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Duplex Carotid Vascular Scan in Diabetics.

*Cookey SN, *Asikimabo-Ofori D, *Briggs FK. **Nwazor EO, ***Gomba VE, Harry BB.
**Cardiology Unit, Department of Internal Medicine*
***Neurology Unit, Department of Internal Medicine,*
****Endocrinology Unit, Department of Internal Medicine*
Rivers State University/Rivers State University Teaching Hospital.

Introduction: *Cardiovascular diseases are leading global causes of mortality, with diabetes mellitus (DM) serving as a significant risk factor. Type 2 DM intensifies the atherosclerotic process and causes endothelial dysfunction via glycoxidative products, resulting in vascular complications. This study aims to assess duplex carotid findings in diabetic patients, evaluate the correlation between disease duration and vascular findings, and compare parameters with normal, diabetics and diabetic hypertensive populations.*
Method*: A prospective, comparative study was conducted at a private facility: Haven cardiovascular and Specialist Clinics. Fifty-two diabetic patients were recruited, and duplex carotid scans were performed. Normal variables were matched for age, sex, and BMI. Patients with chronic kidney disease were excluded. Variables such as carotid intima-media thickness (IMT), peak systolic velocity (PSV), and resistive index (RI), Pulsatility Index were analyzed. Statistical analyses included descriptive and comparative methods.*
Conclusion: *Diabetic patients exhibited significant alterations in carotid parameters compared to normal and diabetic hypertensive populations. Findings suggest a strong correlation between disease duration and vascular changes, underscoring the necessity for early vascular assessments in diabetic care.*
Keywords: *Diabetes Mellitus, Duplex Carotid Scan, Atherosclerosis, Endothelial Dysfunction, Hypertension, Carotid Intima-Media Thickness, Vascular Health*

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I. Introduction:

Cardiovascular diseases (CVD) continue to dominate as a primary global health challenge, contributing to approximately 19.91 million deaths in 2021 alone[2]. This staggering figure points to the immense burden posed by CVD on healthcare systems, economies, and societies worldwide. Among the various contributors to this disease group, atherosclerosis—the progressive buildup of plaques within the arterial walls—plays a critical role in triggering both cerebrovascular and cardiovascular events[3].

Atherosclerosis is a complex pathological process driven by inflammation, endothelial dysfunction, lipid accumulation, and plaque formation within arteries[4]. Over time, this condition leads to the narrowing and stiffening of blood vessels, compromising blood flow to vital organs. It is a major underlying cause of ischemic heart disease, myocardial infarction, and strokes, which collectively form a significant proportion of CVD-related mortality[5]. The clinical manifestations of atherosclerosis vary, but in advanced cases, plaque rupture and subsequent thrombus formation can precipitate life-threatening events[3].

The prevalence of atherosclerosis risk factors has been significantly driven by global trends, including aging populations, urbanization, evolving dietary habits, smoking, alcohol consumption, and increasingly sedentary lifestyles. [6],[7] These changes have heightened the incidence of conditions such as hypertension, diabetes mellitus, obesity, and dyslipidemia. Additionally, lack of physical activity further exacerbates these risks. The economic impact of cardiovascular diseases is profound, encompassing substantial healthcare costs and productivity losses due to disability and reduced workforce participation[8].

Efforts to mitigate the impact of CVD include primary prevention strategies, public health awareness campaigns, early detection, and advances in medical and surgical interventions[9]. Despite these measures, the persistent rise in CVD prevalence highlights the critical need for more innovative approaches to address this global health crisis.[9,10]

Carotid atherosclerosis (CA) and carotid artery stenosis (CAS) are recognized as major contributors to ischemic strokes[11]. Carotid intima-media thickness (cIMT) serves as a reliable surrogate marker of vascular disease, with its findings consistent across other vascular territories[12]. Evaluating the carotid arteries is both informative and critical, as up to 15% of strokes have been linked directly to large vessel atherosclerosis, with the extracranial carotid arteries being the most frequently implicated. [13,14]. This highlights the importance of investigating carotid pathophysiology, particularly in high-risk groups such as individuals with diabetes mellitus (DM) or hypertension. The recurrence rates for strokes associated with large-vessel atherosclerosis remain troublingly high; however, timely interventions like carotid endarterectomy have proven effective in preventing stroke recurrence. [15,16].

In individuals with type 2 diabetes (T2D), chronic hyperglycemia and associated metabolic derangements amplify vascular complications through endothelial dysfunction and vascular calcification[6]. Mechanistically, diabetes-associated hyperglycemia enhances O-GlcNAcylation of AKT, leading to increased Runx activity and vascular calcification, including calcification of the carotid arteries[7]. Furthermore, comorbidities such as hypertension, smoking, and hyperlipidemia contribute to destabilizing atheromatous plaques, predisposing them to calcification and increased stenotic burden. [7,17] These factors position diabetic individuals, especially those with long disease durations or comorbid hypertension, at a heightened risk for subclinical CA and CAS.[13] Elevated levels of glucose variability, markers such as matrix metalloproteinase-3 (MMP-3), and other clinical parameters have been associated with the progression of carotid pathology[18].

The clinical implications of these findings are profound. DM not only increases the prevalence and severity of carotid disease but also worsens outcomes after interventions such as carotid endarterectomy or stenting.[9,15] Moreover, DM patients are at heightened risk for contrast-induced acute kidney injury (CI-AKI) during carotid stenting procedures, which can adversely affect both short- and long-term outcomes[19]. Functional changes in the carotid artery, such as altered flow dynamics and endothelial dysfunction, often precede morphological changes, emphasizing the need for early detection and intervention[20].

