Original Research Article

Normal Aortic Diameter on Multi Detector Computed Tomography In Nepalese Population Of Eastern Nepal

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Abstract

The aortic diameter was measured from the intima to intima and from adventitia to adventitia, perpendicular to the axis of rotation of the aorta in straight anterior- posterior [sagittal] and transverse [coronal] planes. Wherever possible, magnified images were used for measurement to reduce operator errors. The diameters of aorta were measured with the help of electronic caliper. The arithmetic mean of antero- posterior and transverse diameter of aorta were calculated at different levels and the values were recorded in the structured proforma for both inner and outer diameter separately. A total of 1204 patients were included in the study out of which 601 patients underwent thoracic CT scan and 603 underwent abdominal CT scan. The mean inner and outer diameter of thoracic aorta was measured in 601 patients at 3 different aortic levels viz. ascending aorta, arch of aorta and descending aorta. Similarly the mean inner and outer aortic diameter of abdominal aorta was measured in another group of 603 patients at 3 different levels viz. suprarenal, infrarenal and aortic bifurcation level. Radiological imaging play important role in diagnosis, treatment and follow up of patient with various aortic diseases such as aortic dissection, stenosis or aneurysm formation; of which preferably aortic aneurysm is a common potentially lethal but treatable disease, particularly if detected before dissection or rupture. The data generated from the present study concludes that both inner and outer diameters of ascending aorta, arch of aorta, descending aorta, suprarenal aorta, infrarenal aorta and aortic bifurcation significantly increased with increase in the age of the patient. Average inner and outer aortic diameters of ascending aorta, arch of aorta, descending aorta, suprarenal aorta, infrarenal aorta and aortic bifurcation were significantly larger in male as compared to female. Mongolian had larger aortic diameter compared to Aryan which is statistically significant. There was positive correlation of both inner and outer aortic diameters with BMI at ascending aorta, arch of aorta, descending aorta and aortic bifurcation levels which was statistically significant. However there was no significant correlation of aortic diameters with BMI at suprarenal and infrarenal aortic levels.

Keywords: Aortic Diameter, Multi Detector Computed Tomography, Nepalese Population, Eastern Nepal, etc.

Introduction

The aorta is the largest artery in the human body, originating from the left ventricle of the heart and extending down to the abdomen, where it divides into two common iliac arteries.[1] The aorta is divided into four sections i.e. ascending aorta, aortic arch, descending thoracic aorta and abdominal aorta.

The aorta is an elastic artery and as such is quite distensible. The vascular wall of aorta like other arteries consists of three layers: the tunica adventitia, tunica media and tunica intima and consist of heterogeneous mixture of smooth muscle, nerves, endothelial cells, fibroblast like cells and complex extracellular matrix. The middle layer of aorta, the tunica media is the fundamental unit of the aorta which is the elastic lamella consisting the smooth muscle and elastic matrix. This layer of the aorta consists of concentric musculo-elastic layers. The smooth muscle component does not dramatically alter the diameter of the aorta but rather serves to increase the stiffness and visco-elasticity of the aortic wall when activated.[2]

With the age aortic wall structure changes, the characteristic feature of aging in the aorta is thickening and atherosclerosis of the intima, along with cystic necrosis, elastin fragmentation, fibrosis and medio-necrosis of the media and fibrosis in adventitia. These changes of aortic aging decrease aortic elasticity [distensibility], which is represented by arterial pulse pressure widening. As a result, the aging process may set up a cycle of events with greater pulse pressure causing more aortic damage and further widening of the pulse pressure.[3] Previous works have reported that male gender is associated with a larger aortic diameter, which is partially related to larger body size in men.[4] Race is also important contributor in the determination of aortic diameter. In few study, it is possible that intrinsic factors within the aortic wall, such as increased fibrosis or crosslinking of extracellular matrix, could be mediating the reduced aortic distensibility leading to increased aortic stiffness and potentially prevention of aortic dilatation in African Americans men compared to their Caucasian counterparts.[5,6,7,8]

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Various pathologies and disease conditions that can cause damage to the aorta include atherosclerotic stenosis & occlusions, aortic dissection, aortic aneurysm, coarctation of the aorta inflammatory disease like Takayasu or Horton disease, hypertension, genetic conditions such as Marfan Syndrome, connective tissue disorders such as Ehler-Danlos disorder, polychondritis, scleroderma, osteogenesis imperfecta, polycystic kidney disease and Turners Syndrome.[9] Tumors also affect the aorta. Benign tumors include endothelial papillary fibro-elastomas arising in the aortic sinuses and intra-aortic myxomas. Malignant tumors of aorta are the sarcomas arising from intimal cells, angio-sarcomas or leimyo-sarcomas, malignant hemangio- endothelioma, schwannoma and fibrous histiocytoma, have also been reported to arise in the great vessels.[10]

The presence of abnormal dilatation of the thoracic aorta posses the risk of wall rupture. An aortic aneurysm represents a permanent dilatation of the aortic wall. This risk is greater with larger aneurysm diameter, advanced age, smoking, and coexistent chronic obstructive pulmonary disease [COPD].[11] In the ascending aorta, a diameter larger than 4 cm is regarded as an aneurysm. In the descending aorta, an aneurysm is present when the luminal diameter exceeds 3 cm.[12] In a true aneurysm, all of the components of the vessel wall [intima, media and adventitia] are present, whereas a false aneurysm [e.g., posttraumatic aneurysm] has an incomplete wall. The shape of the aneurysm may be fusiform [involve the entire circumference of the aortic wall] or saccular [involve only a portion of the wall]. Aneurysm rupture is most likely when aortic diameter exceeds 5 cm and most ruptured aneurysms are greater than 6 cm in diameter. In addition, thoracic aneurysms have been shown to grow at faster rates than their abdominal counterparts, for which close surveillance is recommended.[13]

