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Aneurysms of the Abdominal Aorta in Older Adults

The Rotterdam Study

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To assess the age- and sex-specific prevalence and risk factors for aneurysms of the abdominal aorta, the authors performed a population-based study in 5,419 subjects (42% men, 58% women) aged 55 years and over. The proximal and distal diameter of the abdominal aorta were measured by ultrasound. An aneurysm was defined as a distal aortic diameter of 35 mm or more or a dilatation of the distal part of the abdominal aorta of 50% or more. The mean distal and proximal aortic diameter increased 0.7 mm and 0.3 mm, respectively, with every 10 years of age. In 2.1% (95% confidence interval (CI) 1.7–2.5) of the study population, an aneurysm was present, or in 4.1% (95% CI 3.2–4.9) of the men and 0.7% (95% CI 0.4–1.0) of the women. Subjects with an abdominal aneurysm were more likely to be smokers and they had higher serum cholesterol levels and higher prevalence of cardiovascular disease compared with subjects without an aneurysm.The authors conclude that the ultrasound diameter of the abdominal aorta clearly increases with age in both men and women and that the prevalence of aneurysms of the abdominal aorta in older adults is relatively high, especially in men. *Am J Epidemiol* 1995;142:1291–9.

aneurysm; aorta, abdominal; prevalence; ultrasonography

The question of whether ultrasonographic screening for abdominal aortic aneurysms in asymptomatic subjects is justifiable remains a subject of debate. In 1991, the Canadian Task force on Periodic Health Examination (1) evaluated the literature to provide recommendations on this issue. The Task Force concluded that there is insufficient evidence to warrant screening programs for abdominal aortic aneurysms using physical examination or ultrasonography. By contrast, based on the same literature, Harris (2) recently concluded that there is a need for a national screening program to detect aneurysms of the abdominal aorta.

One of the reasons for this controversy is a lack of essential data. In particular, population-based data on the age- and sex-specific distribution of distal and proximal aorta diameters are scarce (3). Several studies on the prevalence of aneurysms of the abdominal aorta are available. Most of these studies, however, were performed in subgroups of patients, such as men (4–6), limited age groups (7–9), relatives of subjects with an aneurysm of the abdominal aorta (10–14), or subjects with peripheral arteriosclerosis (15–19) or hypertension (20). Furthermore, most of these studies were based on hospital-referred subjects.

To assess the age- and sex-specific distribution of aortic diameters and the prevalence of aneurysms of the abdominal aorta, we conducted a population-based study in 5,419 subjects aged 55 years and older. In addition, risk factors for abdominal aortic aneurysms were studied.

MATERIALS AND METHODS

This study is part of the Rotterdam Study, a prospective follow-up study designed to investigate determinants of the occurrence and progression of chronic diseases in the elderly. Emphasis is on four areas of research, i.e., cardiovascular, neurogeriatric, locomotor, and ophthalmologic diseases. The rationale and design of this study have been described previously (21).

All men and women aged 55 years and older who lived in the same district were invited in cooperation with their general practitioners to take part in the study. Potential participants were identified with help from the municipality of Rotterdam.

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Abbreviation: CI, confidence interval.

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A total of 10,215 subjects were invited to participate in the Rotterdam Study. Baseline measurements comprised a home interview and two visits to the research center. For logistic reasons, ultrasound examination was included in the protocol 6 months after the start of the Rotterdam Study. Subjects who lived in nursing homes (n = 1,056) were excluded because of technical limitations in the transport of the ultrasound equipment. The overall response rate was 78 percent, varying from 83 percent in persons aged 55–60 years to 50 percent in persons aged 80 years or older. We excluded from ultrasound examination 37 subjects (0.7 percent). In 27 subjects, the abdominal aorta already had been replaced by a graft; in four of these persons an aneurysm was documented and in the other 23 individuals grafting took place because of severe peripheral vascular disease. The 10 other subjects were known to have an aneurysm of the abdominal aorta and were being followed by surgeons elsewhere. Ultimately, 5,419 subjects underwent an ultrasound examination of the abdominal aorta. In 173 subjects (3.2 percent), it was impossible to visualize the distal part of the abdominal aorta, and in 299 subjects (5.5 percent), the proximal diameter of the abdominal aorta could not be measured. The present results are based on 5,283 participants in whom at least a measurement of the distal aorta was available. Apart from a small number of subjects with an Asian background, all participants were Caucasian.

