

## Original Research Article

# Carotid artery diameter assessment in men and women and the relation to age, sex and body mass index using ultrasonography

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## ABSTRACT

**Background:** Carotid artery dimensions are increasingly used for detecting early atherosclerosis and predicting clinical complications. Aim was to explore relationships between gender, age and body mass index (BMI) and the diameters of the common carotid artery (CCA) and internal carotid artery (ICA) using ultrasonography.

**Methods:** This was a cross-sectional study carried out at the University of Maiduguri Teaching Hospital between February-October, 2011. The 400 adult males and females above 18 years underwent carotid artery ultrasonography for measurement of the IMT of the common and internal carotid arteries. The influence of age, sex, weight, height, and the basal metabolic index (BMI) was investigated.

**Results:** There were 239 (59.80%) males and 161 (40.20%) females aged between 18 to 81 years (Mean±SD, 36.74±14.79 years). The mean±SD diameters for right common carotid artery (RCCA) and left common carotid artery (LCCA) were 6.39±0.71mm and 6.28±0.74mm respectively. The right internal carotid artery (RICA) and left internal carotid artery (LICA) had mean±SD diameters of 4.63±0.63 mm and 4.61±0.63 mm respectively. The luminal diameters of the carotid arteries increased significantly with age and increased BMI. The luminal diameters of the CCA and ICA were significantly smaller in women than in men.

**Conclusions:** Common carotid and internal carotid artery luminal diameter tends to be larger in men than women among adults and increases with age and BMI. There is no difference in the luminal diameter between the left and right carotid artery.

**Keywords:** Carotid diameter, Age, Sex, BMI, Ultrasonography

## INTRODUCTION

Arterial diameters enlarge in response to wall thickening, plaques, and many atherosclerotic risk factors.<sup>1</sup> Early identification of persons at high risk of cardiac events would improve preventive and clinical care.<sup>2</sup> The major role of ultrasound examination in carotid vessels is the detection of stenotic lesions in the carotid arteries.<sup>3</sup> Measurements of the diameters, IMT and flow velocities are important in this environment in the early detection of

carotid arteries disease using ultrasonography. Ultrasonography (US) of the carotid arteries is a common imaging study performed for diagnosis of carotid artery disease.<sup>4</sup> Studies conducted in the past to establish the normal range of adult CCA and ICA diameters were evaluated and show wide range of variation:<sup>5-7</sup> RCCA- 5.43-7.83 mm, LCCA-5.13-7.57 mm, RICA- 5.17-5.33 mm, LICA-4.42-6.68 mm.<sup>7,8</sup> With development of high-resolution scanners the luminal diameter of the CCA and ICA can be assessed accurately.

Conventional angiography, magnetic resonance angiography (MRA), and computed tomography angiography (CTA) could also be used for assessment of luminal size.<sup>9</sup> However, angiography though considered as the gold standard is an invasive procedure. In addition, angiography as well as computed tomography (CT) uses ionizing radiation.

Because extra cranial carotid artery disease is responsible for more than 50% of all the strokes, carotid ultrasound becomes an important imaging modality to identify disease that may be the potential cause of stroke by measuring the diameters.<sup>10</sup> However, there is paucity of literature on the normal diameters of adult CCA and ICA for reference despite the high prevalence of stroke in our environment.<sup>11</sup> The study therefore aims to establish the baseline values of CCA and ICA diameters in our environment that could be used as reference point in detecting early atherosclerosis and predicting clinical complications.

## METHODS

This was a cross-sectional study carried out at the university of Maiduguri teaching hospital between February to October, 2011. Ethical clearance study was approved by the research and ethical committee of the university of Maiduguri teaching hospital.

Four hundred adult comprising of 239 (59.80%) males and 161 (40.20%) females aged 18 years and above who met the inclusion criteria were selected using convenience sampling technique of non-probability sampling method. These underwent carotid artery ultrasonography for measurements of the diameter of the common and internal carotid arteries. Prior to the ultrasound (USS) examination, clinical parameters which include age, sex, height in meters (M) and weight in kilograms (kg) and subsequently BMI were recorded for each subject. The BMI was calculated as a ratio of the measured weight to square of the measured height ( $\text{kg/m}^2$ ). BMI of  $<18.50$  was termed underweight, 18.50 as normal and 25.00-29.99 as overweight.