In the United States, Abdominal aortic aneurysms [AAAs] are mostly to the result of atherosclerosis. Infectious [mycotic, syphilitic], inflammatory [e.g.Takayasu arteritis], congenital [e.g., Marfan syndrome], or traumatic causes are uncommon. The vast majority of AAAs are infrarenal in location. The applied pressure load in this location is greater because of the tapering geometry of the aorta and reflected pressure waves from the aortic bifurcation.[14] Following LaPlace's law, in which wall tension increases geometrically with radius, larger aneurysms tend to grow at a more rapid rate than smaller ones. In one study, the annual growth rates for abdominal aortic aneurysms is less than 4 cm, between 4 and 5 cm, and greater than 5 cm in diameter were 5.3 mm, 6.9 mm, and 7.4 mm, respectively. Similarly, the incidence of rupture varies directly with the size of the aneurysm. Whereas the incidence of rupture is negligible for aneurysms less than 3.9 cm in diameter, the risk exceeds 20% annually for aneurysms larger than 5 cm in diameter.[15]

It is important to note that, for a given diameter, the risk of rupture is four times higher in women than in men, perhaps reflecting the generally smaller initial diameter of the aorta in women. Hence, the threshold for intervention in women should be somewhat lower than for men.[16,17] Accepted indications for repair of AAAs include size greater than 5 to 5.5 cm, rapid rate of aneurysm expansion [increase of 5 mm or more in 6 months], known mycotic aneurysm, pain, concomitant occlusive disease, iliac or femoral artery aneurysms, and peripheral emboli.[16, 18, 19] In general, the abdominal aorta is considered aneurysmally dilated if it exceeds 3 to 3.5 cm in maximal diameter or if the infrarenal aorta is at least 5 mm larger than the renal aorta or if a localized dilation of the aorta is present.[20,21] Hence management decisions often depend strongly on the comparison of measured aortic diameters with normal values.

Reference value of average diameters of aorta from Framingham heart study for men were 34.1 mm for ascending thoracic aorta, 25.8 mm for the descending thoracic aorta, 19.3 mm for the infra-renal aorta and 18.7 mm for lower abdominal aorta [just above the aortoiliac bifurcation]. For women, the average diameters were 31.9 mm for the ascending thoracic aorta, 23.1 mm for the descending thoracic aorta, 16.7 mm for the infra-renal aorta and 16 mm for lower abdominal aorta [just above the aortoiliac bifurcation].[22] Reference value of average aortic diameters in Korean study were 2.99 ± 0.57 cm at the ascending aorta, 2.54 ± 0.35 cm at the transverse aortic arch, 2.36 ± 0.35 cm at the proximal descending thoracic aorta [DTA], 2.23 ± 0.37 cm at the mid DTA, 2.17 ± 0.38 cm at the distal DTA, 2.16 ± 0.37 cm at the thoraco-abdominal junction, 2.10 ± 0.35 cm at the level of the celiac axis, 1.94 ± 0.36 cm at the suprarenal aorta, 1.58 ± 0.24 cm at the aortic bifurcation.[23] Different methods have been used to assess structural changes of aorta at various levels. Conventional radiography can give the diameter of aorta in antero-posterior on lateral projections, in the condition where calcification of both opposing aortic walls is present to outline the aorta, which is commonly seen in aortic aneurysm. A tortuous, calcified aorta may mimic an aortic aneurysm unless both walls can be seen clearly. Hence conventional radiography is not used in the evaluation of diameter of the aorta.[24]

Ultrasonography can be used to measure the diameter of abdominal aorta. However, in a patient who is obese or in whom the bowel is distended with gas, a complete examination of the aorta is technically not possible. Use of ultrasonography is very limited in thoracic aorta. In such instances, another cross-sectional imaging study [e.g. CT, MRI] should be performed.[25] Trans-esophageal echocardiography can also be used and is the method of choice to visualize the ascending and descending thoracic aorta in patients with aortic dissection or after thoracic trauma, whereas, the trans-oesophageal assessment of the aortic arch is limited. The limitations are that it requires a great deal of the physician‟s skill, is invassive and it is not possible in patients suffering from oesophageal stricture/tumours, also its use in abdominal aorta is limited.[26] Magnetic resonance imaging [MRI] can be also used to measure the diameter of aorta. The absence of iodinated contrast material and radiation are advantages of this modality. However, MRI is more sensitive to motion than CT because of longer scan time. In addition, it is more expensive and requires trained manpower for its operation.[27]

Conventional axial CT can also be used to visualize the thoracic aorta. Because only axial planes are available, the diameter of the aortic arch and sometimes that of the ascending aorta are difficult to measure correctly. After the introduction of multi-detector computed tomography [MDCT] in the late 1980s, imaging of the aorta soon became a routine procedure for evaluation of the aorta in patients with aortic dissection, stenosis or aneurysm formation. MDCT has evolved to be the mainstay of evaluation owing to its accuracy and reproducibility as well as its speed, uniform arterial enhancement, lack of motion artefacts, identification of branch of vessels, easy to use and less expensive as compared to MRI. Furthermore, MDCT has been increasingly used for the assessment of aortic involvement in adult patients with connective tissue disease or congenital aortic diseases such as coarctation to quantify an additional hypoplastic aortic arch or a dilated ascending aorta.[28]

In spite of the pivotal role of CT in aortic evaluation, only limited studies on measurements of the aorta have been published. To distinguish the normal from the enlarged aorta, it is necessary to standardize the values of „normal‟ aortic dimensions. But, to our knowledge, there are no reference data of MDCT regarding the physiologic range of aortic dimensions in literature in Nepalese population. Hence, this study was designed to obtain the normal aortic caliber in relation to age, sex, body mass index and different races in Nepalese population so that we can define various entities like hypoplastic aortic arch, stenosis /dilatation of aorta, aortic dissection or aneurysm formation so that it can be used for the management of diseases.