Three assistants were trained to perform ultrasonographic measurements of the abdominal aorta. Interobserver agreement between these assistants was high (Pleumeekers et al., Observer variability of ultrasound measurements of the abdominal aorta, unpublished manuscript). The abdominal aorta was visualized according to the Rotterdam Study scanning protocol. B-mode ultrasound recordings were made using a 3.5 MHz linear array probe (Toshiba SSH 60A (Toshiba Medical Systems, Japan)) with the patient in supine position. Measurements were made throughout the day and no instructions were given about food intake prior to the ultrasound examination. First, a longitudinal scan of the abdominal aorta was made and the anterior-posterior diameter of the widest part of the most distant section of the abdominal aorta was recorded (distal diameter). Further, the anterior-posterior diameter of the aorta was measured at the level of the superior mesenteric artery (proximal diameter), to provide an indication of the normal aortic diameter.

An aneurysm of the abdominal aorta was considered to be present when at least one of the two following criteria was met: 1) the distal diameter of the aorta was 35 mm or larger, or 2) the diameter of the distal aorta was at least 50 percent larger than the diameter of the proximal part of the abdominal aorta. Subjects with an aneurysm of the abdominal aorta according to these criteria were referred to the Department of Vascular Surgery, Academic Hospital Dijkzigt for further evaluation. An aneurysm was considered of the "saccular" type when the ratio between the distal and proximal aorta was 1.5 or more, indicating a local widening of the aorta. A "longitudinal" aneurysm was defined as a distal aortic diameter of 35 mm or larger and a ratio of the distal and proximal diameter of less then 1.5, indicating a widening beyond the mesenteric superior artery.

For all participants, we recorded several cardiovascular risk factors and the presence (or absence) of cardiovascular disease. Blood pressure was calculated as the mean of two consecutive measurements with a random-zero sphygmomanometer at the right brachial artery in sitting position. Diastolic blood pressure was registered at Korotkoff 5th phase. Hypertension was defined as systolic blood pressure of 160 mmHg or more or diastolic blood pressure of 95 mmHg or more, or the use of antihypertensive drugs for the indication hypertension. Diabetes mellitus was defined as the current use of antidiabetic drugs or a blood glucose of 11.0 mmol/liter or over, random or 2 hours after a 75 g oral glucose load. Serum total cholesterol was determined by an automated enzymatic procedure in a non-fasting blood sample. Serum high density lipoprotein (HDL) cholesterol was measured after precipitation of the non-HDL fraction with phosphotungstate-magnesium. Intermittent claudication and a history of angina were diagnosed using the Rose questionnaire (22). Myocardial infarction was defined as a history of myocardial infarction with hospital admission.

To study differences between the prevalence of aneurysms of the abdominal aorta reported in the other population-based screening surveys for abdominal aortic aneurysms, a comparison was made using the Rotterdam Study data set as a reference. The criteria for defining aneurysms of the abdominal aorta used in these studies were applied to the group of participants in the Rotterdam Study with the same age and sex characteristics. Prevalence rates were calculated with exact 95 percent confidence limits.

The association between age and the aortic diameter was studied using a linear regression model. Analyses were performed using STATA software (STATA Corporation, College Station, Texas).

RESULTS

In table 1, general characteristics of the study population are given for men and women separately.

The distribution of the distal and proximal ultrasound diameter of the abdominal aorta and the distri-

TABLE 1. General characteristics of the 5,283 participants for whom ultrasound measurements of the abdominal aorta were obtained: the Rotterdam Study, 1989–1993

Characteristic	Men (n = 2,217)	Women (n = 3,066)
Age (years), mean (SD)*	67.2 (7.5)	68.1 (8.2)
Height (cm), mean (SD)	175.1 (6.9)	161.8 (6.5)
Weight (kg), mean (SD)	78.9 (10.7)	69.6 (10.8)
Systolic blood pressure (mmHg), mean (SD)	138.7 (21.7)	139.4 (22.4)
Diastolic blood pressure (mmHg), mean (SD)	74.7 (11.4)	73.4 (11.1)
Current smoking (%)	24.5	19.2
Serum cholesterol (mmol/liter), mean (SD)	6.3 (1.1)	6.9 (1.2)
Serum HDL cholesterol† (mmol/liter), mean (SD)	1.2 (0.3)	1.5 (0.4)
Hypertension (%)	26.6	32.9
Stroke (%)	3.8	2.4
Diabetes mellitus (%)	10.3	9.3
Intermittent claudication (%)	2.0	1.0
History of angina pectoris (%)	6.2	6.8
History of myocardial infarction (%)	11.2	3.4

