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The Incidence of Small Abdominal Aortic Aneurysms and the Change in Normal Infrarenal Aortic Diameter: Implications for Screening*

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Aim: *to study the incidence of small abdominal aortic aneurysms (AAA), and to investigate what proportion of normal infrarenal aortic diameters (IAD) expand with age.*
Methods: *longitudinal follow-up in a population-based aneurysm screening programme. The infrarenal aortic diameter (IAD) was measured by ultrasound. A second scan was performed in subjects with a normal aorta after an average of 5.5 years.*
Results: *data were analysed from 4072 subjects, 464 with a small AAA and 3608 with a normal aorta. The infrarenal aorta expanded in 15% of subjects, but significant growth (>5 mm) occurred in only 7%. Age and initial diameter were independent predictors for aortic dilatation. The effect of diameter at first screen was non-linear. The relative risk for expansion increased dramatically for IADs over 2.5 cm (test for departure of trend: $\chi^2=52$, p<0.0001). The effect of age was also non-linear, the risk of expansion was highest in the 60–69 year old age group; test for departure of trend ($\chi^2=13$, p=0.002). The incidence of new aneurysms was 3.5 per 1000 person-years (py) (95% CI: 2.8–4.4). The highest incidence of new aneurysms was found in the 60 to 69 year old age group.*
Conclusion: *only a small proportion of the population is prone to aortic dilatation. Patients over 70 with an IAD <2.5 cm can be discharged from follow-up.*

Key Words: Change in normal aortic diameter; Incidence of asymptomatic aneurysms.

Introduction

The Ad Hoc Committee on Reporting Standards of the Society for Vascular Surgery defined an aneurysm as: "a permanent localised dilatation of an artery having at least 50% increase in diameter compared to the expected normal diameter of the artery in question".[1] The increase in prevalence of abdominal aortic aneurysms (AAA) with age is well documented.[2–6] However, surprisingly little is known about the change of the normal aortic diameter with increasing age. Several studies have suggested that the normal infrarenal aortic diameter (IAD) continues to increase throughout life.[7–12] We suggested in a previous report that the IAD expands with age in only a minority of the population.[13] We showed that a greater proportion of aneurysmal aortas could explain the rise in mean IAD in the older age groups. More detailed analysis showed that the IAD remained constant below the 75th percentile in men and the 85th percentile in women. The chief limitation of this study was that the conclusions were derived from cross-sectional data, so conclusive proof that the large majority of "normal" infrarenal aortic diameters do not expand with age is still lacking. The present study uses longitudinal data of patients with aneurysms and normal aortic diameters to examine change in IAD with advancing age. We also aim to describe the proportion of expanding diameters according to initial diameter and to estimate the incidence of aortic aneurysms according to age.

Methods

Data from the Huntingdon aneurysm screening programme were used to investigate change in infrarenal aortic diameter (IAD) with age. The screening programme was started in November 1991. All men over the age of 50 were invited for screening.[14] Age, height, weight, blood pressure and IAD were recorded for all

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Table 1. Main characteristics of re-screened subjects.

Variable	Mean	Range
Age	63 (SD 8.5)	45–95
Diameter first screen	2.3 (SD 0.5)	1–6.8
Proportion AAA ≥3 cm	464 (11%)	
Height in cm	174 (SD 7)	142–199
Weight in kg	81 (SD 12)	41–154
Systolic blood pressure	151 (SD 23)	89–248
Diastolic blood pressure	86 (SD 15)	42–177
Follow-up in years	5.3 (SD 2)	0.5–8

Table 2. Follow-up time in years for 3606 men with a normal infrarenal aortic diameter (IAD ≤2.9 cm) and 464 men with a small abdominal aortic aneurysm (AAA).