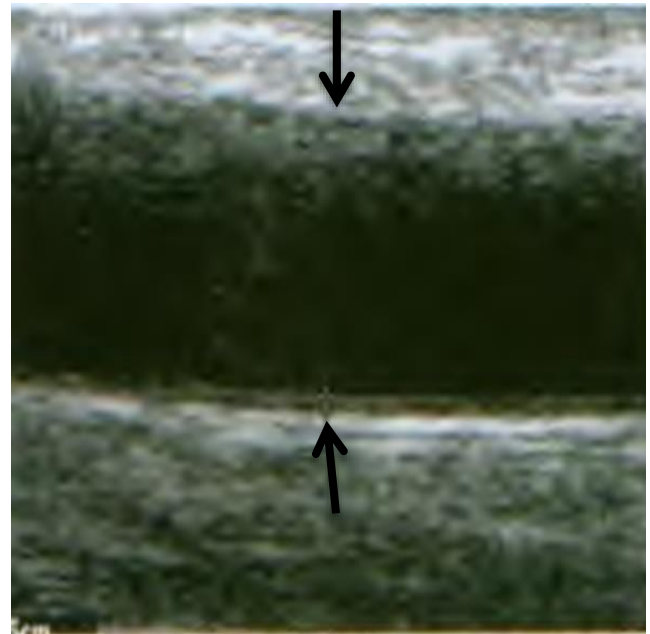
Brief history either for inclusion or exclusion was taken prior to the examination.

Excluded from the study were patients with cardiovascular risk factors which include:

History of stroke including cerebral infarction or transient ischemic attack, myocardial infarction, heart failure, diabetes mellitus (fasting blood glucose  $\geq 126$  mg/dl) or patients on drug for diabetes mellitus, total cholesterol  $\geq 220$  mg/dl or pharmacologic therapy for dyslipidemia. Also, excluded were patients with hypertension (systolic blood pressure [SBP]  $\geq 140$  mmHg, diastolic blood pressure [DBP]  $\geq 90$  mmHg) or on drug treatment for hypertension, BMI  $\geq 30$   $\text{kg/m}^2$ , current smoking and pregnant patients.

Subjects were asked to wear comfortable loose-fitting clothing and remove all jewellery around the neck. The examination was performed using a high-resolution real-time Doppler ultrasound scanner (Aloka, SSD-3500) equipped with 7.5 MHz linear-array transducer. The 7.5 MHz linear-array transducer provides greater resolution for superficial structures such as the carotid artery.

The patient's shoulder was placed on pillow with the neck extended and turned slightly away from the side being scanned. After applying ultrasound gel to the neck, the transducer was placed above the clavicle in a transverse projection initially for the grey-scale examination. The CCA was located and followed proximally as far as the clavicle permitted. The transducer was moved cephalad following the CCA to the level of the carotid bifurcation (thyroid cartilage). The internal carotid artery was followed distally to the angle of the mandible. The longitudinal and transverse views were done. The diameter was obtained at 1 cm proximal to the carotid bulb for the CCA and 1cm above the carotid bulb for the ICA. A single measurement was recorded at each location as shown in the Figure 1.



**Figure 1: Longitudinal view of the CCA showing points of measurement of the diameter.**

Data were analyzed using SPSS version 16 software and Microsoft excel. Results were presented as frequencies and proportions for categorical data and mean $\pm$ SD for continuous variables, respectively.  $P=0.05$  or less were considered significant.

## RESULTS

Of the four hundred (400) healthy adult that enrolled into prospective cross-sectional hospital-based study, 239 (59.75%) were males and 161 (40.25%) females.

The ages ranged between 18 and 81 years (mean=36.74±14.79 years). The mean age for males was 37.18±15.08 years, while for females was 36.08±14.37 years. Majority of the subjects 148 (37%) were in the age group 21 to 30 years consisting of 86 (21.50%) males and 62 (15.50%) females. The least number of patients were in the older age group of 81-90 years with the total number of 2 males (0.50%) (Table 1).