* SD, standard deviation.
† HDL cholesterol, high density lipoprotein cholesterol.

bution of the ratio between the distal and proximal aortic diameter are given in figures 1 and 2. The mean distal diameter was 19.7 mm (95 percent confidence interval (CI) 19.4–19.9) in men and 16.2 (95 percent CI 16.1–16.3) in women. The mean proximal diameter in men was 21.0 mm (95 percent CI 20.9–21.2) and 18.6 mm (95 percent CI 18.5–18.7) in women.

A clear increase in the distal and proximal diameter of the abdominal aorta with advancing age was present in both sexes (figure 3). This trend was more pronounced in men. In men, the increases in the distal and proximal diameter per 10 years increase of age were 1.1 mm (95 percent CI 0.8–1.5) and 0.5 mm (95 percent CI 0.3–0.6), respectively, while in women they were 0.5 mm (95 percent CI 0.4–0.6) and 0.3 mm (95 percent CI 0.2–0.4), respectively. The association between age and the aortic diameter did not materially change after exclusion of the subjects who met the criteria for aortic aneurysms. The ratio of the distal and proximal diameter in men rose with 0.3 (95 percent CI 0.2–0.5) per 10 years increase of age, while the ratio in women hardly increased with advancing age, 0.01 per 10 years increase of age (95 percent CI 0.01–0.02).

In 112 subjects (2.1 percent, 95 percent CI 1.7–2.5), an aneurysm of the abdominal aorta was present. The mean age of the subjects with an aneurysm of the abdominal aorta was 72.1 years (95 percent CI 70.6–73.6) compared with 67.5 years (95 percent CI 67.3–67.7) in subjects without such aneurysms. In 88 subjects (78.6 percent), the maximal distal diameter exceeded 34 mm. A total of 24 subjects (21.4 percent) qualified solely because of an increase of more than 50 percent of the distal diameter compared with the proximal diameter. In this group, the distal diameter lay between 25 and 35 mm. Two-thirds of all aneurysms (n = 79) were of the saccular type and were therefore limited to the distal part of the abdominal aorta. In 33 subjects, the aneurysm was of the longitudinal type. In persons aged 55–70 years, more than 80 percent of the aneurysm was of the saccular type, whereas in those older than 70 years this was only the case in about 55 percent of the aneurysms.

The prevalence of aneurysms of the abdominal aorta by age and sex is shown in table 2. The prevalence in men was 5.9 (95 percent CI 3.7–9.5) times higher than that in women. In both men and women, there was a tenfold increase in the prevalence of abdominal aortic aneurysm from the youngest to the oldest age groups. The prevalence of large aneurysms with a distal diameter of 50 mm or more, commonly accepted as an indication for surgery, was 0.8 percent (95 percent CI 0.3–1.2) in men and 0.13 percent (95 percent CI 0.0–0.2) in women, showing a similar relative risk of 5.8 (95 percent CI 2.0–17.2).

In table 3, several potential risk factors for abdominal aortic aneurysms in subjects with and without an abdominal aortic aneurysm are compared for men and women separately. Subjects with an abdominal aneurysm had a more unfavorable cardiovascular risk profile than did subjects without an aneurysm. In both men and women, current cigarette smoking was significantly more frequent among subjects with an abdominal aortic aneurysm. In addition, the mean serum cholesterol level was higher and intermittent claudication was more prevalent in subjects with an aneurysm, especially in men. In a comparison between 21 subjects with a large aneurysm (distal diameter 50 mm or