The present study was planned to determine aortic caliber [reference value] at various levels using multi- detector computed tomography [MDCT] in patient undergoing CT chest/abdomen for non-aortic and non-cardiac pathology. To establish the effect of age, sex, race and body mass index on aortic caliber in Nepalese population.

Methodology

The study was carried out on cross sectional prospective basis in the Department of Radiodiagnosis and Imaging, B. P Koirala Institute of Health Sciences, Dharan, Nepal over a period of one year [August 2014 to July 2015]. The study was approved by the Institutional Ethical Review Board [IERB], BPKIHS, Dharan. Taking into account the number of patients referred from various departments for CT examination of thorax and abdomen per year in the past in our institution, we had decided to include at least 600 cases for different aortic levels i.e. 600 cases of CT thorax for ascending aorta, arch of aorta and descending thoracic aorta and another group of 600 cases of CT abdomen for suprarenal aorta, infrarenal aorta and at the aortic bifurcation.

All patients of non-cardiac and non-aortic pathology referred for CT scan of chest and abdomen for evaluation of different diseases were included in the study. Patients were excluded if they had the following: signs or symptoms of cardiovascular disease, paraaortic disease or obvious aortic disease, such as aneurysm, thrombus or dissection, any other lesion [e.g thoracic or abdominal neoplasm] which were causing significant mass effect on aorta, obvious atherosclerotic plaque on CT scan. Informed consent was taken from all the patients. Detailed clinical history was taken, general and systemic examinations were done and findings were entered in structured proforma.

The diameter of thoracic aorta was measured at the following 3 different anatomic levels: Ascending & descending thoracic aorta [at the level of pulmonary artery bifurcation] and transverse aortic arch [between the origin of brachiocephalic trunk and left common carotid artery]. Similarly diameter of abdominal aorta was measured at 3 different anatomic levels: suprarenal aorta [just above the orifices of the renal arteries], infrarenal aorta [just below the orifices of the renal arteries] and at the aortic bifurcation. The axial, multi-planer reconstruction [MPR] and curved planner reconstructions [CPR] CT images of the mediastinum/ abdomen were used for measurement of aortic diameter.

The aortic diameter was measured from the intima to intima and from adventitia to adventitia, perpendicular to the axis of rotation of the aorta in straight anterior- posterior [sagittal] and transverse [coronal] planes. Wherever possible, magnified images were used for measurement to reduce operator errors. The diameters of aorta were measured with the help of electronic caliper. The arithmetic mean of antero- posterior and transverse diameter of aorta were calculated at different levels and the values were recorded in the structured proforma for both inner and outer diameter separately.

Results & Discussion:

A total of 1204 patients were included in the study out of which 601 patients underwent thoracic CT scan and 603 underwent abdominal CT scan. The mean inner and outer diameter of thoracic aorta was measured in 601 patients at 3 different aortic levels viz. ascending aorta, arch of aorta and descending aorta. Similarly the mean inner and outer aortic diameter of abdominal aorta was measured in another group of 603 patients at 3 different levels viz. suprarenal, infrarenal and aortic bifurcation level. Radiological imaging play important role in diagnosis, treatment and follow up of patient with various aortic diseases such as aortic dissection, stenosis or aneurysm formation; of which preferably aortic aneurysm is a common potentially lethal but treatable disease, particularly if detected before dissection or rupture.

The study was carried out on cross sectional prospective basis in the Department of Radiodiagnosis and Imaging, B. P Koirala Institute of Health Sciences over a period of one year to determine the reference value of aortic diameter at various levels using multi-detector computed tomography [MDCT] and to establish the effect of age, sex, race and body mass index on aortic caliber in Nepalese population of eastern Nepal.

Table 1: Demographic Details

	Patients who underwent thoracic CT			**Patients who underwent abdominal CT**		
Demographic Data	**Male [n=302]**	**Female [n=299]**	**Total [n=601]]**	**Male [n=328]**	**Female [n=275]**	**Total [n=603]**
Age [Years] / Range	58.44±17.19 [21-92]	53.11±19.37 [21-95]	55.79±18.48 [21-95]	48.94±16.78 [21-84]	45.43±17.25 [21-85]	47.33±17.08 [21-85]
Weight [Kg] / Range	51.60±9.68 [36-79]	45.21±9.52 [25-65]	48.42±10.11 [25-79]	56.80±10.55 [35-85]	50.47±10.10 [29-75]	53.91±10.81 [29-85]
Height [cm] / Range	162.19±8.2 120-184]	151.25±7.41 [136-171]	156.75±9.53 [120-184]	163.76±6.27 [138-178]	151.85±6.17 [138-169]	158.33±8.60 [138-178]
BMI [kg/m^2] / Range	19.72±4.36 [12.17- 8.61]	19.77±4.07 [12.39-31.96]	19.75±4.22 [12.17-48.61]	21.27±3.72 [14.38-40.88]	22.04±4.46 [13.24-38.40]	21.62±4.19 [13.24-40.88]
BSA [ ] / Range	1.531±0.146 [1.29-2.02]	1.374±0.148 [1.03-1.70]	1.453±0.166 [1.03-2.02]	1.607±0.157 [1.17-1.97]	1.445±0.141 [1.13-1.75]	1.533±0.170 [1.13-1.97]