**Table 1: Age group and sex distribution of the sample population.**

Age group (years)	Males, n (%)	Females, n (%)	Total, n (%)
≤20	20 (5.00)	12 (3.00)	32 (8.00)
21-30	86 (21.50)	62 (15.50)	148 (37)
31-40	57 (14.25)	42 (10.50)	99 (24.75)
41-50	29 (7.25)	12 (3.00)	41 (10.25)
51-60	25 (6.25)	20 (5.00)	45 (11.25)
61-70	14 (3.50)	11 (2.75)	25 (6.25)
71-80	6 (1.50)	2 (0.50)	8 (2.00)
81-90	2 (0.50)	0 (0.00)	2 (0.50)
Total	239 (59.8)	161 (40.20)	00

#### Body parameters

Table 2 shows the relationship between the mean body parameters and age group of the participants studied. From the study, all the parameters were highest in the age group 41-50 years. Their weight ranged between 40-96 kg (Mean=63.82 kg±9.87). The highest mean weight (70.63 kg±8.45) was in the age group 41-50 years. The lowest mean body weight (55±0.00) was in the age group 81-90 years.

**Table 2: Mean body parameters in each age group.**

Age group (years)	Frequency (n)	Height (m)±SD	Weight (kg)±SD	BMI (kg/m <sup>2</sup> ) ±SD
≤20	32	1.64±0.80	59.19±7.90	22.30±3.68
21-30	148	1.69±0.74	63.20±9.35	22.30±2.90
31-40	99	1.68±0.74	65.34±12.30	23.20±4.02
41-50	41	1.71±0.05	70.63±8.45	24.24±2.59
51-60	45	1.64±0.42	63.27±6.80	23.56±2.07
61-70	25	1.62±0.11	59.76±4.07	23.06±3.57
71-80	8	1.65±0.31	58.00±5.18	21.27±1.98
81-90	2	1.64±0.00	55.00±0.00	20.40±0.00

The height of the study population ranged between 1.50-1.90 m (mean=1.67±0.75 m). The highest mean height

(1.71±0.05 m) was in the age group 41-50 years. The lowest height (1.62±0.11 m) was observed in the age group 61-70 years.

The BMI ranged 15.10-37.50 (mean=22.87±3.26). The highest BMI (24.24±2.59) was in the aged group 41-50 years and the lowest BMI was in the aged group 81-90 years (20.40±0.00).

Table 3 shows the relationship between overall mean of the body parameters and sex of the participants. All body parameters were lower in females (1.63 m±0.67; 60.54 kg±8.8; 16.31±0.66 kg/m<sup>2</sup>) than males (1.70 m±0.67; 66.03 kg±9.93; 22.86±3.26 kg/m<sup>2</sup>).

**Table 3: Sex and overall mean body parameters (height, weight, and BMI).**

Sex, (n)	Height (m) (Mean±SD)	Weight (kg) (Mean±SD)	BMI (kg/m <sup>2</sup> ) (Mean±SD)
Females (161)	1.63±0.67	60.54±8.8	16.31±0.66
Males (239)	1.70±0.67	66.03±9.93	22.86±3.26

Tables 4 and 5 show the mean diameters of age groups for CCA and ICA in both males and females respectively. From the observations, the highest mean±SD diameter of both the CCA and ICA in males was in the age group above 70 years with mean total diameter of 15.17±0.32 mm and 12.35±0.54 mm respectively and the least mean±SD was in the age group of 20 years and below with mean total diameter of 11.43±0.62 mm and 8.51±0.39 mm in CCA and ICA diameters respectively (Table 4). The luminal diameters of the carotid arteries increased significantly with age and this was shown to be statistically significant (p<0.001). On average, the RCCA and RICA had higher mean±SD diameters than the corresponding LCCA and LICA (Table 4). Similarly, the highest mean±SD in both right and left CCA and ICA in females was in the age group of above 70 years with mean total diameter of 14.70±0.00 mm and 11.70±0.00, while the least was in the age group of 20 years and below with mean total diameter of 11.00±1.00 mm and 8.15±0.50 mm respectively and was statistically significant (p<0.005). The RCCA and RICA diameters had higher±SD than the left in all the age group except the age groups >70 years where the diameter of the LCC is slightly higher as shown in the Table 5.

Figure 2 and 3 show the histogram of the mean total diameter verses age for males and females CCA and ICA. The males had higher mean total diameter in CCA than the females in all the age group except the age group of 61-70 years that had the same diameter. Similarly, the males had higher mean total diameter in ICA than the females in all the age groups except at age group 61-70 years where it is slightly lower.

