Thoracic and abdominal aortic dimension in 70-year-old men and women – A population-based whole-body magnetic resonance imaging (MRI) study

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Objective: **The aim of this population-based study was to determine the optimal dividing-line between normal aorta and aneurysm for different aortic segments in 70-year-old men and women by means of whole-body magnetic resonance imaging.**

Methods: **Two hundred thirty-one subjects (116 men), randomly recruited from a population-based cohort study, were included. The smallest outer diameter (dia) was measured on the axial survey scan on six predefined aortic segments: (1) ascending aorta, (2) descending aorta, (3) supraceliac aorta, (4) suprarenal aorta, (5) largest infrarenal abdominal aorta, and (6) aortic bifurcation. Relative aortic dia were calculated by dividing a given aortic dia by the suprarenal aortic dia. The dividing-line between normal aorta and aneurysm at different aortic segments was estimated by taking the mean dia +2 SD and/or mean ratio of the aortic segment to the suprarenal aorta +2 SD.**

Results: **The mean dia of the six segments were 4.0 cm (SD 0.4), 3.2 cm (0.3), 3.0 cm (0.3), 2.8 cm (0.3), 2.4 cm (0.5), and 2.3 cm (0.3) in men. The corresponding dia in women were 3.4 cm (0.4), 2.8 cm (0.3), 2.7 cm (0.3), 2.7 cm (0.3), 2.2 cm (0.3), and 2.0 cm (0.2). The mean ratio to the suprarenal aorta was 1.4 (SD 0.2) for the ascending aorta, 1.2 (0.1) for the descending aorta, and 0.9 (0.2) for the infrarenal aorta in men. The corresponding ratios in women were 1.3 (0.2), 1.0 (0.1), and 0.8 (0.1).**

Conclusion: **For men the suggested dividing-line (dia and ratio) between normal aorta and aneurysm for the ascending aorta is 4.7 cm dia and 1.8 ratio, for the descending aorta 3.7 cm dia and 1.5 ratio, and for the infrarenal aorta is 3.0 cm dia and 1.1 ratio. The corresponding dividing-lines for women are 4.2 cm dia and 1.7 ratio, 3.3 cm dia and 1.3 ratio, and 2.7 cm dia and 1.0 ratio. (J Vasc Surg 2008;47:504-12.)**

The most striking weakness, concerning epidemiological studies on aortic disease, is the lack of a uniform definition of the disease. The lack of a uniform definition makes it difficult to compare results between studies, and we have previously demonstrated how various definitions strongly influence the reported prevalence of abdominal aortic aneurysm (AAA).[1] With upcoming population-based AAA-screening program[2] and increasing use of computed tomography (CT) and magnetic resonance imaging (MRI), this may become a problem also for the medical society.

The abdominal aorta is easily examined by ultrasonography (US), and population-based normative values are available.[3] There is, however, no general agreement on how to define abdominal aortic pathologies, such as aneurysm. Several proposed definitions of an AAA exist, all based on the diameter of the abdominal aorta.[4-7] The most accepted definition of an AAA is when the maximum infrarenal aortic diameter is 30 mm or more.[4] Other relates the infrarenal aortic diameter to the expected normal diameter, which often refers to the diameter of the adjacent aorta.[5-7]

The thoracic aorta is visualized by CT and MRI. A few selected series with normal thoracic aortic diameters have been published.[8-10] However, no clear definition of a thoracic aortic aneurysm exists (TAA). In a follow-up study by Coady et al, the thoracic aorta was considered aneurysmal if it attained a maximal diameter ≥35 mm.[11] The basis for this "definition" was not explained in the report, and no other proposed definition exists in the literature.

The aim of this population-based study was to determine the optimal dividing-line between normal aorta and aneurysm for different aortic segments in 70-year-old men and women by means of whole-body MRI.

SUBJECTS AND METHODS

Over a 3-year period (November 2002 to November 2005), 264 subjects were examined with a whole-body magnetic resonance angiography (WBMRA). The subjects were randomly recruited from PIVUS (Prospective Investigation of the Vasculature in Uppsala Seniors), a prospective population-based cohort study with the primary aim to evaluate the predictive value of endothelium-dependent vasodilatation in future cardiovascular events. In that study, all 70-year-old men and women living in the municipality

