Relationship of age, gender, race, and body size to infrarenal aortic diameter

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Purpose: To assess the effects of age, gender, race, and body size on infrarenal aortic diameter (IAD) and to determine expected values for IAD on the basis of these factors.
Methods: Veterans aged 50 to 79 years at 15 Department of Veterans Affairs medical centers were invited to undergo ultrasound measurement of IAD and complete a prescreening questionnaire. We report here on 69,905 subjects who had no previous history of abdominal aortic aneurysm (AAA) and no ultrasound evidence of AAA (defined as IAD $\geq$ 3.0 cm).
Results: Although age, gender, black race, height, weight, body mass index, and body surface area were associated with IAD by multivariate linear regression (all $p < 0.001$), the effects were small. Female sex was associated with a 0.14 cm reduction in IAD and black race with a 0.01 cm increase in IAD. A 0.1 cm change in IAD was associated with large changes in the independent variables: 29 years in age, 19 cm or 40 cm in height, 35 kg in weight, 11 kg/m^2 in body mass index, and 0.35 m^2 in body surface area. Nearly all height-weight groups were within 0.1 cm of the gender means, and the unadjusted gender means differed by only 0.23 cm. The variation among medical centers had more influence on IAD than did the combination of age, gender, race, and body size.
Conclusions: Age, gender, race, and body size have statistically significant but small effects on IAD. Use of these parameters to define AAA may not offer sufficient advantage over simpler definitions (such as an IAD $\geq$3.0 cm) to be warranted. (J Vasc Surg 1997; 26:595-601.)

A subcommittee appointed by The Society for Vascular Surgery and the International Society for Cardiovascular Surgery, North American Chapter, has recommended that abdominal aortic aneurysm (AAA) be defined as a 50% or greater increase in

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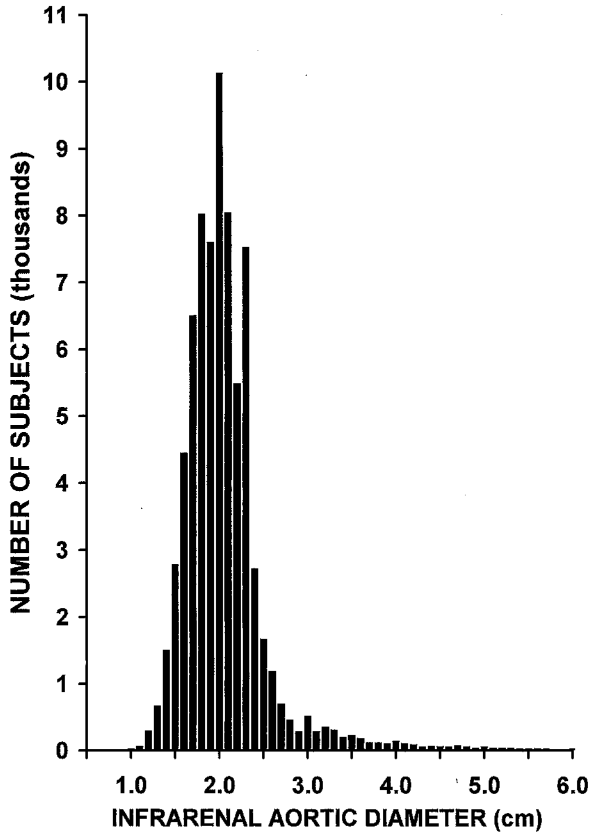

Fig. 1. Distribution of IAD measurements in 73,271 veterans aged 50 to 79 years.

infrarenal aortic diameter (IAD) compared with the expected IAD based on age, sex, and other factors such as body size.[1] However, values for expected IAD have not been well defined. Previous studies of the effects of these factors on IAD have included relatively small numbers of subjects, and their results have often been conflicting.[2-5] To assess the effects of age, gender, race, and body size on IAD and to determine expected values for IAD on the basis of these factors, we analyzed data from a large ultrasound screening program.

METHODS

All active patients at 15 Veterans Affairs (VA) medical centers who were 50 to 79 years of age were invited by mail to undergo ultrasound measurement of their aortic diameter as part of the aneurysm detection and management (ADAM) study. Descriptions of the ADAM study, the screening program, and the prevalence and associations of AAA found in the screening program have been previously reported.[6,7] The study was approved by the human rights committee at the VA Cooperative Studies Program coordinating center and by the institutional review boards at the 15 participating centers.

