Reference Values of Abdominal Aorta Wall Thickness and Doppler Indices in a Nigerian Population

Michael Sunday Okpaleke[1*], Daniel Chimuanya Ugwuanyi[2], Michael Promise Ogolodom[2], Chinedu E. Anyanwu[2], Nwamaka Chizube Ikegwuonu[3], Nathaniel Eja-Egwu[2], and Anayo Okwo Christain[4]

[1]Department of Radiography and Radiation Science, Baze University Abuja Nigeria; [2]Department of Radiography, Nnamdi Azikiwe University, Awka, Nnewi campus; [3]Department of Radiology, Nnamdi Azikiwe University Teaching Hospital, Nnewi Anambra State, and [4]Alex Ekwueme Federal University Teaching Hospital Abakaliki Ebonyi State.

***Corresponding author:** Dr. Sunday Michael Okpaleke. Email address: ms.okpaleke@unizik.edu.ng
DOI: https://dx.doi.org/10.4314/ajhs.v36i3.12

Abstract

INTRODUCTION

There is a paucity of data on the association between Doppler indices, the wall thickness of the abdominal aorta and the development of atherosclerosis in Nigeria. This study aimed to establish reference data of the abdominal aorta wall thickness and their selected Doppler indices in Abuja, Nigeria.

METHODOLOGY

This cross-sectional prospective study enlisted volunteer healthy subjects who consented and met the inclusion criteria by convenience sampling. The abdominal Aorta wall thickness (AAWT), as well as selected Doppler indices which are: the resistivity and pulsatility indices (RI & PI) of the abdominal aorta (AA) of four hundred and twelve male and female volunteer healthy subjects, were measured sonographically using standard protocols. Data was analyzed using SPSS v 23 and inferential analysis was done with a level of significance set at 5 %.

RESULTS

The mean ± SD of the AAWT in the volunteer healthy subjects were 1.54 ± 0.33mm and 1.29 ± 0.32mm in male and female healthy volunteers respectively. The mean ± SD of the RI and PI for male volunteer healthy subjects were 0.81 ± 0.06, and 1.09 ± 0.20. Also, the mean ± SD of the RI and PI for female healthy volunteers was 0.59 ± 0.06, and 1.10 ± 0.21 respectively.

CONCLUSION

The reference AAWT, RI and PI in the locality were 1.51 ± 0.33mm, 0.6 ± 0.06 and 1.02 ± 0.19. The RI, PI and AAWT values were higher in males (p >0.005) than in female volunteer healthy subjects.

Keywords: *Abdominal aorta, Pulsatility index, Reference values, Resistivity index, Aorta Wall Thickness*

[*Afr. J.* *Health Sci*. 2023 36 (3): [299-307]

Introduction

The abdominal aorta (AA) is the largest artery in the body and it descends from the thorax as a continuation of the thoracic aorta until it reaches the pelvis, where it divides into the right and left common iliac arteries and the middle sacral arteries. The abdominal aorta is made of three separate layers surrounding the lumen, or hollow centre of the artery [1]. The tunica intima is the innermost layer that is in contact with the lumen and the blood passing through it. It is made of the endothelium, a specific type of stratified squamous epithelial cells that maintain the integrity of the vessel walls. The epithelium plays an important role in preventing blood cells from leaking out of the artery or sticking to the walls and forming clots.

The next layer, the tunica media, is much thicker than the tunica intima and contains many elastic fibres and smooth muscle tissue [2]. These structures work together to give the artery strength and elasticity and the ability to contract to help propel blood through the body. Finally, the tunica externa forms the outermost layer of the abdominal aorta and is made of dense irregular connective tissue containing many collagen fibres. This tissue gives the artery a strong but flexible outer coat and helps to attach the abdominal aorta to the surrounding tissues. Atherosclerosis of the abdominal aorta is often associated with the development of cardiovascular disease risk factors such as hypertension, hyperlipidaemia, and Diabetes [3].