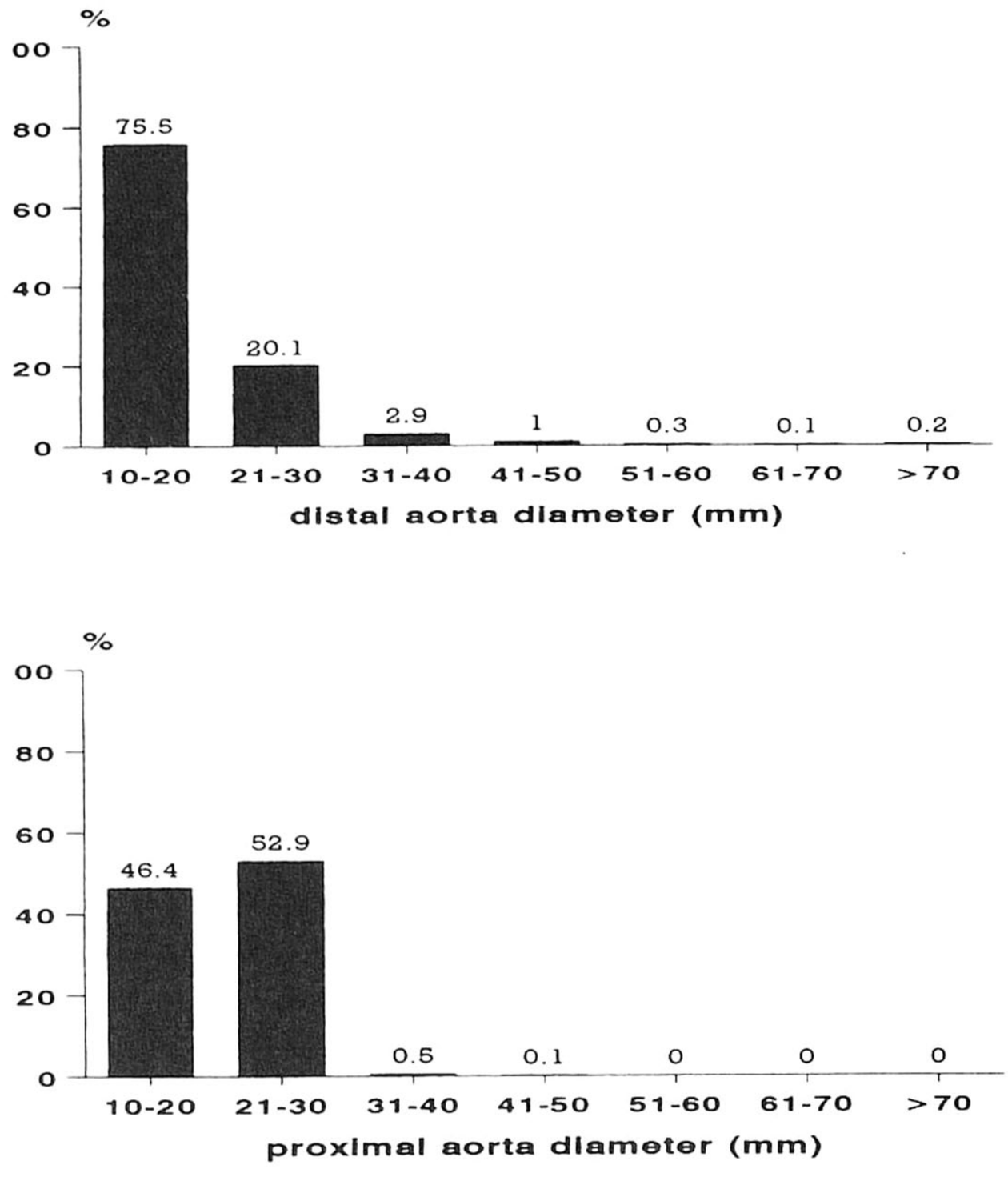

FIGURE 1. The distributions of the distal and proximal diameters of the abdominal aorta and the ratio between both measurements in 2,217 men: the Rotterdam Study.

more) and those with smaller aneurysms, no clear differences in age (mean age 72 years in both groups) or in other risk factors could be demonstrated.

DISCUSSION

In 5,283 participants in the Rotterdam Study, the prevalence of aneurysms of the abdominal aorta was 2.1 percent, varying from 0.2 percent in women aged 55–60 years to 10.3 percent in men aged 80 years and older. Men are almost six times more likely to have an aneurysm of the abdominal aorta than are women. A clear increase is demonstrated in the prevalence of aneurysms of the abdominal aorta and of the proximal and distal diameter of the abdominal aorta with advancing age.