In light of these insights, the study of carotid artery disease in DM patients is crucial for developing targeted screening and prevention strategies. By integrating clinical, genetic, and molecular data, future research can optimize the management of carotid disease in this high-risk population. This study explores the duplex carotid ultrasonography findings in diabetic patients. By analyzing vascular parameters such as intima-media thickness (IMT), peak systolic velocity (PSV), and resistivity index (RI), and comparing them with hypertensive and healthy populations, we aim to better understand the pathophysiology of CA and CAS in diabetes. This evaluation not only highlights potential biomarkers of carotid pathology but also underscores the necessity for early screening and management strategies tailored for at-risk individuals. The study set out tonbdetermine duplex carotid findings in diabetic patient, to explore the differences in cardiovascular and carotid artery parameters across the study population, between normal , diabetics and Hypertensives. Also ascertain the prevalence of plaques in diabetics.

II. Method

Study Design

This was a cross-sectional, observational study, conducted to evaluate the impact of diabetes on the carotid vessels. The study compared Doppler carotid vascular parameters in a diabetic population with matched values obtained from a non-diabetic population (controls). It also compared values for the diabetic hypertensives and non hypertensive diabetics. Ethical clearance was obtained from Haven Cardiovascular and Specialist Clinics Ethics Committee, and all participants provided informed consent after appropriate counseling.

Study Setting

The study was carried out Haven Cardiovascular Laboratory

Sample Size

The minimum sample size was determined using the formula:

$$n = \frac{Z^2(pq)}{e^2}$$

where n = minimum sample size, $Z = 1.96$ (95% CI), $p = prevalence$, $q = 100 - p$, and $e = 5\%$ (margin of error). Based on existing prevalence rates of carotid vascular disease in diabetics, the sample size was calculated to be 37; however, 52 diabetic patients were recruited to account for potential variability. and to ensure reliability and robustness of the findings. This larger sample size enhances the statistical power of the study, allowing for the detection of significant differences or correlations. It also accounts for potential dropouts or incomplete data, ensuring that the study remains adequately powered. Additionally, the increased number accommodates the variability in the diabetic population, capturing a broader range of patient characteristics such as age, BMI, and disease severity.

Population: - Diabetic Patients: Fifty-one diabetic patients aged 18 years and above, with fasting blood sugar ≥ 7.0 mmol/L or HbA1c ≥ 6.5%, were recruited, who consented were recruited. Patients with chronic kidney disease or incomplete consent were excluded. BMI was computed from measured weight and height.

Control Population: Data for controls were retrieved from previous studies on normal subjects (non-diabetic, non-hypertensive), matched for age, sex, and BMI.

Ultrasound Procedure: The study utilized the Sonoscape SS1 8000 duplex ultrasound machine with a 5–15 MHz linear array probe. The procedure was conducted by placing the probe along the carotid axis to evaluate the common carotid artery (CCA) and internal carotid artery (ICA). Parameters measured included:
1. Vessel Diameter.
2. Intima-Media Thickness (IMT).
3. Peak Systolic Velocity (PSV).
4. End-Diastolic Velocity (EDV).
5. Resistivity Index (RI).
6. Pulsatility Index
6. Ratio of PSV to EDV (S/D Ratio).

Patients were positioned supine, with the neck extended and turned away from the examined carotid artery. The scans began at the proximal CCA and moved distally to the bifurcation in both transverse and longitudinal planes. Color Doppler imaging was used to assess vessel patency and highlight potential stenosis. To ensure accurate measurements, the Doppler sample volume was placed at the center of the vessel to avoid wall-induced turbulence. Two successive readings were taken for each parameter, and the average value was calculated.

III. Data Analysis:

Comprehensive analysis of parameters including age, BMI, fasting blood sugar, systolic/diastolic blood pressure, and carotid parameters (IMT, PSV, RI, PI, S/D). Results were compared across diabetic, non-diabetic, and hypertensive populations.

Results: Fifty-two (52) diabetic participants were enrolled in the study see table 1 for a detailed breakdown across various demographics and carotid artery parameters. Out of the 52 participants, the majority were female, accounting for 63.5% (33 individuals), while males constituted 36.5% (19 individuals). The duration of DM among the participants varied, with a total of 51 valid responses and one missing entry (1.9%). The most frequent durations were 4 years (23.1%) and durations of 1, 5, 6, 10, and 12 years, each accounting for 11.5%. Less frequent durations included 3, 8, and 11 years, each at 5.8%. This indicates a broad spectrum of disease progression among the cohort.

Majority of the Participants (43) had Type 2 diabetes, comprising 80.7 % of participants, while type 1 diabetes (class 2) represented 17.3% (9 individuals). Among the participants, 63.5% (33 individuals) were diabetics but non-hypertensive, while 36.54% (19 individuals) had both diabetes and hypertension (DM/HTN). The majority of participants 36 (69.2%) did not report any complications. Among those with complications, retinopathy was the most common, observed in 11.5% (6 individuals). Other reported complications included peripheral neuropathy (5.8%, or 3 individuals), stroke/eye/heart conditions (5.8%, or 3 individuals), ulcers (1.9%, or 1 individual), and a combination of ulcers, peripheral neuropathy, and hypertensive heart disease (5.8%, or 3 individuals).

Occupation The occupations of participants varied significantly. Traders formed the largest group (28.8%, or 15 individuals), followed by retirees and health workers, each representing 17.3% (9 individuals). Other occupations included civil servants (11.5%, or 6 individuals), business owners (5.8%, or 3 individuals), lawyers (5.8%, or 3 individuals), public servants (5.8%, or 3 individuals), and welders (5.8%, or 3 individuals). One unidentified entry accounted for 1.9%.

