Original Article

Sonography of Common Carotid Arteries' Intima: Media Thickness in the Normal Adult Population in Sudan

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Abstract

Background: Carotid ultrasonography is a useful diagnostic tool for assessing carotid disease. It is highly reliable, has no radiation risk, and has no risks when compared to conventional angiography. **Aim:** The study was to determine the common carotid artery (CCA) intima–media thickness (IMT) in the normal adult Sudanese so as to create standards for defining abnormalities. **Materials and Methods:** In 440 participants, the intima–media thickness was obtained sonographically in the supine position at the point of 1 cm section distal to the carotid bulb. Due to ethnic variations, participants were divided into a five ethnic groups according to their geographic distribution in Sudan. **Results:** The ranges of IMT found in the study were from 0.04 cm to 0.07 cm in carotids. Ethnically, males and females from West and East of Sudan show the highest IMT (0.070 ± 0.00 cm and 0.065 ± 0.01 cm) for CCA while males and females from the South of Sudan show the lowest IMT (0.055 ± 0.01 cm and 0.058 ± 0.004 cm). **Conclusion:** Mean carotids' IMT was slightly higher in females compared to males. No significant differences were found between IMT and different ethnics but significance was noted among participants' age and IMT of both sexes.

Keywords: Common carotid artery, Ethnic groups, Intima–media thickness, Ultrasound

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Introduction

Measurement of common carotid artery intima–media thickness (CCA-IMT) with a B-mode ultrasonography is a valid approach for identifying and quantifying the presence of subclinical disorders. It is a noninvasive, sensitive, and reproducible technique for identifying and quantifying atherosclerotic risk. It is also a well-validated research tool that has been translated into clinical practice.[1-3] Normative values and correlates of mean common carotid IMT in the Korean rural middle-aged population were identified in adults aged 40-70 years using a B-mode ultrasonography. The values are closely associated with age, obesity, gender, and diabetes mellitus.[4] The availability of reference carotid IMT ranges in the Spanish population could be helpful to assess the presence of subclinical disease in clinical practice. Carotid IMT measures were systematically higher in men than in women and were associated with age and pulse pressure. In addition, smoking was a significant determinant of carotid IMT only in men.[5] Also in healthy Korean adults IMT was significantly increased as age increased. Independent risk factors of IMT were age, systolic blood pressure, body mass index (BMI) for healthy subjects, and age and duration of diabetes.[6]

Reproducibility of carotid IMT measurements in young adults is greatest when combining values from both carotid arteries from the maximal and minimal arterial diameters. IMT measurements were greater in the right

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carotid artery than in the left and were significantly related to BMI.[7] Carotid IMT is greater in African Americans compared with white Americans.[8] Although vascular dysfunction is considered a function of the aging process, "premature arterial senility" has been reported in normotensive African American men as young as 21 years of age when studying the racial differences in central blood pressure and vascular function in young men.[9-13]

Ethnic specific cutoffs for abnormal common carotid IMT apply to Andean Hispanics supports several risk associations seen in other populations and can be used to identify Andean Hispanics at increased risk for atherosclerotic cardiovascular disease. In the reference sample, 95th percentile common carotid IMT values were both age and gender dependent. In stepwise regression, selected predictors of increasing common carotid IMT were older age, impaired fasting glucose, diabetes mellitus, higher systolic blood pressure, higher cholesterol level, smoking, and male gender.[14] In Brazilian individuals no differences were observed in CCA-IMT between the Euro-descendants and Afro-descendants main Brazilian ethnic groups. Euro-descendants and Afro-descendants had similar IMT values, even when the groups were stratified by degree of IMT and presence of stroke or transient ischemic attack. Also Chinese and Hispanics had less of a change in IMT than did non-Hispanic whites.[15,16]

This study was designed with an aim to determine the ultrasonic common carotid arteries IMT in normal adult Sudanese to create standards for defining common carotid arteries abnormalities in Sudanese.

Materials and Methods

After the nature of the exam was fully explained, we obtained written informed consent from all patients prior to each common carotid arteries ultrasound scan. Our Institutional Review Board approved this study. In addition, a review and authorization of the study protocols were done by the Ethical Committee available at Sudan University of Science and Technology (SUST).

