Original Article

Spectrum of Carotid Arterial Doppler Abnormalities Among Stroke Patients at a Tertiary Care Centre in North West Nigeria

Abstract

Background: Stroke is the second most common cause of death worldwide. It also represents one of the most common causes of disability, affecting both children and adults. The identification of risk factors for stroke is critical in preventing its occurrence. Carotid atherosclerosis is one of the most significant risk factors of stroke, yet it is not routinely evaluated in these patients. **Materials and Methods:** We prospectively recruited 119 patients aged ≥18 years with stroke confirmed by computed tomography scan. The risk factors for stroke in these patients were identified, and carotid artery Doppler was performed to identify those with atherosclerosis. **Results:** Eighty-one (68%) of the 119 subjects showed abnormalities in the carotid arteries in the form of increased IMT or atheromatous plaque. The mean ± SD IMT of the right common carotid artery (CCA) was 1.07 ± 0.25 mm and 1.08 ± 0.26 mm for the left CCA. The IMT mean ± SD of the right and left ICA were 0.99 ± 0.18 mm and 0.99 ± 0.17 mm, respectively. There were 36 patients (30.2%) with atheromatous plaques, of which 57.8% were unstable and liable to rupture. The carotid bulbs were the most common sites for plaques, accounting for 47.2% of cases. No abnormalities in velocimetric indices were recorded. **Conclusion:** Carotid atherosclerosis is common in stroke patients and is a major risk factor. The evaluation of stroke patients for carotid atherosclerosis is rarely done, as most of the subjects examined only had it for the first time in this study after development of stroke.

Keywords: *Carotid abnormalities, doppler, North West Nigeria, stroke, ultrasound*

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Introduction

The carotid arteries arise from two different origins for the right and left, with the right common carotid artery (CCA) arising from the brachiocephalic trunk as one of its terminal branches, while the left CCA arises directly from the aortic arch as its second branch in majority of individuals.[1] The course, calibre, and the three layers of the wall of the carotid arteries are routinely visualised on grey-scale ultrasound scan.[2,3] The carotid arteries are seen on colour Doppler with uniform colour filling, whereas on pulsed Doppler they show biphasic spectral waveforms with turbulence in the carotid bifurcation displayed as a mixture of colour patterns.[4] The normal peak systolic velocity (PSV) of the CCA is 30–40 cm/sec; however, there is usually an increase in PSV of the CCA from the carotid bifurcation towards the aortic arch.[5]

The introduction of carotid duplex ultrasound has made possible the non-invasive evaluation of both morphology and flow characteristics of the carotid arteries and thus revealed the frequency of carotid abnormalities (CA).[6] It was reported that CA were present in more than half of the patients with cardiovascular or cerebral ischaemic symptoms using ultrasound, and these abnormalities were mainly related to ageing and traditional vascular risk factors linked to atherosclerosis.[6]

Abnormal ultrasonographic findings in carotid arteries have been identified as subclinical markers of early coronary atherosclerosis and are associated with modifiable and non-modifiable risks. The occurrence of new carotid artery plaques has been linked to increased subsequent risks of new or recurrent stroke and myocardial infarction in affected individuals.[7] Studies have shown that as many as 30% of all major hemispheric events (stroke, transient ischaemic attack,

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or amaurosis fugax) are thought to originate from disease at the carotid bifurcation.[8] This is mainly caused due to atherosclerosis with intima media thickness (IMT) changes, formation of plaques, and stenosis of the carotid arteries.[9]

The aim of this study was to analyse the spectrum of carotid arterial Doppler abnormalities among stroke patients at a tertiary care centre in North West Nigeria using sonography.

