ORIGINAL ARTICLE

A RETROSPECTIVE STUDY OF THE VARIATIONS IN THE DIMENSION AND PREDICTION OF AORTIC ARCH IN SOME STATES IN SOUTH-SOUTH NIGERIA USING COMPUTED TOMOGRAPHY SCAN.

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ABSTRACT

BACKGROUND:

For decades, the arch of aorta has been an area of interest for many cardiothoracic surgeons, researchers in radiology and researchers in anatomical sciences. The increasing rate of pathologies and surgical complications involving the cardiovascular system has served to propel further research in developmental and adult anatomical features of the arch of aorta. The present study, set out to determine the anatomical variation in the dimension and prediction of aortic arch dimensions in some States in South-South Nigeria using computed tomography scan. Two hundred (200) retrospective tomographs from Computed tomography (CT) scans were used for data collection and the tomographs met all the inclusion criteria. 108 were males while 92 were females. With the use of DICOM software, images were reviewed accordingly and the branching patterns as well as positions were noted.

The ages ranged from 26 to 72years, with a mean age of 51.21 years, SEM of 0.85 and SD of 12.02. From the 200 subjects, the aortic length of age group 25-34years for females was 37.43±0.62, while males 39.91±0.00 at P<0.05 and diameter is 28.00±0.24 and 30.12±0.00 for females and males respectively. At ages 35 – 44years there was also an overwhelming variation existing in both sexes with the aortic arch length, diameter and thoracic antero-posterior diameter measuring 36.45±0.47 and 45.46±0.63; 27.15±1.19 and 37.94±0.99; 255.94±10.66 and 297.63±6.83 for females and males respectively. Again, the aortic arch length for ages ranging from 45-54 years was 36.78±0.80 and 43.73±1.32 for females and males respectively. Arch diameter for females was 25.45±1.74 and for males was 34.00±1.99. Their diameter was significantly different with females having 253.94±9.04 and male with value of 313.15±7.65 at P<0.05. Patients that fell within the age range of 55-64 years had high variations noted in the dimensions of their aortic arch and the length, interestingly the highest number of males fall in this age group. Age >65 years shows significant difference between both sexes and females in this age group is the least having just six (6). From the study, it has been unearthed that the aortic arch dimension increases with increase in age and males have higher values than females. Also, the aortic arch diameter and length can be predicted from the observed values for both males and females.

KEYWORDS: Aortic Arch, Computed Tomography, Variation, Dimension, Prediction Equation

INTRODUCTION

Knowledge of the diameters of the aortic arch both in infants and adults is essential towards improving surgical outcomes during cardiovascular surgeries.[1] The aorta represents a complex organ system which begins in the aortic ring adjacent to the aortic root with the origin of the two major coronary arteries, and ends at the iliac bifurcation. The subdivision into seven segments seems to be clinically important - the aortic root, the ascending aorta, the ascending aortic arch, the

vessel bearing arch, the aortic isthmus, the thoracic descending and abdominal aorta. The aorta as an organ can be regarded as a biological "windkessel", storing kinetic energy during systole which is delivered during diastole in order to maintain a relative constant mean aortic pressure. In particular, a high diastolic blood pressure is important for the coronary perfusion.[2]

The size of the aorta decreases with distance from the aortic valve in a tapering fashion. The normal diameter of the ascending aorta has been defined as <2.1 cm/m^2 and of the descending thoracic aorta as <1.6 cm/m^2. The normal diameter of the abdominal aorta is regarded to be less than 3.0 cm. The normal range has to be corrected for age and sex, as well as daily workload.[2,3]

During life the size of the aorta increases. The normal expansion rate is about 1–2 mm/year. It involves all segments which, during childhood and in young aduluthood, result in an increase of the luminal diameter of the entire aorta. In adulthood, the aortic size is related to exercise and workload. The ageing of the aorta is accompanied by a loss of compliance and an increase of wall stiffness caused by structural changes including an increase in the collagen content and formation of intimal atherosclerosis with calcium deposits.[2-5]

In recent years, several researchers have sought to decipher the accurate dimensions of this great vessel of clinical importance. Rylski *et al.*[6] investigated gender-related changes in aortic geometry throughout life, using contrast-enhanced computed tomography scans of all aortic segments in 195 subjects (94 women, 101 men, average age 57 ± 20 years).