Progressive childhood atherosclerosis results in the deposition of fats, calcium, cholesterol and other substances in the walls of the abdominal aorta which leads to abnormal thickening of the walls of the abdominal aorta from childhood, adolescence, adulthood and old age [3]. Similarly, plaques may begin to develop in the aortic intima-media complex, especially in adulthood and old age [4]. These changes in the wall of the abdominal aorta compromise the normal luminal dimension of the abdominal aorta and predispose individuals to some cardiovascular diseases [5]. Atherosclerosis of the abdominal aorta is often associated with the development of cardiovascular disease risk factors such as hypertension, hyperlipidaemia, and Diabetes [6]. Cardiovascular disease has been a global health concern with high morbidity, especially in Nigeria. Cardiovascular diseases have increased in Nigeria in the last 20 years and contribute to 11% of all deaths due to non-communicable diseases [7,8]. Therefore, Cardiovascular morbidity is a burden to the Nigerian health system and the control of cardiovascular disease risk factors has not been optimised in Nigeria.

Diagnostic imaging of cardiovascular disease risk factors includes cardiac Magnetic Resonance Imaging, Computed Tomography Angiography, Electron Beam Computed Tomography and Ultrasonography. Atherosclerosis results in pathological processes, including stroke, coronary artery and peripheral artery diseases. The occult nature and progression of atherosclerotic diseases therefore require the use of easily available and effective surveillance tools to identify, evaluate and follow up the progression of atherosclerotic conditions [9]. Both grey scale and Doppler ultrasound imaging provide cost-effective and efficient ways to identify atherosclerotic plaques and provide subclinical risk assessment. Intravascular ultrasound procedures are known to provide a specific risk assessment of atherosclerotic lesions and track the progression of anti-atherosclerotic therapies over time [9]. Ultrasonography is the best imaging modality compared to the others because of its availability, low cost, non-invasiveness and ease of use [4]. One study that projected the value of ultrasound in the assessment of atherosclerosis in men was the BioImage study of 2015 [10]. The study assessed vascular imaging biomarkers for early atherosclerotic events in 5808 asymptomatic adults. All the subjects were evaluated using carotid artery calcification and Doppler ultrasound evaluation of the carotid artery with a quantitative 3D ultrasound score. The reported major cardiac events increased with higher carotid plaque burden and coronary artery calcification. The study concluded that ultrasound vascular evaluation of the carotid artery can identify imaging biomarkers that directly diagnose atherosclerosis [10]. This study highlighted the importance of ultrasonography in the identification of atherosclerotic plaques and the diagnosis of some cardiac events. Atherosclerosis and age influence Doppler parameters in the diagnosis of renal artery stenosis [11]. The latter study concluded that Doppler parameters (peak systolic volume, renal aortic ratio, renal-interlobar ratio and acierating time) for patients presenting with atherosclerosis aged 46 years or older and younger than 46 years were different. This shows that cut-off values may be established for variations in Doppler parameters with atherosclerosis/age based on a 46-year-old borderline for the renal aortic ratio and renal interlobar ratio. Another related study also found a direct influence of Doppler parameters on the development of atherosclerosis [12]. The cross-sectional study appraised different ultrasonography indices in patients with carotid artery atherosclerosis during which the resistive index (RI), pulsatility index (PI), Intima-Media Thickness (IMT), Dichrotic Notch Index (DNI) and Mean Wavelength Entropy (MWE) were investigated in 144 Iranian men. The subjects were grouped into four namely control, severe, moderate, control and mild atherosclerotic subjects/stenosis. The study results indicated that patients with mild, moderate, and severe stenosis had significantly different RI, PI, far wall intima-media thickness, and mean wavelength entropy in their common carotid artery when compared to the control group. The study concluded that the use of the identification and measurement of the PI, RI far wall intima-media thickness can help physicians identify patients at risk of cardiovascular diseases. In the present study, we desire to establish reference values of AA wall thicknesses and Doppler indices in a Nigerian population. These reference values will help clinicians in the early identification of patients at risk of atherosclerosis and cardiovascular diseases.