Table 1: Cardiovascular and Carotid Artry Variables

Variable	Mean ± SD
AGE (years)	59.82 ± 12.12
BMI (kg/m²)	25.10 ± 6.46
FBS (mmol/L)	8.66 ± 3.36
SBP (mmHg)	130.59 ± 7.32
DBP (mmHg)	81.76 ± 7.13
LCC/DIAM (cm)	0.62 ± 0.13
LCC/IMT (cm)	0.08 ± 0.02
LCC/PSV (cm/s)	51.96 ± 12.02
LCC/EDV (cm/s)	14.14 ± 4.09
LCC/RI	0.74 ± 0.06
LCC/PI	1.31 ± 0.16
LCC/SD	4.00 ± 0.88
LIC/DIAM (cm)	0.72 ± 0.15
LIC/IMT (cm)	0.08 ± 0.03
LIC/PSV (cm/s)	48.86 ± 9.31
LIC/EDV (cm/s)	15.01 ± 6.14
SCI/RI	0.68 ± 0.12
SCI/IP	1.29 ± 0.43
LIC/SD	3.74 ± 1.53
RCC/DIAM (cm)	0.64 ± 0.11

RCC/IMT (cm)	0.09 ± 0.03
RCC/PSV (cm/s)	56.85 ± 12.48
RCC/EDV (cm/s)	17.46 ± 7.43
RCC/RI	1.31 ± 2.38
RCC/PI	1.24 ± 0.24
RCC/SD	3.63 ± 1.08
RIC/DIAM (cm)	0.66 ± 0.16
RIC/IMT (cm)	0.08 ± 0.04
RIC/PSV (cm/s)	49.44 ± 17.05
RIC/EDV (cm/s)	14.41 ± 4.49
RIC/RI	0.72 ± 0.10
RIC/PI	1.26 ± 0.30
RIC/SD	3.97 ± 1.73

AGE (age in years), BMI (Body Mass Index in kg/m²), and FBS (Fasting Blood Sugar in mmol/L). Blood pressure measurements are represented as SBP (Systolic Blood Pressure in mmHg) and DBP (Diastolic Blood Pressure in mmHg). Carotid artery parameters are categorized into the left and right common carotid (LCC and RCC) and the left and right internal carotid (LIC and RIC). These include DIAM (Diameter in cm), IMT (Intima-Media Thickness in cm), PSV (Peak Systolic Velocity in cm/s), EDV (End-Diastolic Velocity in cm/s), RI (Resistivity Index), PI (Pulsatility Index), and SD (Systolic to Diastolic Ratio).

Table 2: Paired Samples T-Test for Diabetic Population Vs Normal Carotid Variables

Variable	Diabetic (Mean ± SD)	Normal (Mean ± SD)	WITHOUT	T	DF	P-value
AGE (years)	59.32 ± 11.69	51.96 ± 10.24	1.53	4.82	49	0.00
BMI (kg/m²)	24.99 ± 6.47	26.16 ± 4.08	1.19	-0.99	49	0.33
SBP (mmHg)	130.23 ± 7.31	128.27 ± 10.60	2.20	0.89	43	0.38
DBP (mmHg)	81.82 ± 7.24	79.64 ± 7.87	1.75	1.25	43	0.22
LCC/DIAM (cm)	0.62 ± 0.13	0.69 ± 0.10	0.02	-2.92	43	0.01
LCC/IMT (cm)	0.08 ± 0.02	0.09 ± 0.03	0.00	-0.25	41	0.81
LCC/PSV (cm/s)	51.49 ± 11.37	52.80 ± 16.13	2.96	-0.44	43	0.66
LCC/EDV (cm/s)	14.29 ± 3.92	13.24 ± 5.92	1.04	1.02	43	0.32
LCC/RI	0.74 ± 0.06	0.77 ± 0.07	0.01	-2.20	43	0.03
LCC/SD	3.93 ± 0.83	4.25 ± 1.03	0.19	-1.69	43	0.10
LIC/DIAM (cm)	0.72 ± 0.16	0.81 ± 0.16	0.03	-2.52	42	0.02
LIC/IMT (cm)	0.08 ± 0.03	0.07 ± 0.02	0.01	0.42	36	0.68
LIC/PSV (cm/s)	48.84 ± 9.51	46.08 ± 19.07	3.57	0.77	35	0.45
LIC/EDP (cm/s)	13.90 ± 4.95	11.20 ± 4.67	1.22	2.22	35	0.03
LIC/RI	0.71 ± 0.12	1.36 ± 2.39	0.41	-1.58	33	0.12
LIC/SD	3.84 ± 1.47	4.39 ± 1.88	0.40	-1.41	33	0.17
RCC/DIAM (cm)	0.64 ± 0.11	0.72 ± 0.10	0.03	-2.86	37	0.01
RCC/IMT (cm)	0.09 ± 0.03	0.09 ± 0.02	0.00	1.24	35	0.23
RCC/PSV (cm/s)	57.00 ± 12.21	46.81 ± 17.59	3.36	3.03	37	0.00
RCC/EDV (cm/s)	17.37 ± 7.03	12.24 ± 6.15	1.61	3.18	37	0.00
RCC/SD	3.57 ± 1.00	4.30 ± 1.31	0.23	-3.13	37	0.00
RIC/DIAM (cm)	0.66 ± 0.16	0.80 ± 0.11	0.03	-4.54	31	0.00
RIC/IMT (cm)	0.08 ± 0.04	0.08 ± 0.01	0.01	0.88	27	0.39
RIC/PSV (cm/s)	50.59 ± 15.11	43.09 ± 16.00	4.41	1.70	23	0.10
RIC/EDV (cm/s)	14.81 ± 5.22	9.59 ± 5.97	1.58	3.31	23	0.00
RIC/RI	0.74 ± 0.08	0.72 ± 0.19	0.04	0.39	23	0.70
RIC/SD	3.98 ± 1.57	5.56 ± 2.62	0.63	-2.50	23	0.02

AGE (age in years), BMI (Body Mass Index in kg/m²), and FBS (Fasting Blood Sugar in mmol/L). Blood pressure measurements are represented as SBP (Systolic Blood Pressure in mmHg) and DBP (Diastolic Blood Pressure in mmHg). Carotid artery parameters are categorized into the left and right common carotid (LCC and RCC) and the left and right internal carotid (LIC and RIC). These include DIAM (Diameter in cm), IMT (Intima-Media Thickness in cm), PSV (Peak Systolic Velocity in cm/s), EDV (End-Diastolic Velocity in cm/s), RI (Resistivity Index), PI (Pulsatility Index), and SD (Systolic to Diastolic Ratio).

