Measurement of the Aortic Diameter in the Asymptomatic Thai Population in Siriraj Hospital: Assessment with Multidetector CT

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ABSTRACT

Objective: The purpose of this study was to determine normal reference values of intra-thoracic and abdominal aortic diameters of asymptomatic Thai adults obtained by multidetector computed tomography. Secondary end points were evaluation of relationships between aortic diameters and patients' demographic data or potential risk factors of cardiovascular disease.
Methods: Three hundred and ten Thai adults in Siriraj Hospital who had no any signs or symptoms of cardiovascular disease that examined with computed tomography (CT) of chest and whole abdomen were investigated in this study. Aortic diameters were measured at eight predefined intra-thoracic and abdominal levels on CT images, including ascending aorta, proximal transverse aortic arch, distal transverse aortic arch, aortic isthmus, thoracoabdominal junction, celiac axis, suprarenal aorta and aortic bifurcation. Analysis of data was performed with regard to patients' demographic data (age, sex, weight, and height) and three potential risk factors of cardiovascular disease (hypertension, dyslipidemia and diabetes mellitus). Furthermore, we also recorded the co-morbid non-cardiovascular underlying diseases which were classified into seven groups, including tumors (malignant and benign tumors), infectious diseases, inflammatory diseases, autoimmune diseases, degenerative diseases, psychiatric diseases and others.
Results: Aortic diameters were 3.14±0.40 cm. at the ascending aorta, 2.88 ± 0.34 cm. at proximal transverse aortic arch, 2.65±0.30 cm. at distal transverse aortic arch, 2.46 ± 0.31cm. at aortic isthmus, 2.10± 0.27 cm. at thoracoabdominal junction, 1.99 ± 0.26 cm. at celiac axis, 1.81 ±0.25 cm. at suprarenal aorta, and 1.47±0.21 cm. at aortic bifurcation. Overall aortic diameters tend to continuously significantly decrease aortic diameters from proximal to distal direction from ascending aorta to aortic bifurcation. Men had slightly more enlarged aortic diameters in all eight predefined levels than women with statistical significance ($p<0.05$). Increasing age is an independent and the most influential predictor of increasing size of aortic diameter in all aortic levels. Furthermore, age was classified into three age groups; 18-50 years, 51-70 years and 71-94 years. There were significant differences of aortic diameter in all aortic levels, except two age groups which are 51-70 years and 71-90 years when considered at celiac trunk and aortic bifurcation levels. Aortic diameters increased as weight increased at only one aortic level which was aortic bifurcation, with statistical significance ($p<0.001$). Weight was an independent influential predictor of aortic diameter in various levels, which were 5-46 percentages of influent degree. All aortic diameters were not increased with underlying hypertension, dyslipidemia and diabetes mellitus.
Conclusion: This study delineates normal intra-thoracic and abdominal aortic diameters, including relationships with age and sex in asymptomatic Thai adults.

Keywords: Aortic diameter, measurement, multi-detector CT

Siriraj Med J 2016;68:247-256
E-journal: http://www.tci-thaijo.org/index.php/sirirajmedj

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Received 3 March 2016
Revised 7 April 2015
Accepted 19 April 2016

INTRODUCTION

An enlargement of the aortic diameter exceeding at least 50% of the normal range represents an ectasia, which results in aneurysm formation, when ectasia exceeds tolerance limits.[1] Nowadays, aortic aneurysm is a common, potentially lethal, but treatable disease, particularly if detected before dissection or rupture. Since the helical CT in the late 1980s, imaging of the aorta has become accepted and widely used as routine procedure for evaluate of patients with aortic dissection, stenosis, or aneurysm formation. Recently, the incidence of thoracic aortic aneurysms has been estimated to be increasing and there are around 10.4 cases per 100,000 person-years.[2] According to the American College of Cardiology Foundation/American Heart Association guidelines, for patients with isolated aortic arch aneurysms between 3.5-4.4 cm. in diameter, it is reasonable to reimage using computed tomographic imaging or magnetic resonance imaging at 12-month intervals to detect enlargement of the aneurysm. Also for patients with degenerative or traumatic aneurysms of the descending thoracic aorta exceeding 5.5 cm., saccular aneurysms, or postoperative pseudo-aneurysms, endovascular stent grafting should be considered when feasible.[3]

Accurate assessment of aortic size is a key component in the detection of aneurysms and in guiding therapeutic decisions. CT has evolved to be the mainstay of evaluation owing to its accuracy and reproducibility, as well as its speed, simplicity, and true 3-dimensional capabilities. In spite of the pivotal role of CT in aortic evaluation only limited 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. However, to our knowledge, no publication up until now has reported on these aortic measurements in a population of Thai adults.