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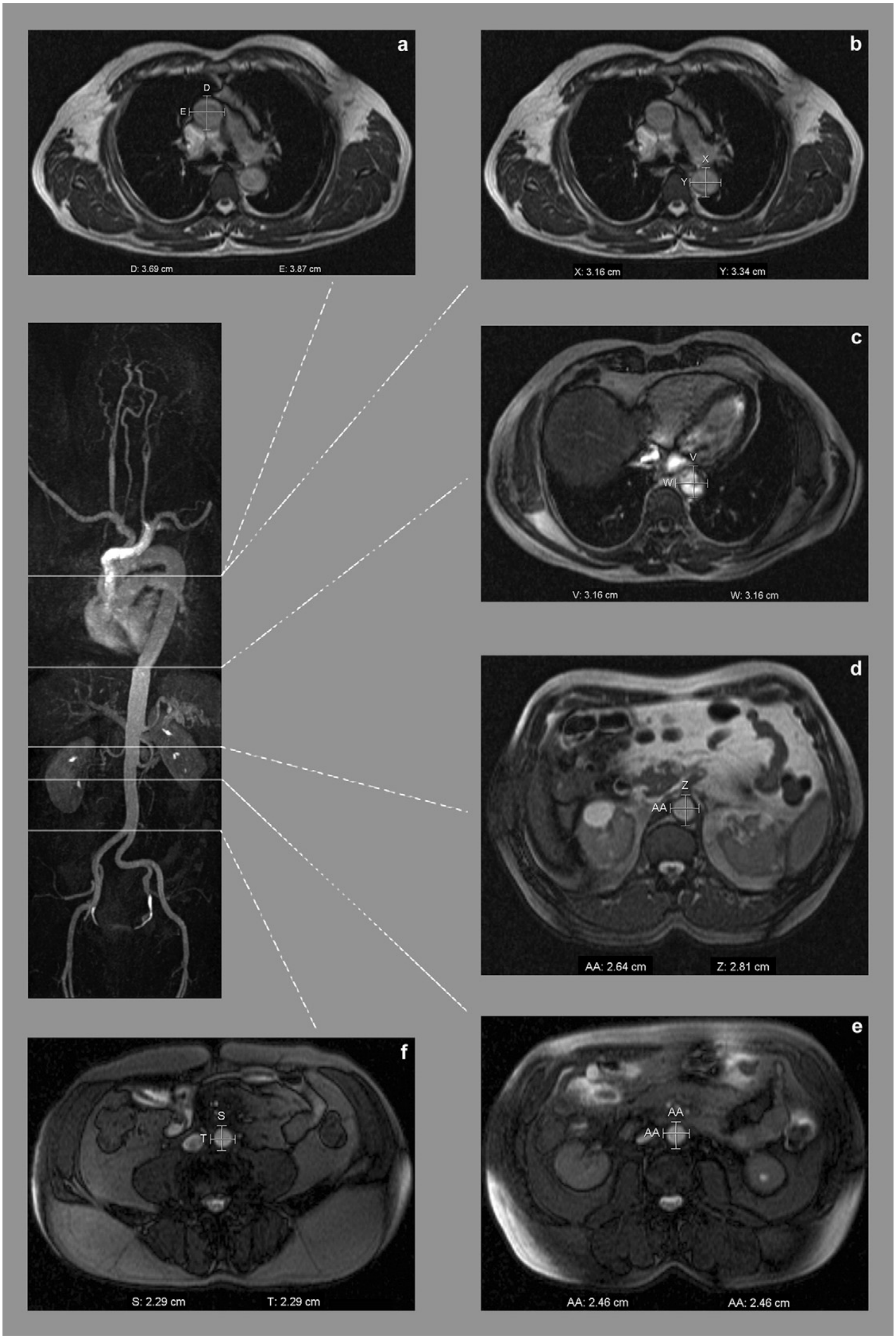

Fig 1. Maximum intensity projection of the aorta with the corresponding survey slices of the (**a**) ascending aorta, (**b**) descending aorta, (**c**) supraceliac aorta, (**d**) suprarenal aorta, (**e**) infrarenal aorta, and (**f**) aortic bifurcation.

of Uppsala were invited. Of 2025 subjects invited, 1016 participated (50.1%).[12] The principal aim of the WBMRA-examination was to assess the atherosclerotic burden.[13] The present study of aortic dimension was performed as an ad hoc study to the WBMRA-examination. The study was approved by the Ethics Committee of Uppsala University, and all participants gave their written informed consent.

WBMRA was performed with a standard quadrature body coil in a 1.5 Tesla Gyroscan Intera scanner (gradients: amplitude 30 mT/m, rise time 200 μs, slew rate 150 mT/m/ms) using standard software (Philips Medical System, Best, The Netherlands). 40 ml of gadodiamide (Omniscan, GE Healthcare, Oslo, Norway) was injected intravenously. The images used for the analysis of the aortic diameter were the transverse balanced fast-field-echo acquisition performed to plan the WBMRA. The acquisition parameters were as follows: time to repeat (TR)/time to echo (TE)/flip = 3.8/1.9/70 with a slice thickness of 10 mm and a 256 × 256 matrix with a field of view (FOV) of 420 mm. The images were zero-filled and reconstructed to a resolution of 1.2 × 1.4 mm.

The outer diameter on six predefined aortic segments were evaluated: (1) the ascending aorta, proximal to the brachiocephalic trunk (Fig 1, *a*), (2) the descending aorta, distal to the left subclavian artery (Fig 1, *b*), (3) the supraceliac aorta, at the dome of the right hemidiaphragm (Fig 1, *c*), (4) the suprarenal aorta, above the most cranial renal artery (Fig 1, *d*), (5) the largest infrarenal abdominal aorta (Fig 1, *e*), and (6) the aortic bifurcation, (Fig 1, *f*). The measurements were made in straight anterior-posterior (sagittal) and transverse (coronal) planes using the estimated outer margins of the aortic wall. To compensate for vessel angulations, the smallest diameter of these two measurements was used as the best estimate of the true cylindrical diameter. When there was an oblique orientation in the reference slice, at visual examine, we tried to obtain a more precise cross-sectional measurement (ie, cylindrical diameter) 1-2 slices cranial or 1-2 slices caudal. If a cross-sectional orientation was not possible to obtain in any of those four adjacent slices the smallest oblique measurement was used.

One experienced radiologist (RT) evaluated all examinations. The inter- and intra observer variability of the measurements was tested by a repeated measurement (RT) and by a second observer (LJ) in 17 cases, 6 months after the primary measurement. The location of the widest part of the infrarenal aorta was determined by the two reviewers blinded from each other. The diameter of the infrarenal aorta was measured in the anterior-posterior and transverse directions. The average of the absolute difference between the two measurements was calculated.

Aortic diameters (cm) were presented as mean values with standard deviation (SD). Pearson correlation coefficient was used to analyze the correlation between body surface area (BSA) and aortic diameter. Scatter-plots of the diameter of different aortic segments and BSA were drawn separately for men and women. Regression lines were calculated by using a linear regression model. BSA was calculated using the Du Bois formula (BSA, cm^2 = weight$^{(0.425)}$, kg × height$^{(0.725)}$, cm × 71.84). Relative aortic diameters (ratio) were calculated by dividing a given aortic diameter by the suprarenal aortic diameter. Independent sample *t* test was used for comparison of aortic diameter and ratio between men and women.

Table I. Basic characteristics of the total PIVUS cohort of 70-year-old men and women and the present sample

	Total PIVUS cohort	*Present sample*
N	1016	231
Female (%)	50.2	49.8
Height (cm)	169 ± 9	169 ± 9
Weight (kg)	77 ± 14	77 ± 13
BMI (kg/m^2)	27 ± 4	27 ± 4
SBP (mm Hg)	150 ± 23	150 ± 22
DBP (mm Hg)	79 ± 10	79 ± 9
Ever smoking (%)	52	48

PIVUS, Prospective Investigation of the Vasculature in Uppsala Seniors; *SBP,* systolic blood pressure; *DBP,* diastolic blood pressure; *BMI,* body mass index.
Means are given ±SD (standard deviation).

