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CLINICAL & BASIC RESEARCH

Correlation between Carotid Artery *Intima-Media* Thickness and Luminal Diameter with Body Mass Index and Other Cardiovascular Risk Factors in Adults

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علاقة سمك البطانة الداخلية والوسطى وقطر اللمعية للشريان السباتي مع مؤشر كتلة الجسم وعوامل الخطورة القلبية الوعائية الأخرى عند البالغين

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abstract: ***Objectives:*** This study aimed to examine the correlation between carotid artery *intima-media* thickness (IMT) and luminal diameter (LD) with body mass index (BMI) and other cardiovascular risk factors. ***Methods:*** This observational cross-sectional study took place between June 2013 and March 2014 in the Radiology Department of Rizgary Teaching Hospital in Erbil, Iraq. Non-randomly selected subjects ≥20 years old (n = 140) were divided into BMI groups and evaluated for the following cardiovascular risk factors: gender, age, hypertension (HTN), diabetes (DM), smoking, alcohol consumption, blood pressure, serum total cholesterol and triglyceride (TG) levels. IMT and LD of the extracranial carotid arteries were measured by B-mode ultrasonography. ***Results:*** The mean IMT was 0.8 ± 0.3 mm, ranging from a total mean of 0.7 mm in the normal BMI group to 1.0 mm in the extremely obese group. A significant correlation was found between IMT and BMI (P = 0.04), but not between BMI and LD (P = 0.3). No significant difference in mean IMT or LD was seen between genders. Significant correlations were found between IMT and age, HTN, DM, high serum cholesterol and TG levels (P <0.001). An increase of one BMI unit caused a 0.009 mm increase in IMT and an increase of one year in age caused a 0.011 mm increase in IMT. ***Conclusion:*** Age, obesity, HTN, DM, high serum cholesterol and TG levels were found to have an impact on carotid IMT, which is a strong marker for the early development of atherosclerosis.

Keywords: Carotid Intima-Media Thickness; Ultrasonography; Atherosclerosis; Body Mass Index; Risk Factors; Iraq.

الملخص: الهدف: تهدف هذه الدراسة إلى فحص العلاقة بين سمك البطانة الداخلية والوسطى (IMT) وقطر اللمعية (LD) للشريان السباتي مع مؤشر كتلة الجسم وغيرها من عوامل الخطورة القلبية الوعائية. الطريقة: أجريت هذه الدراسة مستعرضة الرصد في الفترة ما بين يونيو 2013 و مارس 2014 في قسم الأشعة في مستشفى رزكاري التعليمي في أربيل، بالعراق. وتم تقسيم الحالات المختارة بطريقة غير عشوائية ≥20 سنة (140 حالة) إلى مجموعات (BMI) و قيمت عوامل الخطر القلبية الوعائية كالتالي: نوع الجنس،السن،ارتفاع ضغط الدم (HTN)، مرض السكري (DM)، التدخين واستهلاك الكحول، و مستويات الكولسترول الكلي والدهون الثلاثية (TG) في الدم. وتم قياس IMT و LD للشرايين السباتية خارج القحف عن طريق الموجات فوق الصوتية نوع B. النتائج: إن متوسط IMT كانت 0.3 ± 0.8 مم، بدءا من المعدل الكلي لـ 0.7 مم في مجموعة BMI العادية ل 1.0 مم في المجموعة ذات السمنة المفرطة للغاية. تم العثور على ارتباط وثيق بين IMT و BMI (P = 0.04) ولكن ليس بين مؤشري كتلة الجسم و LD (P = 0.3). ولم يوجد فرق كبير في متوسط IMT و LD بين الجنسين. تم العثور على ارتباط كبير بين IMT والعمر، HTN، DM، ارتفاع نسبة الكوليسترول وTG في الدم (P <0.001). وقد لوحظ أن زيادة وحدة واحدة لـ BMI تسبب في زيادة 0.009 مم في IMT و زيادة سنة واحدة في العمر تؤدي الى زيادة 0.011 مم في IMT. الخلاصة: خلصت الدراسة إلى أن العمر والسمنة وHTN، وارتفاع نسبة الكوليسترول و DM ومستويات TG في الدم لها تأثير معنوي على IMT للشريان السباتي، والذي يعتبر مؤشرا قويا للنشوء المبكر لتصلب الشرايين.

مفتاح الكلمات: سمك البطانة الداخلية والوسطى للشريان السباتي؛ الموجات فوق الصوتية؛ تصلب الشرايين؛ مؤشر كتلة الجسم؛ عوامل الخطورة؛ العراق.