Materials and Methods

This was a descriptive cross-sectional study carried out over a period of one year (January to December, 2017) in the Radiology department of a tertiary care hospital in Kano, Nigeria. The study sequentially enlisted a total of 119 consenting consecutive subjects aged 18 years and above with clinical diagnosis of stroke, confirmed by computed tomography (CT) scan, either referred from remote health facilities or on admission in our hospital. Sample size was determined using Fisher's statistical formula for descriptive studies.[10-12] Patients with head trauma, intracranial space-occupying lesions, and non-consenting individuals were excluded. Institutional Ethics Review Board approval was obtained from the Hospital Research Ethics Committee. Clinical history of risk factors of cerebrovascular disease, such as previous stroke, cigarette smoking, and pre-eclampsia, were obtained. Blood pressure of all the subjects was measured using a standard technique, and hypertension was defined as systolic/diastolic blood pressure >140/90 mm Hg or being on antihypertensive treatment.[13] Body mass index (BMI) was determined using height/weight scale and deduction of BMI using the World health organization formula following standardised techniques.[14]

All subjects underwent carotid triplex ultrasound using a 7.5 MHz-linear transducer of the Mindray SP Digital Ultrasound Imaging System (Model DP-8800Plus; Shenzhen Mindray Biomed Electronics, China).[4] Carotid IMT for CCA and ICA was measured as the distance between the leading edges of the two echogenic layers of the arterial wall, which represent the blood–intima and media–adventitia interfaces [Figure 1].[4] An average of 3 consecutive measurements were recorded as the IMT, and IMT greater than 0.84mm in males and 0.80mm in females were considered abnormal.[3]

Plaque was defined as a focal structure encroaching into the arterial lumen by at least 50% of the surrounding IMT value or with a thickness of >1.2 mm.[15] Plaques were classified into five types according to the modified Gray-Waele's (Geroulakos) classification based on morphology.[16]

Type I plaques was a hypoechoic appearing lesion with thin echogenic fibrous cap; type II plaques was a predominantly hypoechoic lesion but with echogenic areas representing less than 25% of the plaque; type III plaques was a predominantly hyperechoic lesion with hypoechoic areas representing less than 25% of the plaque; type IV plaques was a homogenously hyperechoic plaque; and type V plaques was unclassified plaques containing calcifications casting acoustic shadows.

Type I and II plaques were graded as vulnerable plaques or unstable (fatty plaques with large size of lipid core),[16,17] types III and IV were graded as mixed or stable plaques, while type V plaques were graded as calcified plaque. (Figure 2 below shows types II and III atheromatous plaques).[18]

The degree of diameter stenosis was measured at sites of stenosis on longitudinal sections, with percentage(s) of narrowing calculated by the manufacturer-calibrated ultrasound machine automatically from these measurements [Figure 3].[4] Carotid artery diameter stenosis was graded as normal to mild stenosis (0%–20% diameter reduction); moderate stenosis (20%–60% diameter reduction); severe stenosis (60%–80% diameter reduction); critical stenosis (80%–99% diameter reduction); and occlude (100% diameter reduction).

Spectral waveforms of the vessels were obtained with a sample volume of 2–3 mm, pulse repetition frequency of 6–10 KHz, and a wall filter of 100–150 Hz,[15] and an angle of correction adjusted to 60°. Velocity measurements were taken at the proximal, middle, and distal aspects of each of the CCA and at the visualised segment of the proximal internal carotid artery. At each segment, the velocities were measured as the average of a minimum

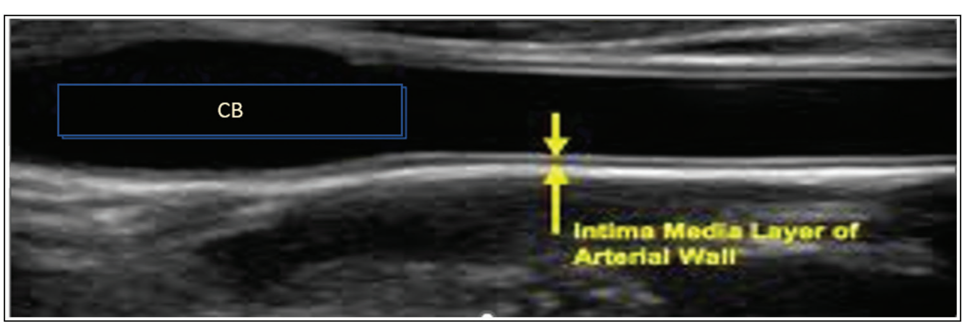

Figure 1: L Measurement of intima media thickness as the distance between the two parallel echogenic lines in the posterior wall of the CCA

