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대한영상의학회지

Measurement of the Aortic Diameter in the Asymptomatic Korean Population: Assessment with Multidetector CT
나선형 전산화단층촬영에서 측정한 무증상 한국 성인의 정상 대동맥 직경

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Purpose: To determine normal reference values for aortic diameters in asymptomatic Korean adults.

Materials and Methods: Three hundred adults without signs or symptoms of cardiovascular diseases were enrolled in this study. Aortic diameters were measured at nine predetermined levels on CT images. Aortic diameter measurements were adjusted for body surface area. Analysis of data was performed with regard to age, sex, weight, height and hypertension.

Results: Aortic diameters 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 thoracoabdominal 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. Men had slightly larger diameters than women ($p < 0.05$). All diameters increased with age and hypertension, with statistical significance ($p < 0.01$). And all aortic diameters increased with height ($p < 0.05$) except at the level of the aortic arch ($p = 0.056$), and increased with weight ($p < 0.05$) except at the level of the suprarenal aorta ($p = 0.067$).

Conclusion: Male sex, higher weight and height, age and hypertension are associated with larger aortic diameters in asymptomatic Korean adults.

Index terms
Aorta
Normal Reference
Computed Tomography

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INTRODUCTION

After introduction of helical computed tomography (CT) in the late 1980s, imaging of the aorta has become an accepted and widely used procedure for the evaluation of patients with aortic dissection, stenosis, or aneurysm formation (1, 2). Aortic aneurysm is a common, potentially lethal, but treatable disease, particularly if detected before dissection or rupture. Recently, the incidence of thoracic aortic aneurysms has been estimated to be increasing and there are around 10.4 cases per 100000 person-years (3). 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. And for patients with degenerative or traumatic aneurysms of the descending thoracic aorta exceeding 5.5 cm, saccular aneurysms, or postoperative pseudoaneurysms, endovascular stent grafting should be strongly considered when feasible (4). 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 (5-

14). To distinguish the normal from the enlarged aorta, it is necessary to standardize the values of "normal" aortic dimensions. But, to our knowledge, no publication up until now has reported on these aortic measurements in a population of Korean adults.

The purposes of this study were to establish reference values of the aorta obtained by helical CT in asymptomatic Korean adults and to analyze the relationship between these values and sex, weight, height, age and hypertension.

MATERIALS AND METHODS

Patients

Aortic diameters were measured prospectively in 300 Korean adults who were scheduled to undergo a CT for a variety of non-vascular clinical problems. The subjects agreed to undergo an extension of their portal phase scan range to cover the entire aorta for participation in this study. The reasons for CT examination of the patients included malignant neoplasm (n = 197), benign neoplasm (n = 28), infectious disease (n = 25), inflammatory disease (n = 24), routine check-up (n = 21), and autoimmune disease (n = 5). 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. And we excluded patients with obvious atherosclerotic plaque on CT in the patient group. In the total patient group, risk factors of atherosclerosis such as smoking and diabetes mellitus were 9.7% and 9%, respectively. The total of 300 patients consisted of 6 age groups [age groups 21-30, 31-40, 41-50, 51-60, 61-70, and 71-80, each group with 25 males and 25 females (Table 1)]. Informed consent was obtained from each subject and the Institutional Review Board of our institute approved this study (R-0603-188-170).

Image Acquisition

Single slice CT examination was performed using Somatom Plus-4 scanner (Siemens Medical System, Erlangen, Germany). All patients fasted for 8 hours or longer prior to the examination. The postcontrast scan was started 60-seconds after starting the intravenous injection of contrast medium that contained 300 mg I/mL iopromide (Ultravist 370®, Bayer Healthcare, Berlin, Germany) in a total volume of 120 mL; this was given via the antecubital vein of the upper extremity at a rate of 3 mL/sec. Measurement parameters included 10 mm/sec table speed, 5 mm thickness, 120 kVp, and 220 mA. The scan levels ranged from the trifurcation level of the aortic arch to the proximal portion of the aortic bifurcation. Helical acquisitions were obtained with one or two breath-holds. Aorta-focused reconstruction with 16 × 16 cm field of view was achieved every 5 mm with the 180° linear interpolation algorithm.