Advances in Knowledge

- *Obesity, age, hypertension, diabetes, high serum cholesterol and triglyceride levels had a large impact on carotid intima-media thickness (IMT) among the studied sample in Iraq. This is important as an increased carotid IMT can be an indicator of early-stage atherosclerosis.*
- *The results of this study found that a one unit increase in body mass index caused a 0.009 mm increase in IMT and a one year increase in age caused a 0.011 mm increase in IMT.*

Application to Patient Care

- *Carotid IMT measurement using B-mode ultrasonography can be used as a surrogate marker for monitoring the development of atherosclerosis.*

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- *Increased IMT measurements in a patient should alert healthcare providers that primary prevention measures may be needed to avoid cardiovascular events.*

Atherosclerosis can develop as a result of the thickening of the intimal layer of the arterial wall; however, it is currently impossible to measure *intima* thickness alone *in vivo*.[1] Ultrasonography is therefore often used to indirectly assess *intima* thickness by measuring the *intima-media* thickness (IMT). In atherosclerotic-prone vasculature, it is known that an increase in IMT is an indicator of intimal thickening.[1]

Before non-invasive procedures were developed, ethical considerations prevented any investigation of the carotid arteries in healthy subjects. Without direct observation and quantification, atherosclerotic changes and their complications were believed to be a manifestation of ageing and hence unavoidable.[1] Assessments of arterial wall atherosclerosis were restricted to pathology and angiography studies.[2] However, the introduction of ultrasound technology permitted the study of healthy subjects as well as those who are symptomatic. Whereas angiography and pulse-wave Doppler sonography measure arterial stenosis, B-mode ultrasonography measures arterial wall thickness and is therefore capable of detecting early atheromatous lesions before they induce disturbed flow patterns.[3] Early phases of atherosclerotic plaque formation may result in thickened arterial walls with simultaneous dilatation, thereby preserving the *lumen*.[1] Thus, there is growing interest in using B-mode ultrasonography as a non-invasive, sensitive, readily available and reproducible technique to measure IMT and luminal diameter (LD) in order to study the natural history of early atherosclerosis changes, long before a decrease in LD would occur naturally.[1] Early detection of arteriosclerosis is crucial to ensure that appropriate prophylactic measures can be undertaken before cardiovascular events occur.

Unfortunately, the drawbacks of studies investigating the incidence of acute vascular disease endpoints include high costs and the need for long timelines and large sample populations. Hence, the use of a surrogate marker is important since it allows researchers to gather reliable data in a reduced timeframe using smaller samples.[4] Carotid IMT (c-IMT) measurements are an accepted surrogate marker of atherosclerosis and impart prognostic information independent of traditional cardiovascular risk factors.[5] Coll *et al*. emphasised the importance of c-IMT measurements, stating that the significance of these measurements are commensurate to traditional cardiovascular risk factors.[4]

Obesity and other atherosclerotic risk factors for myocardial infarction and stroke are very common in Iraq.[6,7] To the best of the authors' knowledge, there are no previous studies from Iraq reporting the effects of being overweight on atherosclerosis of the extra-cranial carotid arteries. This study therefore aimed to investigate the effects of body mass index (BMI) on carotid atherosclerosis using measurements of LD and c-IMT in an Iraqi population. In addition, this study aimed to detect possible relationships between cardiovascular risk factors and early-stage arteriosclerosis.

Methods

This observational cross-sectional study was carried out in the Radiology Department of Rizgary Teaching Hospital in Erbil, Iraq, between June 2013 and March 2014. A total of 150 non-randomly selected adults underwent B-mode ultrasonography of the extra-cranial carotid arteries. Subjects of both genders, diverse ages and with differing BMI measurements were included. Cases were selected non-randomly in collaboration with outpatient clinics to preserve a BMI, age and sex equilibrium and avoid discrepancy in their numbers. Bodybuilders, pregnant women and patients with a history of ischaemic heart disease (IHD) and stroke were excluded from the study as the former two conditions could result in false-high BMIs while the latter two could interfere with the interpretation of the results. Subjects under 18 years of age were also excluded as c-IMT is only affected by age or gender after this cut-off point.[8]

Six female and four male subjects were also excluded from the study due to technical difficulties in determining acceptable IMT and LD measurements from the internal carotid artery (ICA; n = 8) and carotid bifurcation (CBIF; n = 2), resulting in a total sample of 140 subjects.