Furthermore, there is also a paucity of data on the association between Doppler indices, Abdominal Aorta wall thickness and the development of atherosclerosis in Nigeria. As a result, the use of ultrasound to interrogate the abdominal aorta wall thickness to identify subclinical atherosclerosis, especially among high-risk individuals will go a long way toward controlling the risk factors of cardiovascular disease and reducing the cardiovascular disease burden in Nigeria.

Methodology

This was a prospective cross-sectional study carried out on volunteer adult subjects between 18 –92 years in Abuja metropolis, Nigeria between February 2016 and September 2019. Ethical approval (reference No:008/02/2016) was obtained from the Research and Ethics Committees of the College of Medicine, University of Nigeria, Enugu campus. The research was conducted in Abuja, the capital of Nigeria, due to its diverse population which includes major ethnic groups and individuals from different categories. This made it possible to draw inferences from a wider range of individuals and cultures. Informed consent from volunteer subjects was obtained before the study. Two hundred and six healthy male subjects were cross-matched with two hundred and six female volunteer subjects who were recruited for the study by convenience sampling. The volunteer subjects were cross-matched for age and Body mass index (BMI) so that differences observed within each group would not attributed to differences in age or body mass index. All consenting healthy adult subjects and patients who were non-smokers referred to the ultrasound department of Medic-Aid Radiology Wuse Abuja, Nigeria within the period of the study with indications other than abdominal aortic aneurysm, diabetes, hypertension and hyperlipidaemia were included in the study. Subjects with a history of cardiovascular disease or aneurysm and positive laboratory tests for hypertension (Blood pressure was measured using a blood pressure cuff and sphygmomanometer), hyperlipidaemia and type 2 diabetes were excluded from the study. Referrals who met the inclusion criteria were enlisted into the study and their anthropometric data was obtained. To identify hypertension, Systolic and Diastolic pressures were measured using a standard digital blood pressure apparatus (OMPONS; Model: I-Q142; Year of manufacture - 2013). Hypertension was defined as a systolic pressure >140 mm Hg or diastolic pressure ≥90mmHg [13]. A bathroom scale (Hanson & Co, China) was used for the measurement of weight while height was measured using a methe scale and tape recalibrated before use. The measuring tape calibrations were validated through a standard protocol using a pre-calibrated steel tape by mechanical comparison as described by Liyanawaduge (2022) [14]. The weight (in kilogram) of each volunteer subject was divided by the square of the height (in metres) to obtain the Body mass index (BMI). The Cronbach's Alpha measure of the internal consistency reliability of the measuring instruments ranged from 0.70 – 0.71.

Thereafter, the volunteers' Lipid profiles and fasting blood sugar tests were carried out by enzymatic assay by spectrophotometer method (using Erbaspectrophometer, year of manufacture – 2013) and glucose oxidase method (using Chem well analyser (Model: 2910, Year of manufacture 2012) respectively. Hyperlipidaemia or hypercholesterolemia was deemed present when total cholesterol and triglycerides levels were above 200mg/dl, high-density lipoprotein and low-density lipoprotein levels were below 40mg/dl and 135mg/dl respectively [15]. Type 2 diabetes was deemed present when the blood glucose level was above 130 mg/dl [16].

An ultrasonic assessment of the abdominal aorta was carried out by a researcher and an experienced sonographer on subjects who had fasted for 6-8 hours. The assessment was performed using Mindray ultrasound equipment (4D ultrasound, model - DCN3, manufactured in 2013). The fasting blood sugar and lipid profile tests were performed to assess normal levels and rule out cardiovascular disease risk factors in volunteers. Serial longitudinal abdominal scans were performed from the sub-diaphragmatic region to the level of aortic bifurcation where the probe is rotated at right angles and scanning continued upwards to visualise the wall thickness of the abdominal aorta. Measurements were made at the largest widest diameter of the abdominal aorta wall thickness 5mm distal to the bifurcation. This is because the region of aortic bifurcation is a common site for the development of atherosclerosis and thickening of the walls of the AA [3]. Two measurements were made. The diameter of the lumen of the abdominal aorta was measured in Antero-posterior (AP) view and the inner to the inner diameter (ITID) was then made at 90^0 to the longitudinal axis of the abdominal aorta from a frozen longitudinal image to avoid errors due to parallax. The aortic luminal diameter (ITID) was measured by the use of callipers placed at opposite ends of the inner walls of the lumen (tunica intima) of the AA.

