

Reference Diameters of the Abdominal Aorta and Iliac Arteries in the Korean Population

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Purpose: It is important to know the normal diameter of artery throughout the body so that clinicians are able to determine when an artery becomes aneurysmal. However, there are no previous studies on the normal diameter of arteries in the general Korean population. The purpose of this article is to determine the normal reference diameters of the abdominal aorta and iliac arteries in the Korean population. **Materials and Methods:** We recruited the study population from three cities in Korea for the abdominal aortic aneurysm (AAA) screening. We measured the diameter of the aorta and iliac arteries. We analyzed the reference diameter of the population without AAA. The results were analyzed by Student's t-test and ANOVA on SPSS version 19. A p value <0.05 was considered to be statistically significant. **Results:** One thousand two hundred and twenty-nine people were enrolled. 478 men and 751 women, with a mean age of 63.9 ± 10.1 years (range 50 to 91) were examined. Eleven out of 1229 (0.89%) were diagnosed with AAA. In the population of 1218 people without AAA, the mean diameters (cm) of male/female were 2.20/2.11 ($p < 0.001$) at suprarenal, 2.04/1.90 ($p < 0.001$) at renal, 1.90/1.79 ($p < 0.001$) at infrarenal, 1.22/1.17 ($p < 0.001$) at right iliac and 1.47/1.15 ($p = 0.097$) at the left iliac, respectively. There was a significantly larger diameter in the male population. The diameter of each level increased with age. **Conclusion:** The normal reference diameter of the infrarenal abdominal aorta in the Korean population is 1.9 cm in males and 1.79 cm in females. The diameter of the abdominal aorta increases with age.

Key Words: Screening, ultrasonography, diameter, infrarenal aorta, abdominal

INTRODUCTION

Abdominal aortic aneurysm (AAA) is a dilatation of the abdominal aorta. There are several definitions of an AAA. A diameter in excess of 30 mm based on the angiographic study is the most accepted definition.¹ Some definitions relate the infrarenal aortic diameter to the suprarenal aortic diameter.² The International Society for Cardiovascular Surgery/Society for Vascular Surgery Ad Hoc Committee proposed that an AAA is defined as the maximum infrarenal aortic diameter being at least 1.5 times larger than the expected normal infrarenal aortic diameter.³ With this standard definition, it is important to know the normal diameter of abdominal aorta

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so that clinicians will be able to determine when an aorta becomes aneurysmal. The mean diameters at the level of the infrarenal aorta were 16 to 23 mm in males and 15 to 19 mm in females.^{4,6} However, a practical working definition of an AAA is a transverse diameter of 3 cm or greater based on average values for normal individuals.⁷

Ultrasound screening and autopsy series indicate that the prevalence of AAAs (≥ 3 cm) is 3 to 10% for patients older than 50 years in Western countries.⁸ In a Veterans Affairs screening study of more than 73000 patients 50 to 79 years old, the prevalence of AAA ≥ 3 cm was 4.6% and that of AAA ≥ 4 cm was 1.4%.⁹ In a study of an Asian population, the prevalence of AAA was variable. Spark, et al.¹⁰ suggested that the prevalence of AAA in the Asian population was lower than that in the Caucasian population. Another study, however, showed that AAA in the Asian population is not uncommon and the incidence is comparable to that in Western countries.¹¹

Screening ultrasonography to detect AAA is a useful diagnostic modality because it is simple, inexpensive, and involves no exposure to radiation. Several randomized studies suggested that screening is beneficial in a population at higher risk. The purpose of this article is to evaluate the prevalence of AAA in the Korean population and to determine the normal reference diameter of the abdominal aorta and iliac arteries.

MATERIALS AND METHODS

We recruited the study population from three cities in Korea: Hanam, Seoul and Ulsan. All people over 50 years and who consented to the AAA screening were included in the study. We excluded people who were previously diagnosed with AAA, had a history of AAA surgery including open repair or endovascular repair, had a history of abdominal aortic surgery such as aortobifemoral bypass, had life expectancy less than 2 years based on the life table of Statistics Korea, and/or refused AAA screening. In addition, we excluded people with AAA when analyzing the normal diameter.