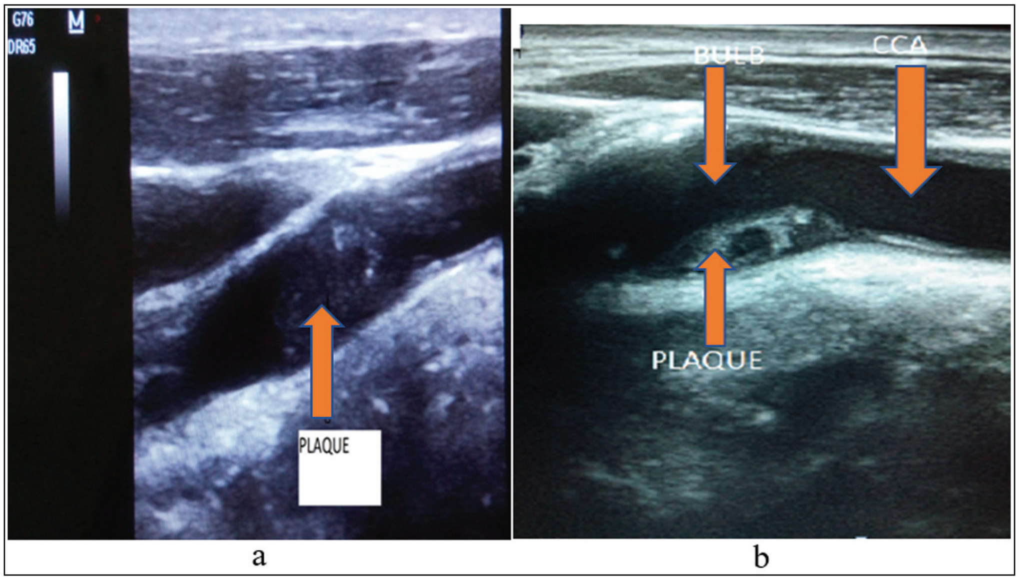

Figure 2: Showing (A) type II and (B) type III atheromatous plaques in the carotid bulb