Subjects were classified according to BMI into the following subgroups: underweight (<18.5 kg/m^2), normal (18.5–24.99 kg/m^2), overweight (25–29.99 kg/m^2), obese (30–39.9 kg/m^2) and extremely obese (BMI ≥40 kg/m^2). The subjects were also divided into age groups (20–29 years old, 30–39 years old, 40–49 years old, 50–59 years old and ≥60 years old).

Ultrasound scans were performed by a radiologist with five years' experience in the field. Each case was examined once but measurements for each segment of interest were taken and revised several times. Mean

Table 1: Demographic characteristics of a sample of Iraqi adults according to body mass index and age group (N = 140)

		BMI category*					Total n (%)
		UW	N	OW	O	EO	
Age group in years	20–29	1	15	12	3	1	**32 (22.9)**
	30–39	0	9	15	10	1	**35 (25)**
	40–49	1	6	8	11	0	**26 (18.6)**
	50–59	1	4	5	10	6	**26 (18.6)**
	≥60	1	7	5	7	1	**21 (15)**
Total, n (%)		**4 (2.9)**	**41 (29.3)**	**45 (32.1)**	**41 (29.3)**	**9 (6.4)**	**140 (100)**

BMI = body mass index; UW = underweight; N = normal; OW = overweight; O = obese; EO = extremely obese.

**Categories were defined as follows: underweight (BMI <18.5 kg/m^2), normal (BMI = 18.5–24.99 kg/m^2), overweight (BMI = 25–29.99 kg/m^2), obese (BMI = 30–39.9 kg/m^2) and extremely obese (BMI ≥40 kg/m^2).*

maximum measurements were recorded to reduce the chance of errors. The ultrasound machine (HD11 XE Ultrasound System, Version 2010, Philips Healthcare, Bothell, Washington, USA) was equipped with a 7–10 megahertz linear array transducer. Subjects were examined in supine positions with their heads slightly elevated and turned to the contralateral side. The site of the carotid segments to be studied was determined according to the distance from the flow divider as follows: common carotid artery (CCA) 1 cm segment proximal to the dilation of the carotid bulb; 1 cm segment proximal to the flow divider (CBIF); and 1 cm segment in the internal branch distal to the flow divider (ICA).[2] c-IMT measurements were taken from the leading edges of the far wall echoes while LD measurements were taken from the leading edge of the near wall *intima-lumen* echo to the leading edge of the echo from the far wall *lumen-intima* interface (the same location as the IMT measurements).[9] Both sides of the carotid arteries were examined with longitudinal scans. When an optimal longitudinal image was obtained, the image was magnified and frozen and the IMT and LD were measured. A transverse scan was occasionally performed when needed.

Plaque identified within the segment of interest was also included in the measurement. To obtain proper measurements in an atherosclerotic region, the same ultrasound acoustic settings (such as dynamic range, gain, mechanical index and probe frequency) used for the normal region (baseline settings) were also applied for the thickened region, with special attention to focal zone adjustment.

Variables for the study included maximum c-IMT values and the means of these maximums. Maximum values for the common c-IMT (CC-IMT), CBIF, ICA and the whole carotid tree were taken for both the right and left side. Subsequently, the means of both sides were taken and stated as the total maximum c-IMT. The same parameters were used for LD. Correlations between the total maximum c-IMT and total maximum carotid LD (c-LD) variables were made with BMI, age and cardiovascular risk factors

Table 2: Correlations between body mass index and the *intima-media* thickness and luminal diameter of carotid arteries among a sample of Iraqi adults (N = 140)