Table 2: Diameter of aorta at different levels

Aortic Level	**Inner diameter [mm]**	**Outer diameter [mm]**
Ascending aorta	30.70±4.44	33.83±4.81
Arch of aorta	26.57±3.60	29.54±3.89
Descending aorta	21.77±3.01	24.35±3.35
Suprarenal aorta	16.45±2.36	18.57±2.56
Infrarenal aorta	14.43±2.19	16.48±2.44
Aortic bifurcation	13.53±1.99	15.82±2.29

Table 3: Thoracic aorta of Patients who underwent thoracic CT

Aortic level	**Male [n=302]**	**Female [n=299]**	**Total [n=601]**	**p Value**
Inner diameter [intima-intima] of thoracic aorta				
Ascending aorta [mm]	31.65±4.46	29.75±4.22	30.70±4.44	<0.001
Arch of aorta [mm]	27.38±3.65	25.76±3.36	26.57±3.60	<0.001

Descending aorta [mm]	23.03±2.79	20.50±2.67	21.77±3.01	<0.001
Outer diameter [adventitia-adventitia]				
Ascending aorta [mm]	34.84±4.67	32.81±4.74	33.88±4.81	<0.001
Arch of aorta [mm]	30.48±3.88	28.58±3.66	29.54±3.89	<0.001
Descending aorta [mm]	25.79±3.09	22.88±2.94	24.35±3.35	<0.001

Table 4: Abdominal aorta of Patients who underwent abdominal CT

Aortic level	Male [n=328]	Female [n=275]	Total [n=603]	p Value
Inner diameter [Intima-Intima] of abdominal aorta				
Suprarenal aorta [mm]	17.28±2.21	15.46±2.15	16.45±2.36	<0.001
Infrarenal aorta [mm]	15.4±2.07	13.27±1.72	14.3±2.19	<0.001
Aortic bifurcation [mm]	14.22±1.85	12.71±1.84	13.53±1.99	<0.001
Outer diameter [adventitia-adventitia] of abdominal aorta				
Suprarenal aorta [mm]	19.44±2.43	17.53±2.33	18.57±2.56	<0.001
Infrarenal aorta [mm]	17.49±2.31	15.28±2	16.48±2.44	<0.001
Aortic bifurcation [mm]	16.61±2.22	14.87±1.99	15.82±2.29	<0.001

Table 5: Patients who underwent thoracic CT

Aortic level	Aryan [n=311]	Mongolian [n=290]	Total [n=601]	p Value
Inner diameter [intima-intima] of thoracic aorta				
Ascending aorta [mm]	29.14±3.91	32.09±4.57	30.70±4.44	<0.001
Arch of aorta [mm]	25.38±3.10	27.85±3.65	26.57±3.60	<0.001
Descending aorta [mm]	21.18±2.90	22.39±3.00	21.77±3.01	<0.001
Outer diameter [adventitia-adventitia] of thoracic aorta				
Ascending aorta [mm]	32.39±4.23	35.37±4.93	33.88±4.81	<0.001
Arch of aorta [mm]	28.28±3.43	30.88±3.90	29.54±3.89	<0.001
Descending aorta [mm]	23.76±3.35	24.97±3.24	24.35±3.35	<0.001

Table 6: Abdominal aorta Patients who underwent abdominal CT

Aortic level	Aryan [n=310]	Mongolian [n=293]	Total [n=603]	p Value
Inner diameter [intima-intima] of abdominal aorta				
Suprarenal aorta [mm]	16.26±2.57	16.65±2.10	16.45±2.36	<0.001
Infra-renal aorta [mm]	14.30±2.42	14.57±1.92	14.3±2.19	<0.001
Aortic bifurcation [mm]	13.21±2.09	13.87±1.81	13.53±1.99	<0.001
Outer diameter [adventitia-adventitia] of abdominal aorta				
Suprarenal aorta [mm]	18.34±2.75	18.81±2.34	18.57±2.56	<0.001
Infra-renal aorta [mm]	16.25±2.62	16.74±2.21	16.48±2.44	<0.001
Aortic bifurcation s[mm]	15.49±2.41	16.15±2.10	15.82±2.29	<0.001

In our study, age of the patients [n=601] who underwent CT scan of the thorax ranged from 21-95 years with mean age of 55.79±18.48 years and the age of the patients [n=603] who underwent CT scan of the abdomen ranged from 21-95 years with mean age of 47.33±17.08 years. In the study conducted by Hager et al [29] for diameters of thoracic aorta [intima-intima] on MDCT, among a total of 70 patients, the age of the patients ranged from 17 to 89 years with mean age of 50.2±16.5 years. Wolak et al [30] conducted study for normal reference value of ascending and descending aorta [adventitia-adventitia] in 2952 and 1931 patients respectively and the age of the patients ranged from 26-92 years and mean age was 55 ±10.2 years. Similarly in a study conducted by Lee et al [23] for determination of normal aortic diameters [adventitia-adventitia] in MDCT, among a total of 300 asymptomatic Korean adults, the age of the patients ranged from 21 to 80 years with mean age of 50.6±16.7 years. Age range and mean age of our study were similar to the studies conducted by Hager et al [29], Wolak et al [30] and Lee et al [23]. Our study was also comparable to various other studies such as Framingham heart study done by Rogers et al [22] for thoracic & abdominal aortic [adventitia-adventitia] diameters in which also mean age was 50±10.4 years.

