CLINICAL STUDY

Evaluation and Prediction of Cardio-Cerebrovascular Disease in End-Stage Renal Disease Patients on Hemodialysis Using Carotid Doppler Scan

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ABSTRACT

Background: The global prevalence of advanced chronic kidney disease (CKD) was more than 10 million, with an associated astronomical increase in morbidity and mortality of about 41.5%. The major reasons for fatality are usually due to carotid vessel diseases leading to stroke and ischemic heart diseases, accounting for a prevalence of about 15.1%. This study aims to evaluate the changes in carotid diameter (CD), carotid intima-media thickness (CIMT), and the presence of plaque using a noninvasive method like Doppler ultrasound in predicting cardiovascular and cerebrovascular disease outcomes to aid early interventions. **Methods:** One hundred and thirty-four patients with end-stage renal disease (ESRD), who were on dialysis for different durations, were consecutively recruited for the research. Details of the lipid profile, blood glucose, smoking, alcohol consumption, body mass index (BMI), and duration on dialysis were documented. A skilled radiologist used Doppler ultrasound to determine the CD, CIMT, and presence of plaque. Data were analyzed using the Statistical Package for the Social Sciences (IBM SPSS), version 23. A p-value of <0.05 was considered statistically significant for all analyses. **Results:** The cumulative prevalence of carotid artery diseases was 44.8%. The prevalence of patients with CD and abnormal CIMT was 41.8% and 6.7%, respectively. There was a positive correlation between CIMT and duration of dialysis ($r = 0.174$, $p = 0.045$), but it was inverse for CD ($r = –0.145$, $p = 0.094$). Alcohol, smoking, and the etiology of CKD have no significant association with carotid vessel disease. **Conclusion:** We conclude that carotid artery disease is highly prevalent among ESRD patients, and it is therefore imperative to identify these risks early and treat them to prevent fatal cerebrovascular and cardiovascular outcomes.

Keywords: Carotid vessel, atherosclerosis, Doppler ultrasound, stroke, carotid plaques

End-stage renal disease (ESRD) is plagued with an increasingly significant risk of cerebrovascular and cardiovascular diseases, with atheromatous carotid diseases initiating a major pathogenesis in the morbidity and mortality of chronic kidney disease (CKD). Globally, the CKD burden is worrisome, with an estimated prevalence of 8%-16% and about 1.2 to 1.3 million people dying from its scourge[1]. The global all-age mortality rate from CKD was documented to be 41.5% in 2017, and it has been increasing exponentially, especially in sub-Saharan Africa[2]. CKD is associated with increased all-cause cardiovascular mortality and brain attack. Among CKD patients, carotid artery disease is particularly prevalent due to chronic inflammation, uremic toxins, and metabolic molecules that promote atherosclerosis. The annual incidence of stroke varies from 8.3% to 15.1% in patients on renal replacement therapy and 9.6% in nondialysis

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CKD patients, with ischemic stroke being commonly reported[3]. The presence of carotid plaques and stenosis in ESRD patients significantly accelerates the risk of ischemic stroke and transient ischemic attack (TIA).

Cardiovascular disease is a fairly common complication that accounts for about 26.9%-39.1% of morbidity and mortality in patients with advanced CKD/ESRD across the regions[3], spanning from Asia, Europe, and America; especially, those patients on conventional hemodialysis[4]. The number of patients receiving hemodialysis globally is more than 2.5 million, and it is projected to double to 5.5 million by 2030, with sub-Saharan Africa accounting for nearly 5% of this population[5,6]. However, despite country-specific efforts to improve dialysis access, statistics indicate that fewer than 5% of patients with CKD in Sub-Saharan Africa receive life-saving dialysis treatment[5,6].

