Normal Thoracic Aortic Diameter in Thai People by Multidetector Computed Tomography

Juntima Euathrongchit MD*, Pariyanoth Deesuwan MD*,
Srun Kuanprasert MD**, Surin Woragitpoopol MD***

** Department of Radiology, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand*
*** Department of Medicine, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand*
**** Department of Surgery, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand*

Objective: *To determine the normal size of the thoracic aorta among Thai people.*
Material and Method: *The aortic diameter of 73 Thai males and 56 Thai females, in four age groups, were measured from thoracic Multidetector Computed Tomography (MDCT) images. Aortic size were analyzed and correlated by age, sex, and vertebral body.*
Results: *All showed normal aortic configuration, i.e. smooth tapering from aortic root to ascending and descending aorta. Mean 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 diaphragm. Males' aorta were larger than females, and all levels of the aorta were significantly enlarged with increasing age. Tapering of the vessel ratio of the ascending aorta/distal aorta at diaphragm was 1.5 without statistical significance. There was a weak correlation between aortic size and vertebral body at all levels. Comparing the size of the aorta to that of the vertebrae, the aorta was larger at the ascending part, equal at the mid arch and smaller at the descending part.*
Conclusion: *Among the Northern Thai people, the average size of the aorta was determined at each level. It was found that aortic size is significantly dependent on age, sex, and vertebral body width.*

Keywords: *Thoracic aorta, Computed tomography*

J Med Assoc Thai 2009; 92 (2): 236-42
Full text. e-Journal: *http://www.mat.or.th/journal*

The thoracic aorta is divided into three parts - the ascending aorta, the aortic arch, and the descending aorta - starting from the aortic root through the ascending aorta running upwardly parallel to the pulmonary trunk. The ascending aorta curves to the left posterior hemithorax, forming the aortic arch at the manubrium, and leads to the main great vessels supplying the head, neck and upper trunk before turning down to the descending portion, after the ligamentum arteriosum. The descending aorta leads to multiple intercostals and bronchial arteries while passing downwardly and entering into the abdomen via the aortic hiatus at the thoracic 10th vertebral body[1].

Correspondence to: Euathrongchit J, Department of Radiology, Faculty of Medicine, Chiang Mai University, Chiang Mai 50200, Thailand. Phone: 053-945-450, Fax: 053-946-136, E-mail: jeuathro@mail.med.cmu.ac.th

Normally, the aortic size varies in each level and varies among different body sizes, sexes, and ages. Several methods have been used to study aortic size, such as Aronberg et al[2], which used Computed Tomography (CT) to measure the aortic diameters from 102 normal subjects. The present study revealed that the average diameter of each part of the aorta was about 3.6 cm at the proximal ascending aorta, 3.51 cm at the distal ascending aorta, 2.63 cm and the proximal descending aorta, 2.48 cm at the distal descending aorta, and 2.42 cm at the diaphragmatic level. The aorta should taper smoothly. Any significant deviation from this should lead to suspicion of an aneurysm.

There are a limited number of normal aortic reports among the Thai population, even though the authors' search included the Thai Index Medicus, Chulalongkorn University Medical Library. Moreover, Multidetector Computed Tomography (MDCT) is a widely used new technology that provides good image quality. This allowed us to study all planes, not only in the axial position, by using Multiplanar Reconstruction (MPR) to the coronal and sagittal planes as well as 3D images for deep understanding the anatomy and relationship between organs[3,4]. This prompted the authors to study the normal aortic size of the Thai people, to find the standard for the Thai population.

Material and Method

The medical records of all patients who underwent MDCT of the thorax in Maharaj Nakorn Chiang Mai Hospital during 2 years (2004-2005) were retrospectively reviewed to prepare the CT data. The exclusion criteria were patients who had a clinical history of renal disease, hypertension, DM, congenital heart disease, valvular heart disease, or connective tissue disease. In addition, cases of mediastinal mass that compressed the aorta were taken out. The data collected from the medical records were age, sex, clinical history of illness, and blood pressure.

