machine equipped with a linear probe operating at 5–7.5 MHz. This imaging technique facilitated the evaluation of parameters such as intima-media thickness (IMT), Peak Systolic Velocity (PSV), End Diastolic Velocity (EDV), Resistive Index (RI), and Pulsatility Index (PI) in both the right and left carotid arteries. The ultrasound examinations were performed by trained medical imaging professionals who adhered to standardized protocols to ensure the accuracy and reliability of the measurements.

Data analysis was conducted using SPSS version 25.0. Descriptive statistics were employed to summarize demographic and clinical characteristics, including age, gender, presence of hypertension, diabetes, ischemic heart disease, and smoking history. Mean values and standard deviations were calculated for continuous variables such as age, IMT, PSV, EDV, RI, and PI. Categorical variables were expressed as frequencies and percentages. An independent t-test was used to compare the Doppler indices between hypertensive and non-hypertensive groups, with statistical significance defined as a p-value of less than 0.05. Graphical representations of the data, including pie charts, bar charts, and histograms, were created to illustrate the distribution of risk factors and Doppler parameters among the study population. The statistical analysis provided insights into the differences in carotid artery characteristics between hypertensive and non-hypertensive patients, highlighting the impact of hypertension on the progression of carotid artery disease.

The study aimed to contribute to the understanding of the relationship between hypertension and carotid artery disease, emphasizing the importance of early detection and intervention to improve clinical outcomes in patients at risk for cardiovascular and cerebrovascular events (1).

RESULTS

The first table displays the descriptive statistics for several vascular parameters, comparing individuals with and without hypertension. Each parameter is presented with its mean, standard deviation, and p-value to assess statistical significance.

For the parameter R.IMT (Right Intima-Media Thickness), there is a noticeable difference between the non-hypertensive group (mean = 0.56) and the hypertensive group (mean = 0.63), with a p-value of 0.05. This suggests that hypertension is associated with a thicker intima-media in the right carotid artery. Similarly, L.IMT (Left Intima-Media Thickness) also shows a significant difference (mean = 0.57 for non-hypertensive, mean = 0.62 for hypertensive) with a p-value of 0.04, indicating a similar pattern on the left side.
The parameter L.PI (Left Pulsatility Index) reveals a significant difference between groups, with the hypertensive group showing a substantially higher mean (2.75) compared to the non-hypertensive group (1.30), and a p-value of 0.01. This finding suggests a higher pulsatility in the left carotid artery among individuals with hypertension, which could be indicative of altered blood flow dynamics associated with the condition.

Other parameters, such as R.RI (Right Resistive Index), R.PI (Right Pulsatility Index), R.PSV (Right Peak Systolic Velocity), R.EDV (Right End-Diastolic Velocity), L.RI (Left Resistive Index), L.PSV (Left Peak Systolic Velocity), and L.EDV (Left End-Diastolic Velocity), do not show statistically significant differences, with p-values exceeding 0.05. These results suggest that these parameters might not be as strongly influenced by hypertension, or the differences may not be substantial enough to reach statistical significance in this sample.

Table 1: Descriptive Statistics for Parameters by Hypertension Status

Parameter	Hypertension	N	Mean	Std. Deviation	p-value
R.IMT	No	48	0.56	0.14	0.05
	Yes	72	0.63	0.16	
R.RI	No	48	0.60	0.16	0.15
	Yes	72	0.57	0.22	
R.PI	No	48	1.20	0.49	0.20
	Yes	72	1.15	0.81	
R.PSV	No	48	-69.25	29.10	0.30
	Yes	72	-67.15	34.09	
R.EDV	No	48	-26.86	13.43	0.10
	Yes	72	-31.26	26.35	
L.IMT	No	48	0.57	0.14	0.04
	Yes	72	0.62	0.14	
L.RI	No	48	0.64	0.15	0.08
	Yes	72	0.61	0.14	
L.PI	No	48	1.30	0.64	0.01
	Yes	72	2.75	13.66	
L.PSV	No	48	-69.36	18.05	0.12
	Yes	72	-63.64	29.12	
L.EDV	No	48	-23.02	9.79	0.25
	Yes	72	-24.54	16.98	

The second table presents the results of inferential statistics, specifically the t-test for equality of means, under the assumption of equal variances for each parameter. This analysis provides insights into the significance and magnitude of differences in means between hypertensive and non-hypertensive groups.

For R.IMT, the mean difference of -0.07222 with a standard error of 0.02865 yields a t-value of -2.521 and a p-value of 0.013. This indicates a statistically significant lower R.IMT in the non-hypertensive group, supporting the finding from the descriptive analysis. Similarly, L.IMT shows a mean difference of -0.05347 with a p-value of 0.048, confirming the significance of differences observed in the descriptive data.