It is documented that increased mortality is 20 to 30 times higher than the normal population, especially in those patients with an advanced stage of CKD. In the CHOICE cohort study, the patients who suffered stroke were 35%, with hypertension accounting for the commonest risk factor[7]. Epidemiological surveillance describes the progression, severity, and risks of our CKD populations. The modifiable risk factors that predispose CKD patients to cardiovascular and cerebrovascular diseases are hypertension, diabetes mellitus, hypercholesterolemia, obesity, alcohol, and smoking. Others are CKD stage <60 mL/min and prolonged dialysis duration with non-modifiable risk factors like age, sex, and race[8]. These epidemiological risk factors, along with an interplay of atheromatous agents, chronic inflammatory mediators (C-reactive protein [CRP], interleukin [IL-6]), oxidative stress, endothelial dysfunction, dyslipidemia, medial calcification, and hemodynamic shear stress on the carotid vessels during recurrent dialysis, trigger an increase in carotid intima-media thickness (CIMT) and plaque formation[9]. In a meta-analysis of 21 studies, an estimated glomerular filtration rate (eGFR) <60 mL/min was associated with a 43% higher risk of incident stroke. Carotid stenosis of more than 50% is associated with a higher incidence of ischemic stroke and cognitive impairment due to chronic cerebral hypoperfusion[10]. Carotid plaque burden correlates with left ventricular failure and coronary heart disease, and sudden death among ESRD patients on dialysis[11]. These risks of CKD should be adequately and actively addressed to meet the United Nations Sustainable Development Goal target to prevent and reduce premature mortality from the scourge of noncommunicable diseases by one-third by 2030[12]. It is therefore necessary to adopt a sensitive, cheap, and noninvasive method like carotid ultrasound (Duplex Imaging) to identify and predict carotid vessel diseases. It is the gold standard in assessing intima-media thickness and plaque morphology. Carotid Doppler scan findings include carotid stenosis, intima-media thickness, and atherosclerotic plaques. Other useful diagnostic radiological approaches to evaluate carotid vessel diseases include computed tomography angiography (CTA) and magnetic resonance angiography (MRA), but these imaging techniques are expensive and invasive[13]. Biomarkers like fetuin A, osteoprotegerin, and high-sensitive CRP may also predict carotid diseases and progression in CKD patients[14].

In this light, ESRD patients with CIMT or plaques, if diagnosed promptly with a carotid Doppler scan, could have carotid endarterectomy, carotid artery stenting, in addition to statins, antiplatelets, phosphate binders, vitamin D, antihypertensives, or antidiabetics, as the case may be.

METHODS

This was a cross-sectional study of 134 patients with ESRD attending the Hemodialysis Unit at Lagos State University Teaching Hospital (LASUTH), Lagos, Nigeria, between September 2024 and May 2025. The Nephrology Unit of the Department of Medicine sees an average of 25 patients with CKD per month needing hemodialysis. The minimum sample size was calculated using Cochran's formula for a cross-sectional study with the average prevalence of ESRD at 9.3%. The study population included all patients with ESRD, aged 18 years and above, who consented to the study. Ethical clearance was obtained from the Health Research Ethics Committee (HREC) of LASUTH.

ESRD was defined as an eGFR of <15 mL/min. A skilled radiologist used a Doppler ultrasound of 7.5 MHz to assess the carotid diameter (CD), CIMT, and presence of plaques. The right common carotid artery was used. The average normal CD ranged from 4.5 to 7.7 mm, while CIMT ranged from 0.4 to 0.8 mm. Values outside these ranges and the presence of plaques were considered abnormal changes in the carotid vessels. Details of associated blood lipid profile and glucose abnormalities, including smoking, alcohol, body mass index (BMI), and duration of patients on dialysis, were documented. The data were analyzed using SPSS 23.0. The categorical variables were presented using frequencies and percentages, while numerical data were presented using mean and standard deviation. Significance was set at a p-value of <0.05.

RESULTS

A total of 134 subjects were recruited in this study. The mean age was 49.5 ± 13.7 years, with a male preponderance of 68.6%. The majority (n = 118; 88.1%) were on dialysis for 1 to 12 weeks, whereas the mean BMI, mean CIMT, and mean CD were 25.5 ± 3.2 kg/m^2, 0.09 ± 0.1 cm, and 0.7 ± 0.1 cm, respectively (Table 1). The commonest etiology was hypertension in 60 patients (44.6%) followed by chronic glomerulonephritis in 34 patients (25.4%) and diabetic nephropathy in 24 patients (17.9%) (Table 2). The prevalence of patients with abnormal CD and abnormal CIMT was 41.8% and 6.7%, respectively (Fig. 1). The overall prevalence of carotid disease was 44.8% (Fig. 2).

Table 1. Demographic Characteristics and Clinical Parameters of the Subjects

Variable	Frequency (n = 134)	Percentage (%)
Age group (years)		
18-40	36	25.9
41-60	61	45.5
>60	37	27.6
Mean ± SD	49.5 ± 13.7	
Sex		
Male	92	68.6
Female	42	31.4
Lipid profile		
Abnormal	34	25.4
Normal	100	74.6
Smoking/Alcohol habit		
Alcohol alone	23	17.2
Smoking alone	9	6.7
Smoking and alcohol	20	14.9
None	82	61.2
Plaque		
Present	25	18.7
Absence	109	81.3
BMI (kg/m^2)		
<18.5	1	0.7
18.5-24.9	51	38.1
25-29.9	70	52.2
≥30	12	9.0
Duration of dialysis (weeks)		
1-12	118	88.1
13-24	11	8.2
25-36	3	2.2
37-48	2	1.5
Mean CIMT	**0.09 ± 0.1**	
Mean CD	**0.7 ± 0.1**	

SD = Standard deviation; BMI = Body mass index; CIMT = Carotid intima-media thickness; CD = Carotid diameter.