Wolak, et al,[8] undertook a study to determine normal limits for ascending and descending thoracic aorta diameters in a large population of asymptomatic, low-risk adult subjects and their final analysis revealed 33 ± 4mm and 24 ± 3mm respectively. Bernadi and Dettori[9] discovered that anomalous origins, dimensions and the distribution of the large aortic arch vessels can cause changes in cerebral haemodynamics that may consequently lead to cerebral anomalies.

METHODOLOGY

Site of study: The study was carried out in some South-South States in Nigeria. Cross River State (Asiukpo Diagnostics, Calabar), Akwa Ibom State (Image diagnostics, Uyo) and Rivers State (Image diagnostics, Intercontinental diagnostics and Zitadel Medical and Diagnostics limited, Potharcourt) were used.

Study population: The study population consisted of patients of both genders, aged ≥18 years referred for chest CT scan within centres with CT-scan machine in South-South Nigeria. The images obtained from their database were reviewed and analysed accordingly. Being retrospective, the need for informed consent was waived and the ethical clearance approved by the state ministry of health committee was sufficient.

Ethical clearance: Ethical clearance was obtained from Cross River State ministry of Health Calabar, with reference number: CRSMOH/RP/REC/2018/902. The institutional diagnostic center's requirements and guidelines were met.

Sampling techniques: Tomographs corresponding to the sample size of 200 subjects were collected and carefully observed and analysed with the variations noted within the computer. Some tomographs were discarded using the exclusion criteria.

Study design: A retrospective study of 200 apparently normal CT images of the chest of subjects acquired from the CT scanner was used, with the different variants noted. Images obtained were analysed by the radiologist using the DICOM software and adequately representing both genders. This study lasted for a period of six (6) months only.

Exclusion criteria: Paediatric cases aged ≤17 years were excluded from the study. CT images (tomographs) with request forms or reports indicating conditions such as aneurysms, aortitis, aortic coarctation, aortic stenosis, atherosclerosis, Ehlers-danlos syndrome, Marfan syndrome, Kyphosis, Scoliosis and Lordosis were not used. Cases with history of chest trauma were also excluded from the study. In addition, blurred images were excluded from the study.

Statistical analysis: Data obtained were reported as tables, and bar charts, frequencies and graphs. Data

were expressed using the elements of descriptive statistics. Statistical tools such as the one-way Analysis of Variance (ANOVA) and post hoc (LSD). In addition, correlation and linear regression analysis were used. Analysis of results and findings were done with the use of Statistical Package for Social Sciences (SPSS) version 20.

RESULTS

There were 200 chest CT images of which males are 108 (54%) and females 92 (46%), making up 100% of the subjects. Their ages ranged from 18 to 70 years extending across both sexes.

Table I: Comparison of aortic arch and thoracic dimensions between male and female subjects of different age groups

Age group (year)	Subject	N	Length of arch (mm)	Diameter of arch (mm)	Thoracic anteroposterior diameter (mm)
25-34	Female	17	37.43 ±0.62	28.00 ±0.24	248.62 ±8.97
	Male	2	39.91 ± 0.00*	30.12 ±0.00*	250.57 ±0.00^{ns}
35-44	Female	22	36.45 ±0.47	27.15 ±1.19	255.96 ±10.66
	Male	20	45.46 ±0.63*	37.94 ±0.99*	297.63 ±6.83*
45-54	Female	24	36.78 ±0.80	25.45 ±1.74	253.94 ±9.04
	Male	18	43.73 ±1.32*	34.20 ±1.99*	313.15 ±7.65*
55-64	Female	23	40.87 ±0.86	31.15 ±1.45	286.8 ±8.42
	Male	40	48.01 ±0.68*	41.61 ±1.48*	344.91 ±5.30*
65>	Female	6	46.83 ±0.55	36.28 ±0.80	294.14 ±2.73
	Male	28	48.61 ±0.63*	41.60 ±2.01*	314.55 ±7.52*