The response rate in the Rotterdam Study of about 78 percent is relatively high compared with similar surveys, which have had response rates varying from

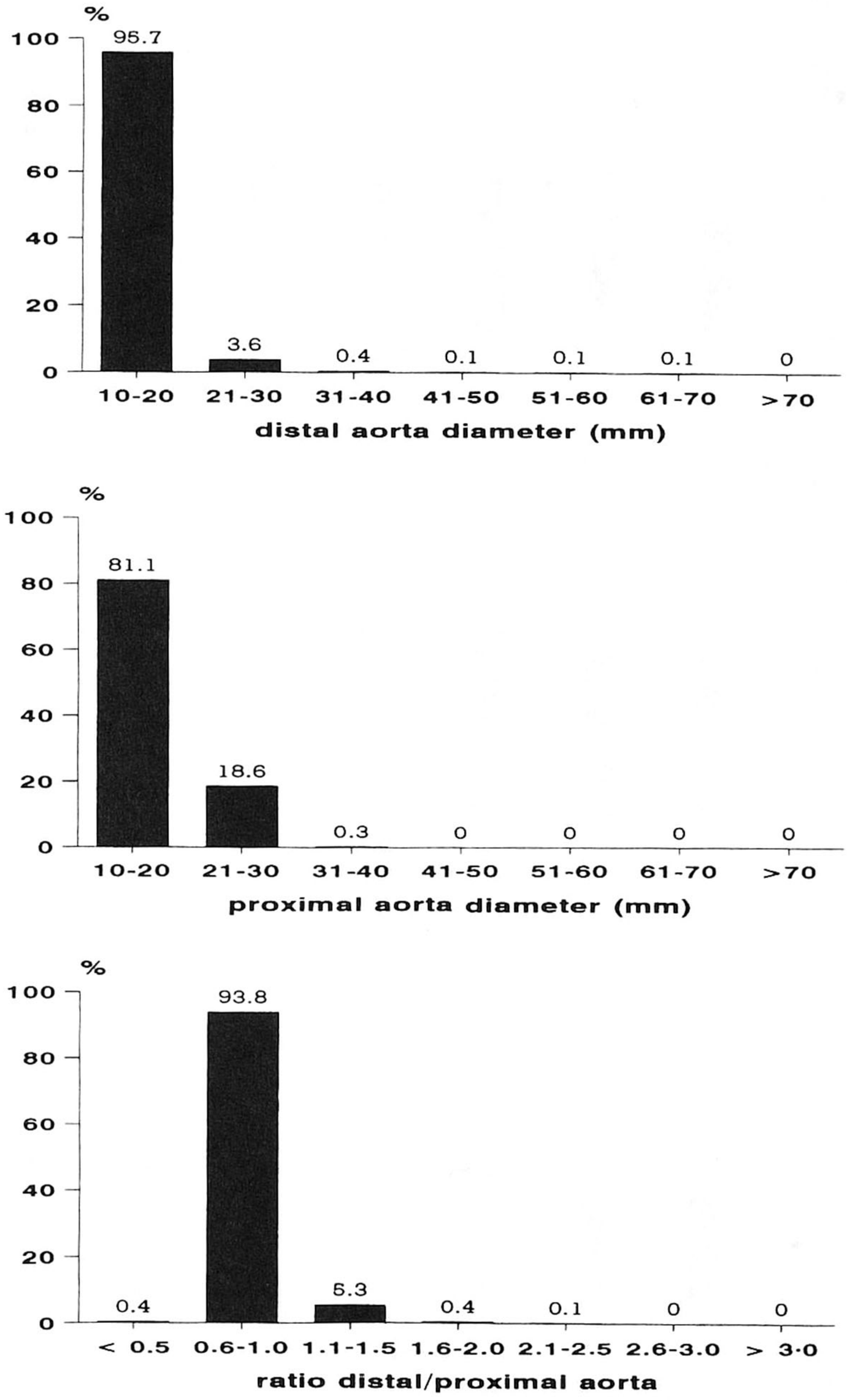

FIGURE 2. The distributions of the distal and proximal diameters of the abdominal aorta and the ratio between both measurements in 3,066 women: the Rotterdam Study.

46.6 to 76 percent (4, 5, 7, 9, 23–25). Because of a lower response rate in the very old and the exclusion of subjects living in nursing homes, the prevalence may have been underestimated for this age group. Although, for logistical reasons, measurements of the abdominal aorta started 6 months after the start of the Rotterdam Study, this is unlikely to have influenced the accuracy of the prevalence estimates, because scheduling of the ultrasound examinations was based on postal codes. This is illustrated by the similar prevalence estimates of abdominal aortic aneurysms observed in the different 6-month periods of the study.