Selection and description of participants

From May 2008 to June 2010, one radiologist performed common carotid arteries ultrasound and made a measure for the IMT of both right and left common carotid arteries in 440 participants. Participants recruitment according to their Sudanese nationality, area of location in Sudan, gender difference either males or females, ages and ethnicities. Sudan's ethnic diversity remained one of the most complexes in the world. There are nearly 600 ethnics groups distributed in the four geographic trends and the center of the country. Because of these ethnic variations, participants were divided into five ethnic groups in which (n = 208; 47%) from Center of Sudan, (n = 140; 32%) from North of Sudan, (n = 16; 3%) from South of Sudan, (n = 55, 12%) from West of Sudan, and (n = 20; 5%) from East of Sudan.

In this retrospective cohort study for the assessment of normative common carotid IMT values, healthy Sudanese participants selected by excluding participants with any of the following conditions: (1) history of storke including cerebral infarction or transient ischemic attack, myocardial infarction, or heart failure; (2) diabetes mellitus (fasting blood glucose ≥126 mg/dL or drug treatment for diabetes mellitus); (3) total cholesterol ≥220 mg/dL or pharmacologic therapy for dyslipidemia; (4) hypertension (systolic blood pressure [SBP] ≥140 mmHg, diastolic blood pressure [DBP] ≥90 mmHg, or drug treatment for hypertension); (5) BMI ≥ 30 kg/m^2, and (6) current smoking. Participants were scanned in the Ultrasound Department, SUST College of Medical Radiological Sciences (CMRS).

Ultrasound equipment

Ultrasound for CCA was performed using a high-resolution general electric (GE) ultrasound medical system, logic 5 expert ultrasound unit equipped with a linear probe of a frequency 6.0 MHz, model 2302650 with serial number of 1028924YM7, manufactured date of April 2005 and made by the Yokogawa medical system, Ltd. 7-127 Asahigaoka 4-chome Hino-shi Tokyo, Japan. Printing facility issued through the ultrasound digital graphic printer, 100 V; 1.5 A; and 50/60 Hz, with the serial number of 3-619-GBI-01 and made by Sony Corporation – Japan.

Methodology

Common carotid arteries were scanned to visualize the IMT in supine position with knee support, and the examiner seated toward the patient's head. The neck scanning was enhanced by tilting and rotating the head away from the side being examined, with possible adjustment for the position of the head and neck during the examination to facilitate visualization of the common carotid arteries. Several transducer positions were used in this research to examine the common carotid arteries in the long-axis (longitudinal) planes. The short-axis (transverse) view of the carotid artery was obtained from an anterior and lateral or posterolateral approach, depending on which best shows the vessels. CCA far wall images obtained in the longitudinal plane at the point along a 1 cm section of the artery distal to the carotid bulb. This method of measuring IMT was proved to be a simple and reproducible method for assessing IMT of the CCA for routine practice.[17,18]

B-mode image of the arterial wall composed of two parallel echogenic lines separated by a hypoechoic space.

Calculation of carotid IMT is arguably the most widely used noninvasive measure of atherosclerosis currently employed by clinicians and clinical investigators, both to quantify the extent of subclinical disease and to monitor change over time.[18] For the far (posterior) wall of the carotid artery, this index can be easily measured by ultrasound as the distance between the leading edge of the luminal echo (first bright line) and the leading edge of the media-adventitia echo (second bright line). For the near (anterior) wall, IMT is measured as the distance between the trailing edge of the first bright line and the trailing edge of the second bright line.[20]

Statistical study

For the statistical analysis, Microsoft Excel Software and Statistical Package for the Social Sciences (SPSS) were used. All results were shown as mean ± SD in a form of comparison tables. The difference between right and left common carotid arteries IMT in the ethnic groups was checked by paired *t*-test and age adjusted analysis of one-way analysis of variance (ANOVA). *P* value terms such as equal and less to be used for significance; *P* value ($P < 0.001$) was considered to be significant.