Table 3; Comparison of Data of Normal, Diabetics and Diabetic Hypertensives using Anova

Parameter	Diabetic Hypertensive (Group 3)	Diabetics Group 2)	Normal (Group 1)	df	F	Sig.
AGE	68.53	54.66	55.41	2, 65	11.67	.000
BMI Diabetic	23.01	26.35	26.19	2, 65	2.05	.137
FBS	7.48	9.43	-	1, 46	4.13	.048
SYSTOLIC BP	132.11	129.69	130.20	2, 62	218	.000
DIASTOLIC BP	78.95	83.44	73.36	2, 63	205.98	.000

LCC/DIAM	0.58	0.64	0.70	2, 62	4.23	.019
LCC/IMT	0.08	0.08	0.08	2, 62	0.41	.667
LCC/PSV	52.37	51.73	53.38	2, 62	0.08	.926
LCC/EDV	14.37	14.00	20.54	2, 62	0.77	.467
LCC/RI	0.74	0.74	0.77	2, 62	1.02	.367
LCC/SD	4.06	3.96	2.59	2, 64	106.25	.000
LIC/DIAM	0.66	0.76	0.70	2, 55	126.62	.000
LIC/IMT	0.08	0.08	46.67	2, 53	87.00	.000
LIC/PSV	50.31	48.00	40.01	2, 56	84.80	.000
LIC/EDV	14.56	15.29	15.80	2, 55	21.53	.000
LIC/RI	0.71	0.67	5.04	2, 55	49.90	.000
LIC/SD	4.15	3.50	2.53	2, 56	33.62	.000
RCC/DIAM	0.62	0.65	12.86	2, 60	79.20	.000
RCC/IMT	0.11	0.08	2.43	2, 60	9.48	.000
RCC/PSV	55.21	57.83	4.68	2, 60	102.96	.000
RCC/EDV	16.66	17.94	0.79	2, 58	24.8	.000
RCC/RI	2.29	0.72	0.70	2, 56	4.43	.016
RCC/PI	1.23	1.24	45.95	2, 57	380.44	.000
RCC/SD	3.47	3.72	10.89	2, 57	24.15	.000
RIC/DIAM	0.66	0.66	0.77	2, 54	1.95	.152
RIC/IMT	0.09	0.08	5.69	2, 51	76.99	.000
RIC/PSV	48.94	49.82	46.40	1, 40	0.03	.870
RIC/EDV	15.94	13.26	13.36	1, 40	3.91	.055
RIC/RI	0.70	0.73	0.72	1, 40	1.17	.287
RIC/PI	1.18	1.32	1.34	1, 40	2.35	.133
RIC/SD	3.63	4.23	3.47	1, 40	1.26	.269

AGE (age in years), BMI (Body Mass Index in kg/m²), and FBS (Fasting Blood Sugar in mmol/L). Blood pressure measurements are represented as SBP (Systolic Blood Pressure in mmHg) and DBP (Diastolic Blood Pressure in mmHg). Carotid artery parameters are categorized into the left and right common carotid (LCC and RCC) and the left and right internal carotid (LIC and RIC). These include DIAM (Diameter in cm), IMT (Intima-Media Thickness in cm), PSV (Peak Systolic Velocity in cm/s), EDV (End-Diastolic Velocity in cm/s), RI (Resistivity Index), PI (Pulsatility Index), and SD (Systolic to Diastolic Ratio).

Table 4: Plaques Distribution across Vessels

Abnormality	Frequency	Percentage (%)
Normal	25	48.1
Left Bulbar Plaque	3	4.3
Left Main Carotid Plaque	9	13.0
Right Bulbar Plaque	9	13.0
Right CC Plaque	3	4.3
Right LT Sided Plaque	3	4.3
Total	52	100

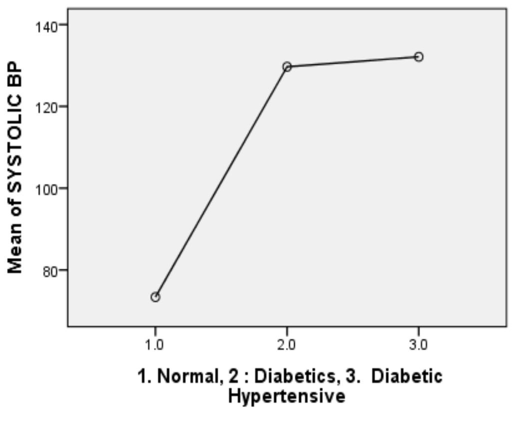


Figure 1Plot between Systolic Blood Pressure across groups

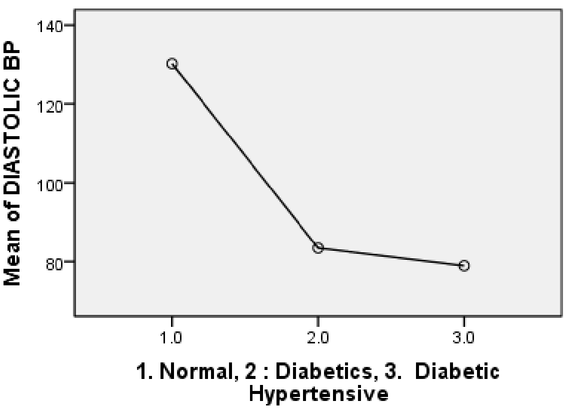
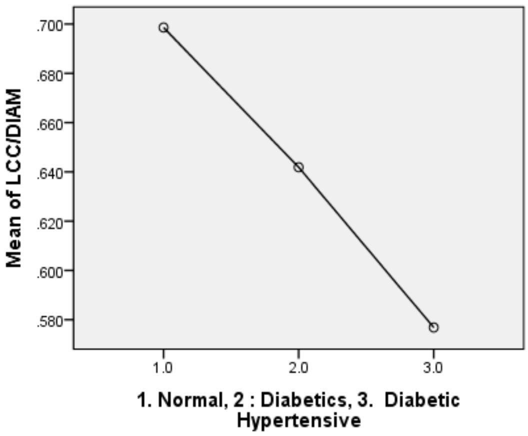