Screening was done in the following sequence: recording of medical history, physical examination, and ultrasound examination. We obtained demographic information with a detailed questionnaire. We investigated the patient for a past history of diabetes, hypertension, hyperlipidemia, heart disease, pulmonary disease, cerebrovascular disease, renal

function impairment, and enquired about their surgical history. The questionnaire included questions about any family history of abdominal aortic aneurysm, stroke and peripheral arterial occlusive disease. Social history investigated smoking history, alcohol history and exercise amount. Subjects were asked whether they had any aneurysm-related symptoms such as abdominal pain or back pain. After history taking, abdominal palpation was done to check for the presence of an abdominal pulsating mass. Finally, duplex scanning was performed. The enrolled population was instructed to not eat anything for 8 hours prior to the examination. Duplex scanning was performed by the experienced sonographers who earned the certification of Registered Vascular Technologist presented by American Registry for Diagnostic Medical Sonography. We used two types of ultrasound equipment-Zonare (Zonare Medical Systems, Mountain View, CA, USA) and HD7 (Philips, Amsterdam, the Netherlands). A 2.5 to 5 MHz convex ultrasound probe was used for examination. Duplex scanning was done from the infra-diaphragmatic level to the bilateral iliac arteries. We measured the maximal diameter of the aorta from the outer to outer layer. The anteroposterior and lateral diameters were measured. We recorded the two diameters at five levels of the aorta: suprarenal, renal, infrarenal, right iliac and left iliac arteries (Fig. 1). The diameter of the "suprarenal" was measured at the level between the superior mesenteric artery and renal artery. The "renal" was the aortic diameter at

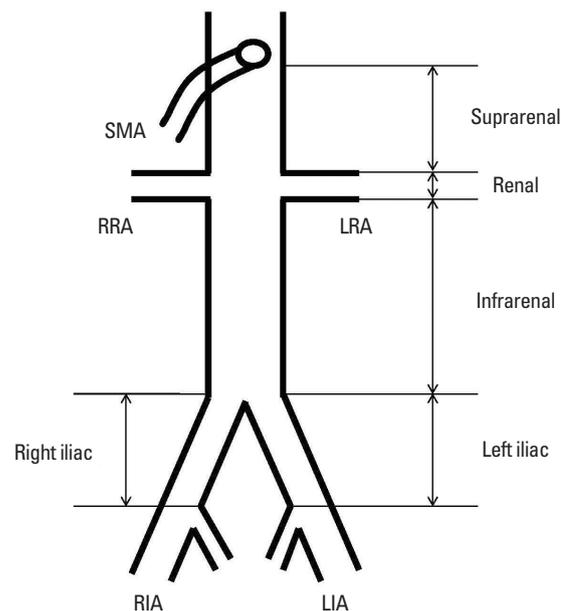


Fig. 1. Levels of measurement. Diameters were measured at five levels of the abdominal aorta: suprarenal, renal, infrarenal, right iliac and left iliac arteries. SMA, superior mesenteric artery; RRA, right renal artery; LRA, left renal artery; RIA, right iliac artery; LIA, left iliac artery.

the level of renal artery. If both renal arteries were projected at the same level, the maximal diameter at the level of renal artery was measured in the anteroposterior plane. The diameter of “infrarenal” aorta was measured at the level between the lower renal artery to aortic bifurcation. The diameters of right and left iliac artery were measured at the common iliac artery between the aortic bifurcation and the origin of internal iliac artery. If the iliac artery was tortuous, the diameter of the iliac artery was measured only in the anteroposterior plane. If it was difficult to measure the diameter due to bowel gas, we asked the people to return for re-examination the next day.

AAA was defined as a maximal aortic diameter of more than 3 cm. The maximal aortic diameter was calculated as the sum of the diameter of the anteroposterior plane and the lateral plane divided by 2. Hypertension and hyperlipidemia were defined as taking medicine to control these risk factors. Cardiovascular risk factors included arrhythmia, coronary artery disease, myocardial infarction, angina and the presence of history for coronary angioplasty or stenting. Cerebrovascular risk factors included transient ischemic attack, reversible ischemic neurologic deficit, and stroke. The respiratory risk factors included chronic obstructive pulmonary disease, asthma, pneumonia or pulmonary tuberculosis. Renal impairment was defined as having dialysis.