Measurements

The aortic diameters were measured at the following nine anatomic levels of the aorta: 1) ascending at the middle level of the right main pulmonary artery, 2) transverse aortic arch, 3) proximal descending thoracic aorta (DTA) at the middle level of the left main pulmonary artery, 4) mid DTA at the level of the mitral valve, 5) distal DTA at the top of the diaphragmatic level, 6) thoracoabdominal junction, 7) celiac axis, 8) suprarenal aorta just above the orifices of the renal arteries, and 9) aortic bifurcation (Fig. 1). The measurement of the maximal external aortic diameter was made on the picture archiving and communication system (Marotec, Seoul, Korea). On transverse images, the shortest

Table 1. Demographic Data

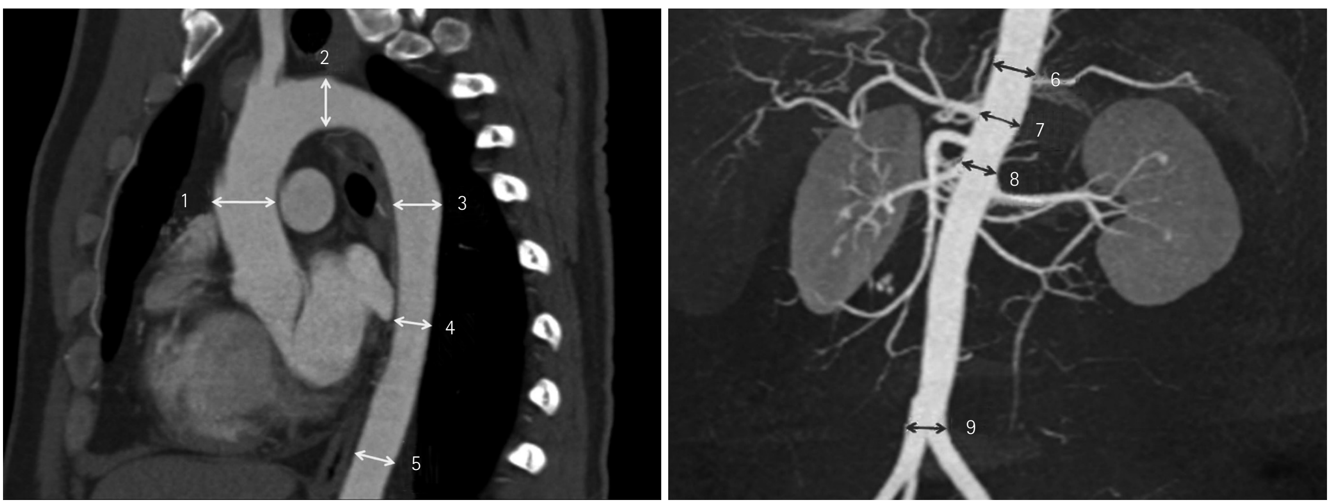
	Female	Male	Total
No.	150	150	300
Age (y) (mean ± SD)	50.9 ± 16.6	50.8 ± 16.9	50.6 ± 16.7
Weight (kg) (mean ± SD)	55.4 ± 9.0	66.5 ± 10.8	60.9 ± 11.4
Height (cm) (mean ± SD)	163.8 ± 9.1	172.3 ± 2.5	168.1 ± 6.0
Adjusted body surface area (m^2) (mean ± SD)	1.51 ± 0.1	1.76 ± 0.1	1.63 ± 0.2
Cholesterol (mg/dL) (mean ± SD)	177.9 ± 35.1	171.0 ± 36.8	174.5 ± 36.0
Blood pressure (mm Hg) (mean)	131.2/84.0	127.1/83.1	129.2/83.6
Hypertension (number of patients) (%)	62 (41.3)	53 (35.3)	115 (38.3)
Diabetes mellitus (number of patients) (%)	14 (9.3)	13 (8.6)	27 (9)
Smoker (number of patients) (%)	3 (2)	26 (17.3)	29 (9.7)

Note.—SD = standard deviation

diameter of the aorta at a predetermined level was measured to avoid overestimation from the non-perpendicular ovoid cross-section of the aorta. The aortic diameter was 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. Wherever possible, magnified images were used in order to monitor the scanning and to reduce operator errors. All images were measured by an experienced radiologist (DJK). The interobserver reliability was evaluated using the intraclass correlation coefficient (ICC) in 30 patients by two experienced radiologists (DJK and LSH). We listed the measured aortic diameter (Fig. 2).