**Table 4: Mean diameters of different age groups for males CCA and ICA.**

Variables	≤20 years M±SD	21-30 years M±SD	31-40 years M±SD	41-50 years M±SD	51-60 years M±SD	61-70 years M±SD	>70 years M±SD
<b>RCCA</b>	5.71±0.31	6.05±0.52	6.60±0.43	6.86±0.45	7.18±0.20	7.42±0.16	7.60±0.17
<b>LCCA</b>	5.72±0.31	6.00±0.54	6.58±0.42	6.90±0.46	7.13±0.20	7.34±0.20	7.58±0.12
<b>Mean total</b>	11.43±0.62	12.06±1.06	13.18±0.84	13.75±0.91	14.31±0.38	14.76±0.36	15.17±0.32
<b>RICA</b>	4.26±0.20	4.38±0.46	4.83±0.65	4.96±0.57	5.30±0.28	5.12±0.54	6.18±0.31
<b>LICA</b>	4.25±0.20	4.39±0.45	4.18±0.67	4.94±0.62	5.23±0.29	5.06±0.55	6.15±0.24
<b>Mean total</b>	8.51±0.39	8.77±0.90	9.64±1.32	9.90±1.19	10.55±0.57	10.20±1.08	12.35±0.54

LD: Luminal diameter, RCCA: Right common carotid artery, LCCA: Left common carotid artery, RICA: Right internal carotid artery and LICA: Left internal carotid artery.

**Table 5: Mean diameters of different age groups for females CCA and ICA.**

LD (mm)	≤20 years M±SD	21-30 years M±SD	31-40 years M±SD	41-50 years M±SD	51-60 years M±SD	61-70 years M±SD	>70 years M±SD
<b>RCCA</b>	5.60±0.44	5.73±0.49	6.20±0.44	6.93±0.37	6.98±0.25	7.50±0.23	7.30±0.00
<b>LCCA</b>	5.40±0.56	5.50±0.49	5.96±0.44	6.70±0.37	6.74±0.29	7.23±0.26	7.40±0.00
<b>Mean total</b>	11.00±1.00	11.24±0.98	12.17±0.88	13.63±0.74	13.71±0.52	14.78±0.49	14.70±0.0
<b>RICA</b>	4.12±0.25	4.25±0.34	4.35±0.56	4.65±0.29	4.90±0.40	5.42±0.57	5.90±0.00
<b>LICA</b>	4.03±0.25	4.21±0.33	4.30±0.51	4.58±0.30	4.88±0.45	5.37±0.54	5.80±0.00
<b>Mean total</b>	8.15±0.50	8.46±0.67	8.65±1.05	9.23±0.59	9.78±0.85	10.79±1.10	11.70±0.0

Table 6 showed the overall range and mean of the diameters of the common and internal carotid arteries of the study population. The RCCA had higher mean ( $\pm$ SD) ( $6.39\pm0.71$  mm) than the LCCA ( $6.28\pm0.78$  mm). Similar observation was also seen in the ICA with the mean ( $\pm$ SD) of RICA ( $4.63\pm0.63$  mm) higher than the LICA ( $4.61\pm0.63$  mm) however, no statistical differences were observed in both RCCA and LCCA diameters:  $t=0.835$ ,  $p=0.325$ , and RICA and LICA diameters:  $t=0.962$ ,  $p=0.063$ . Luminal diameters of CCA and ICA were significantly higher in males as compared to females. Mean CCA diameters was  $6.50\text{ mm}\pm0.70$  in males and  $6.20\text{ mm}\pm0.70$  in females ( $p=0.001$ ) on the right and  $6.50\text{ mm}\pm0.70$  in males and  $6.00\text{ mm}\pm0.70$  in females ( $p=0.001$ ) on the left.