To define a suitable dividing-line between normal aorta and aneurysm at different aortic segments, a threshold-diameter (mean diameter + 2 SD) and a threshold-ratio (mean ratio + 2 SD) was calculated, below which 97.5% of the measurements would be expected to be. To reduce the influence of possible extreme outlier, they were excluded in the calculation of the suggested definitions of aneurysms. Outliers were identified in a box-and-whisker plot and extreme outliers were defined as values of the diameter and the ratio >3 box lengths from the upper edge of the box. Statistical evaluation of the data was carried out with a computer software package (SPSS PC version 14.0; SPSS, Chicago, Ill).

RESULTS

Measurements were not obtained in 27 cases due to technical problems retrieving data from the digital archive at the time of measurements, and data for six cases were incomplete. Basic characteristics of the studied population are given in Table I. Table II and Fig 2 display the diameters of the segments successfully measured in the remaining 231 subjects (116 men). Some aortic segments were not possible to measure due to motion artifacts. The diameter of all aortic segments differed significantly between men and women (Table II). The average intraobserver difference of the anterior-posterior measurements was 1.03 mm (SD 0.89) and of the transverse measurements 1.14 mm (1.23). The corresponding interobserver differences were 0.82 mm (0.89) and 1.36 mm (1.17), respectively.

The mean BSA was 19858 cm^2 (SD 1489 cm^2) for men and 17494 cm^2 (1341 cm^2) for women. In men, there was a significant correlation between BSA and the ascending aortic diameter (r = 0.36, $P < .001$) and between BSA and the descending aortic diameter (r = 0.34, $P < .001$), while no correlation between BSA and the infrarenal aortic diameter was observed (r = −0.12, $P = .19$). The corresponding

Table II. Aortic diameters of different aortic segments successfully measured in 117 men and 114 women

	Men			Women			
Aortic segment	*N*	*Mean diameter (95% CI)*	*SD*	*N*	*Mean diameter (95% CI)*	*SD*	P*
Ascending	116	4.0 (3.9-4.1)	0.4	104	3.4 (3.3-3.5)	0.4	<.001
Descending	116	3.2 (3.2-3.3)	0.3	114	2.8 (2.7-2.8)	0.3	<.001
Supraceliac	115	3.0 (2.9-3.0)	0.3	113	2.7 (2.6-2.7)	0.3	<.001
Suprarenal	116	2.8 (2.7-2.9)	0.3	114	2.7 (2.6-2.7)	0.3	.004
Infrarenal	117	2.4 (2.3-2.5)	0.5	114	2.2 (2.1-2.2)	0.3	<.001
Bifurcation	113	2.3 (2.2-2.3)	0.3	112	2.0 (1.9-2.0)	0.2	<.001

CI, Confidence interval; *SD,* standard deviation.
*Independent sample *t* test.

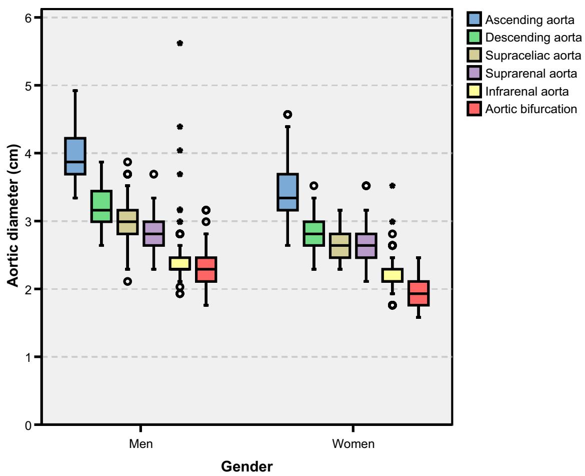

Fig 2. Box-and-whisker plot of aortic diameter determined by means of whole-body magnetic resonance angiography in 231 subjects, showing the 2½%, 25%, 50%, 75%, and 97½% cumulative relative frequencies. Open circles represents cases with values 1.5-3 box lengths from the upper or lower edge of the box and stars represents cases with values >3 box lengths from the upper or lower edge of the box.

correlation coefficients for women were 0.24 (P = .013), 0.33 (P < .001), and 0.18 (P = .055). Figs 3, 4, and 5 display scatter-plots of the ascending-, descending-, and infrarenal aortic diameter and BSA with regression lines and predicting lines (mean +2 SD) below which 97.5% of the measurements would be expected to be.

The ratio between the diameter of different aortic segments and the suprarenal aorta is displayed in Table III and Fig 6. The ratio to the suprarenal aorta differed significantly between men and women for all aortic segments.

Extreme outliers were only observed in the infrarenal aortic segments among men (three cases (2.6%) with a diameter >4 cm and a ratio >1.4). With these cases excluded, the mean diameter was 2.4 cm (SD 0.3 cm) and the mean ratio was 0.9 (0.1). Table IV displays the suggested dividing-lines (diameter and/or ratio) between normal aorta and aneurysm for the ascending-, descending-, and infrarenal aorta.

DISCUSSION

There are several published large population-based US screening studies of the abdominal aorta.[14-18] Published work on the normal dimension of the thoracic aorta is, however, scarce. Only a few selected small series exist,[8,9,10,19] and no population-based report has previously been published. In the present population-based study aortic dimensional variations was defined in 70-year-old men and women by means of MRI.

Traditional axial-imaging lacks the ability to compensate for vessel angulations, and the diameter may be represented by an oblique measurement instead of a more accurate cross-sectional measurement.[20] In a recent publication, axial-CT was found to be unreliable when aortic angulations were greater than 25°.[21] To minimize the risk of false large diameter due to an oblique measurement, the smallest diameter was used as the best estimate of the true cylindrical diameter. Furthermore, the data acquisition was not optimized for the measurements in terms of resolution. A higher resolution, both in-plane and through-plane, could probably have been achieved if aortic measurements would have been the primary purpose of the study. The lower resolution compared with US may cause problems related to partial volume effects and in that way an overestimation of the aortic diameter. The inter- and intraobserver variability do, however, indicate the analysis of the data was robust. The calculated ratio to the suprarenal aortic diameter should not be affected by these limitations.