The purposes of this study were to establish reference values of the aorta obtained by CT of chest and whole abdomen in asymptomatic Thai adults and to analyze the relationship between values of aortic diameters and patients' demographic data (sex, weight, height, and age) and three risk factors of cardiovascular disease (HT, DLM, and DM).

MATERIALS AND METHODS

The study protocol was approved by the Ethics committee of Faculty of Medicine Siriraj Hospital, Mahidol University for which the inform consent was waived due to its retrospective design (Si. 469/2014).

Study population

The retrospective study was performed by searching lists of patients from the radiology report database. Aortic diameters were measured retrospectively in 310 consecutive Thai adults who underwent a CT chest and whole abdomen for a variety of non-vascular clinical problems. Adults in this study were defined as patient's age that was more than or equal to 18 years old and all patients were Thai ethnicity and nationality by history in Siriraj Hospital patient profiles.

The reasons for CT examination of the patients included malignant neoplasm (n =259, 53.3%), benign neoplasm (n = 7, 2.3%), infectious disease (n=33, 10.7%), inflammatory disease (n=32, 10.3%), autoimmune disease (n = 5, 1.6%), degenerative disease (n= 19, 6.1%), psychiatric disease (n=3, 1%), and others (n = 3, 1%). Patients were excluded if they had the following: signs or symptoms of cardiovascular disease, para-aortic disease, or obvious aortic disease, such as aneurysm, thrombus or dissection.

The clinical background of included patients consisted of age, sex, weight, height, co-morbid non-vascular disease and three potential risk factors of cardiovascular disease (HT, DLP, and DM).

Patients who had potential risk factors of cardiovascular disease, consisted of 51 cases of HT (83.5%), 28 cases of DLP (9%) and 32 cases of DM (10.3 %). The gender was female 165 persons and male 145 persons. (The characteristics of patients are shown in Table 1)

Image acquisition

CT examination of chest and whole abdomen were performed using dual-source CT (Siemens Medical system, Erlangen, Germany) and 64 slices CT scanners (GE Healthcare Medical system, USA). All patients fasted for 6-8 hours or longer prior to the examination. The scans consisted of

TABLE 1. Characteristics of patients

Variable	
Age (years)	
Mean ± SD	60.1 ± 14.4
Median (min, max)	61.5 (18, 94)
Gender: n (%)	
Female	165 (53.2%)
Male	145 (46.8%)
Weight (kg)	
Mean± SD	59.2 ± 12.1
Median (min, max)	58.0 (25, 95)
Height	
Mean ± SD	162.1 ± 8.7
Median (min, max)	160.0 (140, 187)
Risk factors of cardiovascular diseases	
Hypertension: n (%)	
Yes	51 (16.5%)
No	259 (83.5%)
Dyslipidemia: n (%)	
Yes	28 (9%)
No	282 (91%)
Diabetes mellitus: n (%)	
Yes	32 (10.3%)
No	278 (89.7%)

three sequences, including pre-contrast, post-contrast and delayed full bladder images. The oral contrast consisted of total 4 glasses, including 2 contrast and then 2 water glasses, each glass was received every 15 minutes, with the last glass received just before entering CT room. Intravenous contrast was performed by intravenous injection of contrast medium that contained 300-350 mgI/mL in a total volume of 100 mL, which was given via the peripheral venous access at a rate of 3 mL/sec. The post-contrast scan was started 40 and 80 seconds after starting the intravenous injection of contrast medium. Measurement parameters included 1.25 mm thickness, 120 kVp, and 250 mAs with dose care protocol. The scan coverage was from thoracic inlet to pubic symphysis on pre and post-contrast images and from iliac crests to pubic symphysis on delayed full bladder sequence.

Measurements

The measurement of the aortic diameters were evaluated at eight anatomic levels of the aorta; (1) ascending aorta: at middle level of the right main pulmonary artery, (2) proximal transverse aortic arch (PTA): at middle level of the left main pulmonary sling, (3) distal transverse aortic arch (DTA): at proximal portion of distal transverse aortic arch, at the middle level of the left main pulmonary artery, (4) aortic isthmus, (5) thoracoabdominal junction, (6) celiac axis, (7) suprarenal aorta: just above the orifice of renal arteries and (8) aortic bifurcation.