Follow up	Normal aorta	Small AAA
≥6 months <1 year	3 (0.1%)	23 (5%)
≥1 year <2 years	162 (4.5%)	102 (22%)
≥2 years <3 years	161 (4.5%)	103 (22%)
≥3 years <4 years	102 (2.8%)	63 (14%)
≥4 years <5 years	130 (3.6%)	59 (13%)
≥5 years <6 years	1272 (35%)	45 (10%)
≥6 years	1776 (49%)	69 (15%)
Total	3606 (100%)	464 (100%)

subjects who attended. A small aneurysm was defined as an IAD of 3 cm or more. Aortic diameters of 2.9 cm or less were considered normal. Initially all subjects with an IAD larger than 2.5 cm were followed up with yearly scans and all subjects with an IAD of 3 cm or more were followed up with 6-monthly ultrasound scans. From 1997 onwards only subjects with an aortic diameter of 3 cm or more were followed up. In June 1998 a second round of screening was started and all men over the age of 55 were invited to attend screening for the second time. This allowed us to investigate longitudinal change for all infrarenal aortic diameters and to estimate the incidence of AAA in different age groups.

Methods of screening were described elsewhere,[15] but to summarise briefly: a longitudinal scan of the abdominal aorta was made and the maximum external antero-posterior diameter was measured at the widest part or the most distal 1 cm of the abdominal aorta, with the patient in supine position. Initially nine ultrasonographers were used; however, from 1993 onwards only two ultrasonographers performed all the scans using a Toshiba Capasee SSA 22OA with a 3.5 MHz curvilinear probe. The inter-observer variability between these two ultrasonographers was similar to the intra-observer variability.[15] Blood pressure was measured automatically with a Dinamap 1846 SXP (Critikon, Kettering U.K.).

Statistical analysis was performed using STATA 5.0 for Macintosh (Stata Corporation, College Station, Texas, U.S.A.). Odds ratios were calculated through logistic regression methods.

Results

Longitudinal data were available for 4070 men, 464 men had been followed up regularly for a small AAA, and 3606 men with a normal infrarenal aortic diameter (IAD) had been invited for the second screening round. The main characteristics of the re-screened subjects are shown in Table 1. The frequency distribution of follow-up time for subjects with small aneurysms and normal aortas is shown in Table 2.

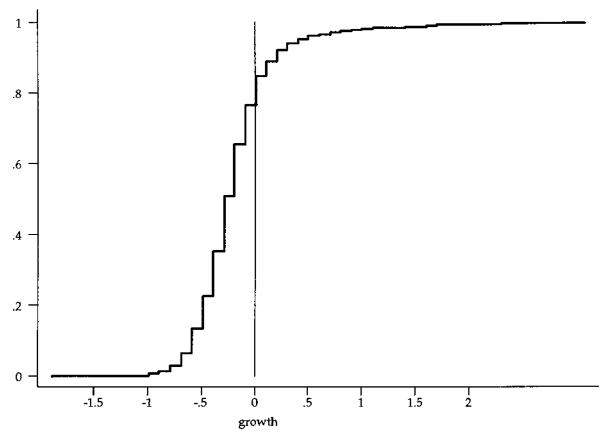

Fig. 1. Cumulative frequency distribution of change in infrarenal aortic diameter (IAD) of 3162 subjects; 114 with a small AAA (IAD = 3 cm)[3] and 3162 with a normal IAD (2.9 cm).[2]

Change in infrarenal aortic diameter

The cumulative frequency distribution of change in aortic diameter for all subjects with a follow-up of 5 years or more is shown in Figure 1. The figure shows that only 15% of aortic diameters have increased in size over the last 5 years. We have shown previously that the limits of variability of ultrasound measurements of the infrarenal aorta are 5 mm.[15] An expanding aorta was therefore defined as an aorta with a change in infrarenal aortic diameter exceeding 5 mm. This corresponds to an expansion exceeding 1 mm per year. Only 6.8% of patients had a significant increase in aortic diameter exceeding 5 mm or 1 mm per year.