The observed mean thoracic aortic diameter (ascending aorta 3.7 cm and descending aorta 3.0 cm) was larger than in other reports, which in part may be explained by differences in age and inclusion criteria. In a CT study of 70 adults aged 17 to 89 years (mean 50 years) without cardiovascular disease, Hager et al found the mean diameter of the ascending aorta to be 3.3 cm and the descending aorta 2.5 cm.[9] In an MR study of 66 subjects aged 19 to 82 years (mean 44 years) whose aorta was normal, Garcier et al found the mean diameter of the ascending aorta to be 3.0 cm and the descending aorta 2.3 cm.[8] Aronberg et al found the mean diameter of the ascending aorta to be 3.6 cm and the descending aorta 2.5 cm, in a CT study of 102 adults without hypertension, diabetes, cardiovascular disease, or renal disease. They showed that the thoracic aortic diame-

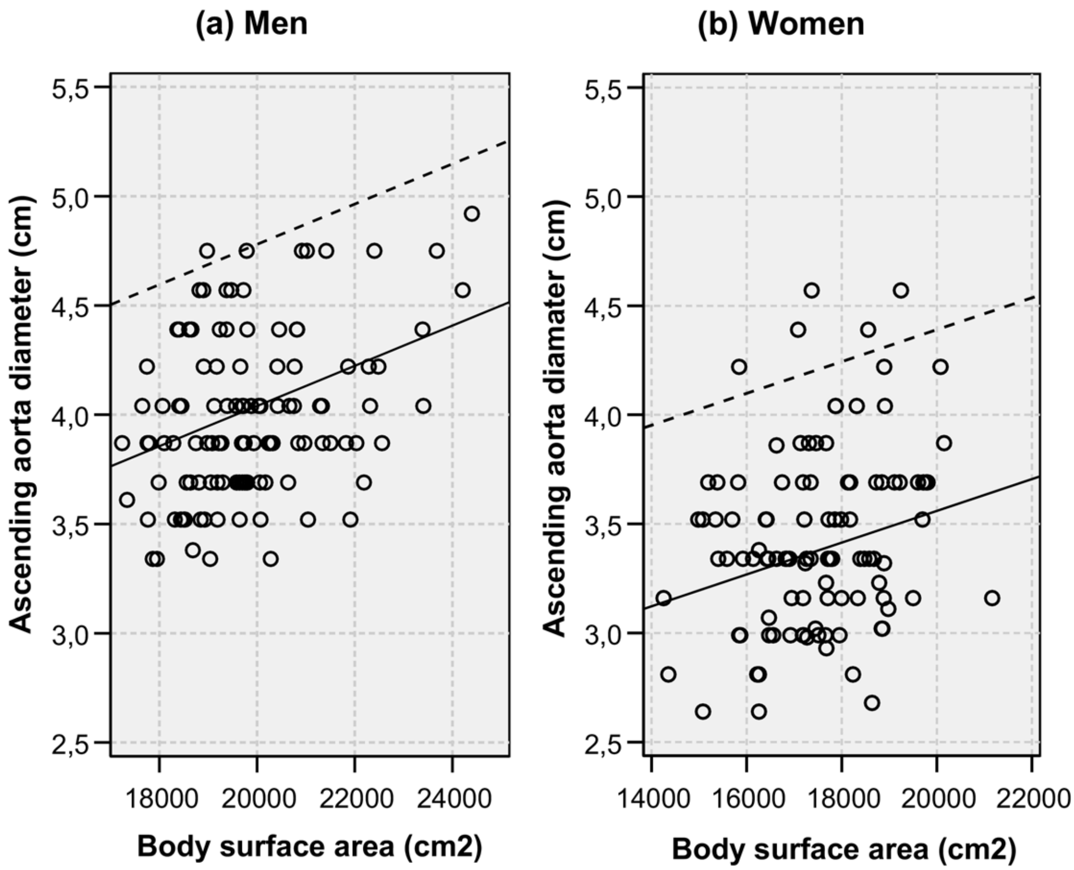

Fig 3. Scatter-plot of ascending aorta diameter (cm) and body surface area (BSA, cm^2). For men (**a**) the regression line is $y = 2.2 + 9.2 \times 10^{-5} \times BSA$ ($R^2 = 0.13$, $P < .001$) and for women (**b**) $y = 2.1 + 7.3 \times 10^{-5} \times BSA$ ($R^2 = 0.06$, $P = .013$), where y is ascending aortic diameter (dotted line is y + 2 SD).

ter increase about 0.1 cm per decade during adulthood.[19] In a recent study from Umeå, Sweden, on 77 patients undergoing CT of the thorax, the upper normal limit for ascending aorta was calculated to D(mm) = 31 mm + 0.16 * age and for descending aorta D(mm) = 21 mm + 0.16 * age.[22] According to this formula, a 70-year-old person has an upper normal limit for the ascending aorta of 4.2 cm and 3.2 cm for the descending aorta.

In a necropsy study of 645 subjects aged 19 to 97 years (mean 56 years) without cardiovascular disease, da Silva et al found the mean diameter of the infrarenal aorta to be 1.7 cm, and among subjects above 70 years old, the diameter was 1.8 to 2.0 cm.[23] In a study by Sonesson et al, the infrarenal aortic diameter in 146 healthy subjects aged 4 to 74 years was measured with US. The diameter increased by 25% between the age of 25 and 70, and was predicted to be 1.2 to 2.7 cm in subjects aged 70 years, depending on gender and body size.[3] In a population-based US screening study of more than 10.000 men aged 60 to 75 years, Grimshaw et al found that changes in the diameter with age occurs for about 25% of the population, although the median diameter (2.1 cm) does not increase with age. Six percent of all men aged 70 years were calculated to have an infrarenal aortic diameter above 3.1 cm and 3% above 4.1 cm.[24] In the present study, 2.5% of the measurements would be expected to be above 3.0, when three extreme outliers were excluded.