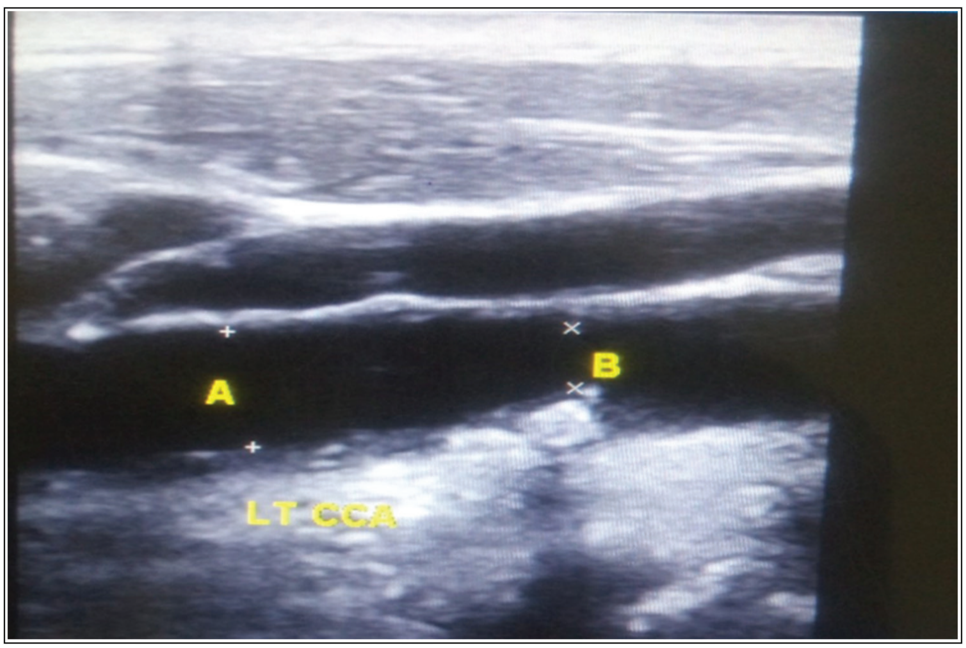

Figure 3: Measurement of percentage of stenosis (A–B/A × 100). (A = diameter across non-stenotic segment; B = diameter across stenotic segment)

of 3–5 spectral waveforms.[18] The highest values of PSV and end diastolic velocity were recorded for each vessel.[18] For patients with atheromatous plaques, measurements were also made at the level of maximum thickness of the plaques.[19]

Data was analysed with Statistical Product and Service Solution (IBM SPSS) version 23.0 software. Descriptive statistics and possible association between the plaque morphology and the severity of the stroke were examined with Chi-square test and Friedman analysis of variance . Differences were considered statistically significant at a P value < 0.05.

Results

Overall, 63/119 (52.9%) of subjects with CT diagnosis of stroke were males, while 56/119 (47.1%) were females, giving a non-statistically significant more male subject (P < 0.05). The mean ± SD age for male and female subjects with CT scan diagnosis of stroke was 59.9 ± 10.8 and 58.60 ± 10.6 years, respectively. Majority of subjects belonged to the 58–67 years age group, and males were older; however, this finding was not statistically significant (P = 0.53). The mean BMI of all subjects was 23.0 kg/m^2. However, only the BMI of 106 (89%) of 119 subjects was recorded, and 29/106 (28%) were obese, while 7/106 were overweight, with a total of 36 (33.9%) having an abnormal BMI. Obesity was found to be significantly more among females than male patients ($P < 0.05$). The BMI of 13 subjects was not measured due to their inability to stand erect and comply with instructions required for anthropometric measurements.

Majority of subjects with CA had a clinical history of hypertension (69/119, 57.9%), history of previous stroke (25%), cigarette smoking (7.6%), pre-eclampsia (2.5%), sickle cell disease (2.5%), and were obese (24.4%) as shown in Figure 4.

Seventy-nine patients (79/119, 66.4%) had ischaemic stroke (IS), while 40 patients(40/119, 33.6%) had haemorrhagic stroke (HS) [Figure 5]. IS was significantly more common than HS ($P < 0.001$).

Multi-focal infarcts were found in 10/79 patients (12.7%) and among subjects with HS, 34 patients (4/40, 85%) had intracerebral haemorrhage, while 6 patients (6/40, 15%) had subarachnoid haemorrhage [Figure 5].

A total of 81 patients (68%) showed carotid artery abnormalities in the form of increased IMT or atheromatous plaque. The IMT mean ± SD of the right CCA was 1.07 ± 0.25 mm, while it was 1.08 ± 0.26 mm for the left CCA. The IMT mean ± SD of the right and left ICA were 0.99 ± 0.18 mm and 0.99 ± 0.17 mm, respectively [Table 1]. The mean IMT of male subjects was significantly higher than female subjects for both CCA and ICA, with males having significant abnormal IMT values in all carotid arterial segments ($P = 0.01$).

The mean ± SD right and left CCA IMT of the subjects with IS were 1.14 ± 0.24 mm and 1.14 ± 0.26 mm, while