Table 2. Commonest Etiology among the Subjects

Variable	Frequency (n = 134)	Percentage (%)
CGN	34	25.4
DM nephropathy	24	17.9
HIVAN	5	3.6
HTN	60	44.6
Obstructive nephropathy	5	3.6
Sickle cell disease	2	1.5
SLE	4	3.0

CGN = Chronic glomerulonephritis; HIVAN = Human immunodeficiency virus-associated nephropathy; HTN = Hypertension; SLE = Systemic lupus erythematosus.

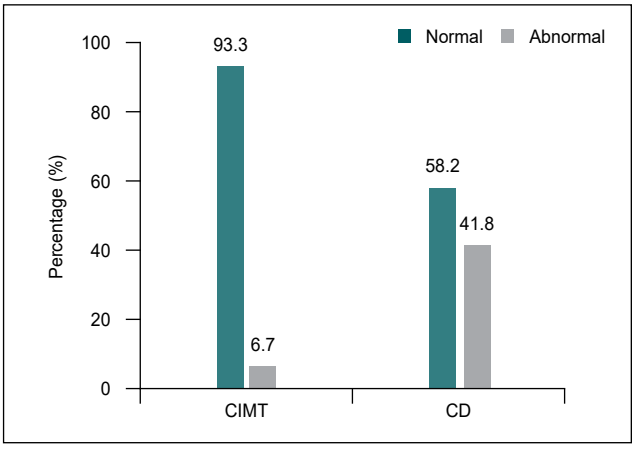


Figure 1. Prevalence of patients with abnormal CD and abnormal CIMT.

CIMT = Carotid intima-media thickness; CD = Carotid diameter.

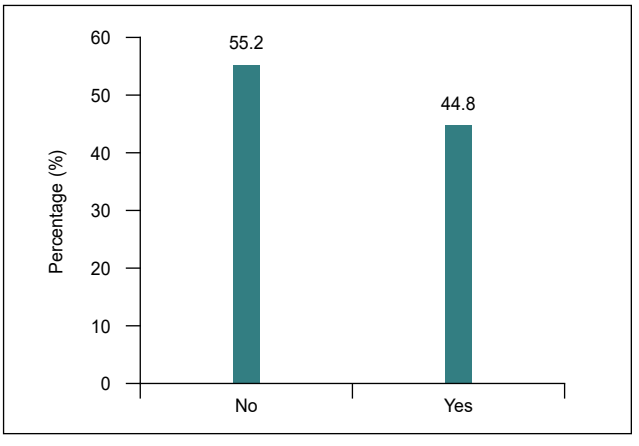


Figure 2. Overall prevalence of carotid disease.

More than half (55.6%) of the smokers presented with abnormal CD. Neither alcohol alone nor smoking affected CIMT, whereas a combination of both alcohol and smoking had a slight effect on the CIMT, albeit this effect was not significant. Those (75%) who presented with systemic lupus erythematosus (SLE) also had abnormal CD. There was no significant association between etiology and CD (Table 3). The odds of having abnormal CIMT were 49.9 times significantly higher among subjects who presented with plaque, while the likelihood of having abnormal CD was 11.8 (3.683-37.395) times significantly higher among subjects who presented with plaque (Table 4). There was a positive correlation between CIMT and duration on dialysis;