Table I. Characteristics of 69,905 veterans aged 50 to 79 years with IAD < 3.0 cm

Characteristic	*Value**
Age (yr)	66 ± 7
Male sex	97%
Race	
White	87%
Black	8%
Other	5%
Height (cm)	176 ± 7
Mean weight (kg)	85 ± 16
Waist circumference (cm)	96 ± 11
Body mass index (kg/m^2)	27 ± 5
Body surface area (m^2)	2.0 ± 0.2
Infrarenal aortic diameter (cm)	2.0 ± 0.3
Suprarenal aortic diameter (cm)	2.1 ± 0.3

*Plus-minus values are means ± SD.

The study ultrasonographers used 3.5 MHz realtime sector scanners to measure the abdominal aorta above and below the renal arteries in the anteroposterior and lateral planes and were instructed to record the maximum external diameter in any direction at the widest point of any dilatation for both the suprarenal and infrarenal segments. The ultrasonographers met twice during the study to review techniques and compare measurement distributions. Subjects who were screened from the beginning of the program in October 1992 through March 1995 are included in this report.

Age, gender, race, height, weight, and waist circumference were recorded in a questionnaire completed by all subjects before the ultrasound examination. Because we wished to define expected normal values for IAD, subjects who had a previous history of AAA or who had an AAA detected by ultrasound (defined as IAD ≥3.0 cm) were excluded from analysis.

The relationships between IAD and age, gender, race, and body size were determined by univariate and multivariate linear regression using IAD as the dependent variable. Three methods of modeling body size were considered. The first model was constructed using the independent variables from the questionnaire (height, weight, and waist circumference). In the second model, body mass index [BMI; calculated as (weight in kg)/(height in m)^2], a measure of obesity, was substituted for weight. In the third model, body surface area [BSA; calculated in m^2 by the method of DuBois[8] as: 0.007184 (height in cm)$^{0.725}$ (weight in kg)$^{0.425}$], a measure of body

Table II. Multivariate linear regression models of IAD in 68,414 veterans aged 50 to 79 years with IAD < 3.0 cm

	Factor	*F test*	*p*	*Slope**	*95% CI of slope*
Model 1 (Height and weight)	Age (per 10 years)	557	<0.001	0.034	0.032, 0.037
	Female sex (vs male)	512	<0.001	−0.140	−0.153, −0.128
	Black race (vs white)	15	<0.001	0.014	0.007, 0.021
	Other race (vs white)	1	0.30	−0.005	−0.014, 0.004
	Waist circumference (per 10 cm)	6	0.13	0.004	0.001, 0.007
	Height (per 10 cm)	257	<0.001	0.025	0.022, 0.028
	Weight (per 10 kg)	573	<0.001	0.028	0.026, 0.031
	Medical center	2085	<0.001		
Model 2 (Height and BMI)	Age (per 10 years)	566	<0.001	0.035	0.032, 0.038
	Female sex (vs male)	508	<0.001	−0.140	−0.152, −0.128
	Black race (vs white)	14	<0.001	0.013	0.007, 0.021
	Other race (vs white)	1	0.34	−0.004	−0.013, 0.005
	Waist circumference (per 10 cm)	4	0.06	0.003	0.000, 0.006
	Height (per 10 cm)	117	<0.001	0.053	0.050, 0.056
	BMI (per 10 kg/m^2)	600	<0.001	0.091	0.084, 0.098
	Medical center	2087	<0.001		
Model 3 (BSA)	Age (per 10 years)	568	<0.001	0.034	0.031, 0.037
	Female sex (vs male)	552	<0.001	−0.140	−0.152, −0.129
	Black race (vs white)	15	<0.001	0.014	0.007, 0.021
	Other race (vs white)	1	0.26	−0.005	−0.014, 0.004
	Waist circumference (per 10 cm)	8	0.004	0.004	0.001, 0.006
	BSA (m^2)	1319	<0.001	0.290	0.274, 0.305
	Medical center	2087	<0.001		

$R^2 = 0.338$ for each of the three models.
*Change in IAD (cm) per unit change in factor.
CI, Confidence intervals.

size, was substituted for height and weight. A set of indicator variables to represent the different medical centers was also included in the models. Subjects with missing responses or extreme values for numerical responses were deleted from analyses involving that response.

RESULTS

During the study period, 320,000 letters were mailed out, of which 91,000 were returned by subjects indicating their willingness to be screened. A total of 73,943 subjects aged 50 to 79 years who did not have a previous history of AAA underwent screening; 492 of them were excluded because the aorta could not be visualized, and 180 were excluded because the IAD was recorded only as "less than 3.0 cm." The distribution of IAD in the remaining 73,271 subjects is shown in Fig. 1. After exclusion of 3366 subjects who had IADs of 3.0 cm or greater, the remaining 69,905 constitute the study group (described in Table I), of whom 68,414 had complete data for all variables. Though our study group was 97% male (Table I), it included 2004 women.