Results

The study population comprised 440 healthy participants made up of 272 (61.8%) males and 168 (38.2%) females (ratio of 3:2). Their ages ranged from 17 to 46 years, with mean age and standard deviation (SD) of 25 ± 8.00 years.

In female population, 84 subjects were in the age group 17-26 years, representing 50% of the population. The age group of 37-46 years was the smallest (3%) of the population [Table 1]. The highest mean ± SD of the IMT was (0.07 ± 0.004 cm) found in the age group 27-36 years while the lowest mean ± SD of the IMT was (0.05 ± 0.01 cm) found in the age group 37-46 years for the right and left CCA [Table 1].

In the population of males, 167 subjects were in the age group 17-26 years, representing 61.4% of the population. The age group of 37-46 years was the smallest (2.2%) of the population [Table 2]. The highest mean ± SD of IMT was (0.07 ± 0.004 cm) found in the age group 27-36 years while the lowest mean ± SD of IMT was (0.05 ± 0.01 cm) found in the age group 17-26 years for the right and left CCA [Table 2].

Females showed mean IMT of (0.061 ± 0.01 cm) which is slightly larger than the mean value of males (0.060 ± 0.01 cm). This finding is considered to be not statistically significant (*P* value = 0.3087). However, the mean BMI was higher for females (27.9) than males (25.7) [Table 3].

For ethnic consideration, females from East of Sudan show the highest IMT (0.07 ± 0.00 cm) for the right CCA

Table 1: Age distribution of mean IMT in the–females-study population for Rt. and Lt. CCA

Age group		IMT (cm) for Rt. CCA		IMT (cm) for Lt. CCA		Average CCA-IMT (cm)
Years	*N*	Range	Mean±SD	Range	Mean±SD	
17-26	84	0.04-0.07	0.06±0.01	0.04-0.07	0.05±0.01	0.055
27-36	79	0.05-0.07	0.07±0.004	0.05-0.07	0.07±0.004	0.07
37-46	5	0.04-0.07	0.05±0.01	0.04-0.07	0.05±0.01	0.05

IMT: Intima–media thickness; CCA: Common carotid artery

Table 2: Age distribution of mean IMT in the – males - study population for Rt. and Lt. CCA

Age group		IMT (cm) for Rt. CCA		IMT (cm) for Lt. CCA		Average CCA-IMT (cm)
Years	*N*	Range	Mean±SD	Range	Mean±SD	
17-26	167	0.04-0.07	0.05±0.01	0.04-0.07	0.05±0.01	0.05
27-36	99	0.04-0.07	0.07±0.004	0.05-0.07	0.07±0.003	0.07
37-46	6	0.05-0.07	0.06±0.01	0.05-0.07	0.06±0.01	0.06

IMT: Intima–media thickness; CCA: Common carotid artery

Table 3: Comparison of the mean CCA-IMT and body parameters in different genders

Gender (*N*)	Mean IMT (cm)		Average CCA-IMT (cm)	Mean weight (kg)	Mean height (m)	BMI
	Rt. CCA	Lt. CCA				
Males (272); mean±SD	0.059±0.01	0.061±0.01	0.060±0.01	72.5±4.5	1.73±0.05	25.7
Females (168); mean±SD	0.062±0.01	0.060±0.01	0.061±0.01	73.8±9.5	1.74±0.07	27.9
P value	*P*=0.0024*	*P*=0.31*	*P*=0.31*	*P*=0.05*	*P*=0.08*	-

*Significant at *P*≤0.001; IMT: Intima–media thickness; CCA: Common carotid artery; BMI: Body mass index

while females from South of Sudan show the lowest IMT (0.055 ± 0.01 cm) [Table 4].

An age-adjusted analysis by using one-way analysis of variance (ANOVA), applied to compare the IMT among the different ethnic groups of Sudanese females. No significant differences found between CCA-IMT and ethnic difference in female participants [Table 5].

Males from East of Sudan show the highest IMT (0.65 ± 0.01 cm) while males from the South of Sudan show the lowest IMT (0.058 ± 0.004 cm) for the right and left CCA [Table 6].