Adequate sample size was calculated by the equation “$n = Z^2\sigma^2/E^2$”[5]: sample size (n at least = 107), Z-value at 95% confidence interval ($Z = 1.96$), variation of population ($\sigma = 0.14$), E = the maximum difference between the observed sample mean x and the true value of the population mean μ, $|x-\mu|$, ≤ 0.07 cm.

Finally, all images of 129 patients from 16 slides MDCT (Aquilion, Toshiba, Tochigi-Ken, Japan) were reviewed by board radiologists using a computer workstation. Oblique coronal reformatted images (Fig. 1) were done to find the reference level for measurement as in the Aronberg study[2]. The references consisted of: level A, a 1 cm caudal to the top of the aortic arch; level B, a 1 cm cranial to the aortic root; and level C, at the diaphragmatic level as well as the additional mid arch level. All diameters were measured on the correlated axial plane (Fig. 1). The mid arch level, between the left common carotid and left subclavian artery, was measured on the mid oblique coronal view. The coronal width of the thoracic vertebral body was measured at all reference levels.

The authors determined the mean aorta and searched for a relationship between the aortic size and age, sex and vertebral bodies in each level. The authors compared aortic size between male and female and in different age groups by using independent

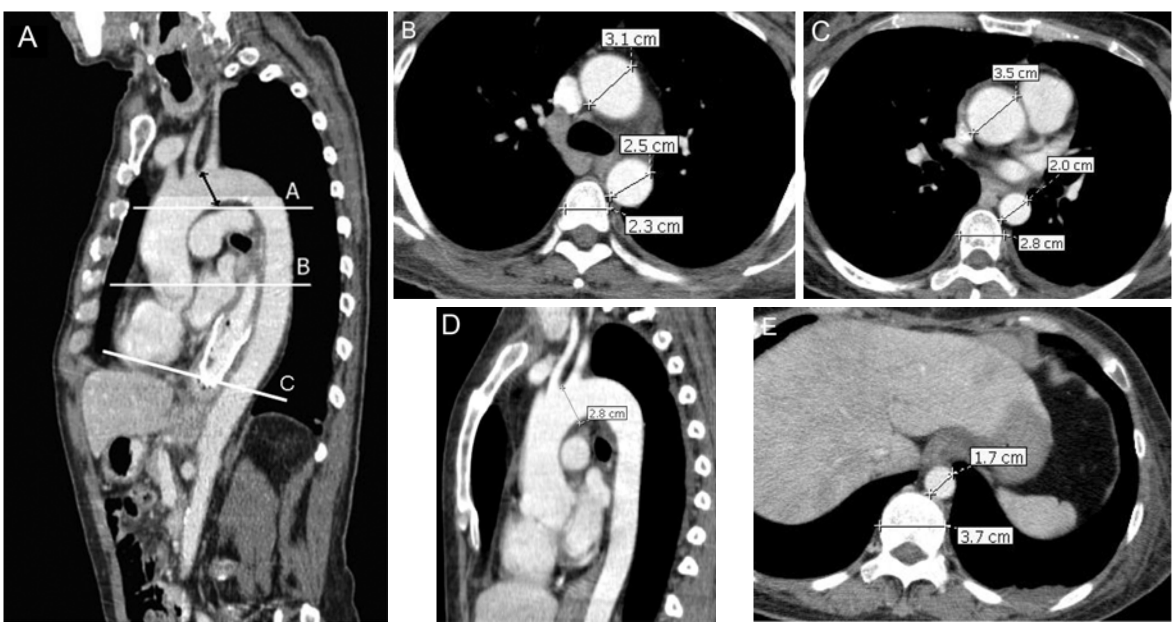

Fig. 1 Coronal oblique and axial MDCT of the thorax: (A) coronal oblique image shows mid coronal aortic plan and measurement levels, A-C. (B) axial image of the level A is below the top of aortic arch about one centimeter, while (C) axial image of level B is a centimeter above the aortic root. The mid arch level is the point between the left common carotid artery and the origin of the left subclavian artery demonstrated on coronal oblique image (D). (E) axial image of level C is the diaphragmatic level

t-test and a significance level at 0.05. Relationships between age groups were examined by one way analysis of variance and significance level at 0.05. The correlation between aortic size and vertebral body in the same level was analyzed using Pearson correlation and significance at the 0.01 level. The proportion between mean aortic diameter and vertebral body width at each level was determined in each age group by using one-way analysis of variance at p-value < 0.05.