*Values are expressed as mean ±SEM, * = significantly different from female subjects at p<0.05, ns = not significantly different from female subject at p<0.05*

The aortic length of age group 25-34years for females was 37.43±0.62, while males 39.91±0.00 at P<0.05. The diameter of arch at the same age range is 28.00±0.24 and 30.12±0.00 for females and males respectively. The males in this group happen to be the least. At age 35 – 44years there was also an overwhelming variation existing in both sexes with arch of length of 36.45±0.47 (females) and 45.46±0.63 (males). For the diameter of aortic arch females had 27.15±1.19 while males had 37.94±0.99 with thoracic anterior posterior diameter of 255.94±10.66 and 297.63±6.83 for females and males respectively. Again, the aortic arch length for ages ranging from 45-54years was 36.78±0.80 and 43.73±1.32 for females and males respectively. Arch diameter for females was 25.45±1.74 and for males was 34.00±1.99. Their diameter was significantly different with females having 253.94±9.04 and male with value of 313.15±7.65 at P<0.05. Patients that fall within the age range of 55-64years had high variations existing in both sexes in their length of arch, diameter of arch and anterior posterior diameter (Table 1). Interestingly the highest number of males fall in this age group. Age >65years shows significant difference between both sexes and females in this age group is the least having just 6 in the group.

Table II: Aortic arch and thoracic dimensions of the overall subjects

Parameters	N	Minimum	Maximum	Mean	SEM	SD
Age (year)	200	26.00	72.00	51.21	0.85	12.02
Length of arch (mm)	200	29.11	55.02	43.00	0.43	6.05
Diameter of arch (mm)	200	10.12	58.10	34.41	0.70	9.85
Thoracic antero-posterior diameter (mm)	200	202.98	396.50	295.04	3.58	50.64

The dimensions of the aortic arch and thoracic diameter of the overall subjects of study as well as their ages are represented in the above table (Table 2). The minimum and maximum ages being 26 and 72 years respectively and a mean age of 51.21, SEM of 0.85 and SD of 12.02. The length of aortic arch has its minimum to be 29.11mm and maximum of 55.02mm with a mean of 43.00, SEM of 0.43 and SD of 6.05. The diameter of aortic arch shows minimum and maximum values of 10.12 and 58.10 respectively. Mean, SEM and SD is 34.41, 0.70 and 9.85 respectively. The thoracic

anteroposterior diameter has minimum and maximum of 202.98 and 396.50 respectively. The mean is 295.04, SEM is 3.85 and SD is 50.64.

Table III:
Comparison of aortic arch dimensions and thoracic dimensions between male and female subjects

Parameters	Male (n = 108)	Female (n = 92)	t-value	p-value
Age (year)	54.88 ±1.04	46.89 ±1.25	4.952	<0.05
Length arch (mm)	46.83 ±0.43	38.50 ±0.45	13.327	<0.05
Diameter of arch (mm)	39.48 ±0.89	28.46 ±0.71	9.481	<0.05
Thoracic anteroposterior diameter (mm)	321.24 ±3.8	44.59 ±4.65	9.563	<0.05

Prediction equations for Aortic dimensions

Table IV:
Prediction equations for length of aortic arch using age and thoracic anteroposterior diameter in male and female subjects

Subject	Prediction equation
Male	Arch length = 29.033 + (0.163 x age) + (0.028 x thoracic anteroposterior diameter)
Female	Arch length = 20.600 + (0.103 x age) + (0.049 x thoracic anteroposterior diameter)

Table V:
Prediction equations for diameter of aortic arch using age and thoracic anteroposterior diameter in male and female subjects

Subject	Prediction equation
Male	Arch diameter = -11.994 + (0.099 x age) + (0.143 x thoracic anteroposterior diameter)
Female	Arch diameter = 4.950 + (0.038 x age) + (0.082 x thoracic anteroposterior diameter)

Comparison of observed values with the predicted values.