Another age-adjusted analysis by using one-way analysis of variance (ANOVA), applied to compare the CCA-IMT among the different ethnic groups of Sudanese males. Also no significant differences found between CCA-IMT and ethnic variability in males [Table 7].

Common carotids' IMT found in the study ranged from 0.04 cm to 0.07 cm. There was a significant

Table 4: Comparison between right and left CCA-IMT among different ethnics of females in Sudan

Sudanese females (*n*=168; mean age=26.4±8.00 years)

Ethnics	Rt. CCA IMT (Mean±SD)	Lt. CCA IMT (Mean±SD)	Average CCA-IMT (Mean±SD)	*P* value between Rt. and Lt. CCA IMT
Females from center of Sudan (*n*=60)	0.061±0.01	0.059±0.01	0.059±0.01	*P*=0.28*
Females from North of Sudan (*n*=72)	0.062±0.01	0.061±0.01	0.062±0.01	*P*=0.55*
Females from East of Sudan (*n*=4)	0.070±0.00	0.060±0.00	0.070±0.00	*P*=0.21*
Females from West of Sudan (*n*=28)	0.063±0.01	0.062±0.01	0.061±0.01	*P*=0.71*
Females from South of Sudan (*n*=4)	0.055±0.01	0.045±0.01	0.055±0.01	*P*=0.21*

*Significant at *P*<0.001; IMT: Intima–media thickness; CCA: Common carotid artery

Table 5: Age-adjusted CCA-IMT measures in the five ethnic groups of females in Sudan

Sudanese females (*n*=168; mean age=26.4±8.00 years)

Mean IMT (cm±SD)	Females from center of Sudan (*n*=60)	Females from North of Sudan (*n*=72)	Females from East of Sudan (*n*=4)	Females from West of Sudan (*n*=28)	Females from South of Sudan (*n*=4)	*F*	*P* value
Rt. CCA IMT	0.061±0.01	0.062±0.01	0.070±0.00	0.063±0.01	0.055±0.01	1.363	0.25*
Lt. CCA IMT	0.059±0.01	0.061±0.01	0.060±0.00	0.062±0.01	0.045±0.01	2.859	0.03*
Mean CCA-IMT	0.059±0.01	0.062±0.01	0.070±0.00	0.061±0.01	0.055±0.01	1.967	0.10*

*Significant at *P*<0.001; IMT: Intima--media thickness; CCA: Common carotid artery

Table 6: Comparison between right and left CCA-IMT among different ethnics of males in Sudan

Sudanese males (*n*=272; mean age=25±7.9 years)

Ethnics	Rt. CCA IMT (Mean±SD)	Lt. CCA IMT (Mean±SD)	Average CCA-IMT (Mean±SD)	*P* value between Rt. and Lt. CCA IMT
Males from center of Sudan (*n*=148)	0.058±0.01	0.060±0.01	0.058±0.01	*P*=0.09*
Males from North of Sudan (*n*=68)	0.063±0.01	0.062±0.01	0.063±0.01	*P*=0.56*
Males from East of Sudan (*n*=16)	0.064±0.01	0.066±0.01	0.065±0.01	*P*=0.58*
Males from West of Sudan (*n*=28)	0.062±0.01	0.063±0.01	0.062±0.01	*P*=0.71*
Males from South of Sudan (*n*=12)	0.057±0.004	0.059±0.004	0.058±0.004	*P*=0.23*

*Significant at *P*<0.001; IMT: Intima–media thickness; CCA: Common carotid artery

Table 7: Age-adjusted CCA-IMT in the five ethnic groups of males in Sudan

Sudanese males (*n*=272; mean age=25±7.9 years)

Mean IMT (cm±SD)	Males from center of Sudan (*n*=148)	Males from North of Sudan (*n*=68)	Males from East of Sudan (*n*=16)	Males from West of Sudan (*n*=28)	Males from South of Sudan (*n*=12)	*F*	*P* value
Rt. CCA IMT	0.058±0.01	0.063±0.01	0.064±0.01	0.062±0.01	0.057±0.004	4.350	0.002*
Lt. CCA IMT	0.060±0.01	0.062±0.01	0.066±0.01	0.063±0.01	0.059±0.004	2.000	0.10*
Mean CCA-IMT	0.058±0.01	0.063±0.01	0.065±0.01	0.062±0.01	0.058±0.004	4.564	0.001*

*Significant at *P*<0.001; IMT: Intima–media thickness; CCA: Common carotid artery

correlation between CCA-IMT and the subject's age ($P < 0.001$) [Table 8]. The average CCA-IMT was higher in females (0.061 ± 0.01 cm) rather than that of males (0.060 ± 0.01 cm) as shown in a correlation between mean CCA-IMT and participants [Table 8].