Multi-planar reconstruction was generated on Advantage Workstation version 4.4 (General Electric Medical System, Milwaukee, WI) with program of vessel analysis by senior radiologist (more than 30 years' experience), senior third-year resident in radiology and senior radiologic technologist (more than 30 years' experience). They used the sagittal slices to manually select the each predefined aortic level. Then, each predefined aortic level was automatically measured on transverse section images, including the minimum and maximum aortic diameters, which were obtained strictly perpendicular to the course of the aorta. The aortic diameters were measured from the outer edge of the wall to the outer edge of the opposite wall, perpendicular to the axis of rotation of the aorta. Then, the program automatically recorded the mean measured aortic diameters on each predefined aortic level which was calculated by minimum and maximum diameters. (The example of aortic measurements was shown on Fig 1)

Statistical Analysis

Data were prepared and analyzed using PASW statistics 18.0 (SPSS). Continuous data were described as mean and standard deviation (SD) or median and range, as appropriate. Number and percentage were expressed for categorical data. Spearman's rank correlation coefficient was used to assess the association between continuous data while point-biserial correlation was used for dichotomous data. Unpaired t test or Mann-Whitney U test, as appropriate, was used to compare continuous data between groups. Multiple linear regression was performed to examine the associations between aortic diameters with age and sex, adjusting for other potential factors. All factors with $p<0.20$ in univariate analysis were included in multivariate analysis. One-Way ANOVA or Kruskal-Wallis test with post hoc test was used to compare the aortic diameters among the three age groups. All tests of significance were two tailed, and p value <0.05 was considered significant.

RESULTS

Aortic diameters (mean ± SD) had the following measurements: 3.14 ± 0.40 cm. at the ascending aorta, 2.88 ± 0.34 cm. at proximal transverse aortic arch, 2.65 ± 0.30 cm. at distal transverse aortic arch, 2.46 ± 0.31cm. at aortic isthmus, 2.10 ± 0.27 cm. at thoracoabdominal junction, 1.99 ± 0.26 cm. at celiac axis, 1.81 ± 0.25 cm. at suprarenal aorta, and 1.47 ± 0.21cm. at aortic bifurcation levels.

The mean aortic diameters ± SD and median (min, max) of the total 310 Thai adults of eight aortic levels were classified by gender and three age groups as shown in Table 2 and Table 3, respectively.

Trend of aortic diameters: There was continuously significantly decreased aortic diameters from proximal to distal direction from the ascending aorta, proximal transverse aortic arch, distal transverse aortic arch, aortic isthmus, thoracoabdominal junction, celiac axis, suprarenal aorta until aortic bifurcation, respectively ($p<0.001$) as shown in Fig 2.

Age: For age variable, the results of Spearman correlation showed that the correlation between age and aortic diameters increased at ascending aorta, proximal transverse aortic arch, aortic isthmus and thoracoabdominal junction. All correlations were positive moderate with $p<0.001$. Whereas for the remaining aortic levels that is celiac axis, suprarenal aorta, and aortic bifurcation yielded weakly negative correlation with age. The results of univariate and multivariate regression analyses revealed that there was the influence of age on aortic diameters at all aortic levels with statistical significance ($p<0.001$). Additional, multivariate regression analysis showed that the factor which yielded the most influence on aortic diameters at all aortic levels was the age.

Gender: Men had slightly enlarged aortic diameters, in all eight predefined levels, more than women with statistical significance ($p<0.05$) as shown in Fig 3.

Furthermore, age was classified into three age groups, i.e., 18-50 years, 51-70 years, and 71-94 years. In comparison between genders by three age groups, the results showed that there were significant differences of aortic diameter in all aortic levels, except two age groups which were 51-70 years and 71-90 years when considered at celiac trunk and at aortic bifurcation levels as shown in Fig 4.