An important limitation of the present study is that the suggested dividing line between normal aorta and aneurysmal aorta does not include the influence of age. However, the ADAM-study with over 120,000 subjects aged 50 to 79 years included, the largest population-based US AAA screening study ever, found that although age was significantly associated with aortic diameter, the effect was small, and 0.1 cm change in diameter was associated with 29 years change in age.[25] Furthermore, most patients with a clinical relevant aneurysm has an age close to the one studied in the present report. In the Swedish Vascular Registry (Swedvasc), the mean age of all patients operated on for AAA was 72 years, 70% was 70 years or older, and 95% was 60 years or older.[26] Considering the small influence of age, we therefore believe that a study of people 70 years of age is relevant to define a normal and aneurysmal aorta.

Gender is, together with age, the most important factor related to aortic dimension. The sex-differences ranged from 0.1 cm to 0.6 cm in the present study, which corre-

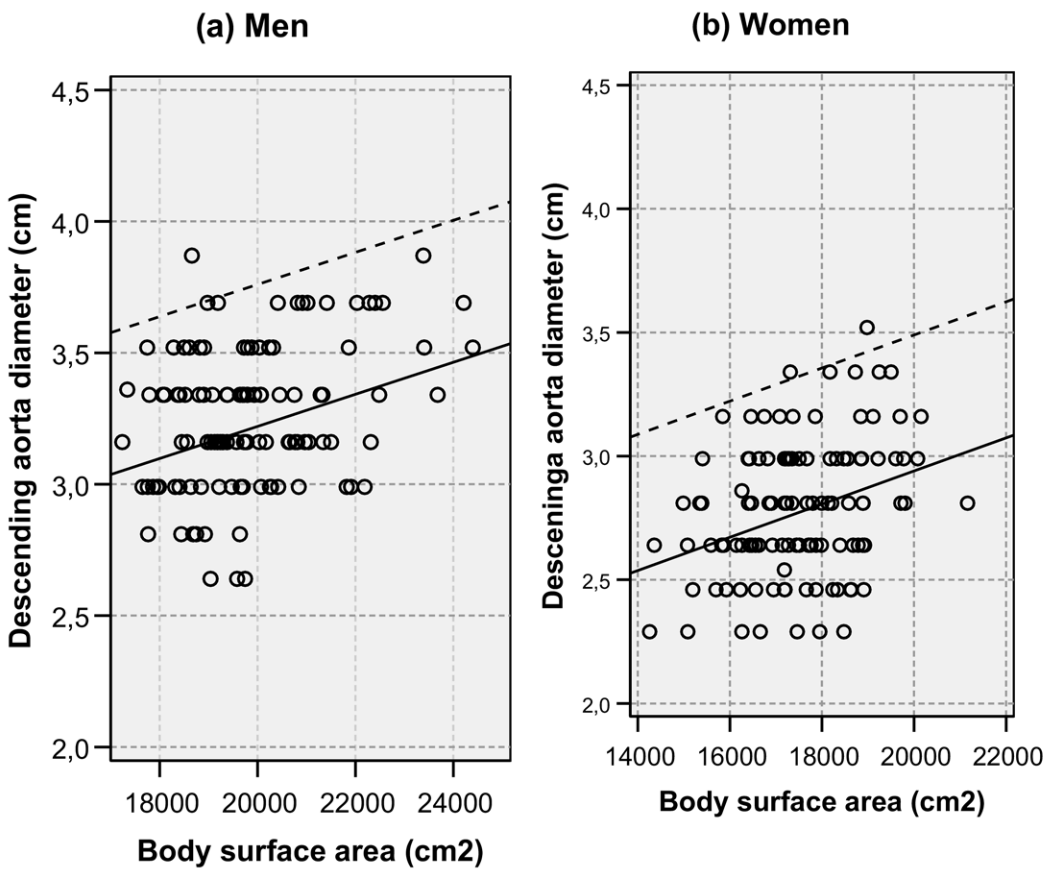

Fig 4. Scatter-plot of descending aorta diameter (cm) and body surface area (BSA, cm^2). For men (**a**) the regression line is $y = 2.0 + 6.1 \times 10^{-5} \times BSA$ ($R^2 = 0.11$, $P < .001$) and for women (**b**) $y = 1.6 + 6.7 \times 10^{-5} \times BSA$ ($R^2 = 0.11$, $P < .001$), where y is descending aortic diameter (dotted line is y + 2 SD).

sponds well with previous reports. The thoracic aortic dimension differed about 0.5 cm between men and women in the study by Garcier et al,[8] while the difference was lower, about 0.3 cm, in the study by Hager et al.[9] The gender difference in infrarenal aortic diameter was reported to be 0.3 cm in 70-year-old subjects by Sonesson et al,[3] while female sex was associated with a 0.14 cm reduction in infrarenal aortic diameter in the ADAM-study,[24] similar to the findings by da Silva.[23]

The observed differences between men and women in the present study were only partly explained by gender. Also, differences in body size influenced the aortic diameter that was most prominent in the thoracic aorta. Although correction for body size may be appropriate when evaluating the aortic diameter, the results ($R^2 < 0.13$) indicate that the variability in aortic diameter was only to a smallest amount explained by variation in body size.

The present study showed that the infrarenal aorta was the site of most abnormities (Fig 2), an observation consistent with the reported prevalence and incidence of aortic diseases.[27] It is generally not recommended to exclude outliers in a population-based material. However, the SD of the mean infrarenal aortic diameter, and thereby the suggested definition of an AAA, was significantly affected by a few extreme outliers. To reduce the influence of extreme cases on the suggested definition of an AAA, we performed a separate analysis with extreme cases excluded, while all cases were included in the descriptive baseline analysis. In previous reports, subjects with for example cardiovascular disease or known aneurysms were excluded from the analysis. These studies were, however, all based on small series and not population-based.