In contrast, parameters like R.RI and R.PI have mean differences of 0.03194 and 0.04833, respectively, with p-values of 0.387 and 0.713. These results highlight the lack of statistically significant differences for these parameters between the two groups.

Table 2: Inferential Statistics for Parameter Differences

Parameter	Mean Difference	Std. Error Difference	t-value	df	p-value (Sig.)
R.IMT	-0.07222	0.02865	-2.521	118	0.013
R.RI	0.03194	0.03675	0.869	118	0.387
R.PI	0.04833	0.13098	0.369	118	0.713
R.PSV	-2.09722	5.99856	-0.350	118	0.727
R.EDV	4.39514	4.12353	1.066	118	0.289
L.IMT	-0.05347	0.02673	-2.001	118	0.048
L.RI	0.03514	0.02733	1.286	118	0.201
L.PI	-1.44368	1.97606	-0.731	118	0.466
L.PSV	-5.72153	4.71386	-1.214	118	0.227
L.EDV	1.52083	2.71024	0.561	118	0.576

The parameter L.PI, despite showing significant differences in the descriptive analysis, has a mean difference of -1.44368 with a p-value of 0.466 in the inferential analysis. This discrepancy might be due to the large variability indicated by the high standard deviation in the hypertensive group, affecting the precision of the mean estimate.

Overall, the inferential statistics confirm the significance of differences in some parameters like R.IMT and L.IMT, while other parameters do not show significant differences when accounting for variability. This analysis highlights which vascular parameters are most strongly associated with hypertension in this sample.

DISCUSSION

The study aimed to assess the relationship between carotid intima-media thickness (CIMT) and the presence of carotid plaque in both hypertensive and non-hypertensive patients, with a particular focus on understanding the impact of hypertension as a significant risk factor for stroke. The results highlighted that hypertensive patient had significantly increased CIMT in both the right and left carotid arteries compared to non-hypertensive individuals, aligning with previous research that established hypertension as a critical contributor to arterial wall thickening and plaque formation (1, 2). This finding is consistent with studies by Salonen et al., which demonstrated a significant correlation between elevated blood pressure and increased CIMT, thus reinforcing the association between hypertension and atherosclerotic changes in the carotid arteries (3).

The study also explored other Doppler indices, such as Resistive Index (RI), Pulsatility Index (PI), Peak Systolic Velocity (PSV), and End Diastolic Velocity (EDV), to evaluate vascular changes in the carotid arteries. However, no statistically significant differences were found between hypertensive and non-hypertensive groups for these parameters. This could suggest that while CIMT is a sensitive marker for detecting early atherosclerotic changes, other Doppler indices might not be as strongly influenced by hypertension or may require larger sample sizes to detect subtle differences (4).

The study's strengths include its focused assessment of carotid artery disease using a well-established imaging modality, Doppler ultrasound, which is known for its reliability and non-invasive nature in evaluating vascular changes (5). The study's methodology was robust, with a clear selection of participants based on clinical indications of carotid artery disease and the use of standardized imaging protocols. Furthermore, the study included both hypertensive and non-hypertensive individuals, allowing for a direct comparison of carotid artery changes between these groups.

However, there were several limitations to consider. The use of convenient sampling might have introduced selection bias, potentially affecting the generalizability of the findings. Additionally, the relatively small sample size may have limited the ability to detect significant differences in some Doppler indices between the two groups. Future studies with larger and more diverse populations could provide more comprehensive insights into the relationship between hypertension and carotid artery disease. Furthermore, the cross-sectional design of the study prevented the assessment of causal relationships; longitudinal studies would be beneficial to understand the progression of carotid artery changes over time in hypertensive patients.

The study's findings underscore the importance of regular monitoring of blood pressure and early detection of increased CIMT to mitigate the risk of cardiovascular and cerebrovascular events in hypertensive patients. Given the role of hypertension in accelerating atherosclerosis, early intervention and aggressive management of hypertension could significantly improve outcomes in patients at risk for carotid artery disease. Clinicians should consider incorporating routine CIMT assessments into the management plan for hypertensive patients, as this may aid in the early identification of individuals at increased risk of stroke and other vascular complications (6, 7)..

CONCLUSION

In conclusion, the study demonstrated a significant association between hypertension and increased carotid intima-media thickness (CIMT), underscoring hypertension's role as a major risk factor for carotid artery disease and subsequent stroke. These findings emphasize the critical need for vigilant blood pressure monitoring and proactive management strategies to prevent the progression of atherosclerosis in hypertensive patients. Early detection and intervention can mitigate the risk of adverse cardiovascular and cerebrovascular events, thereby improving patient outcomes and reducing the overall healthcare burden. Integrating CIMT assessments into routine clinical practice for hypertensive individuals can facilitate the early identification of at-risk patients, enabling timely therapeutic interventions and contributing to better long-term health outcomes

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