		Mean maximum IMT in mm								Mean maximum LD in mm								Mean maximum TC in mm	
		CCA		CBIF		ICA		Whole carotid		CCA		CBIF		ICA		Whole carotid			
		RT	LT	RT	LT	RT	LT	RT	LT	RT	LT	RT	LT	RT	LT	RT	LT	IMT	LD
BMI category*	UW	0.9	0.8	1.4	0.9	0.7	0.8	0.98	0.8	5.9	5.5	6.8	6.7	4.9	4.5	5.9	5.6	0.9	5.8
	N	0.6	0.7	0.8	0.8	0.7	0.7	0.7	0.7	5.7	5.7	6.8	6.7	4.7	4.6	5.7	5.7	0.7	5.7
	OW	0.7	0.7	0.7	0.8	0.7	0.7	0.7	0.7	6.0	5.9	7.4	7.1	4.8	4.5	6.1	5.8	0.7	6.0
	O	0.8	0.8	0.9	0.9	0.8	0.8	0.8	0.8	6.1	5.9	7.2	7.2	4.6	4.8	6.0	6.0	0.8	6.0
	EO	0.9	0.8	1.1	0.9	0.9	0.9	1.0	0.9	5.8	5.8	7.3	7.3	4.8	4.7	6.0	5.9	1.0	6.0
Total		0.7	0.7	0.8	0.8	0.7	0.7	0.8	0.8	6.0	5.8	7.1	7.0	4.7	4.6	5.9	5.8	0.8	5.9
SD		0.2	0.2	0.4	0.4	0.3	0.3	0.3	0.3	0.7	0.7	1.1	1.0	0.8	0.8	0.8	0.7	0.3	0.67
***P* value**		<0.001	0.06	0.003	0.8	0.6	0.1	0.001	0.21	0.3	0.4	0.1	0.2	0.8	0.4	0.3	0.3	0.04	0.3

IMT = intima-media thickness; LD = luminal diameter; TC = total carotid; CCA = common carotid artery; CBIF = carotid bifurcation; ICA = internal carotid artery; RT = right; LT = left; BMI = body mass index; UW = underweight; N = normal; OW = overweight; O = obese; EO = extremely obese; SD = standard deviation.

**Categories were defined as follows: underweight (BMI <18.5 kg/m^2), normal (BMI = 18.5–24.99 kg/m^2), overweight (BMI = 25–29.99 kg/m^2), obese (BMI = 30–39.9 kg/m^2) and extremely obese (BMI ≥40 kg/m^2).*

Table 3: Mean maximum luminal diameter and *intima-media* thickness values among a sample of Iraqi adults according to body mass index and gender (N = 140)

		Mean maximum IMT in mm		Mean maximum LD in mm	
		Male	Female	Male	Female
BMI category*	Underweight	0.86	1.03	5.56	6.16
	Normal	0.74	0.67	5.80	5.46
	Overweight	0.72	0.64	6.10	5.40
	Obese	0.79	0.79	6.23	5.70
	Extremely obese	-	0.91	-	5.96
Total		0.75	0.75	6.02	5.63
***P* value**		0.6	0.02	0.11	0.1

IMT = intima-medial thickness; LD = luminal diameter; BMI = body mass index.

**Categories were defined as follows: underweight (BMI <18.5 kg/m²), normal (BMI = 18.5–24.99 kg/m²), overweight (BMI = 25–29.99 kg/m²), obese (BMI = 30–39.9 kg/m²) and extremely obese (BMI ≥40 kg/m²).*

for atherosclerosis.

Cardiovascular risk factors for atherosclerosis were determined using a standardised questionnaire administered to every participant. Risk factors included a personal history of diabetes mellitus (DM), hypertension (HTN), smoking and alcohol consumption. Family histories of stroke and IHD were also evaluated. Height and weight were assessed on a single scale. Blood pressure was measured using mercury sphygmomanometers (ALPK2, Danyang Sai Fukang Medical Instrument Co. Ltd., Tokyo, Japan) with participants in a sitting position. Serum total cholesterol and triglycerides (TG) measurements were taken for each subject; however, low- and high-density lipoprotein testing was not performed due to technical issues.

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS), Version 16.0 (IBM Corp., Chicago, Illinois, USA). Descriptive quantitative data were presented as frequencies or means ± standard deviation (SD). Side-to-side differences between right and left sides and differences between BMI groups were tested with independent sample t- and analysis of variance tests. A *P* value of <0.05 was considered statistically significant.

This study was approved by the Research Ethics Committee of Hawler Medical University in Erbil, Iraq. Informed consent was obtained from all participants before inclusion.

Results

A total of 140 subjects between 20–88 years old were included in the study (mean age: 43.11 ± 15.47 years old). There were 84 males (60%; mean age: 41.95 ± 15.79 years old) and 56 females (40%; mean age: 44.84 ± 14.95 years old). The demographic characteristics of the subjects by BMI category and age group are shown in Table 1.