The supraceliac- and suprarenal aorta were the most constant segments, which was the rational for using the suprarenal aortic diameter as a reference level, as suggested by others.[9] Despite differences in measured diameters, the observed ratio was very similar to the one reported by Hager et al.[9] According to the International Society for Cardiovascular Surgery (ISCVS)/Society for Vascular Surgery (SVS) Ad Hoc Committee, an aneurysm is a permanent localized dilatation of an artery having at least a 50% increase in diameter compared with the expected normal diameter of the artery in question,[7] which in clinical practice often referrers to the arterial diameter proximal to a dilatation. One important observation in the present study was that the mean infrarenal-suprarenal ratio was 0.9 for men and 0.8 for women and that

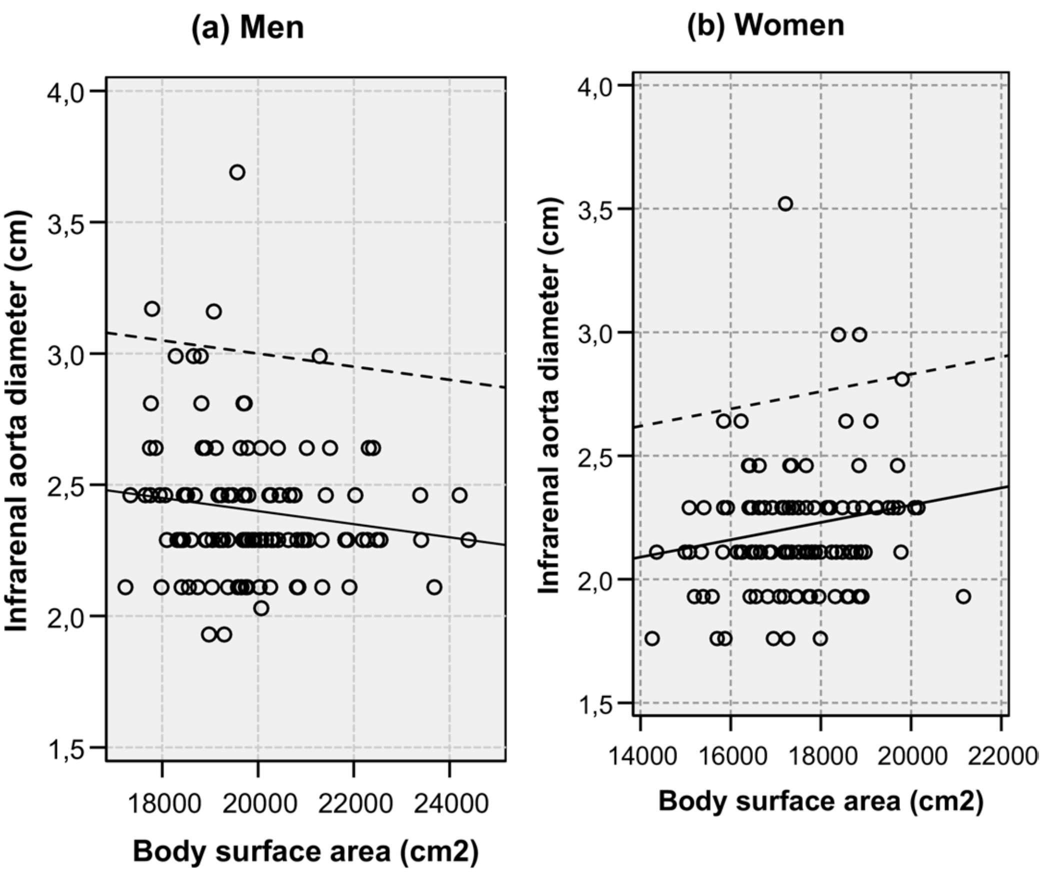

Fig 5. Scatter-plot of infrarenal aorta diameter (cm) and body surface area (BSA, cm^2). For men* (**a**) the regression line is $y = 2.9 - 2.5 \times 10^{-5} \times BSA$ ($R^2 = 0.02$, $P = .19$) and for women (**b**) $y = 1.6 + 3.5 \times 10^{-5} \times BSA$ ($R^2 = 0.03$, $P = .055$), where y is infrarenal aortic diameter (dotted line is y + 2 SD). *Three extreme outliers (diameter >4 cm and ratio >1.4) were excluded from the calculation and is not shown in the scatter-plot.

Table III. Ratio between the diameter of different aortic segments and the suprarenal aorta

	Men			*Women*			
Aortic segment	*N*	*Mean ratio (95% CI)*	*SD*	*N*	*Mean ratio (95% CI)*	*SD*	P[a]
Ascending	115	1.4 (1.4-1.5)	0.2	104	1.3 (1.3-1.3)	0.2	<.001
Descending	115	1.2 (1.2-1.2)	0.1	114	1.0 (1.0-1.0)	0.1	<.001
Supraceliac	114	1.1 (1.1-1.1)	0.1	113	1.0 (1.0-1.0)	0.1	<.001
Infrarenal	116	0.9 (0.9-0.9)	0.2	114	0.8 (0.8-0.8)	0.1	<.001
Bifurcation	112	0.8 (0.8-0.8)	0.1	112	0.7 (0.7-0.8)	0.1	<.001

CI, Confidence interval; *SD,* standard deviation.
[a]Independent sample *t* test.