Results

Seventy-three male and 56 female patients between 20 and 82 years of age were enrolled in the present study. The oldest case was an 82-year-old male. The authors categorized all patients into four age groups, which were 20-35 years old (n = 16), 36-50 years old (n = 35), 51-65 years old (n = 52) and over 65 years old (n = 26). The maximum, mean and minimum aortic sizes of male and female in each group are shown by Table 1. The mean caliber in each level was 3.9 cm at the aortic root (B1) and gradually decreased in size to 2.03 cm at the distal descending aorta, the aortic hiatus level. Table 2 shows the ratio of aortic size between each level and B1 to C level as well as the tapering ratio from B1 to C, which calculated by the mean measurement of B1 minus the mean measurement of C, and there was no statistical significant at $p < 0.05$ by using one way analysis of variance. The ratio of ascending to descending aorta at each level was unrelated with age ($p > 0.05$). The average ratio of B1/C was 1.54:1. The ascending aorta near the aortic root (B1) was larger than the distal thoracic aorta at diaphragmatic hiatus (C), which was 1.08 cm on average. Generally, the ascending limb was larger than the descending aorta in all patients, except in 12 patients where the diameter at level B1 was less than

Table 1. A summary of the mean, maximum and minimum sizes of the thoracic aorta of all levels among the patients in each age group

Level	Age (years)	Mean (min-max) (cm)		Mean (range) (cm)	SD
		Male	Female		
B1	20-35	2.75 (2.4-3.3)	2.72 (3.0-3.6)	3.12 (2.4-3.9)	0.34
	36-50	3.11 (2.5-3.6)	2.93 (2.6-3.6)		
	51-65	3.27 (2.8-3.8)	3.09 (2.5-3.5)		
	> 65	3.40 (2.8-3.9)	3.32 (3.0-3.6)		
A1	20-35	2.59 (2.1-3.2)	2.53 (3.0-3.3)	2.95 (2.1-3.7)	0.33
	36-50	2.90 (2.4-3.2)	2.77 (2.4-3.6)		
	51-65	3.07 (2.4-3.7)	2.94 (2.2-3.3)		
	> 65	3.28 (2.8-3.6)	3.18 (3.0-3.3)		
Mid arch	20-35	2.25 (1.8-2.6)	2.35 (2.5-2.7)	2.59 (1.8-3.2)	0.29
	36-50	2.58 (1.9-2.9)	2.45 (2.0-3.1)		
	51-65	2.69 (2.1-3.2)	2.57 (1.9-3.0)		
	> 65	2.87 (2.5-3.2)	2.60 (2.5-2.7)		
A2	20-35	2.10 (1.6-2.7)	1.98 (2.1-2.8)	2.33 (1.6-3.0)	0.31
	36-50	2.40 (1.7-2.8)	2.08 (2.4-2.6)		
	51-65	2.65 (2.1-3.0)	2.21 (1.6-2.7)		
	> 65	2.65 (2.2-2.9)	2.35 (2.1-2.8)		
B2	20-35	1.96 (1.6-2.3)	1.78 (2.0-2.4)	2.14 (1.5-2.9)	0.26
	36-50	2.18 (1.6-2.5)	1.89 (1.8-2.4)		
	51-65	2.44 (2.0-2.5)	2.09 (1.5-2.4)		
	> 65	2.45 (2.1-2.9)	2.13 (2.0-2.4)		
C	20-35	1.73 (1.3-2.2)	1.78 (1.9-2.3)	2.03 (1.3-2.6)	0.28
	36-50	2.02 (1.5-2.3)	1.77 (1.5-2.3)		
	51-65	2.18 (1.8-2.5)	2.01 (1.5-2.2)		
	> 65	2.34 (1.9-2.6)	2.07 (1.9-2.3)		