Change in aortic diameter according to initial aortic

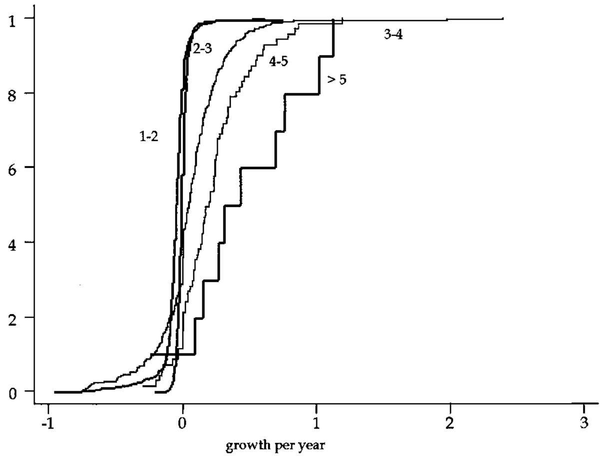

Fig. 2. Cumulative probability of change in infrarenal aortic diameter in mm per year according to diameter at first screen.

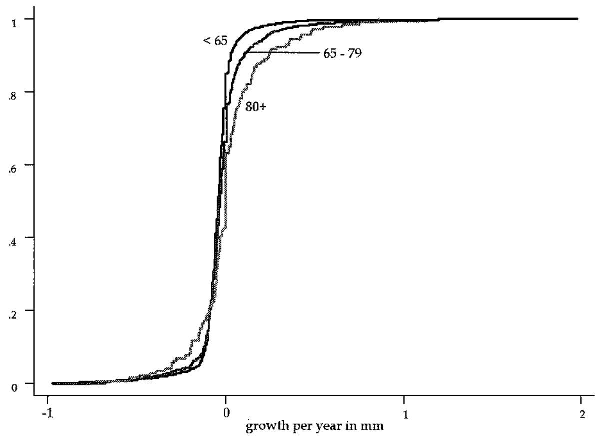

Fig. 3. Cumulative frequency distribution of change in infrarenal aortic diameter in mm per year, by age group.

diameter is shown in Figure 2. Figure 2 shows that substantial aortic dilatation was rare in aortas with an initial infrarenal aortic diameter below 3 cm. More than half of all aortas between 3 and 4 expanded, whilst almost all aortas bigger than 4 cm showed an increase in IAD. Initial size is a significant predictor of the risk of expansion ($p<0.0001$). Each millimetre increase in initial size increases the relative risk (RR) of expansion with 20% (95% CI: 18%–23%). However the effect of initial diameter was non-linear; test for departure of trend ($\chi^2=52$, $p<0.0001$).

Change in aortic diameter according to age at first screen is shown in Figure 3. Figure 3 shows that more aortas dilate in the older age-groups. This could be a diameter effect, because aneurysms are more prevalent in the older age groups. However, age remained an independent risk factor for expansion in a model that adjusted for initial size. The effect of age was non-linear: test for departure of trend ($\chi^2=12.8$, $p=0.0017$). The relative risk for expansion was highest in the 60- to 69-year-old age group. Blood pressure and body habitus: height, weight, body surface area were not significantly associated with the risk of expansion in a model that adjusted for initial diameter and age. The risk of expansion for initial diameter and age is shown in Table 3.

Incidence of asymptomatic AAA

A new aneurysm is defined as an aorta with an initial diameter smaller than 3 cm that has expanded by more than 5 mm. Seventy-one new aneurysms (2.0%) were found in 3606 patients with a normal aorta who were re-screened after an average of 5.5 years. The frequency distribution of the last diameter of the new aneurysms is shown in Table 4. The average growth in the last group was 2 mm per year (range 1 mm to 7 mm) The total person years follow-up in this group was 20 013 person-years. The incidence of new aneurysms was 3.5 per 1000 py (95% CI: 2.8–4.4). The highest incidence of new aneurysms was found in the 60- to 69-year-old age group (Table 5). Initial diameter and age were independently associated with the risk of a new aneurysm (Odds Ratio for each millimetre increase in initial size: 1.25; 95% CI: 1.15–1.35). The effect of diameter at first screen was non-linear; test for departure of trend ($\chi^2=7$, 1 df, $p<0.0001$) A threshold effect is seen at 25 mm (Table 6). The effect of age was again non-linear: test for departure of trend ($\chi^2=10.07$, 2 df, $p=0.007$). Height, weight, body surface area, and blood pressure were not independently associated with the risk of a new aneurysm.