In about 97 percent of the measurements, we succeeded in visualizing the abdominal aorta. According to the Rotterdam Study protocol, the time available for ultrasound measurements of the abdominal aorta was

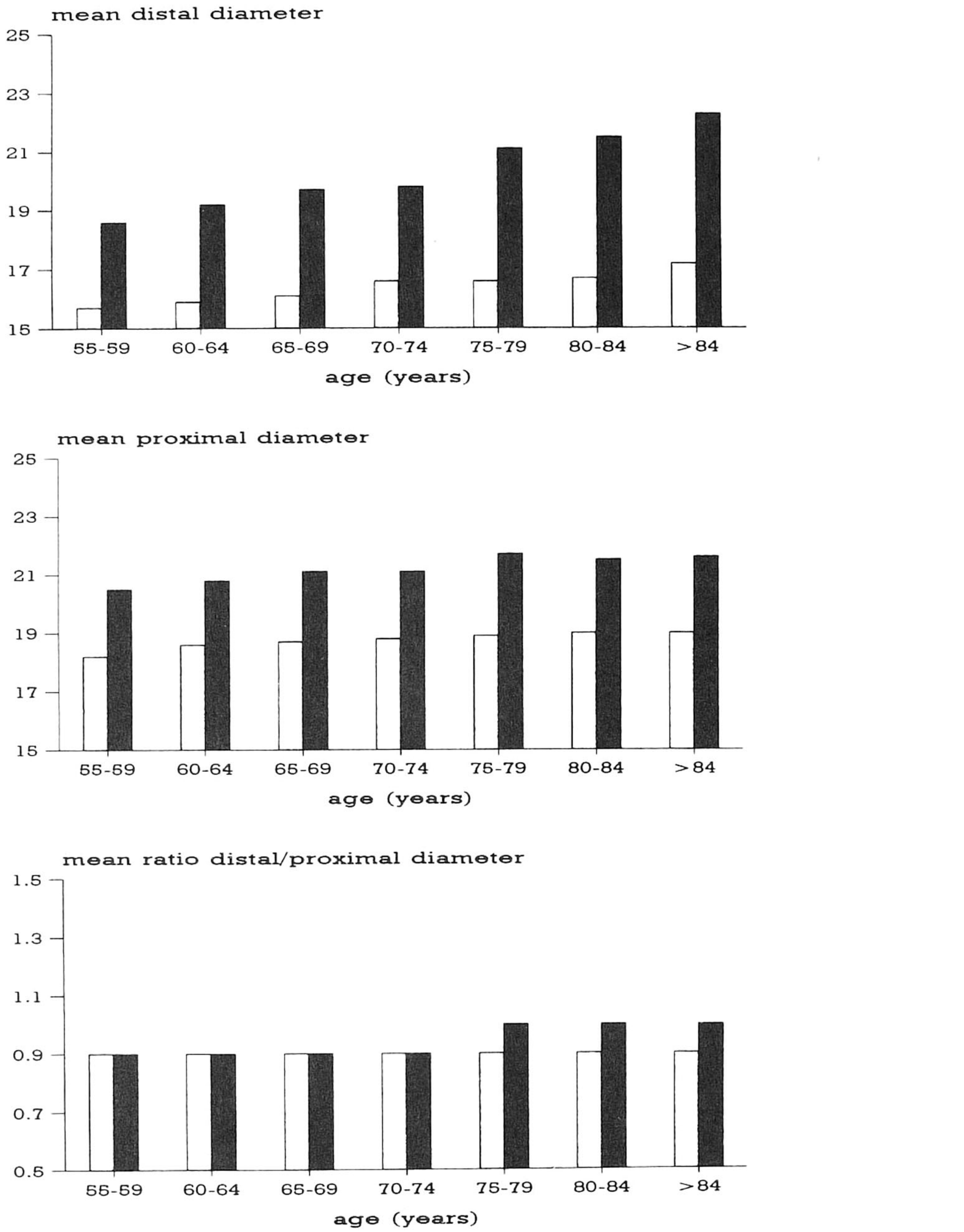

FIGURE 3. The distribution of the mean distal and proximal diameters (mm) of the abdominal aorta and the mean ratio between both measurements in 5-year age categories for men (black bars) and women (white bars): the Rotterdam Study.