Min = minimum; Max = maximum; B1 and B2 = ascending and descending aorta at 1 cm cranial to aortic root, respectively; A1 and A2 = Ascending and descending aorta at 1 cm caudal to aortic arch, respectively; Mid arch = mid portion of aortic arch; C = distal descending aorta at aortic hiatus

Table 2. The ratio between ascending and descending aorta in each level among different age groups

Mean ratio in each age group	Male				Female			
	20-35	36-50	51-65	> 65	20-35	36-50	51-65	> 65
A1/A2	1.24	1.21	1.21	1.24	1.30	1.34	1.33	1.36
B1/B2	1.42	1.43	1.45	1.40	1.54	1.55	1.47	1.55
B1/C	1.61	1.54	1.51	1.46	1.55	1.65	1.57	1.61
Tapering ratio from B1 to C	0.97	1.08	1.1	1.06	0.95	1.15	1.09	1.25

level A1. For instance, on Fig. 2, a 41-year-old man had MDCT of the chest performed due to empyema thoracis. His aortic diameter at level B1 was less than level A1 about 0.1 cm. Though the difference ranged from 0.1-0.2 cm, there was no statistically significant influence to mean aortic size. Of these 12 patients, seven were female and five were male. Three cases were aged 20-35, three cases were aged 36-50, four cases were aged 51 -65, and two cases were more than 65 years of age.

Fig. 3 shows the comparison between the mean aortic size between male and female patients. The authors found that the male aorta was significantly larger than the female aorta ($p < 0.05$). Fig. 4 reveals that the relationship of mean aortic size increases with age in all levels. Overall, the ascending aortic

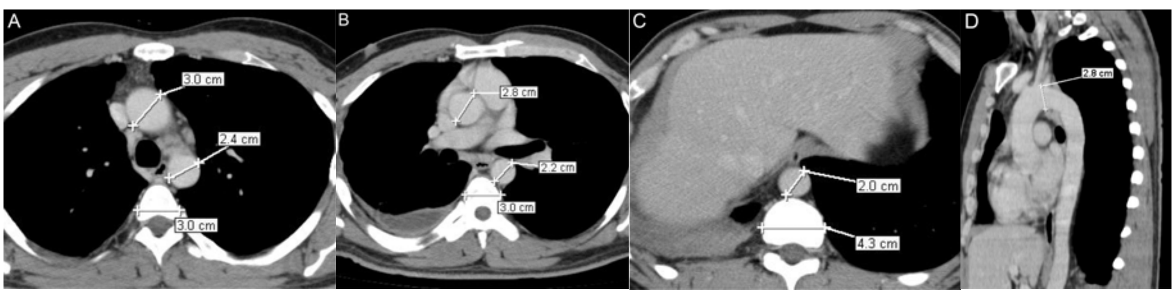

Fig. 2 Axial and coronal oblique MDCT of the chest show measurement of aortic diameter in each level. (A-C) represent axial images at the level A, B and C, respectively. Mid arch measurement is shown on coronal oblique image (D). Note small amount of right pleural effusion on (B, C)

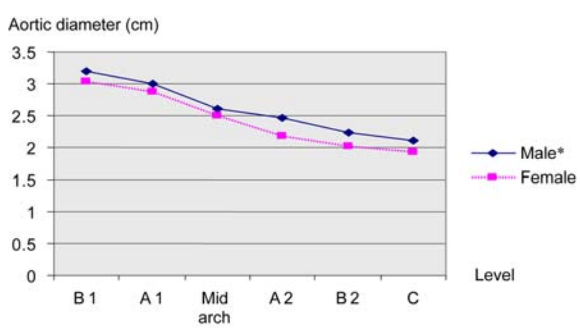

Fig. 3 Lines presentation of mean aortic size of male and female in each level. The mean aortic size among males is larger than of females at all levels with statistical significance (*p < 0.05)