Weight: Aortic diameter increased as weight increased at only one aortic location, i.e. aortic bifurcation, with statistical significance ($p<0.001$) on the Spearman correlation. Regression analysis of the influence of weight on aortic diameters revealed an influence of age at various aortic levels as; ascending aorta on both single and multi-regression analysis with statistical significance ($p<0.001$) which had r square = 0.053 (5.3 %), proximal transverse aortic arch on multi-regression analysis with statistical significance

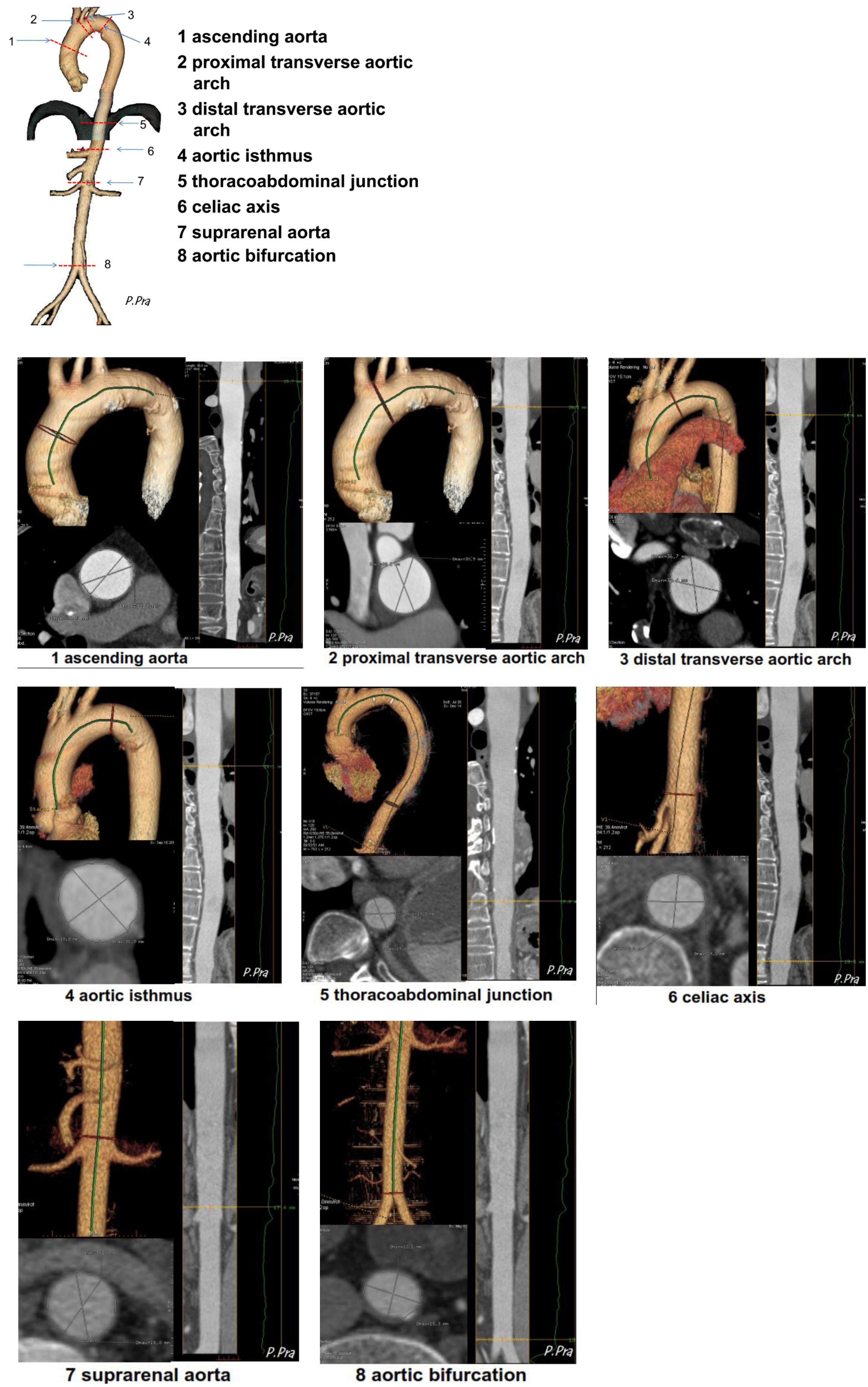

Fig 1. Diagram of aorta with the levels at which the diameters were measured.

($p<0.05$) which had r square = 0.397 (39.7%), distal transverse aortic arch on both single and multi-regression analysis with statistical signifi-cance ($p<0.001$) which had r square = 0.068 (6.8%) and 0.089 (8.9%), respectively, aortic isthmus on single and multi-regression analysis with statistical significance ($p<0.05$) which had r square = 0.218 (21.8%) and 0.436 (43.6%), respectively, thoracoabdominal junction on multi-regression analysis with statistical significance ($p<0.001$) which had r square = 0.459 (45.9%), celiac axis on multi-regression analysis with statistical significance ($p<0.001$) which had r square = 0.362 (36.2%), suprarenal aorta on multi-regression analysis with statistical significance ($p<0.001$) which had r square = 0.372 (37.2%), and aortic bifurcation on single and multi-regression analysis with statistical significance ($p<0.001$) which had r square = 0.184 (18.4%) and 0.316 (31.6%), respectively.