Discussion

High-resolution ultrasound using B-mode for the CCA is the most useful diagnostic tool for evaluating IMT. Numerous published studies of normative IMT reported the diagnostic value of CCA ultrasound using B-mode in evaluating IMT and IMT well correlated with the age and degree of atherosclerosis and are a predictor of cardiovascular morbidity and mortality.[1-20] The study group compromised 272 (61.8%) males and 168 (38.2%) females. Study population ages ranged from 17 to 49 years, with mean age and SD of 25 ± 8.00 years. The age parameter was unevenly distributed with many (57.05%) of the participants falling in the age group 17-26 years.

The unevenness of our population was a result of the randomized selection process, which unfortunately might affect the accuracy of the age influence on our measurement parameters. The methods followed in the measure of IMT in common carotids of participants were supported in a quality-controlled study about a simple and reproducible method for assessing IMT of the CCA. It was reported that when using the distal CCA at 1 cm distal to the carotid bulb to measure IMT was considered an accurate and reproducible method for assessing the IMT of the carotid artery. This method avoids measurements at multiple sites, uses standard measuring equipment, and targets a readily recognizable and clearly defined area in the CCA, which is known to be affected by flow stresses and to reflect atherosclerotic risk.[18]

Table 8: Correlation between mean CCA-IMT and participants (males and females) age between right and left common carotid artery

Gender (*N*)	Mean IMT (cm)		
Males/ Females	**Rt. CCA**	**Lt. CCA**	**Average CCA-IMT (cm)**
Males (272); mean±SD	0.059±0.01	0.061±0.01	0.060
Males age mean±SD	25±8.71	25±8.71	-
P value	<0.0001	<0.0001	-
Females (168); mean±SD	0.062±0.01	0.060±0.01	0.061
Females age mean±SD	26±8.04	26±8.04	-
P value	<0.0001	<0.0001	-

*Significant at *P*<0.001; IMT: Intima–media thickness; CCA: Common carotid artery

The author observed in the study that most of the average common carotids' IMT measured was slightly greater in females (0.061 ± 0.01 cm) rather than in males (0.060 ± 0.01 cm) and this was elaborated form age-adjusted analysis in [Tables 5 and 7] which is in line with the fact that a substantial proportion of the variability in carotid IMT is explained by genetic factors in aortic diameter, aortic stiffness, and wave reflection increase with age,[9] low arterial compliance in young African American males[11] and racial differences in central blood pressure and vascular function in young men,[12] but unlike the observation reported in genetic and environmental contributions to atherosclerosis phenotypes in men and women: Heritability of carotid IMT.[21]

Values of carotid IMT in females against age showed that IMT peak levels at 27-36 years for right and left CCA [Table 1] and also in males the IMT peak levels at 27-36 years for right and left CCA [Table 2]. Such findings of normative IMT in genders versus participants age were confirmed in many studies of normative common carotids' IMT as in Ando *et al*.'s[22] where in middle-aged and elderly population, an increase in the IMT-CCA showed a moderate relationship with local atherosclerosis and age.