Discussion

This study has shown that the vast majority of normal aortas do not dilate with age. Only 17.5% of aortic diameters had increased at all after a mean follow-up period of more than 5 years. Initial diameter and age group were both independent predictors of the risk of aortic expansion. This study is one of the first reports of a longitudinal study in which subjects with a normal aorta were re-screened. The results from this study confirm a previous report that estimated that only 15–25% of normal infrarenal aortic diameters increase with age.[13] Lederle *et al.* reported that the mean infrarenal aortic diameter in a second screening round had decreased slightly between the first and second ultrasound measurements. The time gap between first and second measurement in their study

Table 3. Effect of age and infrarenal aortic diameter on first screen. Odds ratios are calculated in a logistic regression model adjusted for age and diameter at first screen.

Variable	Odds ratio	95% conf. interval	*p* value
Initial diameter ≤2.0	1		
Initial diameter 2–2.5	1.0	0.5–1.9	
Initial diameter 2.6–3	7	3.8–12	
Initial diameter 3.1–3.5	21	11–38	$p<0.0001$
Initial diameter 3.6–4	53	28–100	
Initial diameter 4.1–4.5	40	17–96	
Initial diameter >4.5	60	25–147	
Age 50–59	1		
Age 60–69	1.9	1.2–3.0	
Age 70–79	1.2	0.7–2.0	$p=0.0017$
Age 80+	0.9	0.4–1.7	

Table 4. Frequency of last diameter as measured in incident aneurysms. An incident aneurysm is defined as an aorta with an initial diameter smaller than 3 cm that has expanded by more than 5 mm. Last diameter is the infrarenal aortic diameter (IAD) as measured on the most recent ultrasound scan.

Last diameter	*n*	%
21–25 mm	6	9
26–30 mm	10	14
31–35 mm	20	28
36–40 mm	18	25
41–45 mm	9	13
46–50 mm	5	7
>50 mm	3	4
Total	71	100

Table 6. Number and proportion of new aneurysms in second screening round. Relative risk is adjusted for initial diameter and age in a logistic regression model. A new aneurysm is defined as an aneurysm with a change in aortic diameter exceeding 5 mm and an initial diameter smaller than 3 cm.

Diameter/age	*n*	Odds ratio	95% CI
≤20 mm	14 (1.2%)	1	—
21–25 mm	28 (1.4%)	1.2	0.6–2.2
26–30 mm	29 (6.7%)	4.8	2.5–9.4
50–59	17 (1.1%)	1	—
60–69	37 (2.9%)	3.0	1.3–4.3
70–79	15 (2.3%)	1.6	0.8–3.2
80+	2 (2.4%)	0.9	0.2–4.0

was only 4 years. Although no attempt was made to study the frequency distribution of change in aortic diameter in more detail, their study does indicate that most aortas do not dilate with age.[16]

This study is the first to estimate the incidence of small aneurysms. The proportion of new aneurysms detected (2.0%) was very similar to the 2.2% described by Lederle.[16] Our estimated incidence was lower because of the longer follow-up time. A striking finding is that the incidence seems to peak in the 60- to 69-year-old age group. This confirms earlier estimates based on prevalence data,[5] and is in keeping withthe trends seen in death rates and proportional mortality.[5,17] This age-specific incidence pattern is consistent with the existence of a minority of men susceptible to the development of AAA. The fact that less than one-fifth of normal aortas dilated over time confirms this. On the other hand, the finding that age is an independent risk factor for aortic expansion and incidence of new aneurysms shows that environmental influences are important in predisposed subjects.