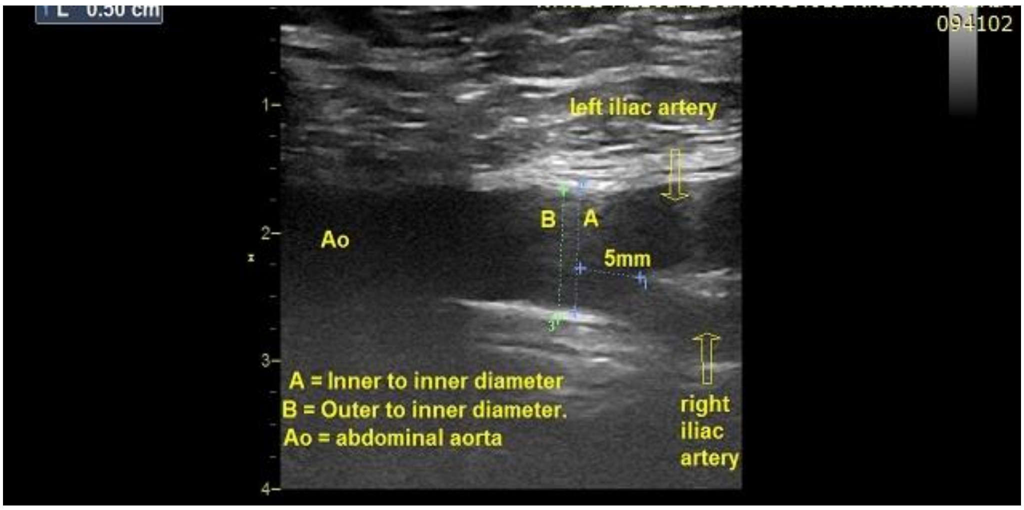

Figure I:
Doppler Sonography of the longitudinal section of the abdominal aorta in healthy subjects showing the measurement of the inner to the inner diameter and outer to inner diameters of the abdominal aorta from which the WT of the abdominal aorta was obtained.

The OTID was measured similarly by placing one end of the calliper at the inner wall of the tunica intima and the other end at the opposite end of the outer layers of the tunica media of the AA. The ITID and OTID were measured twice each and the mean of two measurements was recorded. The T-test showed no significant difference between pairs of measurements ($p > 0.005$). The AA wall thickness was obtained by subtracting the mean ITID from the mean OTID. Both the RI and the PI of the AA were calculated automatically from the velocity spectral display using the onboard software as callipers are placed at the peak systolic velocity (PSV) and end-diastolic velocity EDV) using the formulae; RI = PSV-EDV/PSV and PI = PDV-EDV/ Time-averaged velocity ie TAV [17].

Descriptive statistics were used to express the recorded values of the luminal diameter, AA wall thickness and Doppler indices in healthy subjects. Upper and Lower limits of normality of the AA wall thickness and Doppler indices were displayed using Percentile values. The percentile values are used to display the 5^{th} – 95^{th} normal ranges of values for the AA wall thickness diameter and Doppler parameters (RI and PI). The independent samples T-Test was used to determine the differences in AAWT, RI and PI in both male and female volunteer healthy subjects in the studied population.

Results

Table 1.1 shows that 206 (50%) male healthy subjects were recruited and cross-matched with 206 female healthy subjects with the same age and BMI in the study. Table 2 shows the 5th to 95^{th} percentile values of the wall thickness, resistivity and pulsatility indices in volunteer subjects. Abdominal Aorta wall thickness increased with RI and PI from the 5^{th} - 95^{th} percentile. Table 3 shows the variations in mean values of the wall thickness for the volunteer healthy subjects. Volunteer male healthy subjects have higher mean values of Wall thickness than volunteer female healthy subjects.