Statistical analysis revealed a significant correlation between BMI and mean maximum total c-IMT ($P = 0.04$) while the correlation between BMI and mean maximum total c-LD was not significant ($P = 0.3$) [Table 2]. There was no significant difference for side-to-side LD or IMT in the paired CCA, CBIF and ICA values. Additionally, no significant differences were noted between mean maximum IMT or LD values in males and females [Table 3]. Pearson correlation plots demonstrated close relationships between c-IMT and

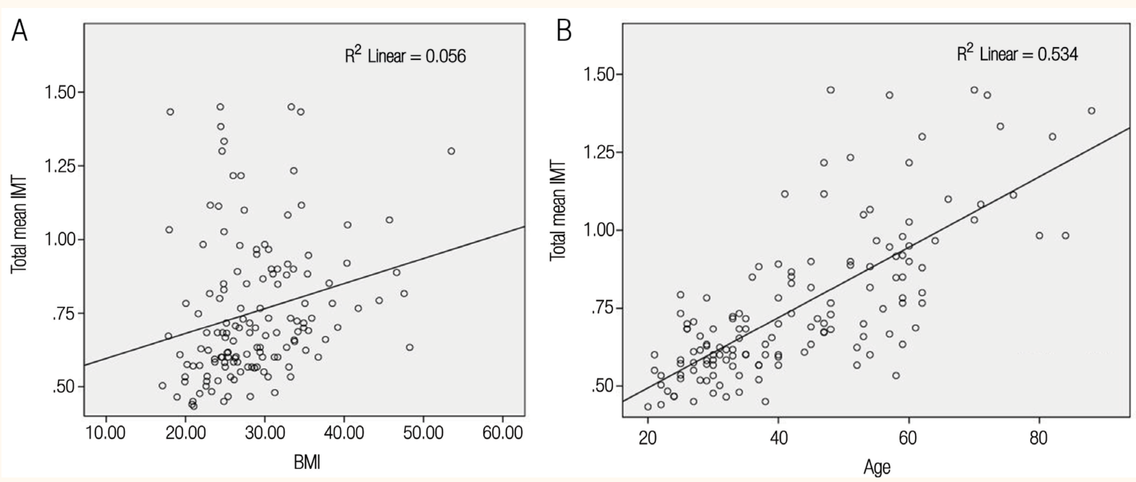

Figure 1A & B: Pearson correlation plots showing (**A**) a fair correlation between BMI and carotid IMT ($P = 0.005$; Pearson correlation coefficient = 0.236) and (**B**) a strong correlation between age and carotid IMT ($P < 0.001$; Pearson correlation coefficient = 0.731) among a sample of Iraqi adults (n = 140).

IMT = intima-media thickness; BMI = body mass index.

Table 4: Expected differences in mean wall thickness between participants differing in age by one year and body mass index by one unit among a sample of Iraqi adults (N = 140)

Carotid segment in mm	Total BMI	Age		
		Total	Male	Female
TC	0.009	0.011	0.011	0.012
RT C	0.009	0.012	0.011	0.013
RT CCA	0.010	0.010	-	-
RT BIF	0.007	0.015	-	-
RT ICA	0.009	0.011	-	-
LT C	0.008	0.011	0.009	0.010
LT CCA	0.007	0.009	-	-
LT BIF	0.008	0.015	-	-
LT ICA	0.010	0.009	-	-

BMI = body mass index; TC = total carotid artery; RT = right; C = carotid; CCA = common carotid artery; BIF = bifurcation; ICA = internal carotid artery; LT = left.

BMI [Figure 1A] and age [Figure 1B].

A regression coefficient analysis between IMT and BMI and between IMT and age was used to find the rate of wall thickness progression [Table 4]. A one-unit increase in BMI caused a 0.009 mm increase in IMT. A one year increase in age caused a 0.011 mm increase in IMT. A one unit increase in BMI was equivalent to a 0.81 year (9.81 month) increase in age.

A significant correlation between HTN and both mean maximum IMT and mean maximum LD was observed (P <0.001 for both). Additionally, DM and high serum cholesterol and TG levels showed significant correlations with IMT (P = 0.016, 0.028 and 0.045, respectively) but not with mean maximum LD. No correlation was detected between either IMT or LD with regards to other risk factors, including a family history of stroke or IHD, alcohol intake and smoking [Table 5].