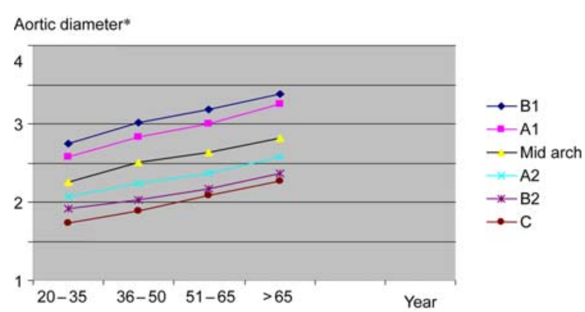

Fig. 4 Lines presentation of mean aortic diameter in each level and age. The aortic diameters increased with age at all levels with statistical significance (*p < 0.05)

diameters (B1) increased slightly more than 0.12 cm per decade.

Table 3 illustrates the correlation of mean aortic size with vertebral body width in all levels, significantly at $p < 0.01$, but the degree of correlation was weakly positive. The proportion of mean aortic diameter and vertebral body width increased significantly with age ($p < 0.05$) (Table 4) and remained significant only in male patients. At level B1 and A1 levels in the over 35 years age groups, the mean aortic size was 10% larger than the vertebral body width. In the 20-35 years age group, most of the ascending aortas were smaller than the vertebral bodies, except in four cases (25%) where the proportion between the aorta and the vertebral body was more than 1. Almost all the diameters of the aorta at the mid arch level were nearly equal or equal in size to vertebral body width. At levels B2 and C, none of the patients in the present study had an aortic diameter larger than that of the vertebral body.

Table 3. The Pearson correlation between aortic size and vertebral body width at each level

Aortic level	Vertebral level			
	at B	at A	at Mid arch	at C
B1	0.301**	0.316**	0.109**	0.280**
A1	0.296**	0.279**	0.374**	0.273**
Mid arch	0.295**	0.346**	0.381**	0.277**
A2	0.427**	0.442**	0.502**	0.328**
B2	0.451**	0.467**	0.475**	0.288**
C	0.434**	0.452**	0.421**	0.286**

VW = vertebral body width
** p < 0.01

Table 4. The mean proportion between the aortic diameter and the vertebral body width (VW) at different level among different age groups

Proportion	Age groups (year)			
	20-35	36-50	51-65	> 65
B1: VW	0.94	1.10	1.11	1.11
A1: VW	0.99	1.07	1.11	1.18
Mid arch: VW	0.86	0.96	0.95	1.01
A2: VW	0.80	0.84	0.87	0.94
B2: VW	0.65	0.74	0.76	0.78
C: VW	0.48	0.54	0.55	0.58

Discussion

The aorta is the largest artery in the body, rising from the heart, distributing oxygenated blood throughout the body. Normal variation of this vessel is well known[2] not only in texture, but also in its size. The average size in each age group was studied by many centers to determine the standard size for Northern Thai people. Many aortic diseases can be diagnosed by looking at the percentage of change of its size, especially in determining the risk of a ruptured aortic aneurysm.

MDCT is the newest noninvasive technique to investigate the aorta. Aorta anatomy is clearly demonstrated not only on axial plan and on coronal, sagital, coronal-oblique, and three dimension images by computed reconstruction on advanced workstation. Right now, it is popular to use evaluation of endovascular treatment. Since the introduction of high speed hardware and easily used application, loading thin slice axial images to the workstation and selecting of the multiplanar reconstruction program is easy. The coronal, sagital, and coronal-oblique MPR images are presented and the time required for reconstruction is greatly reduced while the image quality is improved compared to the last decade[3,4] or Aronbreg study[2].

Compared with the Aronberg study[2], the aortic size of Northern Thai people is slightly smaller at all levels, but the degree of aortic tapering is similar. These may be due to ethnic differences.

The correlation of the vertebral body and aortic size was also similar to the Aronberg study[2]. However, the authors found that 12 patients had slightly smaller B1 level than A1 level, to a minimal degree. All cases had no underlying disease, so after rechecking the measuring method, the authors determined that this could simply be normal variation.