97.5% of all measurements would expect to be below 1.1 and 1.0, respectively. Thus, a ratio of 1.5, as suggested by the ISCVS/SVS-guidelines[7] and others[5] may be appropriate with the infrarenal aortic neck as a reference diameter, while a ratio of 1.5 to the suprarenal aortic segment would be equivalent to an increased diameter by about 80%, and to an infrarenal aortic diameter above 4 cm. Instead, a 50% increase in infrarenal aortic diameter corresponds to a ratio to the suprarenal aortic segment of 1.2, which was suggested to define an AAA by Alcorn et al.[28]

It should be noted that other aspects of the disease, for example pathophysiological aspects such as the expansion pattern, is not included in any of the proposed definitions. Misclassification is a possible source of error in studies of the natural course of small aneurysms. It is notable that some very small AAAs (<3.5 cm), as well as small TAA (<4 cm), do not expand at all,[29-33] and it is questionable whether these represent true aneurysmal disease. A desirable definition should be highly sensitive (ie, have a high probability of classifying sick individuals as being sick) and

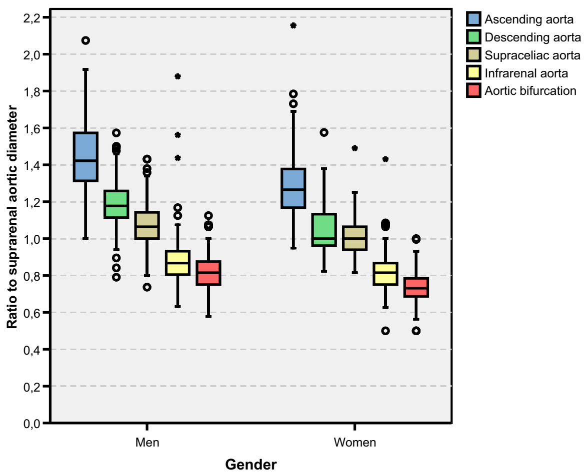

Fig 6. Box-and-whisker plot of the ratio between different aortic segments and the suprarenal diameter, showing the 2½%, 25%, 50%, 75%, and 97½% cumulative relative frequencies. Open circles represents cases with values between 1.5 and 3 box lengths from the upper or lower edge of the box, and stars represents cases with values more than 3 box lengths from the upper or lower edge of the box.

Table IV. Suggested dividing-lines (diameter and/or ratio) between normal aorta and aneurysm for the ascending-, descending-,and infrarenal aorta in 70-year-old men and women

	Men		*Women*	
Aortic segment	*Diameter*[a]	*Ratio*[b]	*Diameter*[a]	*Ratio*[b]
Ascending	4.7 cm	1.8	4.2 cm	1.7
Descending	3.7 cm	1.5	3.3 cm	1.3
Infrarenal	3.0 cm[c]	1.1[c]	2.7 cm	1.0

[a]Mean diameter +2 SD.
[b]Mean ratio to suprarenal aortic diameter +2 SD.
[c]Three subjects (extreme outliers) with an infrarenal aortic diameter >4 cm and a ratio to suprarenal aorta >1.4 were excluded from the calculation.

specific (have a high probability of classifying healthy individuals as healthy). Unfortunately, there is often a trade-off between these two qualities. For a potential life-threatening but treatable condition, such as aortic aneurysm, a definition with high sensitivity is important. For example, the most accepted AAA definition, defining an AAA as the maximum infrarenal aortic diameter being 30 mm or more, fulfills this prerequisite, at least for men. However, adopting such wide criteria increases the risk to define false-positive subjects as having AAA. A more specific definition may confirm or rule-out a diagnosis that has been suggested by other less specific criteria. In order to demonstrate a true widening of the aorta, the relation to adjacent aortic segments must be assessed. Furthermore, to demonstrate an expansion of a potential aneurysm, a follow-up period with repeated assessments is required. Thus, a fix diameter may not be a proper definition of an aneurysm, but an excellent cut-off level for further assessment and/or follow-up. Previous reports suggested that the suprarenal aorta is difficult to visualize and measure with US.[34] Advancements in technology in the last decades and specialization of US-technicians may, however, have changed this situation. A more accurately measurement of the suprarenal aortic segment with US would be an important advancement in the diagnosis of AAA, allowing aspects of relative diameters to be used more frequently, including in any future screening program.

The present suggested dividing-lines between normal aorta and aneurysm in 70-year-old men and women include both a fix diameter as well as a ratio to the suprarenal aorta. However, before adopting these dividing-lines, they should to be validated in clinical practice and follow-up studies.

CONCLUSIONS

The present population-based study defined aortic dimensional variations in 70-year-old men and women by means of MRI. For men, the suggested dividing-line (diameter and/or ratio) between normal aorta and aneurysm for the ascending aorta is 4.7 cm and/or 1.8, for the descending aorta 3.7 cm and/or 1.5, and for the infrarenal aorta 3.0 cm and/or 1.1. The corresponding dividing-lines for women are 4.2 cm and/or 1.7, 3.3 cm and/or 1.3, and 2.7 cm and/or 1.0.

AUTHOR CONTRIBUTIONS

Conception and design: AW, RT, HA, LL, LJ
Analysis and interpretation: AW, RT, LJ
Data collection: RT
Writing the article: AW
Critical revision of the article: RT, HA, LL, LJ
Final approval of the article: AW, RT, HA, LL, LJ
Statistical analysis: AW
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Overall responsibility: AW

REFERENCES

1. Wanhainen A, Bjorck M, Boman K, Rutegard J, Bergqvist D. Influence of diagnostic criteria on the prevalence of abdominal aortic aneurysm. J Vasc Surg 2001;34:229-35.
2. Wanhainen A, Lundgren E, Bergqvist D, Bjorck M. Abdominal aortic aneurysm screening starts now. First out with the invitation of all 65-year-old men is the county of Uppsala. Lakartidningen 2006;103: 2038-9.
3. Sonesson B, Lanne T, Hansen F, Sandgren T. Infrarenal aortic diameter in the healthy person. Eur J Vasc Surg 1994;8:89-95.
4. McGregor JC, Pollock JG, Anton HC. The value of ultrasonography in the diagnosis of abdominal aortic aneurysm. Scott Med J 1975;20: 133-7.
5. Sterpetti A, Schultz R, Feldhaus R, Cheng S, Peetz D. Factors influencing enlargement rate of small abdominal aortic aneurysms. J Surg Res 1987;43:211-9.
6. Collin J, Walton J, Araujo L, Lindsell D. Oxford screening program for abdominal aortic aneurysm in men aged 65 to 74 years. Lancet 1988;i: 613-5.
7. Johnston K, Rutherford R, Tilson M, Shah D, Hollier L, Stanley J. Suggested standards for reporting on arterial aneurysms. J Vasc Surg 1991;13:452-8.