We used SPSS version 19.0 software (SPSS, Inc., an IBM Company, Chicago, IL, USA) for the statistical analysis. Student’s t-test was used to evaluate the difference in diameter between men and women. ANOVA was used to evaluate the difference in diameter with age.

RESULTS

One thousand two hundred and twenty-nine people were enrolled in our screening project. All of the study population completed all questionnaires and underwent examination. The 478 men and 751 women examined had a mean age of 63.9±10.1 years (range 50 to 91). We visited the two cities of Hanam and Ulsan to perform the screening. In Seoul, we invited 143 people and visited certain districts for the screening of 75 people. Eleven out of 1229 (0.89%) were diagnosed with AAA. Among them, two (0.16%) had AAA with a maximal diameter of more than 5.5 cm. Two people in the Seoul study group had an AAA more than 3 cm. We excluded these two people because they had already been diagnosed with AAA by another AAA screening program (Table 1).

The screened population had a family history of AAA in 59 (4.8%) participants, stroke in 231 (18.8%), and peripheral arterial occlusive disease in 62 (5.0%). The distribution of AAA with age is shown in Table 2. The prevalence of AAA increased with age. There was no AAA patient between the ages of 50 to 59 years. Two out of 438 (1.1%) and 8 out of 320 (7.2%) had AAA at the age of 60 to 69 years and at the age of 70 to 79 years, respectively. Two people had an AAA with a diameter of more than 5.5 cm. These patients were referred to the hospital for treatment of the AAA. According to the Centers for Medicare and Medicaid Services (CMS) guideline, the following population would benefit from AAA screening: people who have a

Table 1. Prevalence of Abdominal Aortic Aneurysm

District	Type of screening	Number	Aneurysm (%)	Aneurysm ≥5.5 cm (%)
Ulsan city	Visited	35	1 (2.86)	0
Seoul city	Invited*	218	0 [†]	0
Hanam city	Visited	976	10 (1.02)	2 (0.20)
Total		1229	11 (0.89)	2 (0.16)

*Including the visited screening in 75 population.

[†]Two people had an abdominal aortic aneurysm (AAA) ≥5.5 cm. These people were excluded from our study because they had already been diagnosed with AAA by another screening study.

Table 2. Distribution of Abdominal Aortic Aneurysm with Age

Age	Number	Sex		Aneurysm		Aneurysm ≥5.5 cm	
		Male	Female	Male	Female	Male	Female
50-59	409	162	247	0	0	0	0
60-69	438	186	252	2 (1.1)	0	0	0
70-79	320	111	209	8 (7.2)	0	2 (1.8)	0
80≤	62	19	43	1 (5.3)	0	0	0
Total	1229	478	751	11 (2.3)	0	2 (0.4)	0

family history of AAA, men aged 65 to 75 years old who have smoked at least 100 cigarettes throughout their life. When we analyzed in this group in our study, 10 out of 223 (4.5%) had AAA.

Hypertension was the most common risk factor. 621 (50.5%) of the population was diagnosed with hypertension and took medicine for hypertension. The population with a cardiovascular risk factor, mainly ischemic heart disease, was 6.1%. The population with a cerebrovascular problem including transient ischemic attack, reversible ischemic neurologic deficit, and stroke was 5.6% (Table 3). When risk factors were analyzed in the population diagnosed with AAA, all were smokers (Table 4).

We analyzed the normal diameter of the abdominal aorta and the bilateral iliac arteries in 1218 people except for the population diagnosed with AAA (Table 5). The mean diameter at the level of the suprarenal aorta was 2.14 cm, 1.95 cm at the level of the renal artery, and 1.83 cm at the level of the infrarenal aorta. The diameter of the right iliac artery was 1.19 cm at and the diameter of the left iliac artery was 1.27 cm. There were significantly larger diameters in the male population compared with the female population on Student's t-test except for the left iliac artery. We analyzed the normal diameter of each level with increase in age (Table 6). Mostly, the diameters of each level increased with age.