Table VI:
Comparison of mean values of observed and predicted lengths and diameters of aortic arch of female subjects

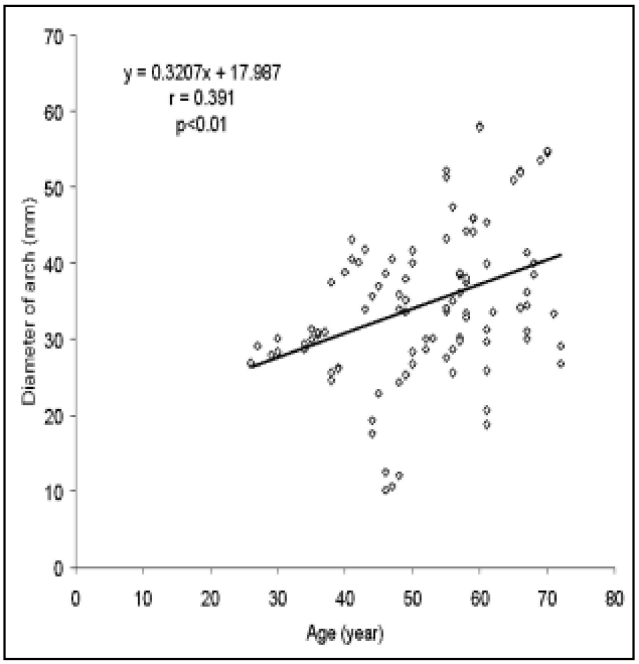
	Observed mean	Predicted mean	p-value
Length of aortic arch (mm)	38.50±0.45	38.38 ±0.30	0.721
Diameter of aortic arch (mm)	28.46±0.71	28.40 ±0.40	0.925

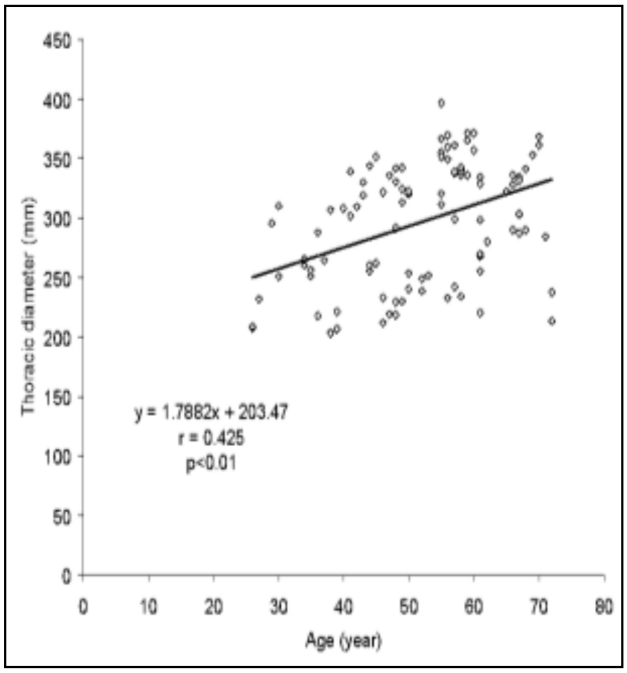
Values are expressed as mean ±SEM, n = 92

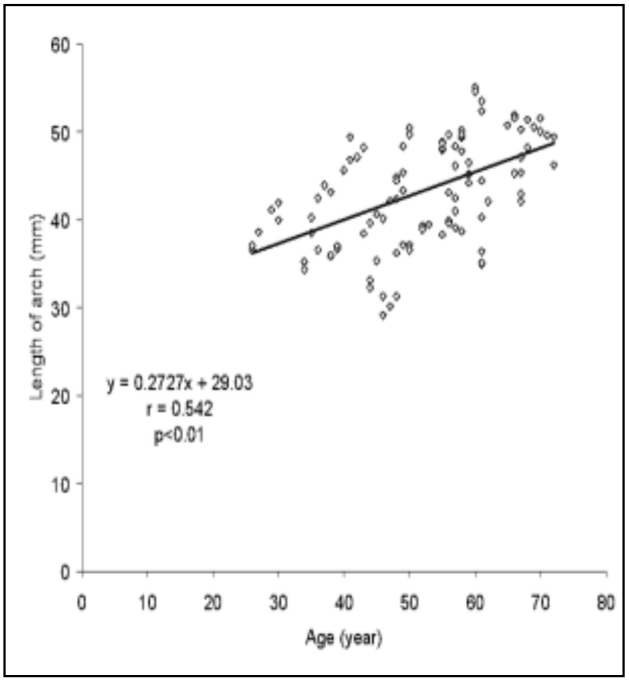
Table VII:
Comparison of mean values of observed and predicted lengths and diameters of aortic arch of male subjects