Table 3. Association Between Carotid Vascular Diseases and Risk Factors

Variable	CD			CIMT			Plaque		
	Abnormal	Normal	P value	Abnormal	Normal	P value	No	Yes	P value
Gender			0.494			0.164			0.051
Male	39 (42.4)	53 (57.6)		8 (8.7)	84 (91.3)		71 (77.2)	21 (22.8)	
Female	17 (40.5)	25 (59.5)		1 (2.4)	41 (97.6)		38 (90.5)	4 (9.5)	
Alcohol/Smoking			0.103			0.455			0.034*
Alcohol only	5 (21.7)	18 (78.3)		0 (00.0)	23 (100.0)		23 (100.0)	0 (00.0)	
Smokers only	5 (55.6)	4 (44.4)		0 (00.0)	9 (100.0)		7 (77.8)	2 (22.2)	
Both	7 (35.0)	13 (65.0)		2 (10.0)	18 (90.0)		15 (75.0)	5 (25.0)	
None	39 (47.6)	43 (52.4)		7 (8.5)	75 (91.5)		64 (78.0)	18 (22.0)	
Lipid profile			0.300			0.166			0.057
Abnormal	16 (47.1)	18 (52.9)		4 (11.8)	30 (88.2)		24 (70.6)	10 (29.4)	
Normal	40 (40.0)	60 (60.0)		5 (5.0)	95 (95.0)		85 (85.0)	15 (15.0)	
Etiology			0.189			0.651			0.396
CGN	8 (25.5)	26 (76.5)		1 (2.9)	33 (97.1)		31 (91.2)	3 (8.8)	
DM nephropathy	11 (45.8)	13 (54.2)		2 (8.3)	22 (91.7)		20 (83.3)	4 (16.7)	
HIVAN	2 (40.0)	3 (60.0)		1 (20.0)	4 (80.0)		4 (80.0)	1 (20.0)	
Hypertension	29 (48.3)	31 (51.7)		6 (10.0)	54 (90.0)		44 (73.3)	16 (26.7)	
Obstructive nephropathy	2 (40.0)	3 (60.0)		0 (00.0)	5 (100.0)		4 (80.0)	1 (20.0)	
Sickle cell disease	1 (50.0)	1 (50.0)		0 (00.0)	2 (100.0)		2 (100.0)	0 (00.0)	
SLE	3 (75.0)	1 (25.0)		0 (00.0)	4 (100.0)		4 (100.0)	0 (00.0)	

*Statistically significant.

CD = Carotid diameter; CIMT = Carotid intima-media thickness; CGN = Chronic glomerulonephritis; DM = Diabetes mellitus; HIVAN = Human immunodeficiency virus-associated nephropathy; SLE = Systemic lupus erythematosus.

Table 4. Association Between the Presence of Plaque, CD, and CIMT

			CD			
Variable	**Abnormal**	**Normal**	**P value**	**COR (95% CI)**	**P value**	**AOR (95% CI)**
Presence of plaque						
Yes	21 (84.0)	4 (16.0)	0.001*	11.1 (3.542-34.789)	0.001*	11.8 (3.683-37.395)
No	35 (32.1)	74 (67.9)				
			CIMT			
Presence of plaque						
Yes	9 (36.0)	16 (64.0)	0.001*	60.8 (7.207- 512.049)	0.001*	49.9 (5.421-458.552)
No	1 (0.9)	108 (99.1)				

*Statistically significant.

CD = Carotid diameter; CIMT = Carotid intima-media thickness; COR = Crude odds ratio; AOR = Adjusted odds ratio; CI = Confidence interval.

Table 5. Correlation Between Age, Duration on Dialysis, BMI, CD, and CIMT

Variable		Duration on dialysis	BMI	Age	CIMT	CD
CIMT	r	0.174	–0.178	0.073	1	–0.233
	Sig. (2-tailed)	0.045*	0.039*	0.403	—	0.007*
	N	134	134	134	134	134
CD	r	–0.145	–0.008	–0.010	–0.233	1
	Sig. (2-tailed)	0.094	0.928	0.913	0.007*	—
	N	134	134	134	134	134

BMI = Body mass index; CD = Carotid diameter; CIMT = Carotid intima-media thickness.

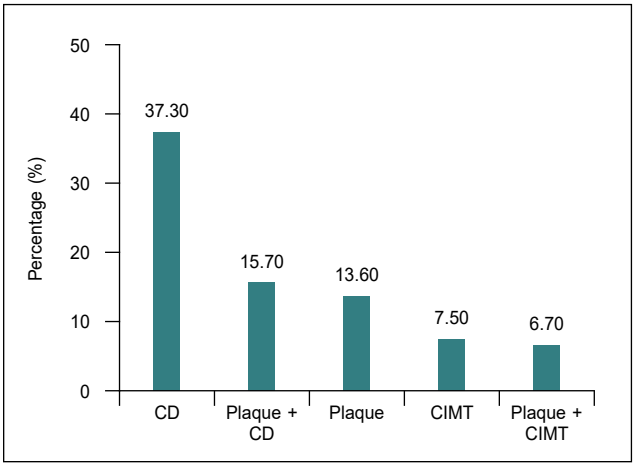


Figure 3. Plaque patterns in different carotid vessel diseases.

as the duration on dialysis increased, the CIMT also increased (r = 0.174, p = 0.045). There was, however, no significant negative correlation between CD and duration on dialysis. As the duration of dialysis increased, the CD decreased. There was, however, a negative correlation between CD and CIMT; as the CIMT increased, the CD decreased (r = −0.233, p = 0.007). There was also a negative correlation between BMI and CIMT; as the CIMT increased, the BMI decreased (r = −0.178, p = 0.039) (Table 5). CD was the commonest carotid vessel disease with plaque (15.7%) (Fig. 3).