Table 5. Normal Diameter of Abdominal Aorta for Different Anatomic Level (n=1218)

Anatomic level	Male (n=467) mean±SD (cm)	Female (n=751) mean±SD (cm)	p value*	Total mean±SD (cm)
Suprarenal	2.20±0.30	2.11±0.31	<0.001	2.14±0.31
Renal	2.04±0.34	1.90±0.27	<0.001	1.95±0.31
Infrarenal	1.90±0.36	1.79±0.28	<0.001	1.83±0.32
Right iliac	1.22±0.23	1.17±0.22	<0.001	1.19±0.23
Left iliac	1.47±4.13	1.15±0.21	0.097	1.27±2.57

SD, standard deviation.

*With Student's t-test.

Table 6. Normal Diameter of Abdominal Aorta with Age (n=1218)

(mean±standard deviation, cm)

Age	Number	Suprarenal*	Renal [†]	Infrarenal [‡]	Right iliac [§]	Left iliac
50-59	409	2.05±0.30	1.87±0.28	1.75±0.30	1.14±0.22	1.13±0.21
60-69	436	2.15±0.29	1.97±0.32	1.81±0.31	1.19±0.22	1.43±4.27
70-79	312	2.24±0.30	2.02±0.30	1.94±0.34	1.24±0.22	1.24±0.57
80≤	61	2.25±0.36	2.05±0.34	1.92±0.34	1.24±0.28	1.20±0.26

Statistical analysis with ANOVA (p value <0.05).

*50s-60s-70s/80s.

[†]50s/60s-70s/80s.

[‡]50s-60s/70s/80s.

[§]No subset <0.05.

^{||}No subset <0.05.

Hyphen means statistically significant and slash means statistically not significant.

DISCUSSION

There are 3 modalities for aortic diameter measurement: ultrasonography (US), computed tomography (CT), and

Table 3. Risk Factors in the Screened Population

Risk factors	Number (%)
Hypertension	621 (50.5)
Hyperlipidemia	409 (33.3)
Cardiovascular*	75 (6.1)
Cerebrovascular [†]	69 (5.6)
Respiratory [‡]	26 (2.1)
Renal impairment	20 (1.6)

*Mainly ischemic heart disease.

[†]Including transient ischemic attack, reversible ischemic neurologic deficit, and stroke.

[‡]Mainly chronic obstructive pulmonary disease.

Table 4. Risk Factors in Patients with Abdominal Aortic Aneurysm (n=11)

Risk factors	Number (%)
Smoking	11 (100)
Current smoker	6 (54.5)
Ex-smoker	5 (45.5)
Hypertension	6 (54.5)
Hyperlipidemia	6 (54.5)
Coronary artery disease	1 (9.1)
Chronic obstructive pulmonary disease	1 (9.1)

magnetic resonance imaging. In our study, the measurement of aortic diameter was made using US. The CT is less operator-dependent and more objective. In addition, CT-based measurements are not affected by gastrointestinal gas or other body features. Lederle, et al.¹² analyzed the variation in aortic diameters measured with both CT and ultrasonography in 258 patients. They reported a difference of less than 0.2 cm in 44% and at least 0.5 cm in 33%. The US-based measurements were smaller than the CT-based measurements by an average of 0.27 cm. But Wanhainen, et al.¹³ reported that US-based measurements were larger by 2.8 mm than CT-based measurements. The difference and variability of measurements between US and CT depends on the diameter of the aorta and how it is measured. There is no gold standard of measuring the aortic diameter. US is used as the most practical method for screening and the follow-up of small sized infrarenal AAA, while CT has become the preferred preoperative imaging technique for conventional open repair or endovascular repair. However, US have several advantages such as ease of use, low cost, and no radiation.

There are a few reports evaluating racial differences in the aortic diameter. In this study, the diameter of the infrarenal aorta was 19.0 mm in males and 17.9 mm in females in a Korean population. In a similar study on an American population by Ouriel, et al.,⁵ the diameter was 23 mm in males and 19 mm in females. In another study, Sariismanoglu, et al.⁴ reported that the mean aortic diameters were 16 mm in males and 15 mm in females in a Turkish population. Differences in the infrarenal aortic diameter are due to different methods of measurement and different levels where the aorta was measured. There is a report evaluating the difference in aortic diameter between the races. Laughlin, et al.¹⁴ reported that the aortic diameter of people of Chinese, African, and Hispanic descent is smaller than the aortic diameter of Caucasians even after adjusting for differences in body size and other factors.