Figure 2: Plot between Diastolic Blood Pressure across groups



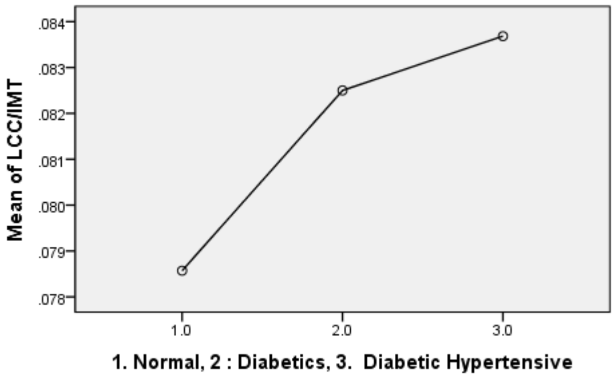


Figure 3: Plot between LCC/ Diam across groups

Figure 4: Plot between LCC/CIMT a cross groups

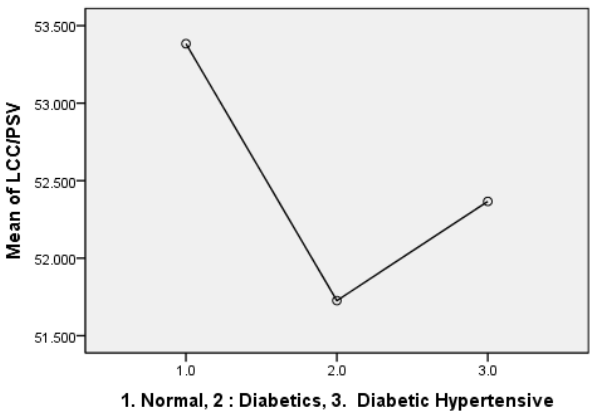


Figure 5: Plot between LCC/ EDV across groups

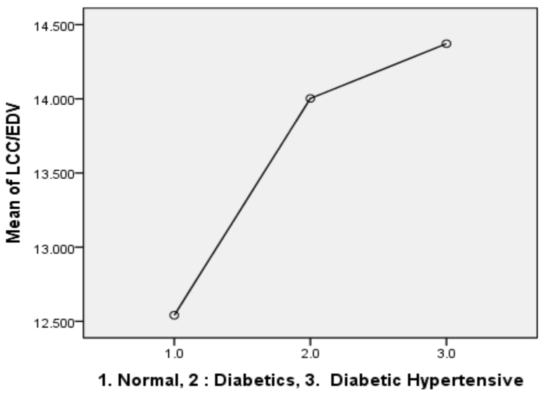


Figure 6: Plot between LCC/EDV across groups

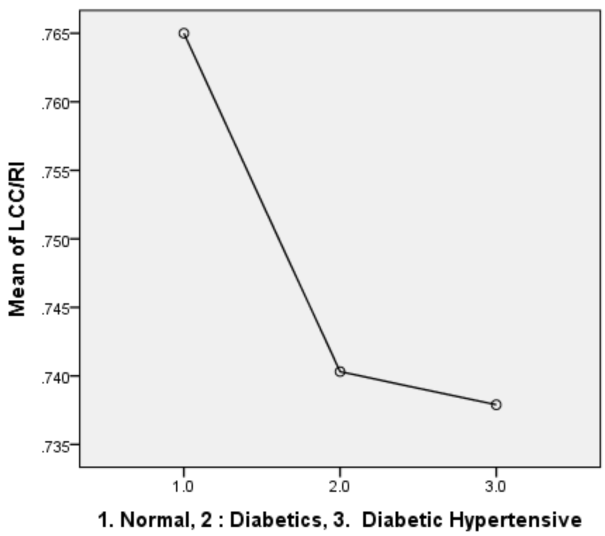


Figure 7: Plot between LCC/ RI across groups

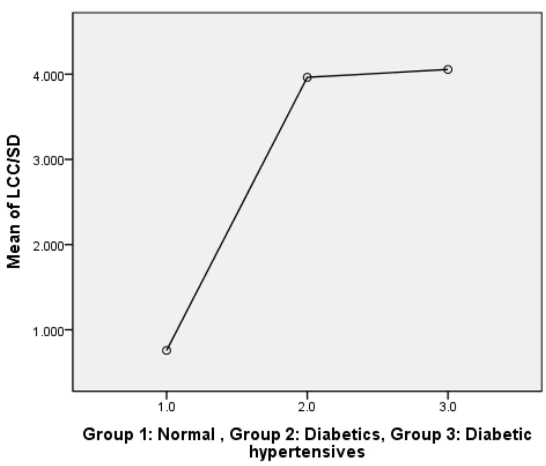


Figure 8: Plot between LCC/SD across groups

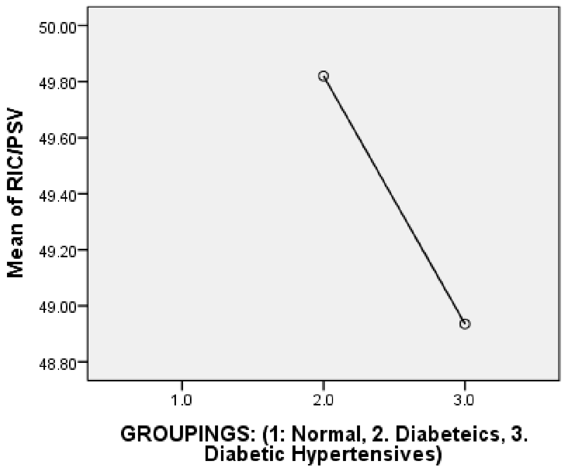


Figure 9: Plot between RIC/ PSV across groups

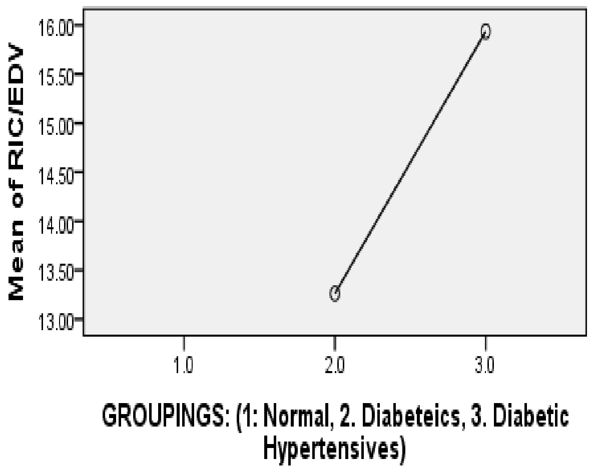


Figure 10: Plot between RIC/EDV across groups

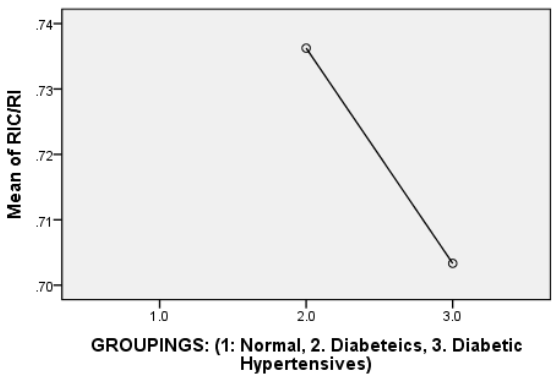


Figure 11: Plot between RIC/ RI across groups

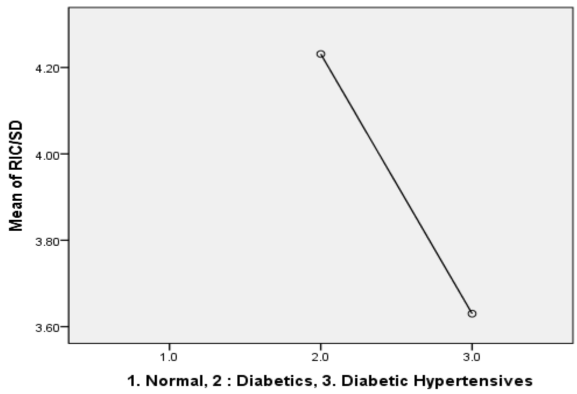


Figure 12: Plot between RIC/SD across groups

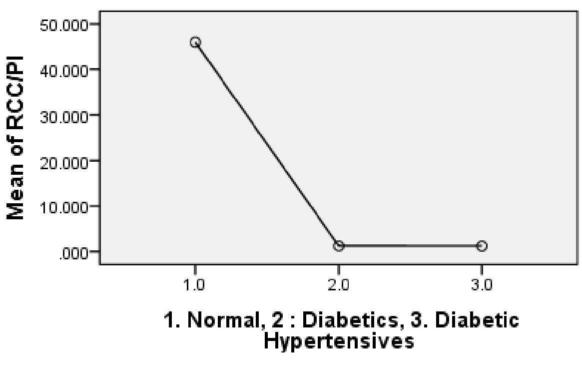


Figure 13: Plot between RCC/ PI across groups

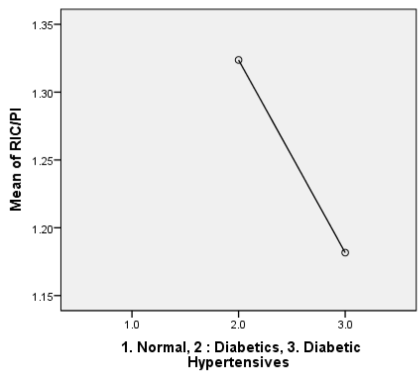


Figure 14: Plot between RIC/PI across groups

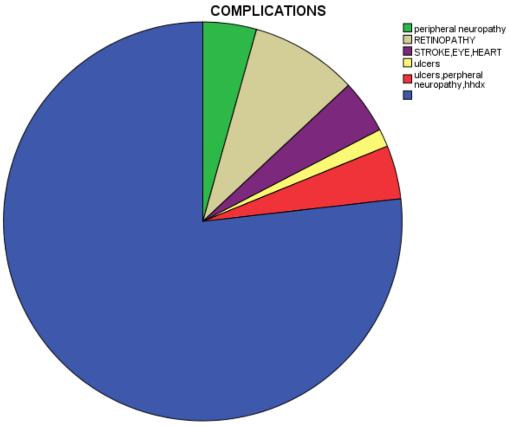


Figure 15: Pie Chart of Complications in Diabetics

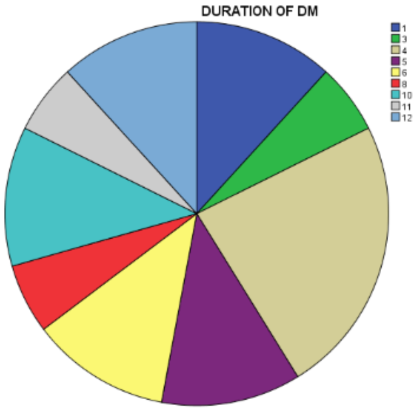


Figure 16: Pie Chart of Duration of Diabetes.

IV. Discussion

This study examined the demographic characteristics, clinical parameters, and carotid artery findings of 52 diabetic participants and compared with data for normal carotid parameters.The results provide valuable insights into the vascular health of individuals with diabetes, with a specific focus on factors such as gender distribution, duration of diabetes, the prevalence of hypertension, complications, and occupational demographics.

The predominance of female participants (63.5%) is consistent with findings from studies such as Gregg et al., which identified a higher prevalence of diabetes among women in certain age groups, especially middle-aged populations in specific regions .[21] This pattern may be linked to gender-specific risk factors, including hormonal fluctuations, metabolic differences, or differences in healthcare-seeking behavior. Notably, the analysis showed that age was significantly higher among the diabetic hypertensive group, with a mean age of 68.53 years, compared to 54.66 and 55.41 years in other groups. Additionally, 36.5% of participants had both diabetes and hypertension (DM/HTN), illustrating the frequent coexistence of these conditions. Hypertension is a well-known comorbidity in diabetics and significantly exacerbates cardiovascular risks, as supported by studies like those conducted by Hypertension Canada ,[22] which demonstrated a strong correlation between DM/HTN and complications such as nephropathy and stroke.