DISCUSSION

Patients with ESRD who are dialysis-dependent have an inherently increased risk of cardiovascular morbidity and mortality, with carotid arterial pathology playing a critical role in the development of ischemic heart disease, stroke, and other adverse cardiovascular outcomes[15-17].

Doppler duplex ultrasound of the carotid vessels is a sensitive gold standard in this study. It is favored as a valuable screening tool because it is noninvasive, radiation-free, cost-effective, accessible, and provides real-time assessment of blood flow, making it suitable for follow-up compared to imaging modalities like MRA or coronary arteriography[16,17].

Studies have reported that ESRD patients have a high prevalence of cardiovascular and cerebrovascular events due to artery stenosis and atherosclerosis, which are significant contributors to cardiovascular disease in this population[18,19]. The current study found a mean CIMT of 0.09 ± 0.1 cm, which is lower than the mean value of CIMT. Also, Rebić et al found that dialysis patients with carotid calcification and intima-media-thickness had 0.9 mm higher value when they had inflammatory markers of dyslipidemia. These differences may be due to the variation in the duration of dialysis. Suffice it to state that the duration on dialysis has been implicated as a significant predictor of CIMT in patients with ESRD[20,21]. Furthermore, in our study, almost half of the subjects presented with carotid disease. A similar study in the United States reported that 20% of dialysis patients exhibited carotid stenosis. Another research study from South Africa submitted a 70% prevalence among those on continuous ambulatory peritoneal dialysis[22,23]. The observed high prevalence of carotid diseases in our study, which was comparable to that seen in the United States, may partly be due to the limited availability of health care resources and nephrologists in our region, which affects the management and detection of such conditions.

Hypertension has been established as a known risk factor for carotid disease, especially among patients in ESRD. In our study, the commonest etiology was hypertension, with a prevalence of 44.6%. These findings are consistent with the results obtained in similar studies by Hafeez et al and Mahmood et al, who reported a prevalence of 90.7% and 93.8% among ESRD patients, respectively[24,25]. Less than a quarter

(18.7%) of the subjects in our study presented with plaques. This differs from the prevalence documented in another study by Cho et al, who reported that 71% of ESRD patients had calcified plaques in the carotid and femoral arteries[26]. We also found a significant association between the presence of plaque, CD, and CIMT with the odds of abnormal CIMT being 49.9 times higher among subjects with plaque and CD, 11.8 times higher in subjects with plaque. These observations are in agreement with the findings of Afolabi et al in a study conducted in south-west Nigeria, who noted that coronary plaques in ESRD patients were characterized by increased media thickness and marked calcification[27].

Although specific studies directly linking alcohol consumption to plaque formation in ESRD patients are scarce, yet a previous research reported by Cheungpasitporn et al noted that alcohol consumption influences plaque composition in patients with cardiovascular disease, with moderate consumption associated with more stable plaque phenotypes and reduced cardiovascular events[28]. Our study, however, found an association between lifestyle factors such as smoking and alcohol consumption with the onset of plaques in ESRD.

Prolonged dialysis has been implicated as being associated with increased CIMT, which is a marker of atherosclerosis and cardiovascular risk. The present study found a positive correlation between duration of dialysis and CIMT. This is consistent with the results obtained previously by Muzasti et al in Indonesia, who reported a significant correlation between dialysis duration and CIMT[29]. Conversely, larger carotid artery diameter has been linked to lower survival rates in hemodialysis patients, indicating that changes in CD could have prognostic implications. Our study found a negative correlation between duration of dialysis and CD, suggesting a decrease in CD with prolonged duration on dialysis. This finding is in accordance with the results obtained by Stolić et al in another research from Indonesia, who noted that the duration of dialysis negatively correlates with the carotid artery cross-section, indicating a reduction in CD over time on dialysis[30].

CONCLUSION

Our study reveals a high prevalence of carotid disease in ESRD patients on dialysis, with the incidence of CIMT and plaques correlating positively with prolonged duration of dialysis. In contrast, alcohol, smoking, obesity, and etiologies of CKD had no significant correlation among ESRD patients on dialysis. Through this study, we highlight the prevalence of carotid vessel diseases and the need for early detection of carotid vessel atherosclerosis, stenosis, calcification, and plaques using a sensitive and noninvasive duplex ultrasound to prevent cardiovascular disease or stroke.

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