In our study the mean inner diameter of ascending aorta, arch of aorta and descending aorta were 30.70±4.44, 26.57±3.60, 21.77±3.01 mm respectively. In the study conducted by Hager et al [29] mean thoracic aortic diameters [intima-intima] were 3.09. ± 0.41 cm at the ascending aorta, 2.94 ± 0.42 cm proximal to the innominate artery, 2.77 ± 0.37 cm at the proximal transverse arch, 2.61 ± 0.41 cm at the distal transverse arch and 2.47 ±0.40 cm at the isthmus, which is comparable to our study.

Similarly in our study, the mean outer diameter of ascending aorta, arch of aorta and descending aorta, were 33.83±4.81, 29.54±3.89, 24.35 ±3.35 mm respectively. The study is comparable to study done by Wolak et al [30], where the mean aortic diameters [adventitia-adventitia] were 33 ± 4 mm for the ascending and 24±3 mm for the descending thoracic aorta. Euathrongchit et al [31] conducted a similar type of study in Thai population to determine the normal size of the thoracic aorta and the reference value for mean outer aortic diameters were 3.12 cm at proximal ascending aorta, 2.95 cm at distal ascending aorta, 2.59 cm at mid arch, 2.33 cm at proximal descending aorta, 2.14 cm at distal descending aorta, and 2.03 cm at level of diaphragm which is also comparable to our study. However in our study we only did the measurement at the level of mid ascending, mid arch and proximal descending aorta.

In present study, the mean outer diameter of suprarenal aorta, infrarenal aorta and aortic bifurcation were 18.57±2.56, 16.48±2.44, 15.82±2.29 mm respectively which is similar to the study done by Lee et al [23] were they studied asymptomatic Korean population to determine the normal reference value of aortic diameter and in their study the normal reference value for the outer diameter of abdominal aorta were 19.4±3.6 mm at suprarenal aorta and 15.8±0.24 mm at aortic bifurcation levels.

Age-related arterial functional change is considered as an important independent factor of cardiovascular morbidity and mortality. As the aorta is subjected to constant pulsatile stress, so that the elastic components of the aortic media fragment and eventually break down to be partially replaced by mostly fibrotic non-elastic tissue. These histological processes lead to stiffening of the aortic wall and increased mean aortic blood pressure, and finally to transverse dilation of the aorta. Our study showed that age has significant influence on both thoracic and abdominal aortic diameters, and aortic diameters increases significantly with the age. Dixon et al [32] concluded that aortic dilatation was part of the natural aging process.

Hager et al [47] conducted a study to determine the normal diameter of thoracic aorta and establish the effect of age and they concluded that all diameters increased with age. Lee et al [23] in their study also concluded that age was significantly associated with large aortic diameters in asymptomatic Korean population. Wolak et al [29] conducted a similar type of study to determine the ascending and descending thoracic aortic diameters in asymptomatic low risk adult subject and in their study they found that age was directly associated with thoracic aortic dimensions. Rogers et al [22] also studied distribution, determinants and normal reference values of thoracic and abdominal aortic diameters by computed tomography [from the Framingham heart study] and they concluded that average diameters of the thoracic and abdominal aorta vary significantly with age. Jasper et al [33] studied the effect age on abdominal aortic diameters in Indian population using MDCT and concluded that there was a significant positive correlation between the age of the patient and the average aortic diameter in the supra and infrarenal aorta measured at T12 and L3 vertebral levels in both men and women.

In our study diameters of thoracic aorta increased about 1mm per decade in 21-70 years age groups for ascending & arch of aorta and for descending thoracic aorta in 21-50 years age groups. Aronberg et al [34], Hager A et al [29] and Lee et al [23], also studied the normal thoracic aortic diameters and showed that the thoracic aortic diameters increased about 1 mm per decade during adulthood. Age related changes could be the possible cause of increase in aortic diameter per decades. However this age related increase in aortic diameter per decade did not hold true for abdominal aorta in our study. This is also supported by study conducted by Pearce et al [35] and Benvenuti et al [36]. Pearce et al [34] discussed a multifactorial pathophysiologic factor affecting the diameter of aorta. The most important factors are plaque formation and elastin fragmentation by elastolytic enzymes without elastin formation, which ceases after the first few years of life. For the increasing diameters in the thoracic aorta, the elastic components might be more pronounced than in the abdominal aorta. In another study, Benvenuti et al [36] concluded that atherosclerosis in the thoracic segment of the aorta is closely associated with fat deposition within the plaques, resulting in positive remodelling of the vessel. On the other hand, in the abdominal segment, atherosclerosis may or may not be associated with fat deposition. In the case where atherosclerosis is associated with fat deposition, there would be positive remodelling of the vessel with arterial dilation, which could be related to the genesis of aneurysm; conversely, in the case where it is not associated with fat deposition, plaques would have more fibrosis and calcification, and the increased rigidity of the wall would prevent compensatory dilation, thus originating the obliterative form of the disease. These reasons could be possible cause of less increase in aortic diameter of abdominal aorta per decades and less abdominal aortic aneurysm in comparison to thoracic aorta.

Our study showed that mean diameters [inner and outer diameters] of thoracic aorta is decreased continuously from ascending aorta to descending aorta. Similarly the mean diameter [inner and outer diameters] of abdominal aorta is also decreased continuously from suprarenal aorta to aortic bifurcation level. Lee et al [23] also reported that aortic diameters decreased continuously from the ascending aorta to aortic bifurcation level. Euathrongchit et al [31] studied normal thoracic aortic diameter in Thai population on MDCT, to determine the normal size of the thoracic aorta and their result showed that in normal aortic configuration there is smooth tapering form aortic root to ascending to descending aorta.

