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Sonographic assessment of the common carotid artery luminal diameter in adults with co-existing diabetes mellitus and hypertension

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Abstract

Background: Diabetes mellitus (DM) and hypertension (HTN) are known to cause major in changes in arterial morphology and function, (remodelling) including alterations in carotid intima media thickness (CIMT), carotid artery luminal diameter (CALD), and arterial compliance and blood flow velocity. However, there is a paucity of data evaluating common carotid luminal diameter (CCALD) in an adult with both DM and HTN (DM+HTN) in the study locality.

Objective: This study is therefore aimed at evaluating the CCALD in adults with DM+HTN.

Methodology: One hundred and fifteen (115) adult subjects with co-existing DM+HTN and one hundred and fourty four (144) healthy controls participated in the study. Their ages ranged from 18 to 80 years. The common carotid artery luminal diameter (CCALD) at the diastolic phase of the cardiac cycles was scanned and measured using a venue 50 ultrasound scanners with electronic calipers and high frequency linear array transducer.

Result: The overall mean CCALD was 6.43±0.87 mm and 5.88±0.77 mm for subjects with DM+HTN and healthy controls, respectively. The mean CCALD value was significantly higher in subjects DM+HTN compared to the healthy controls (0.000). The mean CCALD correlated positively with age in males with DM+HTN hypertensive females, while no significant correlations were observed among healthy controls. Males had significantly higher mean CCALD value when compared to their female counterparts in both subjects with DM+HTN and healthy controls.

Conclusion: In this study, the mean CCALD value in subjects with DM+HTN is significantly higher compared to those of healthy controls.

Keywords: Diabetes mellitus; Hypertension; Carotid artery; Ultrasound

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1. Introduction

Diabetes mellitus (DM) and hypertension (HTN) are among the leading non-communicable diseases and cardiovascular risk factors, respectively, globally, and their prevalence increases with age[1]. High blood pressure (BP) levels are a common finding in patients with DM and are thought to reflect, the impact of the underlying insulin resistance on the vasculature and kidney. [1] On the contrary, strong evidence suggests that disturbances in carbohydrate metabolism are more common in hypertensive individuals[2,3] thereby indicating that the pathogenic between DM and is actually bidirectional[4].

DM and HTN may lead to changes in the morphology and function of the carotid arteries thereby increasing the prevalence and severity of carotid artery disease, as well as poly-vascular diseases[5].Chronic hyperglycemia play an important role in the initiation of vascular complications of diabetes while high blood pressure is an important risk factor for diabetes-associated vascular complications relationship, because HTN itself is characterized by vascular dysfunction and injury[6] .Hypertension development in an individual with DM can increase risk of developing both the macrovascular and microvascular complications[2]leading to the atherosclerotic cardiovascular disease[7].Thickening of the carotid intima-media and luminal diameter enlargement are closely associated with the morphological changes generally proceeding in tandem which produces a complex relationship between the two parameters and atherosclerosis[8].Changes in both structural and functional aspects of arteries have been research concerns for several years as they are considered risk factors for cardiovascular events. Generally, arterial wall thickening may be in intima-media or muscular layer. As the carotid artery is elastic, the muscular layer is relatively small. Hence, the thickening of the carotid arterial wall is essentially due to intima-media thickening.[9] consequently, some researchers have made remarkable effort to develop a subject-specific mathematical models that can serve as a better predictor of wall shear stress (WSS) distribution in the carotid artery, which may be of use for early prediction of possible atherosclerotic sites[10].

Studies have shown that the CCALD increases over-proportionally during the early stages of the atherosclerosis[11,12] . Increased CCALD have also been independently related to numerous cardiovascular risk factors [12,13]. Accordingly, carotid distension has been associated with incident cardiovascular events[14]. Another study has also found that CCALD was associated with a higher risk of any cardiovascular event and mortality, despite adjusting for other carotid parameters such as arterial stiffness and pulse wave velocity[15].