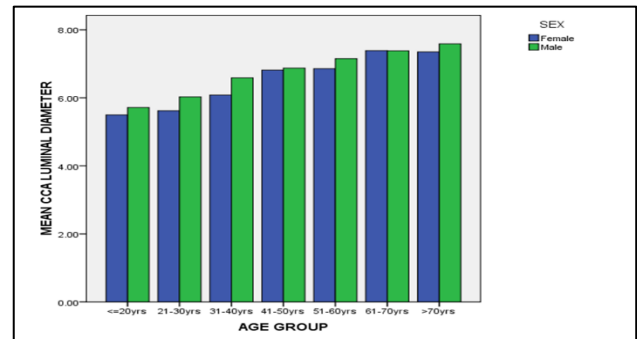
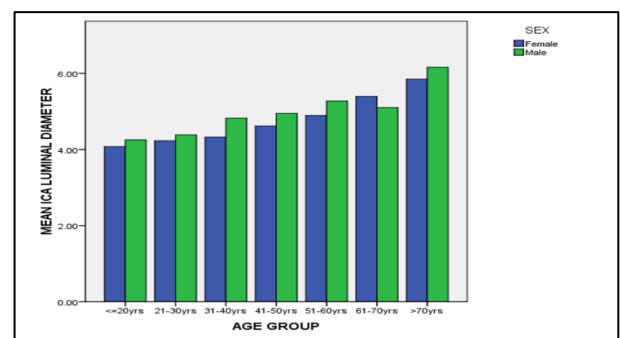
**Table 6: Overall range and mean of CCA and ICA diameter.**

Diameter (mm)	Sample size (n)	Range	Mean±SD
<b>RCCA</b>	400	4.90-7.80	$6.39\pm0.71$
<b>LCCA</b>	400	4.70-7.80	$6.28\pm0.74$
<b>RICA</b>	400	3.50-6.50	$4.63\pm0.63$
<b>LICA</b>	400	3.60-6.40	$4.61\pm0.63$

**Table 7: Mean (M) total luminal diameter verses BMI.**

BMI	Males, CCA	ICA	Females, CCA	ICA
<b>Under weight</b>	$6.31\pm0.90$	$4.26\pm0.33$	$5.45\pm0.33$	$4.08\pm0.27$
<b>Normal weight</b>	$6.34\pm0.67$	$4.64\pm0.64$	$6.03\pm0.70$	$4.39\pm0.56$
<b>Over weight</b>	$6.98\pm0.38$	$4.95\pm0.54$	$6.59\pm0.67$	$4.73\pm0.4$

The relationship of BMI with luminal diameter was shown in Table 7. The mean total diameter was higher in the overweight individuals than the normal and the underweight individuals in the CCA and ICA in both males and females.

**Figure 2: Histogram of mean total CCA luminal diameter verses age for males and females.****Figure 3: Histogram of mean total ICA luminal diameter verses age for males and females.**



## DISCUSSION

Measurement of cerebral blood flow is an important parameter in the diagnosis and follow-up of ischaemic cerebrovascular disease.<sup>12</sup> Several studies have been carried out to determine the normal dimensions of common and internal carotid arteries.<sup>5,7,8</sup>

In a prospective study by Limbu et al in which a group of 123 healthy individuals aged 21-60 years (mean±SD, 35.66±8.84 years) noted the range of CCA diameter of 4.30 mm to 7.70 mm.<sup>13</sup> Differences were not noted between right and left common carotid arteries luminal diameters with the overall mean diameters of 5.86±0.66 mm and 5.78±0.57 mm respectively. In a similar study by Jaroslaw et al where they found the overall mean for all measurements of CCA diameter of 6.81±0.88 mm and ranged between 5.30 mm to 7.50 mm.<sup>5</sup> In another study by Burhan et al on-ultrasound assessment of cerebral blood flow measurements of the extracranial carotid arteries in Turkish.<sup>12</sup> In their study he evaluated 96 healthy adults and found the range of CCA diameter of 5.60 mm to 7.50 mm. The overall mean CCA diameters in this study was 6.39±0.71 mm and 6.28±0.74 mm on the right and left respectively which is in agreement with the above findings and well in the range of the referenced studies. This study also showed the range of CCA diameters to be between 4.90 mm-7.80 mm and 4.70 mm-7.80 mm for the right and left respectively which is in corroboration with the aforementioned publications. Jaroslaw et al established the normal range of ICA diameter of 3.80 mm to 6.98 mm (mean±SD; 4.67±0.84 mm).<sup>5</sup> Burhan et al found the range of ICA diameter of 3.20 mm to 5.30 mm.<sup>12</sup> This present study showed the overall mean diameters of 4.63±0.63 mm and 4.61±0.63 mm with the ranged of 3.50 mm-6.50 mm and 3.60 mm to 6.40 mm for the right and left respectively and thus collaborated with their findings.