Like the prior report[2], the mean aortic size of male patients is larger than that of female patients. This could be because the body size of males is larger than that of females, as per Gilsanz V et al[6] and Molgaard C et al[7], both of which indicated that the vertebral body of boys at puberty was larger than that of girls at puberty, with rapid growing of the axial skeleton in boys.

BA Towfiq et al[8] showed that the effects of changing blood pressure on the aortic cross-sectional area and the relationship between stroke distance and stroke volume influenced aortic size, which therefore changed with age. This information supported the authors' data, which was that aortic size was larger in the older age group than the younger age group.

Regarding a significant correlation between the aortic diameter and the vertebral body width, the authors know that the vertebral body shows no change in size after the age of 18 years[9,10]. Thus, it was determined that the proportion between aortic diameter and vertebral body can be used as a guideline for estimating the normal aortic diameter at each level.

At the ascending aorta in the over-35 age-group, the aortic dimension was 10% larger than the vertebral body. The aorta was larger than the vertebral body at the B1 level of young adult period in only four cases (25%). At the B1 level, the aortic diameter was constant in size in the over age 50 group. At the mid arch level, the aortic diameter was nearly equal or equal to the vertebral body width. At the aortic hiatus level (C), the aorta was about one-half the size of the vertebral body. Most of the aortic diameters at the A2 level were smaller than the vertebral bodies, and none of the patients had an aortic diameter larger than the vertebral body at the B2 and C levels.

It is important to recognize that the aorta can vary considerably in its diameter in different patients, as indicated by the ranges of values listed in the results. In an individual patient, the aorta should taper in a consistent fashion along its length. The ratio of the proximal ascending aorta (above aortic root)/distal descending thoracic aorta at the aortic hiatus (B1/C) should normally be 1.5 to 1 in all age groups. Any significant deviation from this should be considered reason to suspect an aneurysm.

The thoracic aorta should be considered abnormal if the aortic diameter exceeds the mean for a given age by at least two standard deviations. The use of these standards will enable confident distinction between a normal and an abnormal thoracic aorta based on a CT scan of the chest.

In conclusion, the aortic size varied according to age, sex, and the size of the vertebral body. In Northern Thai people, the thoracic aorta was largest at the ascending aorta and gradually tapered to the descending aorta. Mean aortic diameters of each level were 3.12 cm at the proximal ascending aorta (B1), 2.95 cm at distal ascending aorta (A1), 2.59 cm at mid arch, 2.33 cm at proximal descending aorta, 2.14 cm at distal descending aorta (B2) and 2.03 cm at aortic hiatus levels (C). Over the age of 35, the proportion between the ascending aorta and the vertebral body was about 1.1, mid arch and vertebral body was nearly 1 and distal descending aorta at the hiatus was about one half of the vertebral body width. The authors could use vertebral body as reference to evaluate abnormality of aortic size.

Acknowledgement

The authors wish to thank Mr. Chitsanukorn Pornpannuvitch, and the statisticians at Phare Hospital, for statistical analysis.

References

1. Naidich DP. Aorta, arch vessels and great veins. In: Naidich DP, Muller NL, Krinsky GA, Zerhouni EA, Siegelman SS, editors. Computed tomography and magnetic resonance of the thorax. 3rd ed. Philadelphia: Lippincott Williams & Wilkins; 1999: 505-602.
2. Aronberg DJ, Glazer HS, Madsen K, Sagel SS. Normal thoracic aortic diameters by computed tomography. J Comput Assist Tomogr 1984; 8: 247-50.
3. Tatli S, Yucel EK, Lipton MJ. CT and MR imaging of the thoracic aorta: current techniques and clinical applications. Radiol Clin North Am 2004; 42: 565-85.
4. Gotway MB, Dawn SK. Thoracic aorta imaging with multisclice CT. Radiol Clin North Am 2003; 41: 521-43.
5. Riffenburgh RH. Sample size required in a study. In: Riffenburgh RH, editor. Statistics in medicine. 2nd ed. California: Elsevier; 2006: 397-417.
6. Gilsanz V, Kovanlikaya A, Costin G, Roe TF, Sayre J, Kaufman F. Differential effect of gender on the sizes of the bones in the axial and appendicular skeletons. J Clin Endocrinol Metab 1997; 82: 1603-7.
7. Molgaard C, Thomsen BL, Michaelsen KF. Influence of weight, age and puberty on bone size and bone mineral content in healthy children and adolescents. Acta Paediatr 1998; 87: 494-9.
8. Towfiq BA, Weir J, Rawles JM. Effect of age and blood pressure on aortic size and stroke distance. Br Heart J 1986; 55: 560-8.
9. Hinck VC, Clark WM Jr, Hopkins CE. Normal interpediculate distances (minimum and maximum) in children and adults. Am J Roentgenol Radium Ther Nucl Med 1966; 97: 141-53.
10. Hurxthal LM. Measurement of anterior vertebral compressions and biconcave vertebrae. Am J Roentgenol Radium Ther Nucl Med 1968; 103: 635-44.