In this study, the diameter of the abdominal aorta increased with age increment. The infrarenal aortic diameter was measured at 17.5 mm for people in their 50s, 18.1 mm for people in their 60s, and 19.4 mm for people in their 70s. In another study, aortic diameter showed significant correlation with age.⁴ Länne, et al.¹⁵ investigated the changes in the diameter of the distal abdominal aorta in 76 healthy Caucasian males aged 5 to 71 years old by means of an ultrasound phase-locked echo-tracking system. The diameter of the abdominal aorta increased with age, and the increase

was about 30% between the ages of 25 and 71 years. The pressure strain and stiffness of the aorta increased in an exponential manner with age. The ranges for both pressure strain and stiffness were much larger in the aneurysm group than in the control group, indicating possible involvement of pressure strain and stiffness in the pathogenesis of abdominal aortic aneurysm.

There are many reports that provide evidence supporting the value of abdominal aortic aneurysm screening. Ashton, et al.¹⁶ enrolled a population-based sample of men (n=67800) aged 65 to 74 years. They were randomly allocated to either receive an invitation for an abdominal ultrasound scan (invited group, n=33839) or not receive an invitation (control group, n=33961). There were 65 (0.19%) aneurysm-related deaths in the invited group, and 113 (0.33%) in the control group, with a 53% reduction of mortality in those who attended screening. The results provided reliable evidence of the benefit of screening for abdominal aortic aneurysm. Lindholt, et al.¹⁷ performed the screening to determine whether screening Danish men aged 65 years or more for AAA reduced mortality. 4860 men were screened. The prevalence of abdominal aortic aneurysm was 4.0%. Deaths due to abdominal aortic aneurysms occurred in nine patients in the screened group and 27 in the control group. They concluded that screening for AAA in men aged 65 or more reduced mortality from AAA. Thompson, et al.¹⁸ investigated the mortality benefit of screening men aged 65-74 years for AAA in the longer term. The 10-year follow-up data showed that there was a 48% reduction in relative risk of mortality. A meta-analysis of the data showed that there is evidence of a significant reduction in mortality from AAA in men aged 65 to 79 years who undergo ultrasound screening. However, there is insufficient evidence to demonstrate a benefit for women.¹⁹

AAA was not uncommon in Korean population. In this study, AAA was detected in 11 (0.89%) people among the 1229 person population. AAA \geq 5.5 cm, which needed elective repair was detected in 2 (0.16%). Ten people (4.5%) had AAA in the high risk group (223 people), which was suggested by CMS. Darwood, et al.²⁰ reported the results of Gloucestershire Aneurysm Screening Program in men aged more than 65. 2412 (4.57%) had AAA after ultrasound screening. One hundred and forty eight men among 52690 had an AAA \geq 5.4 cm in diameter and were referred for possible treatment. According to the National Health Service abdominal aortic aneurysm screening programme in men \geq 65, the prevalence of AAA was 1.7%.²¹ Norman, et al.²²

reported the results of AAA screening in Western Australia. The AAA prevalence was 7.2% for aortic diameter ≥ 3 cm and 0.5% for diameter ≥ 5.5 cm in 41000 men aged 65-83 years.²²

There are several risk factors for AAA. Fleming, et al.²³ reported the odds ratio for the risk factors of AAA. After adjustment for other risk factors, significant risk factors for an AAA 4.0 cm or greater include family history (1.94), coronary artery disease (1.52), hypercholesterolemia (1.44) and cerebrovascular disease (1.28). Family history of AAA is the strongest risk factor among other factors. Smoking is a significant risk factor for the development of AAA. Kent, et al.²⁴ reported the effect of smoking history on the risk of AAA. Risk of AAA was higher for current smokers than for past smokers and increased with duration of smoking and quantity of cigarettes smoked per day as well as declined over time after quitting. Male gender was another strong risk factor. In the study of Cornuz, et al.,²⁵ the odds ratio of male gender for AAA was 5.69. The development of AAA increased with age.²⁴⁻²⁶ The odds ratio for an age increase of 7 years was 1.7.⁹

In conclusion, the normal reference diameter of the infrarenal abdominal aorta in the Korean population is 19.0 mm in males and 17.9 mm in females. The diameter of the abdominal aorta increases with age.

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