The carotid artery is considered as a model to reflect conditions common to all injured arteries[16]. Detection of structural and functional disorders of the common carotid artery (CCA) using B-mode high-resolution ultrasound is the most preferable method in evaluating systemic artery atherosclerosis which is a powerful predictor of future cardiovascular events[17]. Ultrasound is cheap, reproducible, and readily available, ionizing radiation free and reliable imaging modality of choice which makes it possible to assess carotid arteries at different points. Early detection of atherosclerosis is essential from a diagnostic and therapeutic point of view, and improves the knowledge of pathophysiological mechanisms. The progressive plaque formation associated with arterial wall changes can be reduced by improving the DM and HTN control. To the best of our knowledge, no study has yet compared the CCALD in adults with DM+HTN and healthy control subject in the study locality. This study is therefore aimed at comparing the CCALD in adults with DM+HTN and healthy controls.

2. Material and methods

This is a prospective, case-control study conducted at the ultrasound unit of the Maimusari clinic between October 2021 and January 2022. A total of 259 individuals comprising 115 subjects with DM+HTN and 144 healthy control adult volunteers were recruited in to this study. Informed consent to participate in the study was obtained from all the participants. The participant's age, disease conditions, disease history and lifestyle were documented.

The participants' height in metres (m) was obtained using a stadiometer with the patient standing erect and backing the scale. A weighing scale was used to measure weight (kg) and calculate body mass index (BMI), body adiposity index (BAI) and body surface area were calculated. Fasting blood sugar (FBS) level and blood pressure measurements were also obtained and documented.

Non-probability (purposive) sampling method was adopted and participants were selected among the patients attending general outpatient clinic. Ethical approval was obtained from the Ethical committee of the state ministry of health.

2.1. Inclusion criteria

Individuals of either gender diagnosed with DM+HTN, between the ages of 18 and 80 years and consented to participate voluntarily were included in the study. The healthy control subjects are non diabetic, non hypertensive healthy individuals of either gender, non-pregnant and or without any history disease condition that might affect the morphology and function of the carotid artery. They were recruited from the general population and their age and gender distribution is similar to the hypertensive subjects.

2.2. Exclusion criteria

Individuals who are either less than 18 or greater than 80 years of age and adults with a history of stroke were excluded. Pregnant women were also excluded because of the physiological changes and associated dilatation of the carotid artery during pregnancy. Healthy controls are individuals with a history of DM, HTN, or any clinical features suggestive of vasculitis were excluded.

2.3. Sonographic examinations

At the commencement of the examination, the researcher asked each participant to remove jewelleries and any other ornaments around the neck. The carotid artery was examined with the participant lying in supine position, right to the Sonographer/researcher on the ultrasound couch. The neck was hyper-extended (30^0) and placed on a small thick cylindrical foam pad to ensure adequate exposure of the neck depending on the subject's body physique. The head was then turned away from the examined side at about 45^0 from the midline to the opposite side. An ultrasound gel was applied to the antero-lateral aspect of the neck along the anterior border of the sternocleidomastoid muscle from the root of the neck to the base of the skull. This is to ensure proper transducer-skin contact and to reduce friction between the two surfaces. At the beginning of the examination, the carotid arteries were evaluated in B-Mode with appropriate optimizing factors.

The study protocol involved scanning the far wall and lumen of the right and left carotid artery which span from the superior aspect of the clavicle to the angle of the mandible while the internal jugular vein was used as a window. Sonograms of the carotid arteries were obtained for measurements using two antero-lateral scanning views (transversal and longitudinal) for each of the carotid artery. A transversal scanning view of the carotid vessel from the root of the neck to the carotid bulb and to the base of the angle of the mandible (C3 vertebra) was performed to localize any plaque. A transversal scanning view of the vessel with the transducer placed anterior border of the sternocleidomastoid muscle (1 cm below the carotid bulb) to measure the CCALD. A single measurement was recorded at each location for CCALD, which was taken as the distance between the leading edges of the lumen intima interface and the media-adventitia interface (second bright line) of the far wall. All the measurements were taken at the diastolic phase of the cardiac cycle.