Table 5: Prevalence of cardiovascular risk factors and correlation with carotid *intima-media* thickness and luminal diameter among a sample of Iraqi adults (N = 140)

Risk factor	n (%)	Presence of risk factor	Mean max. IMT in mm	*P* value	Mean max. LD in mm	*P* value
HTN	25 (17.9)	No	0.7	<0.001	5.76	<0.001
		Yes	0.96		6.33	
DM	9 (6.4)	No	0.74	0.016	5.85	0.26
		Yes	0.94		6.11	
High SC	20 (14.3)	No	0.7	0.028	5.85	0.12
		Yes	0.82		6.13	
High STG	37 (26.4)	No	0.69	0.045	5.83	0.14
		Yes	0.78		6.04	
AC	4 (2.85)	No	0.75	0.7	5.86	0.58
		Yes	0.7		6.08	
Smoking	30 (21.4)	No	0.74	0.7	5.8	0.09
		Yes	0.78		5.99	
FH of stroke	25 (17.9)	No	0.74	0.41	5.84	0.32
		Yes	0.79		5.99	
FH of IHD	21 (15)	No	0.75	0.81	5.89	0.25
		Yes	0.76		5.71	

max. = maximum; IMT = intima-media thickness; LD = luminal diameter; HTN = hypertension; DM = diabetes mellitus; SC = serum cholesterol; STG = serum triglycerides; AC = alcohol consumption; FH = family history; IHD = ischaemic heart disease.

Discussion

In the current study, a significant positive correlation was observed between c-IMT and BMI. The change was greater in higher BMI groups (obese and extremely obese individuals) than in lower groups (normal and overweight individuals), suggesting a more rapid change in IMT for BMI values >30 kg/m^2 (obese and extremely obese groups). Several cross-sectional studies have reported similar positive associations between body weight or BMI with carotid artery IMT.[10–12]

In the current study, an unexpectedly high mean IMT value was detected in the underweight group. However, only four subjects belonged to this group; these subjects were 22, 47, 57 and 70 years old with mean IMT values of 0.50 mm, 0.67 mm, 1.43 mm and 1.03 mm, respectively. These results suggest that age was a more predominant influencing factor than weight in this subgroup. Apart from those who were underweight, the IMT measurements of the younger subjects were normal.

In three of the six carotid artery segments, IMT values were very slightly higher in the normal BMI group than the overweight group. This was also reflected in the total mean IMT measurements. Two explanations for this are possible; first, in the classification of normal IMT and LD values in a previous study, the normal group was defined as those with a BMI of <30 kg/m^2.[5] This classification was made because of a lack of agreement between the IMT values of two groups (normal and overweight individuals) in a previously published study.[13] The second explanation is the effect of age, since vascular ageing is associated with different principal structural and functional changes (*intima-media* thickening, arterial dilatation and the deterioration of elastic wall properties with vascular stiffening).[13] The mean ages of the normal and overweight groups in the current study were very similar, although the SD was higher in the normal group. This was also the cause of failure in a previous study to investigate the impact of BMI on c-IMT.[13] Ozdemir *et al*. did not find a correlation between BMI and carotid artery IMT when comparing participants with normal BMIs to overweight subjects only (BMI = 25–29.9 kg/m^2).[13] However, their results might have differed had they also included obese subjects with BMIs over 30 kg/m^2 in the study. It is important to note, however, that performing tortuous ICA and high-seated bifurcation procedures on obese subjects in the current study was difficult.

In the current study, no significant correlation was found between c-LD and BMI. Crouse *et al*. concluded that IMT is often related to little or no narrowing of the arterial *lumen*.[14] The researchers went on to explain that studies previously indicating straightforward relationships between risk factors and *lumen* reduction may have been influenced by the utilisation of symptomatic population samples and incorrect methodologies.[14] An example of the latter is the use of Doppler ultrasonography, as this technique is unable to determine minor decreases in LD.[14] In contrast, the sample in the current study included both normal and diseased individuals.

In the current study, IMT and LD were found to increase significantly with advancing age in all carotid segments. This finding corresponded with those of Najjar *et al*.[15] Additionally, it was discovered that the mean IMT increased by approximately 0.095 mm/year, 0.015 mm/year and 0.010 mm/year at the CCA, CBIF and ICA, respectively. These findings were very similar to those of a previous study which showed a mean IMT increase of 0.010 mm/year, 0.016 mm/year and 0.011 mm/year at the CCA, CBIF and ICA, respectively.[2] The greatest increase in mean IMT in the current study occurred in the CBIF rather than in the CCA and ICA; this was in accordance with autopsy studies reporting that the extent of atherosclerotic involvement was greatest near the CBIF and in the proximal portion of the ICA.[16,17] Thus, the stronger association between IMT and age at the CBIF and ICA suggest more rapid atherosclerotic progression at these segments.