10 minutes. Compared with other studies, where the abdominal aorta was visualized in 82–99.9 percent (9, 16, 23, 26), our success rate is good.

A significant increase of both aortic diameters with advancing age is present. This increase is more pronounced in men than in women and is larger in the distal than the proximal diameter of the abdominal aorta. It must be stressed, however, that these data are derived from a cross-sectional study and that our findings do not represent estimates of growth of the aortic diameter with advancing age. Follow-up studies are needed to obtain such estimates. Findings from previous studies on the relation between the aortic diameters and age are contradictory. Liddington et al. (27), in a cross-sectional study in men aged 65–74 years, reported a significant association between age and the aortic diameter. O'Kelly et al. (4) could not demonstrate a significant difference in the prevalence of large

TABLE 2. Age- and sex-specific prevalence of aneurysm of the abdominal aorta in subjects aged 55 years and older: the Rotterdam Study, 1989–1993

Age (years)	Men			Women		
	No.*	Prevalence		No.*	Prevalence	
		%	95% CI†		%	95% CI†
55–59	4/426	0.9	0.3–2.4	1/573	0.2	0.0–1.0
60–64	17/540	3.1	1.8–5.0	3/690	0.4	0.1–1.3
65–69	19/483	3.8	2.3–5.9	1/593	0.2	0.0–0.9
70–74	17/387	4.4	2.6–6.9	6/551	1.1	0.4–2.4
75–79	22/265	8.3	5.2–12.3	4/373	1.1	0.3–2.7
≥80	12/116	10.3	5.5–17.4	6/286	2.1	0.8–4.5
Total	91/2,217	4.1	3.3–5.0	21/3,066	0.7	0.4–1.1

* Number of aneurysms divided by the total number of subjects in the category.
† CI, confidence interval.

TABLE 3. Potential risk factors in men and women with and without an aneurysm of the abdominal aorta, adjusted for differences in age: the Rotterdam Study, 1989–1993

Risk factor	Men			Women		
	Aneurysm of the abdominal aorta		*p* value	Aneurysm of the abdominal aorta		*p* value
	Present (*n* = 91)	Absent (*n* = 2,126)		Present (*n* = 21)	Absent (*n* = 3,066)	
Body mass index (kg/m^2), mean	25.4	25.7	0.29	27.4	26.6	0.30
Systolic blood pressure (mmHg), mean	142.0	138.6	0.14	142.8	139.5	0.48
Diastolic blood pressure (mmHg), mean	76.5	74.7	0.14	75.5	73.5	0.41
Current smoking (%)	37.6	23.9	<0.01	56.0	19.1	<0.01
Serum cholesterol (mmol/liter), mean	6.6	6.3	0.04	7.3	6.9	0.11
Serum HDL cholesterol* (mmol/liter), mean	1.2	1.2	0.53	1.4	1.5	0.32
Hypertension (%)	29.2	26.5	0.59	42.1	32.9	0.37
Stroke (%)	1.8	3.9	0.31	9.0	2.3	0.05
Diabetes mellitus (%)	8.6	10.4	0.61	0.0	9.4	–
Intermittent claudication (%)	4.8	1.8	0.04	4.5	1.0	0.12
History of angina pectoris (%)	8.3	6.1	0.39	13.4	6.8	0.24
History of myocardial infarction (%)	15.7	11.0	0.17	8.7	3.3	0.37

* HDL cholesterol, high density lipoprotein cholesterol.

aortas between older and younger subjects. Further studies in this area are needed.

In our study, subjects with an abdominal aortic aneurysm had a more unfavorable cardiovascular risk profile compared with subjects without an abdominal aneurysm, even after adjustment for differences in age. This indicates that cardiovascular risk factors are important in identifying subjects at higher risk of an abdominal aortic aneurysm. A question that remains to be answered is the extent to which aortic aneurysms reflect severe arteriosclerotic vessel disease or may also be determined by factors other than those related to arteriosclerosis.