Statistical Analysis

Measurements were stored in a database and exported to a statistical software package (SPSS, ver 17; SPSS Inc., Chicago, IL, USA) for analysis. A normal distribution of diameters was assumed. Adjusted body surface area (BSA) was evaluated for adjusting the aortic diameter. Analysis was performed to test for influence of the following factors on the aortic diameter: sex, age, weight, height, and hypertension. Variables that showed an influence were analyzed in detail using simple linear regression for age, analysis of covariance (ANCOVA) adjusted by weight, height, age and hypertension with regard to the influence of sex,



A B

Fig. 1. Diagram of aorta with the levels at which the diameters were measured.
A. The curved multi-planar reconstruction image shows: 1) ascending at the mid level of the right main pulmonary artery; 2) transverse aortic arch; 3) proximal descending thoracic aorta (DTA) at the mid level of the left main pulmonary artery; 4) mid DTA at the level of the mitral valve; 5) distal DTA at the top of the diaphragmatic level.
B. The maximum intensity projection image shows: 6) thoracoabdominal junction; 7) celiac axis; 8) suprarenal aorta just above the orifices of the renal arteries; 9) aortic bifurcation.

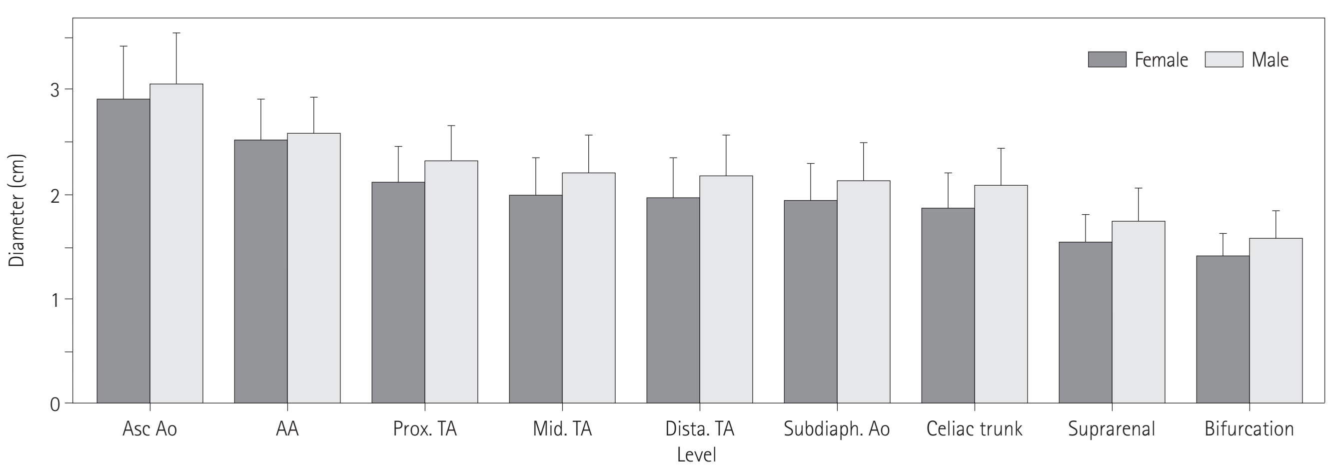


Fig. 2. Mean aortic diameters of both genders at various levels by helical CT in 300 adults.
Note.—AA = ascending aorta, Ao = aorta, TA = thoracic aorta

ANCOVA adjusted by age, sex, weight and height with regard to the influence of hypertension, and partial correlation coefficient adjusted by age, sex and hypertension with regard to the influence of weight and height.

RESULTS

Aortic diameters (mean ± standard deviation) had the following measurements: 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 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 thoracoabdominal junction, 2.10 ± 0.35 cm at the level of the celiac axis, 1.94 ± 0.36 cm at the suprarenal aorta, and 1.58 ± 0.24 cm at the aortic bifurcation (Table 2). The mean aortic diameters of both genders at various levels are shown (Fig. 3). A good interobserver agreement of the average measures (ICC, 0.957; 95% confidence interval, 0.930 to 0.977) was present in 30 patients.