The present study also showed that the both inner and outer diameter of thoracic & abdominal aorta were significantly higher in male in comparison to female. The higher aortic diameters at various levels in men compared to female could be due to larger body size in male. Hager et al [29] also concluded that men have slightly larger diameter of aorta than that of women. The reference value from their study were 3.20±0.42 cm for ascending aorta, 2.84±0.40 cm for proximal transverse arch and 2.55±0.39 cm for descending aorta [aortic isthmus] in men and 2.90±0.34 cm for ascending aorta, 2.65±0.27 cm for proximal transverse arch and 2.32±0.36 cm for descending aorta [aortic isthmus] in women and their results are comparable to our study. Lee at al [23] studied in 300 asymptomatic Korean populations for reference value of normal aortic diameter and they concluded that male sex was associated with larger aortic diameters. The reference values from their study were 3.06±0.58 cm for ascending aorta, 2.59±0.36 cm for aortic arch, 2.46±0.36 cm for proximal thoracic aorta, 2.04±0.31 cm for suprarenal and 1.68±0.22 cm for aortic bifurcation in men. The reference values from their study were 2.92±0.56 cm for ascending aorta, 2.49±0.35 cm for aortic arch, 2.27±0.31 cm for proximal thoracic aorta, 1.68±0.22 cm for suprarenal and 1.47±0.22 cm for aortic bifurcation in women. Rogers et al [22] conducted study for the reference value of average diameters [adventitia-adventitia] of thoracic and abdominal aorta [from the Framingham heart study] separately for men in 1767 participants and women in 1664 participants. In their study the normal reference value for average aortic diameters, for men were 34.1 mm for ascending thoracic aorta, 25.8 mm for the descending thoracic aorta, 19.3 mm for the infra-renal aorta and 18.7 mm for lower abdominal aorta [just above the aortoiliac bifurcation]. Similarly normal reference value for women, the average aortic diameters were 31.9 mm for the ascending thoracic aorta, 23.1 mm for the descending thoracic aorta, 16.7 mm for the infra-renal aorta and 16 mm for lower abdominal aorta [just above the aortoiliac bifurcation], the mean value of aortic diameters at various level which is comparable to the measurement of our study. In their conclusion average diameter of thoracic and abdominal aorta were larger in men compared with women and vary significantly with age and body surface area. Wanhainen et al [37] conducted similar type of study on MRI in 70 year old men and women to determine the optimal dividing line between normal aorta and aneurysm for different aortic segment and measured the mean aortic diameters. The mean outer diameter of ascending aorta, descending aorta, supraceliac aorta, suprarenal aorta, largest infrarenal abdominal aorta, and aortic bifurcation were more in males as compared to females [4.0 ±0.4 cm, 3.2 ±0.3 cm, 3.0 ±0.3 cm, 2.8 ±0.3 cm, 2.4 ±0.5 cm, and 2.3 ±0.3 cm in men and 3.4 ±0.4 cm, 2.8 ±0.3, 2.7 ±0.3 cm, 2.7 ±0.3 cm, 2.2 ±0.3 cm, and 2.0 ± 0.2 cm in females respectively]. Similarly Jasper et al [33] studied the reference value for normal diameters of abdominal aorta in Indian population and found that there was a significant difference in the average diameter of the aorta in men and women [$P < 0.001$]. The mean diameters of the suprarenal and infrarenal abdominal aorta measured at T12 and L3 vertebral levels, in men were 19.0 ± 2.3 mm & 13.8 ± 1.9 mm and in women 17.1 ± 2.3 mm & 12.0 ± 1.6 mm, respectively. Khashram et al [38] conducted study in New Zealand, to determine aortic diameters in individuals undergoing computed tomography colonography [CTC] for gastrointestinal symptoms. During a period of 4-year, CTC scans were performed in 4644 consecutive patients Canterbury in New Zealand. In their conclusion men had larger dimension in all measured aortic segments than women and reference values for median aortic diameters at the supraceliac, suprarenal, infrarenal, mid abdominal aorta, and aortic bifurcation were 2.67, 2.31, 2.09, 2.05, and 1.97 cm in men, and the corresponding values in women were 2.45, 2.06, 1.81, 1.73, and 1.65 cm. In our study also men had larger abdominal aortic diameter in comparison with female and mean abdominal aortic diameter for these age groups were comparable. Our study is also comparable to study done by Pearce et al [35] which showed that average diameters of the thoracic and abdominal aorta were larger in men compared with women.

Race is also important influencing factor in the determination of aortic diameter. Present study showed that race has significant effect on both inner and outer diameters of thoracic and abdominal aorta. The mean values of thoracic and abdominal aorta were significantly larger in Mongolians as compared to Aryans in our study. The larger aortic diameters at various levels in Mongolians in our study can be explained by larger body size [body surface area, body mass index, height and weight] in Mongolians than Aryans.

Chandra et al [8] conducted a study for inter-racial difference in frequency and aortic dimensions and concluded that African-American patients have lesser aortic dimension than Caucasian patients. In study conducted by Din-Dzietham et al [39] concluded that arterial stiffness is greater in African Americans than in whites, which cause less aortic distensibility and lesser aortic diameters. The possible cause of inter- racial variation of aortic diameter may be due to intrinsic factors within the aortic wall, such as increased fibrosis or crosslinking of extracellular matrix, could be mediating the reduced aortic distensibility leading to increased aortic stiffness and potentially prevention of aortic dilatation. [5,6]