Table 4 shows a comparison between the results of eight large screening surveys for abdominal aortic aneurysms and the findings from the Rotterdam Study. When criteria for abdominal aneurysms and population characteristics of these other studies are applied to our own data set, no major differences in the prevalence estimates are found. The most marked difference is seen in regard to the study of Smith et al. (9), where the prevalence is 8.2 percent (95 percent CI 7.2–9.3) compared with the adjusted estimate in the Rotterdam Study data set of 4.8 percent (95 percent CI 3.5–6.4). Little is known about the geographic differences in the occurrence of abdominal aneurysms. Thus, it remains unclear whether this can explain the difference between the results reported by Smith et al. and our findings. Geographic differences in smoking habits or other risk factors for abdominal aneurysms could play a role. In addition, it is possible that differences in the use of ultrasound equipment for routine examination of the abdomen in the period preceding a screening survey could have had an influence on the number of subjects who had surgery for an abdominal aneurysm; this could explain differences in the reported prevalence of abdominal aortic aneurysms during the survey.

TABLE 4. Reported prevalence of aneurysms of the abdominal aorta in eight population-based screening surveys* compared with the 5,283 participants of the Rotterdam Study

Study	Age (years)	Sex	No.	Definition (mm)	Prevalence		Adjusted prevalence in the Rotterdam Study	
					%	95% CI†	%	95% CI
Rotterdam Study	≥55	Men	2,217	>34‡	4.1	3.3–5.0		
		Women	3,066	>34‡	0.7	0.4–1.1		
Collin et al. (7)	65–74	Men	426	>39§	5.4	3.5–8.0	5.2	3.8–7.0
				>39	2.3	1.1–4.3	1.8	1.0–2.9
O'Kelly and Heather (4)	65–74	Men	906	>25	7.8	6.2–9.8	7.4	5.7–9.4
				>40	1.5	0.8–2.6	1.4	0.7–2.5
Loh et al. (5)	≥55	Men	657	>30	2.9	1.7–4.5	4.4	3.5–5.3
Scott et al. (23)	65–80	Men	1,947	>29	7.8	6.5–8.9	5.9	4.6–7.4
		Women	2,290	>29	1.4	0.9–1.9	0.8	0.4–1.4
Akkersdijk et al. (23)	≥50	Men	1,717	>29‡	7.7	6.5–9.1	8.3	7.2–9.5
		Women	2,309	>29‡	2.9	2.2–3.6	2.0	1.5–2.5
Smith et al. (9)	65–75	Men	2,669	>29	8.2	7.2–9.3	4.8	3.5–6.4
				>40	3.0	2.4–3.7	1.5	0.8–2.5
Krohn et al. (25)	≥60	Men	500	>29‡	8.2	5.7–10.7	9.4	8.1–10.8
Lucarotti et al. (24)	65	Men	4,232	>39	1.3	0.9–1.6	1.5	0.2–5.4

* All but one of the screening surveys used records of general practitioners to identify subjects for screening. Akkersdijk et al. (33) used a population referred for abdominal ultrasound measurements.

† CI, confidence interval.

‡ Besides an absolute criterion for abdominal aortic aneurysms, an abdominal aneurysm was considered to be present when the distal aortic diameter was at least 150% of the proximal aortic diameter.

§ Besides an absolute criterion for abdominal aortic aneurysms, an abdominal aneurysm was also considered to be present when the distal aortic diameter exceeded the proximal aortic diameter by 5 mm or more.

The prevalence of abdominal aneurysms is six times lower in women than in men for both small and large aneurysms. This difference is often used as an argument to exclude women from screening surveys (7). In several studies based on population mortality statistics, the incidence of ruptured abdominal aneurysms was only 2–3.5 times higher in men compared with women (28, 29). Additionally, in necropsy studies (30, 31), a ruptured abdominal aorta was only two times more prevalent in men compared with women. Furthermore, several studies (8, 12, 32) have indicated that women are at higher risk of having the familial type of abdominal aneurysm. This type of aneurysm is considered to confer a greater risk of rupture (32). Although differences in the design of these studies make it difficult to draw definite conclusions, they provide some evidence that aneurysms in women are at greater risk of rupture than in men.

We conclude that an aneurysmatic dilatation of the abdominal aorta is not uncommon in older adults, especially in men. Age- and sex-specific prevalence estimates of abdominal aortic aneurysms can be of use in selecting subjects for ultrasound evaluation of the abdominal aorta. Before the decision can be made whether or not to screen for abdominal aneurysms, additional data are needed. In particular, more should be known about the factors that influence aneurysm formation, growth, and rupture.

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