Table II shows the results of the three multivariate linear regression models. Age, gender, black race, height, weight, BMI, and BSA were significantly associated with IAD by multiple linear regression in all three models (all $p < 0.001$), but the effects were small. Female sex was associated with a 0.14 cm reduction in IAD and black race with a 0.01 cm increase in IAD. A 0.1 cm increase in IAD was associated with large increases in the independent variables in the three models: 29 years in age, 40 cm

Table III. Mean IAD by medical center

Medical center	*No. of subjects*	*Mean IAD**
Minneapolis, Minn.	6333	1.7
Denver, Colo.	4263	1.7
Tampa, Fla.	4863	1.8
Milwaukee, Wis.	4138	1.8
Madison, Wis.	3568	1.9
Long Beach, Calif.	5275	1.9
Ann Arbor, Mich.	3727	2.0
Miami, Fla.	4481	2.0
Portland, Ore.	3434	2.0
Little Rock, Ark.	5286	2.1
Cleveland, Ohio	4421	2.1
San Diego, Calif.	6093	2.1
Chicago, Ill.	4450	2.1
Richmond, Va.	3662	2.2
Pittsburgh, Pa.	5911	2.3
Total	69905	2.0

*All standard deviations equal 0.2 or 0.3 cm.

Table IV. Mean IAD by height and weight in men

Height (cm)*	*Weight (kg)*	*No. of subjects*	*Mean IAD†*
150-169	45-64	1732	1.9
	65-79	4435	1.9
	80-94	2118	2.0
	95-119	531	2.1
	≥120	51	2.1
170-179	45-64	2189	1.9
	65-79	12859	2.0
	80-94	13216	2.0
	95-119	4973	2.0
	≥120	518	2.1
180-189	45-64	612	2.0
	65-79	4346	2.0
	80-94	9953	2.0
	95-119	6637	2.1
	≥120	1001	2.1
≥190	45-64	34	2.0
	65-79	178	2.0
	80-94	649	2.0
	95-119	994	2.1
	≥120	274	2.2
Total		67310	2.0

*Ten men with height < 150 cm are not included.
†All standard deviations equal 0.3 cm.

Table V. Mean IAD by height and weight in women

Height (cm)	*Weight (kg)*	*No. of subjects*	*Mean IAD**
120-149	45-59	20	1.7
	≥60	19	1.8
150-159	45-59	153	1.7
	60-69	162	1.7
	70-79	78	1.8
	≥80	90	1.8
160-169	45-59	215	1.7
	60-69	321	1.7
	70-79	243	1.8
	≥80	312	1.9
≥170	45-59	28	1.8
	60-69	83	1.8
	70-79	88	1.8
	≥80	192	1.9
Total		2004	1.8

*All standard deviations equal 0.3 cm.

(model 1) or 19 cm (model 2) in height, 35 kg in weight, 11 kg/m^2 in BMI, and 0.35 m^2 in BSA.

The three models performed similarly, with each model explaining 33.8% of the variability in IAD. The majority of this variability was explained by the indicator variables for medical center. Models constructed without these medical center variables explained only 5.5% of the variability in IAD. Thus variation among medical centers had far more influence on IAD than did the combination of age, gender, race, and body size. The unadjusted mean IAD at the different medical centers ranged from 1.7 cm to 2.3 cm (Table III).

Because height and weight were no less predictive of IAD than BMI or BSA and are more conveniently obtained, they were used for stratification in Tables IV and V. The mean IAD ranged from 1.7 cm for women less than 170 cm in height and 70 kg in weight to 2.2 cm for men 190 cm or more in height and 120 kg or more in weight. Apart from this latter group (which accounted for only 0.4% of men), all the other height-weight groups of men had mean IADs within 0.1 cm of the overall mean for men of 2.0 cm. All height-weight groups of women had mean IADs within 0.1 cm of the overall mean for women of 1.8 cm.