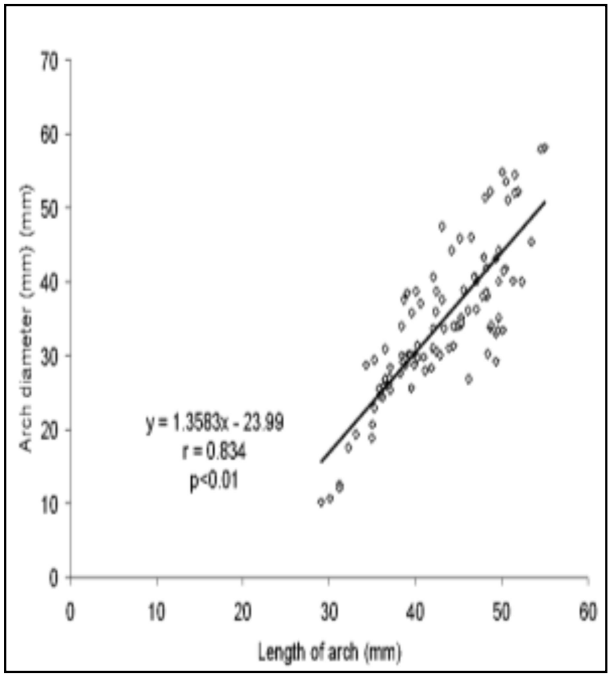
	Observed mean	Predicted mean	p-value
Length of aortic arch (mm)	46.83±0.43	46.97 ±0.22	0.692
Diameter of aortic arch (mm)	39.48±0.89	39.38 ±0.58	0.880

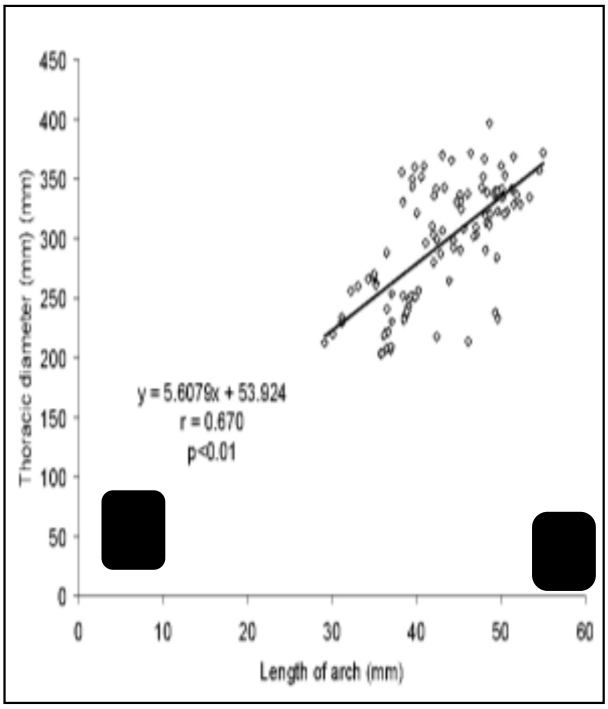
Values are expressed as mean ±SEM, n = 108