Height: For age variable, the results of Spearman correlation showed that the correlation between height and aortic diameter was not increased with all aortic levels, and yielded as weakly negative correlation. The results of univariate and multivariate regression analyses revealed that there was the influence of height on aortic diameters at three aortic levels with statistical significance ($p<0.001$) as ; ascending aorta on both single and multi-regression analysis with statistical significance ($p<0.05$) which had r square = 0.050 (5.0%) and 0.362 (36.2%), respectively, distal aortic arch on both single and multi-regression analysis with statistical significance ($p<0.05$) which had r square = 0.059 (5.9%) and

TABLE 2. Measured aortic diameters of eight predefined intra-thoracic and abdominal aortic levels on CT of chest and whole abdomen in 310 Thai adults by gender

Measured aortic levels	Total (n=310)	Female (n=165)	Male (n=145)	p-value
Ascending aorta				<0.001
Mean ±SD	3.14 ± 0.40	3.05 ± 0.38	3.24 ± 0.39	
Median (min, max)	3.14 (2.21, 4.24)	3.07 (2.21, 4.24)	3.23 (2.29, 4.10)	
Proximal transverse aortic arch				<0.001
Mean ± SD	2.88 ± 0.34	2.80 ± 0.33	2.97 ± 0.33	
Median (min, max)	2.88 (2.00, 3.84)	2.82 (2.00, 3.70)	2.97 (2.16, 3.84)	
Distal transverse aortic arch				<0.001
Mean ± SD	2.65 ± 0.30	2.57 ± 0.26	2.75 ± 0.31	
Median (min, max)	2.64 (1.93, 3.69)	2.55 (1.93, 3.33)	2.72 (1.95, 3.69)	
Aortic isthmus				<0.001
Mean ± SD	2.46 ± 0.31	2.34 ± 0.25	2.59 ± 0.32	
Median (min, max)	2.45 (1.75, 3.72)	2.33 (1.75, 3.15)	2.57(1.81, 3.72)	
Thoracoabdominal junction				<0.001
Mean ± SD	2.14 ± 0.27	2.03 ± 0.25	2.20 ± 0.26	
Median (min, max)	2.10 (1.51, 2.97)	1.99 (1.51, 2.81)	2.20 (1.56, 2.97)	
Celiac axis				<0.001
Mean ± SD	2.00 ± 0.26	1.92 ± 0.23	2.10 ± 0.26	
Median (min, max)	1.98 (1.28, 3.16)	2.07 (1.56, 3.16)	2.07 (1.56, 3.16)	
Suprarenal aorta				
Mean ± SD	1.81 ± 0.251	1.72 ± 0.22	1.91 ± 2.46	<0.001
Median (min, max)	1.78 (1.20, 2.55)	1.73 (1.20, 2.46)	1.89 (1.43, 2.55)	
Aortic bifurcation				
Mean ± SD	1.47 ± 0.21	1.39 ± 0.17	1.55 ± 2.10	<0.001
Median (min, max)	1.46 (1.00, 2.21)	1.40 (1.00, 1.87)	1.52 (1.00, 2.21)	

TABLE 3. Measured aortic diameters of eight predefined intra-thoracic and abdominal aortic levels on CT of chest and whole abdomen in 310 Thai adults by age