Limbu *et al*. demonstrated no relevant side-to-side differences in any of the parameters in the extracranial carotid arteries, with similar CC-IMT readings for both left and right sides.[18] The results of the current study were similar. However, Limbu *et al*. noted a difference between separate left and right LD measurements among men and women for all carotid artery segments.[18] No significant differences were found between women and men with respect to IMT measurements in the extracerebral carotid vessels;[18] this was also reflected in the present research. However, another study reported significantly smaller LD measurements in the left CCA than the right, which was attributed to the right CCA being dominant.[13] The current study showed that both left and right CCA, CBIF and ICA measurements tended to be larger in men than women. Three previous studies reported similar gender-related differences in LD measurements of the CCAs.[2,16,19]

Davis *et al*. reported cross-sectional associations between c-IMT and cardiovascular risk factors and prevalent cardiovascular disease.[20] A previous study found a positive association between c-IMT and the incidence of all types of stroke.[21] In the current study, the correlation between carotid atherosclerosis and HTN was highly significant. Significant correlations also existed between other cardiovascular risk factors (DM and high serum cholesterol and TG levels) and c-IMT, although the same was not true of LD. Early measurement of IMT via ultrasonography is closely associated with plasma lipids (total cholesterol, TG and low- and high-density lipoproteins) and HTN, while smoking and age are the two factors that have been most consistently associated with stroke and carotid atherosclerosis.[2] The present study suggests that increased blood pressure is a strong predictor of early carotid atherosclerosis.

A significant positive association between the severity of carotid atherosclerotic lesions (plaques and stenosis) and cigarette smoking (P <0.0001) has been previously reported.[8] There is also evidence that smoking is positively associated with carotid atherosclerosis in patients with symptomatic IHD, based on both angiographic and ultrasonographic studies.[3] The lack of a relationship between these variables in the present study could be explained by the fact that patients with IHD were excluded and the small sample may not have been representative of the entire population. No correlation between carotid atherosclerosis and a family history of stroke and IHD was found in the current study, although a positive correlation between these factors has been reported previously.[22] This may be because the present study was dependent on a small sample and because familial IHD was determined by history-taking. Additionally, IMT was viewed as a marker for subclinical atherosclerosis.

There are several additional limitations to the current study which should be acknowledged. The effect of IMT on LD may have been misrepresented as LD increases and decreases during the systolic and diastolic periods of the cardiac cycle, respectively.

Additionally, scans for this sample population were performed by a single radiologist who was aware of the other variables in the study, potentially introducing bias. The use of manual B-mode ultrasound technology can also cause technical difficulties and induce inherent variability. There was also a lack of detection of intra-individual variability in the methodology and a lack of multivariate adjustment of the data into different BMI categories for standard risk factors. Finally, the study could have been improved by comparing the ultrasonographic findings to another standard modality, such as computed tomography angiography.

Conclusion

A strong positive association was found between c-IMT and BMI in this Iraqi sample. Additionally, a positive correlation was also noted with age, HTN, DM, high serum cholesterol and TG levels. IMT and LD were found to increase significantly with advancing age in all carotid segments. In overweight patients, an increase in IMT can indicate the early stages of atherosclerosis.