Several additional linear regression analyses were performed to investigate whether our findings were sensitive to (1) choice of arterial segment, (2) definition of AAA to be excluded, or (3) inclusion of medical conditions. When the analyses shown in Table II were repeated with suprarenal aortic diameter substituted for IAD, or with excluded AAA defined as a ratio of infrarenal to suprarenal aortic diameter of ≥1.5 instead of as IAD ≥3.0 cm, all regression coefficients remained similar in magnitude and direction. When the analyses shown in Table II were repeated with variables from the available medical history included (family history of AAA, history of smoking, hypertension, high cholesterol, coronary artery disease, claudication, cerebral vascular disease, deep venous thrombosis, diabetes mellitus, chronic obstructive pulmonary disease, and nonskin cancer), none of these variables was associated with more than a 0.05 cm change in IAD, and the addition of all these variables increased the explained variability of the IAD by less than 1%. Thus our findings were not sensitive to choice of arterial segment, definition of excluded AAA, or inclusion of medical conditions.

DISCUSSION

In this study, mean IAD increased with age, male gender, black race, and body size, but the effects were small and these factors explained very little of the variability in IAD. Height and weight were no less predictive of IAD than BMI or BSA. Nearly all height-weight groups were within 0.1 cm of the gender means, and the gender means differed by only 0.23 cm. These differences were smaller than the mean differences that we observed between medical centers and approximate the variability reported between repeated IAD measurements on the same patient by the same observer under optimal conditions.[9-11]

Previous studies involving multivariate analyses of the effect of various factors on IAD have reported on less than 1000 subjects each. The largest of these included 906 men,[2] another involved 307 subjects, half of whom were undergoing staging for cancer,[3] and two other studies included 160 and 146 subjects, respectively.[4,5] A larger study of 5283 subjects reported unadjusted effects of age and gender on IAD.[12]

All five of these studies reported an increase in IAD with age. No continuous relationship between age and IAD was apparent in the study of 906 men,[13] but a significant difference between the older and younger halves of the population was subsequently reported.[2] The three studies that quantified the increase in IAD with age reported effects that, though somewhat larger than those observed in our study, were still quite small (0.05 to 0.07 cm of IAD per 10 years of age).[3,4,12]

Of the three previous studies to include gender in a multivariate analysis, one found no effect of gender on IAD after adjustment for body size and other variables,[5] and another did not report the magnitude of the effect observed.[4] In the third study,[3] the effect of gender on IAD after adjustment for body size and other variables was 0.26 cm, compared with 0.14 cm in our study. The unadjusted difference between gender means has been reported as 0.23 cm and 0.35 cm by others,[4,12] and was 0.23 cm in our study.

The four previous multivariate analyses of the effect of body size on IAD obtained inconsistent results. One reported no association of IAD with height or weight after adjustment for other variables,[4] two reported an association with BSA but not with height or weight,[3,5] and the fourth reported an association with height but not with weight, BSA, or BMI.[2] Taken together, these findings are consistent with our finding of statistically significant but small effects for all of these variables.

The factor most strongly associated with IAD in our study was the medical center. The influence of medical center on IAD was presumably mediated through local differences in either study population (though Table III does not suggest strong regional trends) or, more likely, in ultrasound measurement technique. Any differences in measurement technique occurred despite our uniform definition of IAD and the two meetings of our ultrasonographers. Larger differences could therefore be expected in usual practice. In any case, our observation that the medical center was more closely associated with IAD than were age, gender, race, and body size casts further doubt on the utility of adjusting the normal range of IAD using these parameters.

The large size of our study greatly reduces the risk, common to all previous studies, of overfitting the multivariate model to the peculiarities of a small sample that is not representative of the general population. It also ensured an adequate number of subjects in each height-weight subgroup. A potential limitation related to the size of our study is that data accuracy may be less than in a small study conducted under carefully controlled conditions. One possible indication of inaccuracy is the variation among medical centers discussed in the preceding paragraph. Another possible indication of inaccuracy in ultrasound measurements is the degree of terminal digit preference or "rounding off." Comparison of Fig. 1 with computed tomogram (CT) readings previously published by our group[11] shows that the IAD measurements in the present study exhibit more digit preference than the central CT readings in the earlier study (which represented a research setting) but considerably less digit preference than the local CT readings (which more nearly represented a practice setting).

Another possible source of inaccuracy in our study was the subjects' self-reporting of age, sex, race, and body size. We have previously compared data from this questionnaire in screened patients who were found to have AAA and later enrolled in the clinical trial with data collected by study nurses on the basis of interview and chart review. This comparison demonstrated essentially perfect agreement on sex and race, a 95% likelihood of being within 3.6 years on age, and good agreement on body size.[7]

Age, gender, race, and body size have statistically significant but small effects on IAD. Use of these parameters to define AAA may not offer sufficient advantage over simpler definitions (such as an IAD $\geq$3.0 cm) to be warranted.

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APPENDIX

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