Table 2. Measured Aortic Diameters and Body Surface Area-Adjusted Aortic Diameters of Nine Different Levels on Helical CT in 300 Adults

Measured Aortic Diameters	**Female (*n* = 150)**	**Male (*n* = 150)**	**Total (*n* = 300)**	***p* Value**
Ascending aorta	2.92 ± 0.56	3.06 ± 0.58	2.99 ± 0.57	0.036
Transverse aortic arch	2.49 ± 0.35	2.59 ± 0.36	2.54 ± 0.35	0.015
Proximal thoracic aorta	2.27 ± 0.31	2.46 ± 0.36	2.36 ± 0.35	0.000
Middle thoracic aorta	2.12 ± 0.35	2.34 ± 0.36	2.23 ± 0.37	0.000
Distal thoracic aorta	2.07 ± 0.35	2.27 ± 0.38	2.17 ± 0.38	0.000
Thoracoabdominal junction	2.05 ± 0.35	2.28 ± 0.36	2.16 ± 0.37	0.000
Celiac trunk	1.98 ± 0.31	2.21 ± 0.36	2.10 ± 0.35	0.000
Suprarenal	1.84 ± 0.39	2.04 ± 0.31	1.94 ± 0.36	0.000
Bifurcation	1.47 ± 0.22	1.68 ± 0.22	1.58 ± 0.24	0.000
Body Surface Area-Adjusted Aortic Diameters	**Female (*n* = 150)**	**Male (*n* = 150)**	**Total (*n* = 300)**	***p* Value**
Ascending aorta	1.95 ± 0.41	1.74 ± 0.37	1.84 ± 0.41	0.000
Transverse aortic arch	1.66 ± 0.27	1.47 ± 0.23	1.57 ± 0.27	0.000
Proximal thoracic aorta	1.51 ± 0.23	1.40 ± 0.23	1.46 ± 0.23	0.000
Middle thoracic aorta	1.41 ± 0.24	1.33 ± 0.24	1.37 ± 0.24	0.008
Distal thoracic aorta	1.38 ± 0.25	1.29 ± 0.25	1.34 ± 0.25	0.003
Thoracoabdominal junction	1.37 ± 0.26	1.30 ± 0.24	1.33 ± 0.25	0.015
Celiac trunk	1.32 ± 0.22	1.26 ± 0.23	1.29 ± 0.23	0.017
Suprarenal	1.23 ± 0.28	1.16 ± 0.20	1.19 ± 0.24	0.015
Bifurcation	0.98 ± 0.14	0.95 ± 0.13	0.97 ± 0.14	0.124

Note.—Measurements are expressed as mean ± SD in centimeters. Body surface area-adjusted measurements are expressed as mean ± SD in cm/m^2.
SD = standard deviation