Table 1:
Age and BMI Distribution of the Volunteer Subjects

Age Range (Years)	Male n (%)	Male Age Years (Mean±SD)	Male BMI Kg/M2 Mean±SD	Female n (%)	Female Age Years (Mean ±SD)	Female BMI Kg/M2 (Mean±SD)	Female BMI Kg/M2 (Mean±SD)	Total n(%)
18-32	54(13.11)	22.54 ±4.0	19.50 ±4.13	54(13.11)	23.54 ± 4.0	19.74± 4.19	19.74 ±4.19	108(26.21)
33-47	63(15.29)	40.27 ±4.01	20.70 ±4.57	63(15.29)	41.27± 4.01	21.00 ±4.57	21.00 ±4.57	126(30.58)
48-62	68(16.50)	53.55 ±4.48	21.48 ±5.18	68(33.01)	52.81±4.48	22.90 ±5.08	22.90 ±5.08	136(33.01)
63-77	15(3.64)	65.47 ±4.87	21.55 ±2.19	15 (3.64)	67.47±4.87	22.47 ±1.83	22.47 ±1.83	30 (7.28)
78-92	6(1.46)	83.17 ±2.92	22.37 ±1.86	6 (1.46)	80.17±2.92	23.52 ±1.37	23.52 ±1.37	12 (2.91)
Total	206 (50)	43.88±15.98	23.31 ±4.81	206(50)	43.88±15.98	23.41 ±4.59	23.41 ±4.59	412(100)

.

Table 2:
Percentile Values of Doppler Indices and Abdominal Aorta Wall Thickness in Healthy Subjects

Percentiles (%)	Wall Thickness (mm)	Resistivity Index	Pulsatility Index
5	.81	.51	.75
10	.84	.52	.82
15	.88	.53	.86
25	1.41	.54	.89
50	1.61	.60	1.05
75	1.67	.66	1.18
90	1.86	.68	1.22
95	1.93	.70	1.24
95	1.93	.70	1.24

Table 4 shows that the mean values of resistivity and pulsatility indices increased with age and are higher in volunteer male healthy subjects than in volunteer female healthy subjects. Table 5 shows no significant differences in AA wall thicknesses, resistivity and pulsatility indices of male and female volunteer healthy subjects using the T-test.

Discussion

In the current study, an equal number of male and female healthy volunteers were recruited for the study to exclude inhomogeneity in the study samples. The mean ± SDs of the AAWT were 1.54± 0.33mm in male subjects and 1.29± 0.32mm in female subjects.

Table 3:
Age and Sex Variations of Mean Abdominal Aorta Wall Thicknesses

Age (years)	Wall thickness (Mean ± SD (mm)		Mean± SD(mm)
	Male healthy subjects	Female healthy subjects	
18-32	1.07± 0.27	1.01± 0.25	1.04± 0.26
33-47	1.63± 0.02	1.58 ± 0.03	1.60 ± 0.04
48-62	1.69 ± 0.03	1.62± 0.05	1.65± 0.05
63-77	1.95± 0.04	1.85± 0.01	1.91 ± 0.04
78-92	2.17± 0.07	1.91 ± 0.03	2.04 ±0.14
Total	1.54 ± 0.33	1.29± 0.32	1.51 ± 0.33

Table 4:
Distribution of age and Selected Doppler indices in healthy subjects

Age range (years)	RESISTIVITY INDEX Mean ± SD (mm)		Mean ± SD (mm)	PULSATILITY INDEX Mean±SD mm)		Mean ± SD (mm)
	Male	Female		Male	Female	
18-32	0.75± .02	0.53± 0.02	0.53 ± 0.01	0.89 ± 0.08	0.79± 0.06	0.84 ± 0.09
33-47	0.77±0.02	0.56 ± 0.02	0.57 ± .03	1.10 ± 0.04	0.89. ± 0.23	0.99±0.20
48-62	0.78± .02	0.63 ± 0.01	0.66 ±0.02	1.13 ± 0.02	0.63 ± 0.01	1.15 ± 0.12
63-77	0.80 ± 0.01	0.64 ± 0.02	0.68 ±0.02	1.24 ± .03	0.89 ± 23	1.23 ± 0.02
78-92	0.81 ± 0.01	0.66 ± 0.01	0.69 ±0.03	1.02 ± .01	1.22 ± 0.03	1.24 ± 0.01
Grand mean	0.81 ± 0.06	0.59 ± 0.06	0.60 ±0.06	1.09 ± 0.20	1.10 ± 0.21	1.02 ± 0.19