Measured aortic levels	Age group 18-50 years (n=66)	51-70 years (n=166)	71-90 years (n=76)	p-value
Ascending aorta				<0.001
Mean ± SD	2.84 ± 0.37	3.16 ± 0.34	3.36 ± 0.36	
Median (min, max)	2.82 (2.21,3.91)	3.13 (2.33, 4.10)	3.36(2.52, 4.24)	
Proximal transverse aortic arch				<0.001
Mean ± SD	2.62 ± 0.32	2.91 ± 0.30	3.08 ± 0.29	
Median (min, max)	2.58 (2.00, 3.36)	2.88 (2.14, 3.84)	3.07 (2.46, 3.71)	
Distal transverse aortic arch				<0.001
Mean ± SD	2.45 ± 0.29	2.67 ± 0.27	2.80 ± 0.28	
Median (min, max)	2.46 (1.93, 3.21)	2.64 (2.10, 3.68)	2.77 (2.26, 3.69)	
Aortic isthmus				<0.001
Mean ± SD	2.23 ± 0.28	2.48 ± 0.26	2.61 ± 0.33	
Median (min, max)	2.19 (1.75, 2.96)	2.47 (1.91, 3.34)	2.57 (2.04, 3.72)	
Thoracoabdominal junction				<0.001
Mean ± SD	1.88 ± 0.22	2.13 ± 0.22	2.28 ± 0.31	
Median (min, max)	1.85 (1.51, 2.48)	2.11 (1.53, 2.68)	2.25 (1.77, 3.47)	
Celiac axis				<0.001
Mean ± SD	1.83 ± 0.23	2.01 ± 0.21	2.11 ± 0.30	
Median (min, max)	1.83 (1.28, 2.44)	2.01 (1.56, 2.67)	2.11 (1.67, 3.16)	
Suprarenal aorta				<0.001
Mean ± SD	1.67 ± 0.23	1.82 ± 0.23	1.93 ± 0.28	
Median (min, max)	1.64 (1.20, 2.35)	1.78 (1.31, 2.55)	1.90 (1.41, 2.76)	
Aortic bifurcation				0.026
Mean ± SD	1.41 ± 0.21	1.48 ± 0.20	1.48 ± 0.23	
Median (min, max)	1.39 (1.03, 2.01)	1.45 (1.00, 2.16)	1.48 (1.00, 2.21)	

0.364 (36.4%), respectively, and aortic bifurcation on both single and multi-regression analysis with statistical significance ($p<0.05$) which had r square = 0.161 (16.1%) and 0.316 (31.6%), respectively. However, weight had no influence on the rest of aortic levels, including aortic isthmus, celiac axis and suprarenal aorta.

Hypertension: All aortic diameters did not increase with underlying HT which showed weak correlation of the Spearman. The result of regression analysis showed that there was no an influence of HT on all aortic levels.

Dyslipidemia: All aortic diameters did not increased with underlying DLP which showed weak correlation of the Spearman. The result of regression analysis showed no an influence on all aortic levels.

Diabetes Mellitus: All aortic diameters did not increase with underlying DM which showed weak correlation of the Spearman. The result of regression analysis showed no influences on all aortic levels.

DISCUSSION

In this study, the aortic diameters were evaluated in 310 Thai adults who had no obvious signs and symptoms of cardiovascular disease. This study showed aortic diameters depend on multiple factors.

Trend of overall of aortic diameters are continuously decreased size from proximal to distal direction from ascending aorta to aortic bifurcation, which matches with the Aronberg and

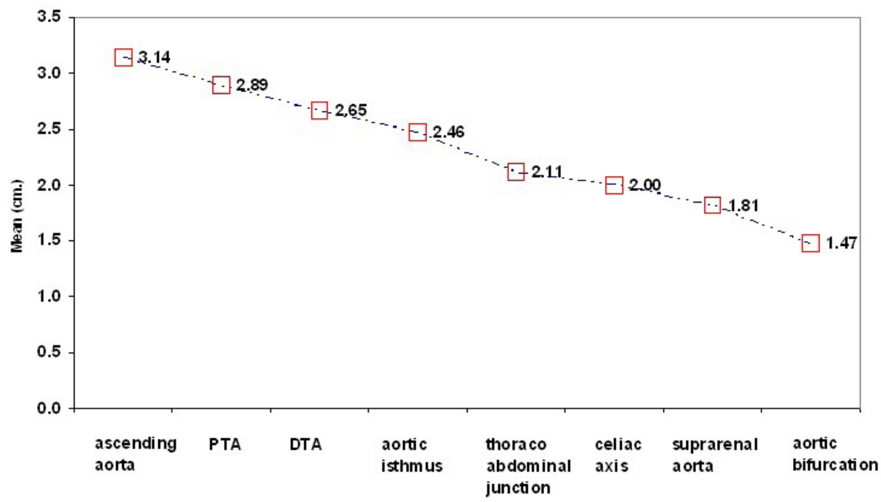

Fig 2. Mean aortic diameters at various levels measured by CT of chest and whole abdomen in 310 Thai adults.

associated study.[4] For the abdominal aorta, Pearce and colleagues[5] discussed a multi-factorial pathophysiologic picture. 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 increased diameters in the thoracic aorta, the elastic components might be more pronounced than in the abdominal aorta.