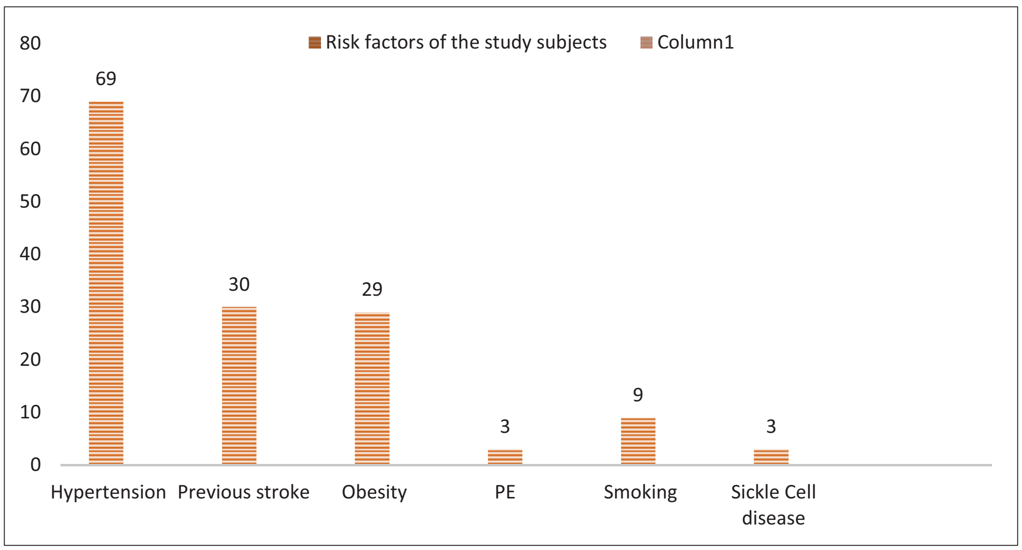

Figure 4: Bar chart showing common risk factors among study subjects

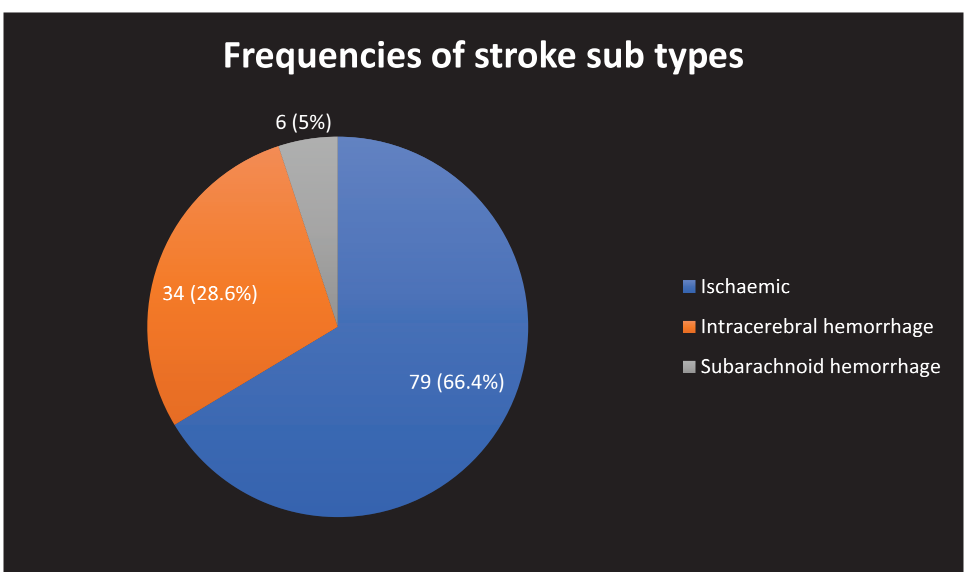

Figure 5: Proportion of stroke subtypes

Table 1: Showing mean and standard deviation of the intima media thickness values of carotid arteries

Artery	Mean ± SD (male)	Mean ± SD (female)	Mean ± SD (overall)	Maximum	Minimum	*P* value
CCA						
Right	1.14±0.27	0.99±0.20	1.07±0.25	1.6	0.45	0.02*
Left	1.15±0.29	1.01±0.22	1.09±0.27	1.7	0.4	0.01*
ICA						
Right	1.03±0.20	0.94±0.15	0.99±0.18	1.4	0.4	0.01*
Left	1.02±0.19	0.95±0.16	0.99±0.17	1.3	0.4	0.03*