Table 5:
Independent Samples T-Test Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
WT HS	Equal variances assumed	.022	.882	.035	420	.972	.00109	.03118	-.06020	.06238
	Equal variances not assumed			.035	419.994	.972	.00109	.03118	-.06020	.06238
PI HS	Equal variances assumed	.131	.717	.176	420	.861	.00351	.01996	-.03574	.04275
	Equal variances not assumed			.176	417.513	.861	.00351	.01996	-.03574	.04275
RI HS	Equal variances assumed	1.034	.310	.869	420	.385	.00299	.00344	-.00377	.00974
	Equal variances not assumed			.869	391.306	.385	.00299	.00344	-.00377	.00974

*WT= Wall Thickness. *HS=Volunteer Healthy Subjects, *PI= Pulsatility Index, *RI = esistivity Index

The 5th to 95th percentile range of values for male and female volunteers were 0.85-1.93mm for the AA wall thickness, 0.51-0.70 for the resistivity index and 1.02-1.24 for the pulsatility index. There were no significant mean differences in both sexes on T-test. Although the AAWT diameter showed no significant differences between male and female healthy volunteers, male healthy volunteers had thicker AAWT diameters than their female counterparts. Similarly, carotid artery intima-media thickness has been reported to be thicker in healthy males than in healthy females as well [5]. The thicker AAWT in healthy males agrees with earlier findings that reported the abdominal aorta luminal diameter and wall thickness diameter to dilate for about 25-30% in healthy subjects especially in males [18] to compensate for wall stress built up in the abdominal aorta over time [19]. Similarly, the build-up of pressure, stress and strain in the abdominal aorta is associated with increased pressure and stiffness of the aorta which increases exponentially with age [20]. Increased wall stress has also been opined to activate the production of smooth muscle tissue components with an increase in the matrix and thickness of the wall of the abdominal aorta wall [21]. The present study found that both male and female healthy volunteers had an increase in abdominal aorta wall thickness (AAWT) from the age of 18 to 92. Additionally, the thickness of the abdominal aorta wall was generally greater in older individuals compared to adolescents and young adults. This is corroborated by the report that the ageing of the aorta is accompanied by loss of compliance and an increase of wall stiffness caused by structural changes including an increase in the collagen content and formation of initial atherosclerosis with calcium deposits resulting in increased wall thickness [19]. This is similar to the findings of Joh and colleagues (2013) [20] wherein they found that the diameter of the abdominal aorta increased with age, and the increase was about 70% in healthy subjects above 71 years of age. Age is therefore an important factor to consider in the assessment of subclinical atherosclerosis in elderly subjects. There were differences in the AAWT especially within and across the five age groups between 18 years and 47 years. These differences in the AAWT diameter in these age groups were attributed to dietary, hormonal and active lifestyles in adolescent and young adult age groups. The mean value of the AAWT in the current study was different from the findings of Koc and Sumbul (2018) [22] in a related study in Turkey. The researchers measured the intima-media thicknesses of the abdominal aorta in 100 healthy subjects in a case-controlled study and found that the value (Mean ± SD) of the intima-media thickness of the AA in healthy subjects was 1.49 ± 0.75 which was slightly lower than the findings in the present study. The difference in measurements between the earlier study and the present study is attributed to differences in methodology as well as dietary and racial factors [23,24,25,26].

Furthermore, the values of the resistivity and pulsatility indices increased simultaneously with increasing age in male and female healthy volunteer subjects. Old age was associated with thicker abdominal aorta diameter and higher resistivity and pulsatility indices. A close analysis of the mean values of the WT, RI and PI in the volunteer healthy subjects showed different values for both volunteer male and female healthy subjects. Further statistical analysis showed that the pulsatility and resistivity indices did not show any statistically significant differences in both healthy male and female subjects on T-test. This shows that both healthy male and female volunteers are equally affected by intrinsic factors that initiate variations in wall thickness, resistivity index and pulsatility index of the abdominal aorta.