Men had slightly enlarged aortic diameters in all eight predefined levels than did women with statistical significance ($p<0.05$), which matches with a previous study of Sang Hwan Lee, et al.[6] In details of interpretation, this study showed sex had weak correlation of the Pearson with the aortic diameters in all levels and sex had influence to the aortic diameters in nearly all levels with statistical significance ($p<0.05$), except at the ascending aorta.

Increasing age is an independent and the most influential predictor of increasing size of aortic diameter in all aortic levels, which matches with the previous studies of Dixon et al., study[7], which concluded that aortic dilatation is part of the natural aging process.

Furthermore, age was classified into three age groups; 18-50 years, 51-70 years, and 71-94 years. In comparison, between genders, by the

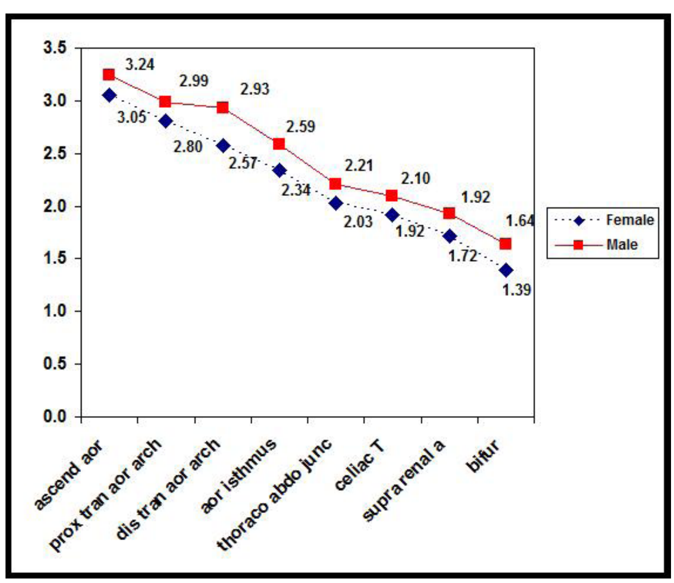

Fig 3. Mean aortic diameters at various levels measured by CT of chest and whole abdomen in 310 Thai adults of female and male.