The incidence of most chronic illnesses such as cardiovascular disease and most cancers increase smoothly with age.[18–20] The incidence of asymptomatic AAA shows a peak. A peak in incidence is seen if there is a cohort effect with changes in environmental exposures related to AAA. The most important environmental exposure associated with AAA is smoking.[21] There is only a marginal decline in the prevalence of current smokers in our cohort and the number of lifelong non-smokers declines with age.[22] Furthermore the effect of smoking on the development of AAA has a long lagtime.[22,23] It seems therefore unlikely that cohort effects would explain the peak in incidence. A peak in incidence is also seen if only a small proportion of the population is susceptible to aneurysm formation.

Table 5. Incidence of new aneurysms in subjects who had an aortic diameter <3 cm and were re-screened after an average of 5.5 years. A new aneurysm is defined as a growth in aortic diameter exceeding 5 mm in an aorta with was initially smaller than 3 cm.

Age	*n* at risk	py follow up	*n* new AAA	Incidence	95% CI
50–59	1601	9 270	17	1.8	1.1–2.9
60–69	1278	7 144	37	5.2	3.7–7.0
70+	727	3 584	17	4.7	2.8–7.4
Total	3606	20 013	71	3.5	2.8–4.4

The incidence declines with increasing age due to drainage of the pool of susceptible subjects, either because they have developed the condition or because they have died. Cancer of the nasopharynx is one of the few cancers that has a peak incidence.[24] It is noteworthy that cancer of the nasopharynx has a very strong genetic component.[25]

Implications for screening

The pattern in probability of aortic expansion according to diameter at first screen, as shown in Table 3, suggests that there is a threshold effect. The probability of aortic expansion increases dramatically in AAA's with a diameter of 3 cm or more. This finding confirms the pragmatic definition of a small AAA as an aorta with an IAD of 3 cm or more. More than 99% of all aneurysms between 3 and 4 cm grow less than 1 cm per year. This vindicates our present policy of offering yearly scans to all men with an IAD between 3 and 4 cm and 6-monthly scans to men with an IAD of 4 cm or more. Table 6 shows that the relative risk of incident aneurysms increases dramatically in men with an IAD of 2.5 cm or more. The incidence of small AAA seems to peak in the seventh decade. The yield of re-screening all men older than 70 with an IAD less than 2.5 cm was six incident aneurysms for 507 scans. A decision to discharge all subject over the age of 70 with an IAD <2.5 cm would have meant that six (8%) of all incident aneurysm would have been missed. The last measured IAD in only three of those was bigger than 3 cm: 3.2 cm in a 78-year-old, 3.8 cm in an 86-year-old and 3.7 cm in an 84-year-old. Each of these patients would be well in their nineties before their aneurysm would reach 5.5 cm, assuming an average growth of 2 mm per year. It seems therefore unlikely that any of them would come to an elective AAA repair. A policy discharging all men over the age of 70 with an IAD <2.5 cm would save around 14% of all scans in subsequent screening rounds. A logical screening policy would be: offer yearly follow-up scans for all men with an IAD of 3 cm or more and 6-monthly scans to all men with an IAD of 4 cm or more. Repeat scans in a next screening round would be offered to all men with an IAD of 2.5 cm or more or men younger than 70 years old. Next screening rounds can be more than 5 years apart, but more data is needed to determine the optimum interval of subsequent screening rounds.

Conclusion

Less than one-fifth of normal aortas expands with age. The incidence of small asymptomatic AAA is 3.5 per 1000 person years and seems to peak in the seventh decade. The incidence of aneurysms of a clinically significant size is negligible in men with an infrarenal aortic diameter maller than 2.5 cm who are older than 70. This group can be discharged from follow-up.

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