References

1. Wikstrand J. Methodological considerations of ultrasound measurement of carotid artery intima-media thickness and lumen diameter. Clin Physiol Funct Imaging 2007; 27:341–5. doi: 10.1111/j.1475-097X.2007.00757.x.
2. Howard G, Sharrett AR, Heiss G, Evans GW, Chambless LE, Riley WA, et al. Carotid artery intimal-medial thickness distribution in general populations as evaluated by B-mode ultrasound: ARIC investigators. Stroke 1993; 24:1297–304. doi: 10.1161/01.STR.24.9.1297.
3. Bonithon-Kopp C, Scarabin PY, Taquet A, Touboul PJ, Malmejac A, Guize L. Risk factors for early carotid atherosclerosis in middle-aged French women. Arterioscler Thromb 1991; 11:966–72. doi: 10.1161/01.ATV.11.4.966.
4. Coll B, Nambi V, Feinstein SB. New advances in noninvasive imaging of the carotid artery: CIMT, contrast-enhanced ultrasound, and vasa vasorum. Curr Cardiol Rep 2010; 12:497–502. doi: 10.1007/s11886-010-0139-0.
5. Al-Asadi JN, Habib OS, Al-Naama LM. Cardiovascular risk factors among college students. Bahrain Med Bull 2006; 28:1–8.
6. Qadir MS, Rampal L, Sidik SM, Said SM, Ramzi ZS. Prevalence of obesity and associated factors among secondary school students in Slemani City Kurdistan Region, Iraq. Malays J Med Health Sci 2014; 10:27–38.
7. Lim TK, Lim E, Dwivedi G, Kooner J, Senior R. Normal value of carotid intima-media thickness: A surrogate marker of atherosclersosis - Quantitative assessment by B-mode carotid ultrasound. J Am Soc Echocardiogr 2008; 21:112–16. doi: 10.1016/j.echo.2007.05.002.
8. Sass C, Herbeth B, Chapet O, Siest G, Visvikis S, Zannad F. Intima-media thickness and diameter of carotid and femoral arteries in children, adolescents and adults from the Stanislas cohort: Effect of age, sex, anthropometry and blood pressure. J Hypertens 1998; 11:1593–602.
9. Coll B, Feinstein SB. Carotid intima-media thickness measurement: Techniques and clinical relevance. Curr Atheroscler Rep 2008; 10:444–50. doi: 10.1007/s11883-008-0068-1.
10. Chambless LE, Folsom AR, Davis V, Sharrett R, Heiss G, Sorlie P, et al. Risk factors for progression of common carotid atherosclerosis: The Atherosclerosis Risk in Communities Study, 1987-1998. Am J Epidemiol 2002; 155:38–47. doi: 10.1161/01.STR.0000088643.07108.19.
11. Li S, Chen W, Srinivasan SR, Bond MG, Tang R, Urbina EM, et al. Childhood cardiovascular risk factors and carotid vascular changes in adulthood: The Bogalusa Heart Study. JAMA 2003; 290:2271–6. doi: 10.1001/jama.290.17.2271.
12. Bonithon-Kopp C, Touboul PJ, Berr C, Magne C, Ducimetière P. Factors of carotid arterial enlargement in a population aged 59 to 71 years: The EVA study. Stroke 1996; 27:654–60. doi: 10.1161/01.STR.27.4.654.
13. Ozdemir H, Artas H, Serhatlioğlu S, Oğur E. Effect of overweight on luminal diameter, flow velocity and intima-media thickness of carotid arteries. Diagn Interv Radiol 2006; 12:142–6.
14. Crouse JR, Goldbourt U, Evans G, Pinsky J, Sharrett AR, Sorlie P, et al. Risk factors and segment-specific carotid arterial enlargement in the Atherosclerotic Risk in Communities (ARIC) cohort. Stroke 1996; 27:69–75. doi: 10.1161/01.STR.27.1.69.
15. Najjar SS, Scuteri A, Lakatta EG. Arterial aging: Is it an immutable cardiovascular risk factor? Hypertension 2005; 46:454–62. doi: 10.1161/01.HYP.0000177474.06749.98.
16. Martin MJ, Whisnant JP, Sayre GP. Occlusive vascular disease in the extracranial cerebral circulation. Arch Neurol 1960; 5:64–72. doi: 10.1001/archneur.1960.00450050050006.
17. Solberg LA, Eggen DA. Localization and sequence of development of atherosclerotic lesions in the carotid and vertebral arteries. Circulation 1971; 43:711–24. doi: 10.1161/01.CIR.43.5.711.
18. Limbu YR, Gurung G, Malla R, Rajbhandari R, Regmi SR. Assessment of carotid artery dimensions by ultrasound in non-smoker healthy adults of both sexes. Nepal Med Coll J 2006; 8:200–3.
19. Weskott HP, Holsing K. US-based evaluation of hemodynamic parameters in the common carotid artery: A nomogram trial. Radiology 1997; 205:353–9. doi: 10.1148/radiology.205.2.9356614.
20. Davis PH, Dawson JD, Riley WA, Lauer RM. Carotid intimal-medial thickness is related to cardiovascular risk factors measured from childhood through middle age: The Muscatine Study. Circulation 2001; 104:2815–19. doi: 10.1161/hc4601.099486.
21. Bots ML, Hoes AW, Koudstaal PJ, Hofman A, Grobbee DE. Common carotid intima-media thickness and risk of stroke and myocardial infarction: The Rotterdam Study. Circulation 1997; 96:1432–7. doi: 10.1161/01.CIR.96.5.1432.
22. Kishimoto C, Hirata M, Hama K, Tanaka M, Nishimura K, Kubo S, et al. Carotid intima-media thickness is increased in subjects with ischemic heart disease having a familial incidence. Exp Clin Cardiol 2006; 11:8–10.