Lee et al [23] reported that German people have a larger aortic diameter than Korean and explained that weight and height play an important role in explaining the differences of aortic diameter with almost same median age. Our study also showed that there was positive correlation of both inner and outer diameters of thoracic aorta [ascending aorta, arch of aorta and descending aorta] with BMI of the patients. Similarly, both inner & outer diameter of abdominal aorta at bifurcation level also showed positive correlation with BMI of the patients. In our study BMI also showed positive correlation with diameter of suprarenal and infrarenal aorta but it was not statistically significant. This could be probably due to small sample size on our study. Lederle et al [40] conducted similar type of study to assess the effects age, gender, race, and body size [BMI and BSA] on infrarenal aortic diameter [IAD] and to determine expected values for IAD on the basis of these factors. They performed their study in 69,905 subjects who had no previous history of abdominal aortic aneurysm in veterans aged groups of 50-79 years. According to their study, although body mass index and body surface area were associated with IAD by multivariate linear regression [all $p < 0.001$], the effects were small. They conclude that age, gender, race, and body size [BMI and BSA] have statistically significant but small effects on IAD. Davis et al [41] assessed normal diameters of the thoracic aorta measured by cardiovascular magnetic resonance imaging and their correlation with gender, body surface area and body mass index. In their conclusion the aortic diameters were larger in males than females at all levels measured of thoracic aorta. Across both genders, obesity, in the absence of traditional cardiovascular risk factors, was characterized by a minor degree of aortic dilatation and there were no significant gender differences in the degree of dilatation with increasing obesity. Jasper et al [33] studied variation of abdominal aortic diameters with age, sex, height weight, body mass index [BMI] and body surface area in the Indian population by using computed tomography. In their study infrarenal aortic diameters correlated positively with BMI in both men and women. Suprarenal aorta is significantly correlated with BMI in men however in women suprarenal aorta BMI show positive correlation with BMI but it was not statistically significant.

Conclusion

The data generated from the present study concludes that both inner and outer diameters of ascending aorta, arch of aorta, descending aorta, suprarenal aorta, infrarenal aorta and aortic bifurcation significantly increased with increase in the age of the patient. Average inner and outer aortic diameters of ascending aorta, arch of aorta, descending aorta, suprarenal aorta, infrarenal aorta and aortic bifurcation were significantly larger in male as compared to female. Mongolian had larger aortic diameter compared to Aryan which is statistically significant. There was positive correlation of both inner and outer aortic diameters with BMI at ascending aorta, arch of aorta, descending aorta and aortic bifurcation levels which was statistically significant. However there was no significant correlation of aortic diameters with BMI at suprarenal and infrarenal aortic levels.

References

1. Dagenais F. Anatomy of the thoracic aorta and of its branches. Thorac Surg Clin. 2011;21(2):219-27.
2. Shadwick RE. Mechanical design in arteries. J Exp Biol. 1999;202(Pt 23):3305-13.
3. Santelices LC, Rutman SJ, Prantil-Baun R, Vorp DA, Ahearn JM. Relative contributions of age and atherosclerosis to vascular stiffness. Clin Transl Sci. 2008;1(1):62-6.
4. Agmon Y, Khandheria BK, Meissner I, Schwartz GL, Sicks JD, Fought AJ et al. Is aortic dilatation an atherosclerosis-related process? Clinical, laboratory, and transesophageal echocardiographic correlates of thoracic aortic dimensions in the population with implications for thoracic aortic an eurysm formation. J Am Coll Cardiol 2003;17;42 (6):1076–83.
5. Malayeri AA, Natori S, Bahrami H, Bertoni AG, Kronmal R, Lima JA, et al. Relation of aortic wall thickness and distensibility to cardiovascular risk factors (from the Multi-Ethnic Study of Atherosclerosis [MESA]). Am J Cardiol. 2008 102(4):491–6.
6. Heffernan KS, Jae SY, Wilund KR, Woods JA, Fernhall B. Racial differences in central blood pressure and vascular function in young men. Am J Physiol Heart Circ Physiol. 2008; 295(6):H2380–7.
7. Din-Dzietham R, Couper D, Evans G, Arnett DK, Jones DW. Arterial stiffness is greater in African Americans than in whites: evidence from the Forsyth County, North Carolina, ARIC cohort. Am J Hypertens. 2004; 17(4):304–13.