The observed coexistence of hypertension and diabetes suggests a late presentation of hypertension in individuals with diabetes, often attributed to factors such as sedentary lifestyles, excessive calorie intake, obesity, inflammation, and oxidative stress .[23] These elements contribute to the complex pathophysiology of hypertension in diabetes, involving insulin resistance, autonomic dysfunction, vascular endothelial dysfunction, and activation of the renin-angiotensin-aldosterone system. Such factors exacerbate cardiovascular and cerebrovascular risks, as highlighted in studies by the American Diabetes Association (ADA), which reported that two-thirds of diabetics either have hypertension or are on antihypertensive medications.[23]

Effective management of diabetes and hypertension requires a comprehensive strategy that includes blood pressure optimization (targeting <130/80 mm Hg), glycemic regulation, and lipid control (22). Lifestyle changes, such as regular exercise, weight management, and dietary modifications, are central to this approach. Pharmacological interventions include angiotensin-converting enzyme inhibitors (ACE inhibitors) and angiotensin receptor blockers (ARBs), known for their renal and cardiovascular protective effects.[24] The advent of newer antidiabetic agents, such as SGLT2 inhibitors and GLP-1 receptor agonists, has offered additional benefits in reducing blood pressure and managing cardiovascular risks.[25]

In terms of body mass index (BMI), no statistically significant differences were observed among the groups ($p = .137$). Nevertheless, BMI remains an important factor in diabetes management due to its association with metabolic differences in Type 1 and Type 2 diabetes (T2D). T2D accounted for 80.7% of study participants, consistent with global statistics that indicate T2D represents 90–95% of diabetes cases.[23] This prevalence reflects the link between T2D and metabolic disturbances, such as insulin resistance and obesity, which are often exacerbated by poor dietary habits and inactivity. In contrast, only 17.3% of participants had Type 1 diabetes, a condition characterized by autoimmune-mediated insulin deficiency and generally not associated with obesity.[23] The study observed a BMI range from 14 to 35, highlighting variability in body mass. While obesity is a prominent factor in T2D, some patients may experience rapid weight loss due to insufficient insulin, leading the body to metabolize fat and muscle for energy.[24] Additionally, medications such as SGLT2 inhibitors and GLP-1 receptor agonists have been associated with weight reduction, further influencing BMI outcomes.[26,27]

The study also analyzed complications associated with diabetes, providing insights into the interplay between glycemic control, diabetes duration, and complication prevalence. While 69.2% of participants reported no complications, retinopathy (11.5%) emerged as the most common complication, in alignment with the

Wisconsin Epidemiologic Study of Diabetic Retinopathy, which identified it as an early microvascular complication of diabetes.[25] Peripheral neuropathy (5.8%) and stroke-related complications (5.8%) underscore the systemic impact of prolonged hyperglycemia.

The duration of diabetes varied widely in this cohort, with a most frequent duration of 4 years (23.1%). Longer diabetes durations, such as 10 and 12 years (11.5%), were also represented. The chronic nature of diabetes progression is evident, as noted in the UK Prospective Diabetes Study (UKPDS), which demonstrated a significant association between longer disease duration and microvascular complications like retinopathy.[24] Blood glucose levels in this study ranged from 4.3 to 18 mmol/L, with a mean of 8.7 mmol/L. The significant difference between diabetes and diabetic hypertensive groups suggests that comorbid hypertension exacerbates complications, as poor glycemic control over time contributes to vascular damage and a higher risk of retinopathy, neuropathy, and nephropathy.

Additional factors influencing complication development include insidious renal pathology, which can impair insulin excretion and result in hyperinsulinemia .[28] Lifestyle factors, including alcohol consumption, smoking, and obesity, further exacerbate the risk of complications by contributing to metabolic and vascular dysfunction .[29] Collectively, these findings highlight the need for individualized, comprehensive management strategies to improve long-term health outcomes in diabetic populations.

Comparative studies, including the UKPDS, have shown that intensive glycemic control reduces the risk of microvascular complications[24,30] by 25% and improves overall outcomes. Effective management strategies should therefore focus on maintaining optimal blood sugar levels, controlling blood pressure, and addressing modifiable risk factors. This multifaceted approach is essential for reducing the burden of complications and improving the quality of life for individuals with diabetes.

Patterns of Blood Flow Across the Carotid Vessels: The Left Common Carotid (LCC) measures show significant variation for "LCC/DIAM" (p = .019), while other parameters such as "LCC/IMT Diabetic," "LCC/PSV Diabetic," "LCC/EDV Diabetic," and "LCC/RI Diabetic" do not demonstrate significant differences. The analysis of the Left Common Carotid (LCC) measures reveals intriguing trends, particularly regarding the diameter (LCC/DIAM) and intima-media thickness (cIMT). although not statistically significant, provide valuable insights. The graphs indicate a reduction in LCC/Diam from the normal group to the diabetic hypertensive group. Conversely, the LCC/cIMT demonstrates an increasing trend as it progresses from the normal group to the diabetic hypertensive group.

This observed pattern of increased cIMT in the diabetic hypertensive group points to the interplay of diabetes and hypertension in vascular remodeling. Thickening of the intima-media layer is often a marker of early atherosclerosis, reflecting chronic endothelial dysfunction and increased arterial stiffness.[31] These changes may result from prolonged hyperglycemia, systemic inflammation, and oxidative stress associated with diabetes and its complications.

On the other hand, the decrease in LCC/Diam in the hypertensive diabetic group might suggest adaptive or compensatory vascular responses influenced by hemodynamic alterations. These findings highlight the importance of closely monitoring LCC measures to detect subclinical atherosclerosis and manage cardiovascular risks effectively in patients with diabetes and hypertension.