Conclusion

The reference AAWT, RI and PI in the locality were 1.51 ± 0.33mm, 0.6 ± 0.06 and 1.02 ± 0.19. The RI, PI and AAWT ($P>0.005$) values were higher in healthy males than in healthy females. Ultrasound evaluation of the abdominal aorta wall thickness can provide an alternative low-cost assessment of subclinical atherosclerosis in individuals at high risk of cardiovascular disorders.

Acknowledgements

We acknowledge the staff and management of Medic Aid Radiology Abuja especially the staff of the laboratory and radiology departments for the opportunity and support to carry out this research work.

References

1. **Komutrattananont P, Mahakkanukrauh P, Das S**. Morphology of the human aorta and age-related changes: anatomical facts. *Anat Cell Biol*. 2019 Jun;52(2):109-114. Doi: 10.5115/acb.2019.52.2.109.
2. **Tucker WD, Arora Y, Mahajan K**. Anatomy, Blood Vessels. [Updated 2022 Aug 8]. In: StatPearls [Internet]. Treasure Island (FL): *StatPearls Publishing;* 2023 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK470401/
3. **Skilton RM, Celemaja SD, Cosmi E, Crisspi F, Gidding SS, Raitakari TO, Urbina ME.** Natural History of Atherosclerosis and Abdominal Aortic Intima-Media Thickness: Rationale, Evidence, and Best Practice for Detection of Atherosclerosis in the Young**.** *Journal of Clinical Medicine. 2019; 8*(8): 1201.
4. **Okpaleke MS, Ikamaise VC, Ogolodom MP, Agbo J, Mbaba AN, Egwuanumku K, Egbeyemi OO, Eja Egwu UN**. Sonographic reference luminal diameter of the abdominal aorta among subjects in Nigeria. *Health Science Journal*. 2020; 2(5): 1-5.
5. **Onwuzu, SWI, Ugwu AC, Mbah GCE, Elo IS**. Measuring wall shear stress distribution in the carotid artery in an African population. Computational fluid dynamica versus ultrasound Doppler Vocimetry. *Radiography*.2020; 27(2): 581-588. Doi: 10.1016/j.radi.2020.11.018.
6. **Maroules CD, Rosero E, Ayers C, Peshock RM, Khera A**. Abdominal aortic atherosclerosis at MR imaging is associated with cardiovascular events: The Dallas heart study. *Radiology*. **2013**; 269: 84–91.
7. **Ike SO, Onyema CT.** Cardiovascular diseases in Nigeria; what has happened in the past 20 years. *Nigerian Journal of Cardiology*.2020; 17 (1):21-26.
8. **World Health Organisation.** Non-communicable Diseases. Country Profiles; 2018. Available from: http://www.who.int>nga_en. [Last accessed on 2019 Dec 30].
9. **Cismaru G, Serban T, Tirpe A**. Ultrasound Methods in the Evaluation of Atherosclerosis: From Pathophysiology to Clinic. *Biomedicines*. 2021 Apr 13;9(4):418. Doi: 10.3390/biomedicines9040418.
10. **Baber U, Mehran R, Sartori S, Schoos MM, Sillesen H, Muntendam P, Garcia MJ, Gregson J, Pocock S, Falk E, *et al*.** Prevalence, Impact, and Predictive Value of Detecting Subclinical Coronary and Carotid Atherosclerosis in Asymptomatic Adults. *Journal of American*. College of Cardiology. 2015; 65:1065–1074. Doi: 10.1016/j.jacc.2015.01.017.
11. ***Li J.C., Xu Z.H., Zhang Y.X. et al*.** Impact of atherosclerosis and age on Doppler sonographic parameters in the diagnosis of renal artery stenosis. *J Ultrasound Medicine*. 2012;31(5): 747–755. DOI: 10.7863/jum.2012.31.5.747.
12. **Rafati, Mehravar & Havaee, Elham & Moladoust, Hassan & Sehhati, Mohammadreza.** (2017). Appraisal of different ultrasonography indices in patients with carotid artery atherosclerosis. *EXCLI Journal*. 2017; 16:727-741.Doi: 10.17179/excli2017-232.
13. **Stergiou G, Palatini P, Asmar R, Sierra A, Myers M, Shennan A, Wang J, O'Brien E, Parati G**. Blood Pressure Measurement and Hypertension Diagnosis in the 2017 US Guidelines. *Hypertension*. 2018;71(6):963-965. https://doi.org/10.1161/HYPERTENSIONAHA.118.10853
14. **Liyanawaduge NP, Sooriyaarchchi A**. A method to calibrate steel length measuring tapes by mechanical comparison. *Sri Lankan Journal of Technology*.2022;3(01):1-7.http://ir.lib.seu.ac.lk/handle/123456789/6412
15. **Clebak KT, Dambro AB.** Hyperlipidemia: An Evidence-based Review of Current Guidelines. *Cureus*. 2020;12(3):e7326. doi: 10.7759/cureus.7326.