In addition mean values of common carotids' IMT (in mm) for healthy reference sample aged 40-49, 50-59, and 60-70 years were 0.55, 0.59, and 0.66 for men and 0.48, 0.55, and 0.63 for women, respectively. In multivariate regression analysis, IMT was correlated with older age that could be compared directly to this study findings as proved by normative values and correlates of the mean common carotid intima–media thickness in the Korean rural middle aged population: The atherosclerosis risk of rural areas in the Korea general population.[4]

Although carotid IMT in both CCA and its bifurcation increased significantly with age, the upper limits (97.5 percentile) of IMT at CCA for participants age 35-39, 40-49, 50-59, and 60 years or older were 0.60, 0.64, 0.71, and 0.81 mm, respectively, whereas for that at bifurcation were 0.83, 0.77, 0.85, and 1.05 mm, respectively.[23] Moreover in this study we found that the males from East of Sudan show the highest IMT (0.065 ± 0.01 cm) while males from the South of Sudan show the lowest IMT (0.058 ± 0.004 cm) for the CCA. In addition, females from East of Sudan show the highest IMT (0.070 ± 0.00 cm) for the CCA while females from South of Sudan show the lowest IMT (0.055 ± 0.01 cm). Such findings were supported by Gepner *et al*.,[3] Youn *et al*.,[4] and Grau *et al*.[5] in common carotids' IMT studies of normative in ethnics.

Increased carotid artery IMT is considered as a marker of early atherosclerotic changes. The normal IMT of CCA as evaluated by B-mode ultrasound imaging

was 0.74 ± 0.14 mm and carotid IMT at or above 1 mm is associated with atherosclerosis and significantly increased CVD risk in any age group.[24] Increased IMT is a physiological effect of aging that corresponds to diffuse intimal thickening, especially in very elderly persons, and that IMT is distinct from the pathological plaque formation[25] where in this study the average common carotids' IMT for Sudanese males is (0.060 ± 0.01 cm) and in Sudanes females it is (0.061 ± 0.01 cm) for both common carotids. Such findings could be used as reference values for IMT in the Sudanese population to test the atherosclerosis condition in carotids.

An adjusted age analysis showed no significant relation between IMT among the different ethnic groups [Tables 5 and 7]. Considering ethnic differences exist in CCA. These differences in IMT are indicators of atherosclerosis and ethnic differences in the prevalence and severity of noninvasive measures of carotid and coronary atherosclerosis are increasingly being reported,[25] but the relationship of these measures to each other has not been widely explored. Blacks have generally been shown to have thicker common carotid IMT and thinner or equivalent internal carotid IMT compared to whites, but similar or lower coronary calcium prevalence,[27,28] despite higher coronary disease morbidity and mortality.[29]

Carotid IMT is increasing in the United Kingdom (UK) African Caribbean even after controlling for conventional risk factors. There are highly significant ethnic differences in the distribution of many potential cerebro-vascular candidate genes. Although in participants IMT examined were nonsignificant with the ethnic difference effects in common carotids' IMT, but other genetic predispositions or environmental exposures could not account for these differences.[30]

This study is limited by its retrospective nature, age groups, sex groups, and ethnic groups were not equally represented. Another potential limitation associated with selection bias may affect any retrospective study, but is likely to be modest in magnitude in this case since the study was population based and the first study done in Sudan to determine the normative of common carotids' IMT values. All the carotid IMT measures in this study were done according to a standard protocol validated in previous studies[19,20] and were interpreted by the same radiologist to avoid measurement errors. However, differences in the ultrasound technology, image capture, carotid artery segmentation, and method of measuring IMT could introduce variability affecting the results.

However, our results for normative common carotids' IMT value provide important insights into the determinants of subclinical vascular disease in this population. A longitudinal study is needed for a better evaluation of the relationships between cardiovascular risk factors, subclinical atherosclerosis, and the risk of cardiovascular events in this population.

Conclusion

In conclusion, statistically females showed average IMT for the CCA of (0.061 ± 0.01) that is slightly higher than the average in males (0.060 ± 0.01). Ethnically females from East of Sudan show the highest average of CCA-IMT (0.070 ± 0.00 cm) while females from South of Sudan show the lowest IMT value (0.055 ± 0.01 cm). Compared to males it was found that males from East of Sudan had the highest average of IMT (0.065 ± 0.01 cm) while males from the South presented the lowest IMT (0.058 ± 0.004) for carotids. No significant differences found between different ethnics and average CCA-IMT. In addition significant differences found between participants age and IMT value ($P < 0.0001$) in both sexes.

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