การศึกษาขนาดของหลอดเลือดแดงใหญ่ในคนไทยโดยการตรวจด้วยเครื่องเอกซเรย์คอมพิวเตอร์แบบมัลติสไลด์

จันทิมา เอื้อตรงจิตต์, ปริยานุช ดีสุวรรณ, ศรันย์ ควรประเสริฐ, สุรินทร์ วรกิจพูนผล

วัตถุประสงค์: *เพื่อหาขนาดปกติของหลอดเลือดแดงใหญ่ในคนไทย*
วัสดุและวิธีการ: *ผู้ศึกษาได้ทำการวัดเส้นผ่านศูนย์กลางของหลอดเลือดแดงใหญ่ของคนไทย เป็นผู้ป่วยชาย 73 คน และหญิง 56 คน จากภาพเอกซเรย์คอมพิวเตอร์ชนิดมัลติสไลด์ส่วนทรวงอก โดยแบ่งเป็น 4 กลุ่มตามช่วงอายุ ข้อมูลที่ได้นำมาวิเคราะห์และหาความสัมพันธ์ของขนาดหลอดเลือดกับอายุ เพศ และกระดูกสันหลัง*
ผลการศึกษา: *ผู้ป่วยทุกรายแสดงลักษณะปกติของหลอดเลือดแดงใหญ่ซึ่งจะค่อยลดขนาดลงจาก หลอดเลือดส่วน aortic root จนถึง descending aorta ขนาดเส้นผ่าศูนย์กลางเฉลี่ยของหลอดเลือดส่วนต้นและปลายของ ascending aorta คือ 3.12 ซม. กับ 2.95 ซม. ส่วน aortic arch เท่ากับ 2.59 ซม. ส่วนต้นและปลายของ descending aorta คือ 2.33 ซม. กับ 2.14 ซม. และส่วนท้ายสุดตรงกะบังลมเท่ากับ 2.03 ซม. หลอดเลือดจะโตตามอายุ พบว่าขนาดหลอดเลือดของผู้ชายจะใหญ่กว่าของผู้หญิงทุกระดับอย่างมีนัยสำคัญทางสถิติ อัตราการลดขนาดจากหลอดเลือดส่วนต้นจนถึงส่วนปลายคือ 1.5 โดยไม่มีความสำคัญทางสถิติ ขนาดหลอดเลือดกับกระดูกสันหลังในทุกระดับมีความสัมพันธ์กันทางสถิติแต่ไม่สูง เปรียบเทียบขนาดหลอดเลือดแดงใหญ่กับกระดูกสันหลัง ส่วน ascending aorta จะใหญ่กว่า ขณะที่ส่วน aortic arch ขนาดจะเท่ากัน และส่วนปลายของ descending aorta ขนาดจะเล็ก กว่าในระดับเดียวกัน*
สรุป: *การศึกษานี้ทำให้ทราบขนาดปกติของหลอดเลือดแดงใหญ่ในคนไทยในแต่ละระดับ และพบว่าขนาดดังกล่าวมีความสัมพันธ์กับอายุ เพศและขนาดกระดูกสันหลังอย่างมีนัยสำคัญ*