16. **American Diabetes Association.** Standard of medical care in Diabetes.*Journal of Clinical Diabetes*.2021;39(1):14-43. https://doi.org/10.2337/cd21-as01.
17. **Abe M., Akaishi T., Miki T**. Influence of renal function and demographic data on intrarenal Doppler ultrasonography.Plus One.2019 ;14(8), e0221244. https://doi.org/10.1371/journal.pone.0221244
18. **Astrand H, Sandgren T, Ahlgren AR, Lanne T.** Noninvasive ultrasound measurement of intima media thickness; implications for in vivo study of aortic wall stress. *Journal of vascular surgery*.2003;37:1270-6.
19. **Kozaburo H, Tomoyuki Y, Akira T, Kohji S**. Clinical assessment of arterial stiffness with cardio–ankle vascular index: theory and applications. *Journal of hypertension*.2015; 33 (9):1742-1757.
20. **Joh HJ, Hyung-Joon A, Park H**. Reference Diameter of the Abdominal Aorta and Iliac arteries in the Korean Population.*Yonsei Medical Journal*.2013; 54 (1): 48-54.
21. **Theruvath TP, Jones JA, Ikonomidis J S**. Matrix Metalloproteinases and Descending Aortic Aneurysms: Parity, Disparity, and Switch. *Journal of cardiac surgery*. 2012; 27 (1): 81-90.
22. **Koc AS, Sumbul HE**. Increased aortic intima-media thickness may be used to detect macrovascular complications in adult type II diabetes mellitus patients. *Cardiovasc Ultrasound.* 2018; 16:8. https://doi.org/10.1186/s12947-018-0127-x
23. **Adam DT, David LT, Levente L, Zsolt G, Kinga K, Viktor B.** Genetic and environmental effects on the abdominal aortic diameter development. *ArquivosBrasileirosCardiologica*. 2016; 106 (1): 13-17.
24. **Oguejiofor OC, Onwukwe CH, Odenigbo CU.** Dyslipidemia in Nigeria: Prevalence and pattern. *Annals of African Medicine*. 2012; 11:197-202. Available from: http://www.annalsafrmed.org/text.asp?
25. **Rosero BE, Peshock MR, Kheara A, Clagett P**. Sex, race, and age distributions of mean aortic wall thickness in a multi-ethnic population-based sample. *Journal of vascular surgery*. 2011; 53 (4): 950 – 957.
26. **Davis AE, Lewandowski, AJ, Holloway CJ, Ntusi NAB, Banerjee R, Nethononda R, Pitcher A, Francis JM, Myerson SJ, Leeson P, Donovan T, Neubauer S, Rider O.J**. Observational study of regional aortic size referenced to body size: production of a cardiovascular magnetic resonance nomogram. *Journal of Cardiovascular Magnetic Resonance. 2004;* 16(1):9. Doi:10.1186/1532-429X-16-9.