8. Garcier JM, Petitcolin V, Filaire M, Mofid R, Azarnouch K, Ravel A, et al. Normal diameter of the thoracic aorta in adults: a magnetic resonance imaging study. Surg Radiol Anat 2003;25:322-9.
9. Hager A, Kaemmerer H, Rapp-Bernhardt U, Blucher 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;123:1060-6.
10. Lucarelli CL, Cerri GG. Evaluation of normal thoracic and abdominal aortic diameters through computerized tomography. Rev Hosp Clin Fac Med Sao Paulo 1996;51:239-46.
11. Coady MA, Rizzo JA, Hammond GL, Kopf GS, Elefteriades JA. Surgical intervention criteria for thoracic aortic aneurysms: a study of growth rates and complications. Ann Thorac Surg 1999;67:1922-6.
12. Lind L, Fors N, Hall J, Marttala K, Stenborg A. A comparison of three different methods to evaluate endothelium-dependent vasodilation in the elderly: the Prospective Investigation of the Vasculature in Uppsala Seniors (PIVUS) study. Arterioscler Thromb Vasc Biol 2005;25:2368-75.
13. Hansen T, Wikstrom J, Johansson LO, Lind L, Ahlstrom H. The prevalence and quantification of atherosclerosis in an elderly population assessed by whole-body magnetic resonance angiography. Arterioscler Thromb Vasc Biol 2007;27:649-54.
14. Lindholt JS, Juul S, Fasting H, Henneberg EW. Screening for abdominal aortic aneurysms: single center randomized controlled trial. BMJ 2005;330:750.
15. Ashton HA, Buxton MJ, Day NE, Kim LG, Marteau TM, Scott RA, et al. Multicenter Aneurysm Screening Study Group. The Multicenter Aneurysm Screening Study (MASS) into the effect of abdominal aortic aneurysm screening on mortality in men: a randomized controlled trial. Lancet 2002;360:1531-9.
16. Norman PE, Jamrozik K, Lawrence-Brown MM, Le MT, Spencer CA, Tuohy RJ, et al. Population based randomized controlled trial on impact of screening on mortality from abdominal aortic aneurysm. BMJ 2004;329:1259.
17. Vardulaki KA, Walker NM, Couto E, Day NE, Thompson SG, Ashton HA, et al. Late results concerning feasibility and compliance from a randomized trial of ultrasonographic screening for abdominal aortic aneurysm. Br J Surg 2002;89:861-4.
18. Lederle FA, Johnson GR, Wilson SE, Chute EP, Hye RJ, Makaroun MS, et al. The aneurysm detection and management study screening program: validation cohort and final results. Aneurysm Detection and Management Veterans Affairs Cooperative Study Investigators. Arch Intern Med 2000;160:1425-30.
19. Aronberg DJ, Glazer HS, Madsen K, Sagel SS. Normal thoracic aortic diameters by computed tomography. J Comput Assist Tomogr 1984;8:247-50.
20. Kritpracha B, Wolfe J, Beebe H. CT artifacts of the proximal aortic neck: an important problem in endograft planning. JEVT 2002;9:103-10.
21. Sprouse L, Meier G, Parent F, DeMasi R, Glickman M, Barber G. Is ultrasound more accurate than axial computed tomography for determination of maximal abdominal aortic aneurysm diameter? Eur J Vasc Endovasc Surg 2004;28:28-35.
22. Hannuksela M, Lundqvist S, Carlberg B. Thoracic aorta-dilated or not? Scand Cardiovasc J 2006;40:175-8.
23. da Silva ES, Rodrigues AJ Jr, Castro de Tolosa EM, Bueno Pereira PR, Zanoto A, Martins J. Variation of infrarenal aortic diameter: a necropsy study. J Vasc Surg 1999;29:920-7.
24. Grimshaw G, Thompson J. Changes in diameter of the abdominal aorta with age: an epidemiological study. Clin Ultrasound 1997;25:7-13.
25. Lederle FA, Johnson GR, Wilson SE, Chute EP, Littooy FN, Bandyk D, et al for the Aneurysm Detection and Management (ADAM) Veterans Affairs Cooperative Study Group. Prevalence and associations of abdominal aortic aneurysm detected through screening. Ann Int Med 1997;126:441-9.
26. Swedvasc Yearly Report 2007. Available at www.swedvasc.se.
27. Svensjö S, Bengtsson H, Bergqvist D. Thoracic and thoracoabdominal aortic aneurysm and dissection: an investigation based on autopsy. Br J Surg 1996;83:68-71.
28. Alcorn H, Wolfson S, Sutton-Tyrrell K, Kuller L, O'Leary D. Risk factors for abdominal aortic aneurysms in older adults enrolled in the cardiovascular health study. Arterioscler Thromb Vasc Biol 1996;16:963-70.
29. Nevitt MP, Ballard DJ, Hallett JW Jr. Prognosis of abdominal aortic aneurysms. A population-based study. N Engl J Med 1989;321:1009-14.
30. Vardulaki KA, Prevost TC, Walker NM, Day NE, Wilmink AB, Quick CR, et al. Growth rates and risk of rupture of abdominal aortic aneurysms. Br J Surg 1998;85:1674-80.
31. Lindholt JS, Vammen S, Juul S, Fasting H, Henneberg EW. Optimal interval screening and surveillance of abdominal aortic aneurysms. Eur J Vasc Endovasc Surg 2000;20:369-73.
32. McCarthy RJ, Shaw E, Whyman MR, Earnshaw JJ, Poskitt KR, Heather BP. Recommendations for screening intervals for small aortic aneurysms. Br J Surg 2003;90:821-6.
33. Coady MA, Rizzo JA, Hammond GL, Mandapati D, Darr U, Kopf GS, et al. What is the appropriate size criterion for resection of thoracic aortic aneurysms? J Thorac Cardiovasc Surg 1997;113:476-91.
34. Ellis M, Powell J, Greenhalgh R. Limitation of ultrasonography in surveillance of small abdominal aortic aneurysm. Br J Surg 1991;78:614-6.

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