*P values which are significant

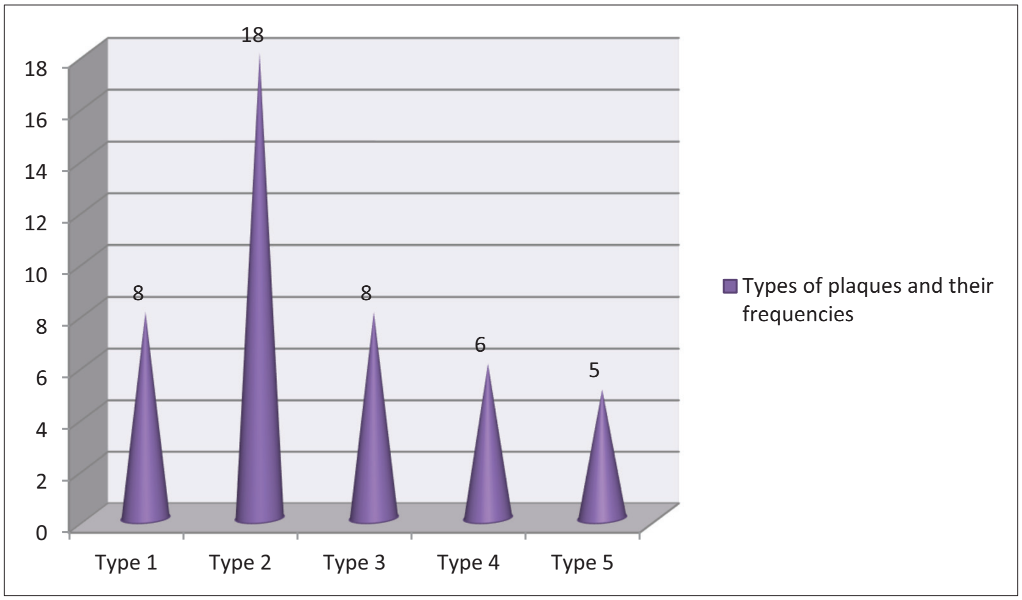

Figure 6: Chart showing types of the plaques and frequencies

the mean ± SD IMT values for the right and left CCA for subjects with HS were 0.93 ± 0.20 mm and 0.95 ± 0.23 mm, respectively. Subjects with IS had significantly higher and abnormal IMT values than those with HS in both CCA and ICA segments ($P < 0.05$). IMT values for both CCA and ICA among study subjects showed significant positive linear correlation with age on both right and left sides ($P < 0.001$).

There were 36/119 subjects with carotid plaques overall (30.3%), with male subjects having a higher plaque burden (20/36, 55.6%) than females (16/36, 44.4%). Twenty-seven (27/79, 34.2%) subjects with IS and 9/40 (22.5%) of subjects with HS had carotid arterial plaques, with subjects with IS having more carotid artery abnormalities.

The commonest plaque locations were the carotid bulbs (17/36, 47.2%), while the least affected segment was the ICA, which recorded an isolated plaque on the right. Also, the right carotid bulb segment (9/17, 25.0%) had fewer plaques than left (12/36, 33.3%). The commonest type of plaque morphology was type II, seen in 18/36 (40.0%), while the least was type V plaque seen in 4/36 (8.9%) subjects. Twenty-six of the plaques (26/36, 57.8%) were grade I (unstable), fourteen (14/36, 31.1%) were grade II (stable), while 5/36 (11.1%) were found to be calcified plaques [Figure 6]. Diameter stenosis of carotid arteries due to atheromatous plaque ranged from 18% to 88.8%, with majority of the plaques (82.2%) associated with about 20%–60% stenosis. The maximum stenosis was found at the right carotid bulb, having 88.8% luminal narrowing, with all plaques in the CCAs associated with <50% stenosis.