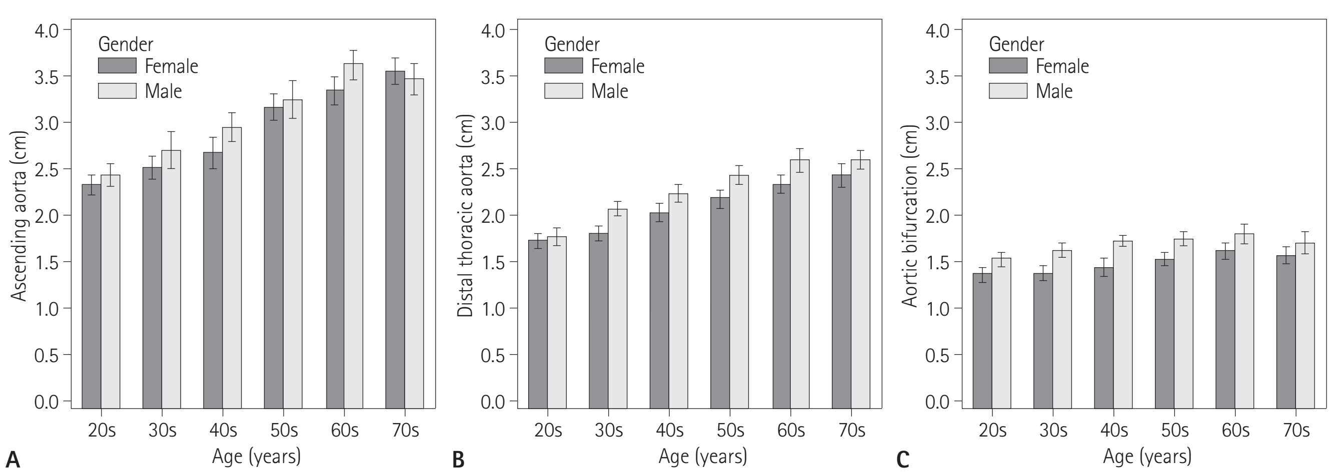


Fig. 3. Mean aortic diameters at the ascending aorta **(A)**, the distal thoracic aorta **(B)** and aortic bifurcation **(C)** derived from helical CT measurements in 300 adults 21-80 years old.

Aortic diameters and BSA adjusted aortic diameters decreased continuously from the ascending aorta to the bifurcation level. Men had slightly larger aortic diameters than women ($p < 0.05$). Women had slightly larger BSA-adjusted aortic diameters than men ($p < 0.05$), but the difference was not statistically significant at the level of the aortic bifurcation ($p = 0.124$). Women's aortic diameters were bigger than men's in terms of the ascending aorta and aortic arch level, while the opposite was true for the aorta between the proximal descending thoracic aorta and the aortic bifurcation ($p < 0.01$), when adjusted by age, hypertension, height and weight. All aortic diameters increased with height ($p < 0.05$), except at the level of the aortic arch ($p = 0.056$), and all aortic diameters increased with weight ($p < 0.05$), except at the level of the suprarenal aorta ($p = 0.067$).

All diameters increased with hypertension when adjusted by sex, age, height, and weight ($p < 0.01$). Age as an influence was also analyzed in detail by simple linear regression analysis (Table 3). There was a significant increase of aortic diameter at all levels throughout adult life ($p < 0.01$).

DISCUSSION

In this study, we showed that aortic diameters in adults vary with sex, weight, height, age, and hypertension. This study matches with the study of Hager et al. (10), which showed that the aortic diameter increased about 1 mm per decade during adulthood.

Previous studies have shown that age and gender have a significant bearing on the aortic diameter (7, 15-18). Dixon et al. (9) concluded that aortic dilatation is part of the natural aging process. Age-related arterial function change is considered to be an important independent determinant of cardiovascular morbidity and mortality (21-23). 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 nonelastic tissue (24). These histological processes lead to stiffening of the aortic wall and increased mean aortic blood pressure, and finally to transverse dilation of the aorta. And we found that women's aortic diameters were meaningfully bigger than men's in terms of the ascending aorta and aortic arch level, while the opposite was true from the proximal descending thoracic aorta to the aortic bifurcation, when adjusted by weight, height, age and hypertension with regard to the influence of sex. Previous studies have shown that there is no difference between men and women in cerebral blood flow (25, 26), while others have suggested a higher cerebral blood flow in women (27-30). We have not yet found the reason why woman's ascending aorta and aortic arch have larger diameters while men's aortas shows a larger diameter at the level of the proximal descending thoracic aorta to below, and so further study is required to investigate this.

The influence of weight, and height on aortic dimensions in adults was apparent in this study. Previous studies have shown that weight and height have a significant bearing on the aortic diameter (15, 16, 19). We speculate that increased peripheral vascular resistance is related to both weight gain and increase in aortic diameter. Blood pressure is well recognized for its effect on the aortic diameter. Previous studies have shown that hypertension has a significant bearing on the aortic diameter (19, 20).

According to a German study by Hager et al. (10), the mean aortic diameters were as follows: at the ascending aorta, 3.09 cm in Germans, and 2.99 cm in Korean; at the transverse arch, 2.77

Table 3. Simple Linear Regression Analysis of the Influence of Age on Aortic Diameter at Nine Different Levels

Level	Slope (cm/y)	Intercept (cm)	r	r^2	p Value
Ascending aorta	0.026	1.70	0.740	0.547	< 0.01
Transverse aortic arch	0.014	1.84	0.651	0.424	< 0.01
Proximal thoracic aorta	0.014	1.68	0.651	0.424	< 0.01
Middle thoracic aorta	0.016	1.41	0.726	0.527	< 0.01
Distal thoracic aorta	0.017	1.32	0.743	0.552	< 0.01
Thoracoabdominal junction	0.016	1.33	0.733	0.537	< 0.01
Celiac trunk	0.015	1.35	0.695	0.483	< 0.01
Suprarenal	0.011	1.37	0.514	0.265	< 0.01
Bifurcation	0.005	1.33	0.333	0.111	< 0.01