In contrast, all measures assessed for the Left Internal Carotid (LIC), including "LIC/DIAM Diabetic," "LIC/IMT Diabetic," "LIC/PSV Diabetic," "LIC/RI Diabetic," "LIC/PI Diabetic," and "LIC/SD Diabetic," exhibit significant differences (p = .000). This reflects substantial variability in LIC parameters across groups, indicating altered hemodynamics potentially driven by diabetes and hypertension.

The Right Common Carotid (RCC) measures also show significant differences across all assessed parameters, suggesting widespread hemodynamic changes. However, the Right Internal Carotid (RIC) measures present a more mixed picture. While "RIC/IMT Diabetic" (p = .000) demonstrates strong significance, other parameters like "RIC/DIAM Diabetic" (p = .152) and "RIC/PSV Diabetic" (p = .870) do not exhibit notable differences. This suggests localized differences in vascular resistance and blood flow dynamics within the RIC.

Overall Trends in PSV, EDV, and RI: Across the groups, a reduction in peak systolic velocity (PSV) was noted, with the highest PSV observed in the normal group. Meanwhile, end-diastolic velocity (EDV) increased progressively across the groups, leading to a widening systolic/diastolic (S/D) ratio. This widening of pulse pressure aligns with the observed blood pressure patterns and signals significant vascular changes, particularly in the diabetic hypertensive group.[13]

The resistivity index (RI) also showed a progressive decrease from normal to diabetic hypertensive groups, indicating vasodilation and a relative increase in diastolic flow. This hemodynamic state may occur due to loss of autoregulation or compensatory mechanisms in response to hypoxia or decreased perfusion. A low RI is a warning sign, indicating increased vulnerability of the brain to injury. The resistivity index (RI) and pulsatility index (PI), key measures of hemodynamic status, are critical in assessing the risk of brain complications such as stroke. A low RI, as seen in this analysis, suggests compromised vascular resistance, which may result from autonomic dysregulation or maladaptive responses to prolonged hyperglycemia and hypertension. These findings are consistent with broader evidence linking low RI to impaired cerebral autoregulation and increased risk of ischemic injury.[31-34]

In terms of clinical implications, carotid Doppler studies have shown that elevated PI correlates with poor stroke outcomes and prolonged hospital stays. For patients with unfavorable outcomes, an increase in PI over time indicates a failure of autoregulation, exacerbating the risk of brain injury. Conversely, reductions in RI and PI, as observed in patients with favorable outcomes, suggest improvements in hemodynamic stability and autoregulatory function.[34]

Clinical Utility and Recommendations: Carotid Doppler serves as a simple yet effective bedside tool to assess cranial vasculature and predict outcomes in patients with acute stroke or at risk for cerebrovascular complications. Monitoring changes in RI and PI over time can help clinicians stratify risk and tailor interventions aimed at restoring vascular stability. These measures may also provide early indicators of autonomic deregulation, necessitating proactive management strategies such as optimizing glycemic and blood pressure control to protect against further complications.

Hypoechoic plaques are characterized by their low echogenicity on ultrasonography, indicating a lipid-rich necrotic core and a thin fibrous cap. These features make them more prone to rupture compared to hyperechoic plaques, which are more stable due to higher fibrous or calcified content. Studies have shown that hypoechoic plaques are strongly associated with adverse cardiovascular events, including myocardial infarction and stroke. For instance, a study on carotid plaque morphology found that hypoechoic plaques were predictive of ipsilateral stroke in patients with asymptomatic carotid stenosis.

In the index study, the prevalence of carotid plaques, was 51.9% (27 out of 52 participants). This is consistent with findings from other research, such as the Wisconsin Epidemiologic Study of Diabetic Retinopathy,[25] which reported a high prevalence of carotid abnormalities in diabetic populations. Additionally, a study comparing carotid plaques in symptomatic patients with transient ischemic attack (TIA) and stroke found that stroke patients had a higher prevalence of lipid-rich necrotic cores and intraplaque hemorrhage, features commonly associated with hypoechoic plaques.

The clinical characteristics of the index study population, including a median diabetes duration of 12 years and a median HbA1c level of 8.2%, suggest a population at high risk for vascular complications. This aligns with findings from the Chinese Atherosclerosis Risk Evaluation study, which reported that longer diabetes duration and poor glycemic control were significant predictors of carotid plaque burden.

The presence of hypoechoic plaques in the index study underscores the need for aggressive management of cardiovascular risk factors in diabetic patients. This includes optimizing glycemic control, managing dyslipidemia, and addressing hypertension. The use of carotid ultrasonography as a non-invasive tool for plaque characterization can aid in risk stratification and guide therapeutic interventions.

V. Conclusion:

Cardiovascular diseases remain a leading cause of mortality worldwide, with diabetes mellitus (DM) serving as a significant risk factor. Type 2 DM accelerates the atherosclerotic process and leads to endothelial dysfunction through glycoxidative damage, increasing the likelihood of vascular complications. This study evaluates duplex carotid findings in diabetic patients, examining correlations between disease duration and vascular changes while drawing comparisons to hypertensive-diabetic populations, and normal non hypertensive and non diabetic population.

The findings highlight the importance of duplex carotid scans in identifying vascular changes, as demonstrated by significant variations in carotid intima-media thickness (cIMT), peak systolic velocity (PSV), and resistive index (RI) across patient groups. The observed patterns, especially in the diabetic hypertensive group, emphasize the detrimental effects of prolonged hyperglycemia and comorbid hypertension on vascular health. Increased cIMT reflects early atherosclerosis and arterial stiffness, while reductions in PSV and RI point to compromised hemodynamics and altered cerebral blood flow. The presence of hypoechoic plaques, as noted in this study, is particularly concerning due to their association with increased risk of cardiovascular events like ischemic stroke and myocardial infarction. These findings are consistent with existing research, which identifies hypoechoic plaques as markers of vulnerability that demand aggressive intervention. The data support the clinical relevance of carotid ultrasonography as a non-invasive diagnostic tool, enabling early detection and improved risk stratification. This study highlights the significance of vascular assessments in diabetic populations, these measures are essential in mitigating the cardiovascular risks associated with diabetes and improving long-term health outcomes in this high-risk population.

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