All the sonographic examinations were performed using the 7-12 MHz, multi-frequency linear array transducer (contact area; 8mm x 28mm) of high resolution, touch screen, Venue 50 ultrasound machine (GE Medical System:2014, made in China) equipped with an electronic calipers. High-frequency transducer (vascular custom preset) was used because it gives a better resolution for superficial structures such as the carotid artery.

2.4. Statistical analysis

The quantitative variables are expressed as mean ± standard deviation, minimum and maximum values, while qualitative variables are presented as frequencies and percentages. The mean CCALD values between subjects with DM+HTN and healthy controls. Male and female subjects were compared using an independent sample t-test. While the mean values for the right and left sides were compared using a paired sample t-test. The association between the CCALD and continuous variables, such the age, BMI, BSA, BAI, BP and FBS levels, was calculated using univariate (Pearson's correlation coefficient). The data was analyzed using Statistical Package for Social Sciences (IBM SPSS]) Version 22.0. All the statistical tests were approved by assuming a null hypothesis of no difference, a $p \leq 0.05$ was considered statistically significant.

3. Results

There were 259 subjects comprising 115 with DM+HTN and 144 healthy control subjects with an age range of 18-80 years. The mean ages of subjects were 56.38±12.49years and 44.45±16.03 years for the subjects with DM+HTN and healthy controls, respectively. There were 42 (36.52%) males and 73(63.48%) females' subjects with DM+HTN, while healthy controls had 81 (56.25%) males and 63 (43.75%) females. There was a predominance of females over males

insubjects with DM+HTN (4:7)while there were more females among the healthy controls (4:3).The predominant age group for both subjects with DM+HTN was 48-57 years while for the healthy controls was38-47 years (Table 1 and 2).

The overall mean CCALD for the subjects with DM+HTN and healthy controls was 6.43±0.87 mm and 5.88±0.77 mm respectively. There was a statistically significant difference between the two subject groups (p=0.000) as presented in table 3. The overall mean CCALD for male and female subjects with DM+HTN was 6.68±1.03 mm and 6.29±0.75mm respectively; the difference was statistically significant (p=0.000). Similarly, the mean CCALD for males and females in healthy controls was 5.98±0.83 mm and 5.75±0.67 mm respectively; there was also a statistically significant difference (p=0.011).The mean CCALD values in males were higher compared to females in both groups as presented in tables 3 and 4. In subjects with DM+HTN, the mean CCALD for the right and left sides was6.62±0.88 mm and 6.23±0.83 mm respectively, while in healthy controls, the mean CCALD for right and left sides was 6.05±0.79 mm and 5.71±0.70 mm respectively; there was a statistically significant difference observed between the right and left sides in both the subjects with DM+HTN and healthy controls, as presented in table 5.

In subjects with DM+HTN, the mean CCALD for the age group 18-27 and >68 years was 5.83±0.65 mm and 6.68±0.84 mm respectively. While healthy controls had 5.93±0.73mm and 5.87±1.06 mm. The CCALD values changes inconsistently with age in both case and control groups (Table 6).The mean CCALD values in subjects with DM+HTN are higher compared with the corresponding healthy control in all the age groups except for age group 18-27 years (Table 6).

In this study, carotid plaques were seen in the common carotid artery (CCA) wall of 8 (6.96%) subjects with DM+HTN in this study, while only 1 (0.53%) was seen in the CCA of healthy controls. These plaques were more common in males (7) than in females and are more evident in the left CCA (6) than in the right side.