8. Chandra S, Lang R, Nicolarsen J, Gayat E, Spencer KT, Mor-Avi V. Bicuspid Aortic Valve: Inter-racial difference in frequency and aortic dimensions: Impact of race in adult BAV in a single center retrospective observational study JACC Cardiovasc Imaging. 2012 ; 5(10): 981–989.
9. Tunick PA, Kronzon I. Atheromas of the thoracic aorta: clinical and therapeutic update. 2000;35(3):545-54.
10. Mader MT, Poulton TB, White RD. Malignant tumors of the heart and great vessels: MR imaging appearance. Radiographics. 1997;17(1):145-53.
11. Juvonen T, Ergin MA, Galla JD, Lansman SL, Nguyen KH, McCullough JN et al. Prospective study of the natural history of thoracic aortic aneurysms. Ann Thorac Surg 1997;63 (6):1533-1545.
12. Erbel R. Diseases of the thoracic aorta. Heart 2001;86 (2):227-234.
13. Gotway MB, Dawn SK. Thoracic aorta imaging with multislice CT. Radiol Clin North Am 2003;41(3):521-543.
14. Dobrin PB. Pathophysiology and pathogenesis of aortic aneurysms: current concepts. Surg Clin North Am 1989;69 (4):687-703.
15. Limet R, Sakalihassan N, Albert A. Determination of the expansion rate and incidence of rupture of abdominal aortic aneurysm. J Vasc Surg 1991;14 (4):540-548.
16. Brady AR, Brown LC, Fowkes FGR, Greenhalgh RM, Powell JT, Ruckley CV, et al. Long-term outcomes of immediate repair compared with surveillance of small abdominal aortic aneurysms. N Engl J Med 2002;346 (19):1445-1452.
17. Powell JT, Greenhalgh RM. Small abdominal aortic aneurysms. N Engl J Med 2003;348 (19):1895-1901.
18. Brown PM, Pattenden R, Gutelius JR. The selective management of small abdominal aortic aneurysms: the Kingston study. J Vasc Surg 1992;15 (1):21-27.
19. Siegel CL, Cohan RH. CT of abdominal aortic aneurysms. AJR Am J Roentgenol 1994;163 (1):17-29.
20. Horejs D, Gilbert PM, Burstein S, Vogelzang RL. Normal aortoiliac diameters by CT. J Comput Assist Tomogr 1988;12 (4):602-603.
21. Singh K, Bonaa KH, Jacobsen BK, Bjørk L, Solberg S. Prevalence of and risk factors for abdominal aortic aneurysms in a population-based study: the Tromso study. Am J Epidemiol 2001;154 (3):236-244.
22. Rogers IS, Massaro JM, Truong QA, Mahabadi AA, Kriegel MF, Fox CS, et al. Distribution, determinants, and normal reference values of thoracic and abdominal aortic diameters by computed tomography (from the Framingham Heart Study). Am J Cardiol. 2013;111(10):1510-6.
23. Lee SH, Lee W, Choi HJ, Kim DJ, Park EA, Chung JW et al. Measurement of the Aortic Diameter in the Asymptomatic Korean Population: Assessment with Multidetector CT. J Korean Soc Radiol. 2013;69(2):105-112.
24. Isselbacher EM. Thoracic and abdominal aortic aneurysms. Circulation. 2005;111(6):816-28.
25. Blasco A, Piazza A, Goicolea J, Hernandez C, Garcia-Montero C, Burgos R, et al. Intravascular ultrasound measurement of the aortic lumen. Rev Esp Cardiol. 2010;63(5):598-601.
26. Nair HC. Transesophageal echocardiaography evaluation of thoracic aorta. Ann Card Anaesth. 2010;13(2):186.
27. Rajiah P. CT and MRI in the Evaluation of Thoracic Aortic Diseases. Int J Vasc Med. 2013;2013:16.
28. Rubin GD. MDCT imaging of the aorta and peripheral vessels. Eur J Radiol. 2003;45 Suppl 1:S42-9.
29. Hager A, Kaemmerer H, Rapp-Bernhardt U, Blücher S, Rapp K, Bernhardt TM, et al. Diameters of the thoracic aorta throughout life as measured with helical computed tomography. J Thorac Cardiovasc Surg 2002;123:1060-1066.
30. Wolak A, Gransar H, Thomson LE, Friedman JD, Hachamovitch R, Gutstein A, et al. Aortic size assessment by noncontrast cardiac computed tomography: normal limits by age, gender, and body surface area. JACC Cardiovasc Imaging 2008;1:200-209.
31. Euathrongchit J, Deesuwan P, Kuanprasert S, Woragitpoopol S. Normal thoracic aortic diameter in Thai people by multidetector computed tomography. J Med Assoc Thai. 2009 ;92(2):236-42.
32. Dixon AK, Lawrence JP, Mitchell JR.Age-related changes in the abdominal aorta shown by computed tomography. Clin Radiol. 1984; 35(1):33-7.
33. Jasper A, Harshe G, Keshava SN, Kulkarni G, Stephen E, Agarwal S.Evaluation of normal abdominal aortic diameters in the Indian population using computed tomography. J Postgrad Med. 2014;60(1):57-60.
34. Aronberg DJ, Glazer HS, Madsen K, Sagel SS et al. Normal thoracic aortic diameters by computed tomography. J Comput Assist Tomogr. 1984 ;8(2):247-50.
35. Pearce WH, Slaughter MS, LeMaire S, Salyapongse AN, Feinglass J, McCarthy WJ, et al. Aortic diameter as a function of age, gender, and body surface area. Surgery. 1993;114:691-7.
36. Benvenuti LA, Onishi RY, Gutierrez PS, Higuchi M de L. Different patterns of atherosclerotic remodeling in the thoracic and abdominal aorta. Clinics. 2005;60(5):355-60.
37. Wanhainen A, Themudo R, Ahlström H, Lind L, Johansson L.Thoracic and abdominal aortic dimension in 70-year-old men and women--a population-based whole-body magnetic resonance imaging (MRI) study. J Vasc Surg. 2008 ;47(3):504-12.
38. Khashram M, Gupta A, Osman M,Jones G,Roake J. Evaluation of Aortic Diameters in a Population Undergoing CT Colonography: Prevalence and Effect on Survival. J Vasc Surg. 2015 ; 62 (2), 537.
39. Din-Dzietham R, Couper D, Evans G, Arnett DK, Jones DW. Arterial stiffness is greater in African Americans than in whites: evidence from the Forsyth County, North Carolina, ARIC cohort. Am J Hypertens. 2004 ;17(4):304–13.
40. Lederle FA, Johnson GR, Wilson SE, Gordon IL, Chute EP, Littooy FN, Krupski WC, Bandyk D, Barone GW, Graham LM, Hye RJ, Reinke DB.Relationship of age, gender, race, and body size to infrarenal aortic diameter. The Aneurysm Detection and Management (ADAM) Veterans Affairs Cooperative Study Investigators. J Vasc Surg. 1997 ;26(4):595-601.
41. Davis AE, Lewandowski AJ, Holloway CJ, Ntusi NA, Banerjee R, Nethononda R, Rider OJ1 Observational study of regional aortic size referenced to body size: production of a cardiovascular magnetic resonance nomogram. J Cardiovasc Magn Reson. 2014 ;16:9.

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