The mean ± SD PSV of the CCA and ICA were 49.7 cm/sec ± 16.13 (Right), 55.98 ± 21.7 cm/sec (Left), and 45.5 ± 22.5 cm/sec (right), 53.5 ± 29.2 cm/sec (left), respectively. There was no significant difference between the mean PSV of CCA and ICA of subjects on either side ($P > 0.005$). The mean ± SD EDV of the CCA and ICA measured 13.1 ± 4.2cm/sec(right), 15.1 ± 6.7 cm/sec (left), and 14.5±6.8cm/sec(right), 17.7±12.6cm/sec(left), respectively. The difference between the mean EDV of the right and left ICA did not achieve statistical significance ($P > 0.005$). However, comparison of mean velocimetric indices of subjects with plaques against those without plaque lesions revealed significantly higher values of PSV and EDV among plaque-burdened subjects [Table 2].

Discussion

This study has shown that carotid artery abnormalities are common in patients with stroke, and therefore, the evaluation of stroke patients should routinely include

Table 2: Comparison of PSV and EDV of the subjects with and without carotid artery plaque(s)

Vessel	Mean PSV (cm/sec)		*P* value	Mean EDV (cm/sec)		*P* value
	Plaque	No plaque		Plaque	No plaque	
Rt CCA	58.65	43.8	0.09	13.9	13.10	0.07*
Lt CCA	67.89	48.0	0.07	18.2	12.96	0.06*
Rt ICA	55.90	38.6	0.02	17.1	12.0	0.01*
Lt ICA	62.86	41.9	0.03	21.3	14.3	0.01*

PSV = peak systolic velocity, EDV = end diastolic velocity, CCA = common carotid artery, ICA = internal carotid artery

carotid artery Doppler ultrasound. Unfortunately, despite the affordability and availability of Doppler ultrasound, it is rarely done in resource-limited settings due to insufficient expertise and advanced equipment for carotid Doppler ultrasound scans.[20] Carotid atherosclerosis is considered a surrogate marker of systemic atherosclerosis and correlates significantly with cardiovascular risk factors.[21]

The mean IMT of the CCAs of the subjects measured 1.07 ± 0.25 mm and 1.09 ± 0.27 mm on the right and left sides, respectively. These values are higher than the mean values obtained by Dambatta *et al*.[22] on normal healthy individuals in Kano, implying that increased IMT occurs in patients with cardiovascular risk factors. It was also observed that lower IMT measurements were obtained by Lawal *et al*.[23] in Kano, who studied carotid IMT in diabetic and hypertensive patients. The mean IMT of the right and left CCA arteries in their study were 1.07 ± 0.25 mm and 1.04 ± 0.38 mm for the diabetic subjects and 0.83 ± 0.26 mm and 0.84 ± 0.24 mm for the hypertensive patients, respectively. Similarly, lower values were obtained by Umeh *et al*.[24] in Ibadan, who studied carotid IMT among adults with primary hypertension, and Ahmadu *et al*.[25] in Maiduguri, who studied IMT among adults with diabetes. Higher IMT obtained in this study is probably due to an increase in the burden of cardiovascular risk factors in patients with stroke than among patients with uncomplicated diabetes and hypertension studied by the abovementioned authors. This is supported by the work of Polak *et al*.[26] in Washington, who reported that up to 29% of variability in the mean IMT could be explained by changes in cardiovascular risk factors, such as hypertension, dyslipidaemia, and male gender, with a very strong association between CCA IMT and age. In our study, IMT increase had a positive linear relationship with increasing age too.

Harris *et al*.[27] in Indonesia found significantly higher IMT values in stroke compared with non-stroke patients. Out of 259 subjects, abnormal IMT was found in 130 stroke patients as against 46 in non-stroke patients with a *P* value of <0.001 for the 2 groups compared. This index study observed that the mean IMT of subjects with IS was significantly higher than that of subjects with HS. This finding may be supported by the fact that the subjects with HS were significantly younger.