Table 1 Age and gender distribution in subjects with DM+HTN

Age (years)	Males (n=42)		Females (n=73)		Total(n=115)	
	Frequency (%)	Mean ± SD	Frequency (%)	Mean ±SD	Frequency (%)	Mean ±SD
18-27	1(0.87)	25.00±00	1(0.87)	22.00±00	2(1.74)	23.5±2.12
28-37	2(1.74)	32.00±5.66	5(4.35)	35.00±2.92	7(6.09)	34.15±3.63
38-47	3(2.61)	43.33±1.53	15(13.04)	42.93±2.46	18(15.65)	43.00±2.33
48-57	6(5.22)	53.17±3.43	25(21.74)	52.12±2.57	31(26.96)	52.32±2.73
58-67	14(12.17)	63.07±2.64	16(13.91)	61.44±3.10	30(26.09)	62.2±2.96
≥68	16(13.91)	70.06±2.93	11(9.57)	73.91±4.7	27(23.48)	71.63±4.14
Total	42(36.52)	60.57±12.09	73(63.47)	53.97±12.16	115(100)	56.38±12.49

Table 2 Age and gender distribution of the healthy controls

Age (years)	Male (n=81)		Female (n=63)		Total(n=144)	
	Frequency (%)	Mean ± SD	Frequency (%)	Mean ±SD	Frequency (%)	Mean ±SD
18-27	13(9.03)	24.54±2.5	9(6.25)	21.88±2.62	22(15.28)	21.68±2.50
28-37	10(6.94)	31.9±3.31	18(12.5)	33.72±2.42	28(19.44)	33.07±2.85
38-47	20(13.89)	41.05±2.21	18(12.5)	41.44±2.71	38(26.39)	41.24±2.43
48-57	8(5.56)	52.75±2.66	12(8.33)	51.58±3.11	20(13.89)	52.05±2.92
58-67	18(12.5)	62.28±2.21	4(2.78)	62.32±36	22(15.28)	62.23±2.4
≥68	12(8.33)	72.92±3.48	2(1.39)	80.00±00	14(9.72)	73.93±4.1
Total	81(56.25)	47.38±25	63(43.75)	40.90±13.20	144(100)	44.45±16.03

Table 3 Comparison of the mean CCALD between subjects with DM+HTN and healthy controls

Measurements	Gender	DM+HTN Mean±SD	Healthy controls Mean±SD	p-value
Mean CCALD (mm)	Male	6.68±1.03	5.98±0.83	0.000*
	Female	6.29±0.75	5.75±0.67	0.003*
Overall mean CCALD (mm)		6.43±0.87	5.88±0.77	0.000*

A p-value of < 0.05 is considered significant

Table 4 Comparison of the mean CCALD between male and female with DM+HTN and healthy controls

Subjects	Males Mean±SD (mm)	Females Mean±SD (mm)	p-value
DM+HTN	6.68±1.03	6.29±0.78	0.000*
Healthy controls	6.02±0.89	5.75±0.67	0.011*

A p-value of < 0.05 is considered significant

Table 5 Comparison of mean CCALD between right and left sides subjects with DM+HTN and healthy controls

Subjects	Right Mean±SD (mm)	Left Mean±SD (mm)	p-value
DM+HTN	6.62±0.88	6.23±0.83	0.000*
Healthy controls	6.05±0.79	5.71±0.70	0.000*

Table 6 Mean CCALD (mm) value with age group in subjects with DM+HTN and healthy controls

Age group (Years)	DM+HTN Mean±SD	Healthy controls Mean±SD
18-27	5.83±0.65	5.93±0.73
28-37	5.98±0.45	5.94±0.55
38-47	5.92±0.71	5.77±0.65
48-57	6.58±0.82	5.75±0.72
58-67	6.53±0.98	6.04±1.02
>68	6.68±0.84	5.87±1.06

4. Discussion

HTN is present in more than 50% of individuals with DM [18]. DM and HTN are two cardiovascular risk factors leading to atherosclerosis, which is the source of most cardiovascular complications.[19] In DM+HTN early structural changes of the arterial wall, with or without hypertrophy, precede or support atherosclerosis.