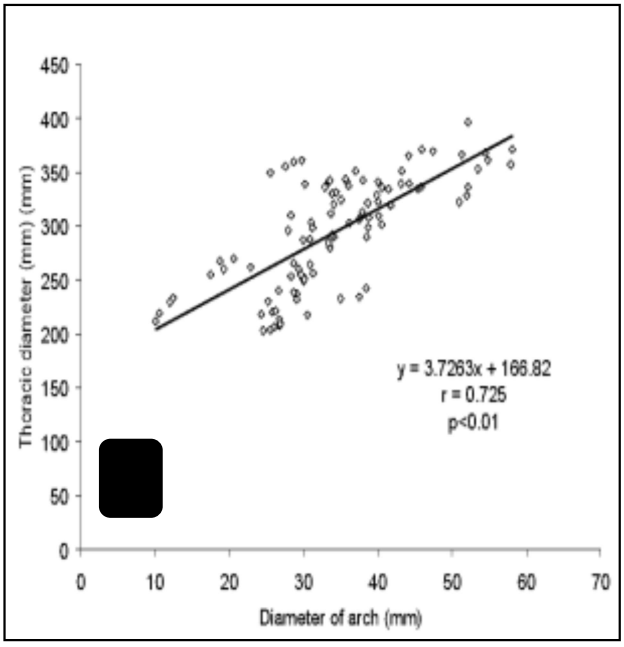

y = 0.3207x + 17.987
r = 0.391
p<0.01
Diameter of arch (mm)
Age (year)


y = 1.7882x + 203.47
r = 0.425
p<0.01
Thoracic diameter (mm)
Age (year)


y = 0.2727x + 29.03
r = 0.542
p<0.01
Length of arch (mm)
Age (year)


y = 1.3583x - 23.99
r = 0.834
p<0.01
Arch diameter (mm) (mm)
Length of arch (mm)





Linear regression graphs showing (A) Relationship between age and diameter of Aortic arch in the general population (B) Relationship between age and length of Aortic in the general population (C) Relationship between age and thoracic anterior-posterior diameter in the general population (D) Relationship between age and thoracic arc diameter in the overall subjects (E) Relationship between length of aortic arch and thoracic anterior-posterior diameter (F)) Relationship between diameter of aortic arch and anterior-posterior diameter in the over all subjects

DISCUSSION

This study assessed the anatomical variation in dimensions and deduced a prediction equation for calculation of aortic arch using computed tomography in some South-South States in Nigeria.

The distribution of result shows an increase in aortic arch parameters in relation to increase in age. This is similar to the findings of Rylski *et al.*[6] in Pennsylvanian university; they substantiated that the dimensions of all aortic segments significantly increased with each decade of life. Total aortic length increased at a rate of 0.98 ± 0.07 cm/10 years (P <0.001), diameter increase rates ranged between 0.06 and 0.11 cm/10 years.

The mean values of all measured dimensions were higher in male subjects than in the females with a significant difference (P <0.001) found in the thoracic anteroposterior diameter. Again, this shows similarities with same studies carried by Rylski *et al.*[6] that the aortic diameters and lengths were greater in men than women at all segments (P < 0.001) with the averaged gender-related absolute diameter difference ranging between 0.2 and 0.3 cm. Furthermore, previous investigations on the relationship between aortic diameter and gender generally showed that male gender is associated with a larger aortic diameter.[6,7,9,10] Similarly, another study[11] that explored relationship among gender, body size, neck size and the common carotid and internal carotid arteries. Patients showed that sex significantly influenced the diameter after correlation of body size, neck size, age and blood pressure with women having smaller carotid artery which further explains the gender gap in natural history and treatment of carotid artery disease. These further buttresses the findings of this study where males had larger arterial dimensions.

Using regression analysis, prediction equations were derived for predicting the aortic arch length and diameter, using age and thoracic anteroposterior diameter as constants for male and female subjects. This was to provide ease of determining aortic arch length without painstakingly taking measurements of these values.

The T-test was used to predict values using the measured data in both males and females, and findings suggested that there was no significant difference between the measured data and the predicted values in aortic arch length and diameter for both sexes. This however, have not been documented or published by any author in Nigeria hence serve as a virgin documentation to predict aortic arch length and diameter. This will also serve as a guide for future researchers to elaborate on aortic dimensions.

This study reveals that the aortic arch dimension increases with increase in age and they have significantly higher values in males than in females. Also, with the use of prediction equations the aortic arch diameter and length can be feasibly predicted from the measured values for both males and females.

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