Several studies have shown that the CCA and ICA diameters increase with age.<sup>14,12</sup> In 2006 Jaroslaw et al explored the relationships among gender and the diameters of the CCA and ICA and found that the CCA and ICA diameters increased with age.<sup>5</sup> In a study by Hüseyin et al, on the effects of over weight on luminal diameter of carotid arteries.<sup>6</sup> They found that the luminal diameters of the CCA and ICA increased significantly with age. Burhan et al in their study on cerebral blood flow measurements of the extracranial carotid arteries in healthy adults noted a significant increase in diameters of the CCA and ICA with age.<sup>12</sup> The present study also found that the luminal diameters of the carotid arteries increased significantly with age. The mean CCA diameter increased from 6.20 mm±0.60 in the age group of 18-50 years to 7.30 mm±0.30 in the age group of 51-81 years (p=0.001) which agree with the above findings. In contrast some previous studies, showed no significant relationships between carotid artery size and age which most likely was due to relatively younger population used in the study.<sup>8,15</sup>

Previous researchers showed the relationship of gender and the diameters of carotid arteries.<sup>5,6,8,12</sup> Jaroslaw et al found that, the mean diameter of ICA (4.66±0.78 mm) and CCA (6.10±0.80 mm) in females were significantly lower than in males: 5.11±0.87 mm and 6.52±0.98 mm respectively.<sup>5</sup> Hüseyin et al evaluate the effects of overweight on luminal diameter, flow velocity and intima-media thickness of carotid arteries.<sup>6</sup> The study showed that the luminal diameters were significantly lower in females than in males (6.87±0.77 mm vs 7.28±0.89 mm; p=0.04). Burhan et al in their study found that luminal diameters of CCA and ICA were significantly higher in males as compared to females.<sup>12</sup> Mean CCA diameter was 6.70±0.80 mm in males and 6.30±0.70 mm in females (p=0.012); ICA diameter was 4.70±0.60 mm in males and 4.40±0.50 mm in females (p=0.03). The present study also shows that, luminal diameters of CCA and ICA were significantly higher in males as compared to females. Mean CCA diameters was 6.50 mm±0.70 in males and 6.20 mm±0.70 in females (p=0.001) and mean ICA diameters was 4.70 mm±0.60 in males and 4.50 mm±0.60 in females (p=0.001). This finding is in agreement with the above studies. The observed increase in vessel diameter associated with increasing age may be due to secondary atherosclerotic changes that cause a decrease in the vessel wall elasticity.<sup>6</sup>

Previous studies to ascertain the relationship between the CCA and ICA diameters with demographic data (height, weight and BMI) were done.<sup>5,6</sup> Joseph et al in their study showed that independent variables showing strong positive association with CCA diameter includes height and weight.<sup>16</sup> Jaroslaw et al found that CCA and ICA diameters show positive relationship with body height, weight and BMI. Hüsenyin et al in their studies evaluated the correlation between luminal diameters of carotid arteries and found that luminal diameters were significantly higher in over weight than the normal individual.<sup>5</sup> However, they found no correlation between subject's height and carotid luminal diameters.<sup>6</sup> The present study showed that there is no correlation between luminal diameters of the CCA and ICA with height (r=0.59; p=0.289) and (r=0.019; p=0.07) for CCA and ICA respectively on the right. Similar findings were also noted on the left side. However, there was correlation between carotid luminal diameter and weight (r=0.410; p=0.000) and (r=0.322; p=0.000) for CCA and ICA on the right respectively and BMI (r=0.416; p=0.000) and (r=0.334; p=0.000) for CCA and ICA on the right. Similar findings were seen on the left side. The findings were in the agreement with studies of Hüsenyin et al.<sup>6</sup>

## Limitations

Though carotid Doppler ultrasound is reasonably accurate, safe and noninvasive procedure, difficulty was frequently encountered in some individuals in appropriately imaging the carotid artery segments especially the ICA-IMT due to variation in body habit like individuals with short neck.

## CONCLUSION

Common carotid artery and internal carotid artery lumen diameter tends to be larger in men than women. There is no difference between left and right carotid artery lumen diameter. The luminal diameters of the vessels increase with age, weight and BMI. Ultrasound plays an important role in the assessment of carotid arterial disease. Carotid Doppler ultrasound is an essential tool in the armamentarium of the stroke physician.

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