In this study, the mean age of subjects with DM+HTN and healthy controls was 56.38±12.49, years and 44.45±16.03 years, respectively. The middle-aged population preponderance noted in this study was because of the fact that a

majority of people with DM+HTN in developing countries are in that age range.[20] The increasing cases of DM+HTN among middle age groups are probably due to population growth, urbanization, unhealthy lifestyles, obesity and physical inactivity.[21]

The current study found that the overall CCALD value in subjects with DM+HTN was significantly higher compared to those of healthy controls. This finding is in agreement with the previous studies reviewed[22, 23]. None of the reviewed literatures has documented contrary findings. These wide differences in the overall CCALD in the two cohort groups were most likely due to the prolonged higher blood pressure levels plus persistent hyperglycaemia in subjects with DM+HTN. The combined effects of increased blood pressure and oxidative due to chronic hyperglycaemia can cause injury to the endothelium of blood vessels and affect its function with subsequent thickening of intima-media complex via medial hypertrophy[24,25].Both DM and HTN can independently affect CCALD. In addition, age can also affect the CCALD as subjects with DM+HTN are older than the healthy controls in this study.

It was observed in this study that the CCALD values on the right side are significantly higher than that on the left side in both cohort groups. This finding is consistent with the study by Kretza, etal[26] who reported a mean CCALD of 6.15±0.91 mm and 6.05±0.87 mm for the right and left sides respectively in females only with no significant difference noted in males. There was no clear reason for such variation. The possible explanation for the higher CCALD value on the right side could be that the LCCA is a direct branch of the thoracic aorta while the RCCA is a branch of the brachiocephalic artery which is a direct branch of the thoracic aorta. Hence, difference may have existed in arterial growth between two the sides and/or that flow-mediated mechanical forces applied to the carotid wall also differ between the two sides.

This study found that the mean CCALD values in males are significantly higher than those of females in both groups. This finding is in agreement with that of Krejza, *et al*[26] who reported a mean CCALD of 6.52±0.98 mm and 6.10±0.80 mm for male and female subjects with combined DM and HTN. The precise reason for this gender difference was not clear but it might be attributed to some of the risk factors that are more peculiar to the male gender such as smoking, alcoholism, physical and emotional stress. This implies that males are more at risk of developing atherosclerosis than females.

In this study, weak positive correlations were noted between the CCALD values and age in both groups. Although the combined effects of DM and HTN with age as an independent risk factor can cause morphological changes, there searcher found no study in the literature correlating either CALD in subjects with DM+HTN. The paucity of studies on DM+HTN to compare with the current study was a limitation for the discussion section of our study. However, it is expected that the current study will provide a basis for future studies in this field. A similar finding has been reported by Dakok et al[27] who reported positive and negative correlations for the right and left sides respectively among apparently healthy population. On the contrary, some other studies have also reported that the CCALD increases with age significantly in the general population.[28-30] This variation in observations might be due to differences in participant sample size, methodology, diet, lifestyle or age range. The reported increase in CCALD with age may be secondary to endogenous physiological mechanisms that favour enlargement of the arterial lumen.

5. Conclusion

This study revealed that the mean CCALD value in individuals with DM+HTN is higher than those of apparently healthy controls. The study also noted that the relationship between the age and CCALD was very weak in both cohort groups. High resolution ultrasound is a cheap, affordable, non-invasive, reliable, readily available and reliable imaging modality that is useful in monitoring DM and HTN and its associated complications.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

Criteria of inclusion of Authors

All the authors conceived the idea of the topic. Alhaji Modu Ali and Anthony Chukwuka Ugwu conceived ideal of the topic and searched/ reviewed the relevant articles and drafted introduction and methodology, Abubakar Shettima and Umar Abubakar analyze the data and presented the result, Onwuzu Sobechukwu and Mohammed Yusuf Mohammed drafted the discussion and conclusion. Alhaji Modu Ali drafted the abstract and all the authors reviewed and corrected the entire manuscript before submission.

Approval by authors

This manuscript was read and approved by all authors before submission

Statement of ethical approval

In line with the Helsinki Declaration, approval for this study was obtained from the Health Research Ethics Committee [HREC] of the Borno state ministry of Health.

Statement of informed consent

The consenting participants were thoroughly explained the procedure and both verbal and written informed consent was obtained from each of them before enrolling them into the study. They were made to be aware of their option to withdraw from the study at any point in time without losing any of the benefits or healthcare services rendered by the Hospital or the Centre.

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