Note.—The slope describes increasing diameters with age.

cm in Germans, and 2.54 cm in Koreans; and at the proximal DTA, 2.47 cm in Germans, and 2.36 cm in Korean. The median age was 50.2 years in Germans, and 50.6 years in Koreans; mean height was 172.4 cm in Germans, and 168.1 cm in Koreans; and mean weight was 73.1 kg in Germans and 60.9 kg in Koreans. The German people have a larger aortic diameter than Koreans. Considering that the two groups have almost the same median age, weight and height play an important role in explaining the aortic diameter differences.

The limitation of our study is the use of data from non-gated helical CT scans. In order to establish more solid normative tables, electrocardiography (ECG)-gated multidetector CT (MDCT) measurements are needed. ECG-gated MDCT provides high resolution images in near isotropic conditions (31). The major difference in the diameter was at the level of the ascending aorta. In two studies with non-gated CT in adult patients, the diameter of the aortic sinus measured between 29.8 and 36.2 mm, and the diameter of the ascending aorta measured between 30.9 and 35.1 mm (7, 10). A Dutch group used gated CT to measure the distance between the aortic valve and the right brachiocephalic artery in 14 patients (32). Their results ranged from 72 to 99 mm. This group also showed that motion and stress forces in the ascending aorta are higher than in the abdominal aorta, with a maximum difference of diameter of up to 27.5% during the cardiac cycle.

Nevertheless, considering that we examined a relatively larger population of up to 300 patients, we expect the mean of the measured values to effectively reflect the true mean value, minimizing possible errors arising from non-gated CT.

And this study is the first step in determining normal reference values for the aorta diameter of Korean adults.

This study reemphasizes that aortic dilatation is a part of the natural aging process. The CT measurement 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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나선형 전산화단층촬영에서 측정한 무증상 한국 성인의 정상 대동맥 직경

이상환 · 이 활 · 최혁재 · 김대진 · 박은아 · 정진욱 · 박재형

목적: 무증상 한국 남녀 성인 대동맥 직경의 정상 참조치를 측정하고자 하였다.

대상과 방법: 심혈관 질환의 징후나 증상이 없는 남녀 성인 300명이 연구 대상에 포함되었다. 이들의 나선형 전산화단층촬영 사진에서 사전에 정해진 9개 레벨에서 대동맥 직경을 측정하였고, 또한 체표면적으로 보정한 대동맥 직경도 평가하였다. 그리고 대동맥 직경 데이터와 연령, 성별, 몸무게, 키, 고혈압과의 관계에 대해 분석하였다.

결과: 남녀 성인의 대동맥 평균 직경은 각 부위에서 다음과 같았다. 상행대동맥(2.99 ± 0.57 cm), 대동맥궁(2.54 ± 0.35 cm), 근위부 흉부대동맥(2.36 ± 0.35 cm), 중간부 흉부대동맥(2.23 ± 0.37 cm), 원위부 흉부대동맥(2.17 ± 0.38 cm), 가슴배연결부(2.16 ± 0.37 cm), 복강축(2.10 ± 0.35 cm), 콩팥위대동맥(1.94 ± 0.36 cm), 대동맥분기(1.58 ± 0.24 cm). 대동맥 직경은 전체 부위에서 남성의 평균 직경이 여성에 비해 더 컸으며, 연령과 혈압이 증가함에 따라 통계적으로 유의하게 증가하였다. 대동맥궁 부위를 제외하고 키가 클수록 각 부위에서 대동맥 직경이 통계적으로 유의하게 증가하였다. 또한 콩팥위대동맥 부위를 제외하고 몸무게가 무거울수록 각 부위에서 대동맥 직경이 통계적으로 유의하게 증가하였다.

결론: 한국 성인의 대동맥 직경은 남성, 고혈압, 그리고 연령, 몸무게, 키가 증가할수록 통계적으로 유의하게 크다.

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