In this study, there were 36 patients with atheromatous plaques (30.3%) at different locations in the CCAs and ICAs on both sides. Comparison of the prevalence of plaques between subjects with IS and their counterparts with HS also showed that 34.2% of the subjects with IS had plaques compared to 22.5% of subjects with HS. The higher prevalence of carotid plaques in IS patients in this study is in agreement with the finding of Zhang *et al* [28] who found atheromatous plaques in both ICA and CCA to be associated with IS rather than HS. However, this prevalence is slightly lower than that reported by Alkali *et al*.[11] in Abuja, who found atheromatous plaques in 17 out of 47 patients (36.2%) with stroke. The lower prevalence of plaques in this study may be due to difference in lifestyle between Abuja, which is more urbanised with more people living sedentary lifestyle, smoking, and drinking alcohol compared to traditional Kano population. It would appear that the prevalence of carotid plaques in this environment is far less than what is obtained elsewhere in the developed world and among Caucasians. Casadei *et al*.[29] in Italy examined 747 stroke patients and found that 69.4% of subjects had atheromatous plaques in the ICA with varying degrees of stenosis.

The present study found a total of 45 plaques, of which 26 (57.8%) were grade I (unstable or vulnerable), 14 (31.1%) were grade II (stable), and 5 (11.1%) were calcified. Among the vulnerable plaques, type II plaques were the most common types (18 out of 26). This heterogeneous nature of plaques in patients with hemispheric symptoms was also found by Adetiloye *et al.*,[30] who found predominantly hypoechoic plaques among symptomatic patients with carotid arterial stenotic diseases, accounting for 64.3% and in 76.9% of non-haemodynamic cases of symptomatic carotid arterial disease presenting with transient ischemic attack. However, the predominant morphological type of plaque obtained by Casadei *et al.*[29] in Italy were type III plaques, the increased echolucency of plaques in the subjects in their study is probably due to clustering of risk factors such as age, male gender, race hypertension, and diabetes among these subjects. Yamashiro *et al*.[31] also observed a significantly higher prevalence of echolucent carotid plaque in patients with clustered risk factors. They found up to 50% of echolucent carotid plaques in patients with 3 or more risk factors of carotid plaques, although the present study slightly differed because all risk factors were studied independently without analysing the effect of clustering of multiple risk factors among some patients. In further support of the relationship between plaque vulnerability and risk of stroke is the work of Mathiesen *et al*.,[32] where they found that in patients with vulnerable plaques without significant carotid stenosis, the relative risk of cerebrovascular events was 13 versus only 3.7 in those with stable ones.

The mean PSV and EDV of the right and left CCA were found to be normal for both groups with and without atheromatous plaque. This was likely from the fact that most of the plaques caused only 20%–60% diameter reduction. The mean PSV and EDV of the right and left ICA were also observed to be normal. However, there was a significant increase in PSV in the group with plaque in comparison to the group without atheromatous plaque. The maximum PSV values were also recorded in the groups with 50% stenosis and above. This is consistent with previous literature on the increase in PSV of the ICA with stenosis. The EDV was also found to vary significantly between the groups with and without plaques. However, the increase in the EDV was not found to reach values compatible with the degree of stenosis. This may not be unexpected, as EDV changes are found to be reliable only in severe forms of stenosis in the range of 80% luminal narrowing, which was just found in only one patient in our present study.

Conclusion

The present study has revealed that carotid artery atherosclerosis, in the form of increased IMT and atheromatous plaques, is common among patients with stroke. It was also observed that a large proportion of patients with atheromatous plaques in their carotid arteries had unstable plaques, which are liable to rupture and greatly increase risks for embolism.

Although measurement of ICA IMT posed some challenges in this study due to its high position among some patients with short necks and the presence of the mandible, especially in patients with high vessel bifurcation; however, these challenges were minimised by lateral and posterior insonation approaches of the vessels. Also, patients' risk factors for stroke were independently assessed without the need to cluster the risk factors for those with multiple risks.

Recommendation:

Carotid Doppler ultrasound should be routinely employed in all patients with major cardiovascular and stroke risk factors to identify and stratify those patients who may require urgent interventions to tamponade further complications following a stroke.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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