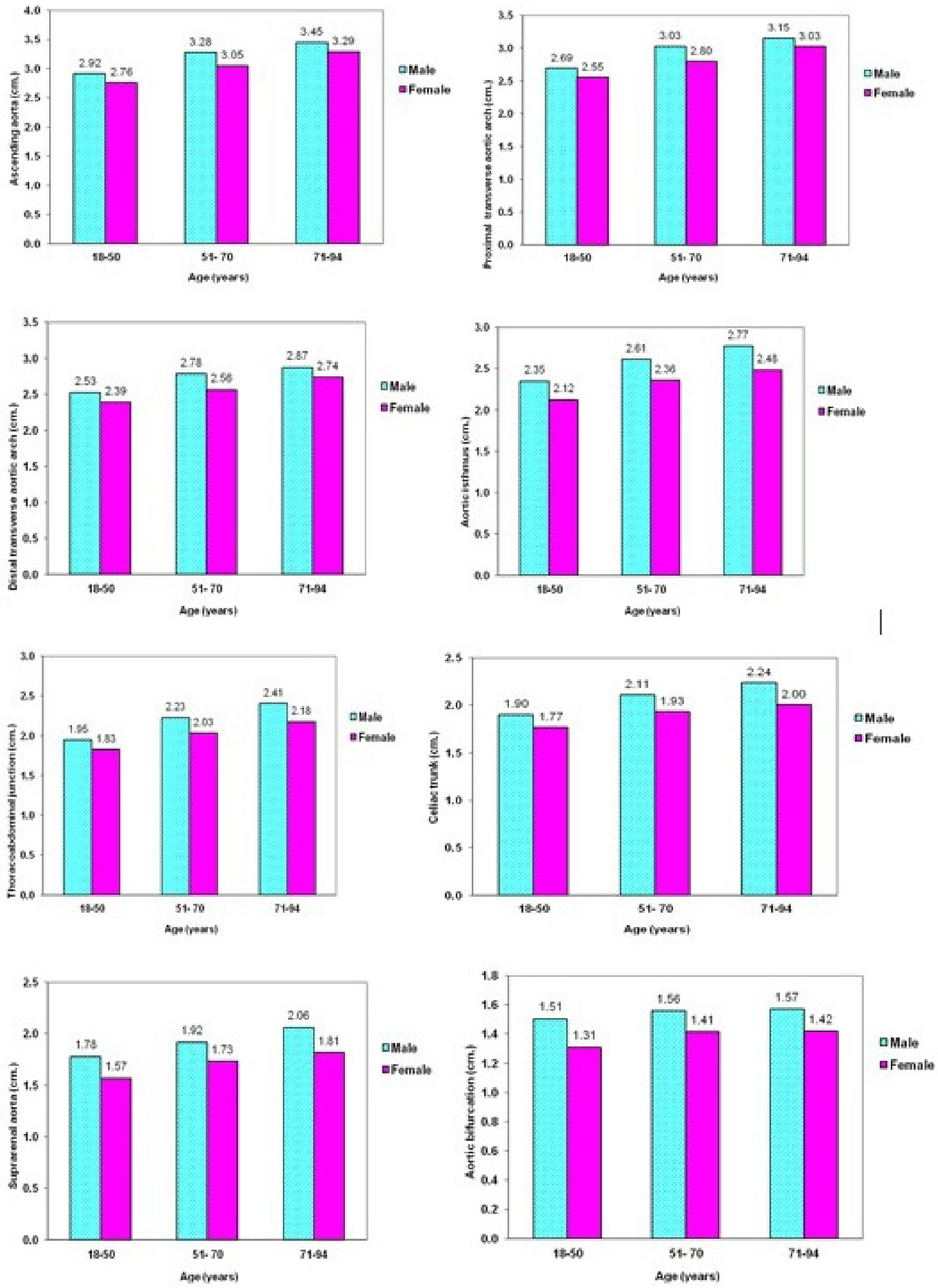

Fig 4. Mean aortic diameters at various levels measured by CT of chest and whole abdomen in 310 Thai adults of female and male.

three age groups, the results showed that there were significant differences of aortic diameter in all aortic levels, except two age groups that were 51-70 years and 71-90 years when considered at celiac trunk and at aortic bifurcation levels.

Age-related arterial function change is considered to be an important independent determinant of cardiovascular morbidity and mortality. The aorta is subject 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 dilatation of the aorta. However, in comparison with a previous study of Hwan Lee et al, the mean aortic diameters in all levels in this study were more than the previous study. This interpretation could be due to the mean age of total population of this study was 60.1 ± 14.4 years, whereas the mean age of Sang Lee, et al, study was 50.5 ± 16.7 years.

This study concluded aortic diameters increased as weight increased at only one aortic location, i.e. aortic bifurcation, with statistical significance ($p<0.001$). Weight was an independent influential predictor of aortic diameter in various levels from regression analysis results, varying in percentages of influence from 5 to 50%; at ascending aorta (5.3 % of the influence), at proximal transverse aortic arch (39.7% of the influence), at distal transverse aortic arch (8.9% of the influence), at aortic isthmus (43.6% of the influence), at thoracoabdominal junction (45.9% of the influence), at celiac axis (36.2% of the influence), at suprarenal aorta (37.2% of the influence), and at aortic bifurcation (31.6% of the influence). We speculate that increased peripheral vascular resistance is related to both weight gain and increased aortic diameter. In regression analysis of this study, the most influence of the weight is at the thoracoabdominal junction, and about 45.9%, could be due to the high pressure of aortic wall received at this level r is more than the other aortic levels.

Height did not increase with all aortic levels. Height was an independent influential predictor of three aortic levels, including ascending aorta, distal transverse aortic arch and aortic bifurcation with 5-16 percentages of quantitative significance.

The potential risk factors of cardiovascular disease that were evaluated in this study were hypertension, dyslipidemia and diabetes mellitus. All aortic diameters did not increase with underlying hypertension, dyslipidemia and diabetes mellitus.

Limitation

This study has limitation about the image technique that we are using data from non-gating helical CT scans. In order to establish more solid normative tables, electrocardiography (ECG)-gated multi-detector CT (MDCT) measurements are needed. ECG-gated MDCT provides high resolution images in near isotropic conditions. However, we had a large study population, about 310 persons, so we expect the mean value minimizes possible errors arising from non-gating CT.

CONCLUSION

This study delineates normal intra-thoracic and abdominal aortic diameters, including relationships with age and sex in asymptomatic Thai adults. The CT measurements of the diameter of the normal aorta for differing genders and age may prove useful when assessing the abnormal state in a variety of disease processes.

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