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RESEARCH

Long term outcomes in men screened for abdominal aortic aneurysm: prospective cohort study

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Abstract

Objective To determine whether there is a relation between aortic diameter and morbidity and mortality in men screened for abdominal aortic aneurysm.

Design Prospective cohort study.

Setting Highland and Western Isles (a large, sparsely populated area of Scotland).

Participants 8146 men aged 65-74.

Main outcome measures Morbidity and mortality in relation to presence of abdominal aortic aneurysm and three categories of aortic diameter (≤24 mm, 25-29 mm, and ≥30 mm).

Results When screened, 414 men (5.1%) had an aneurysm (diameter ≥30 mm), 669 (8.2%) an aortic diameter of 25-29 mm, and 7063 (86.7%) an aortic diameter of ≤24 mm. The cohort was followed up for a median of 7.4 (interquartile range 6.9-8.2) years. Mortality was significantly associated with aortic diameter: 512 (7.2%) men in the ≤24 mm group died compared with 69 (10.3%) in the 25-29 mm group and 73 (17.6%) in the ≥30 mm group. The mortality risk in men with an aneurysm or with an aorta measuring 25-29 mm was significantly higher than in men with an aorta of ≤24 mm. The increased mortality risk in the 25-29 mm group was reduced when taking confounders such as smoking and known heart disease into account. After adjustment, compared with men with an aortic diameter of ≤24 mm, the risk of hospital admission for cardiovascular disease and chronic obstructive pulmonary disease was significantly higher in men with aneurysm and those with aortas measuring 25-29 mm. Men with an aneurysm also had an increased risk of hospital admission for cerebrovascular disease, atherosclerosis, peripheral arterial disease, and respiratory disease. In men with aortas measuring 25-29 mm, the risk of hospital admission with abdominal aortic aneurysm was significantly higher than in men with an aorta of ≤24 mm (adjusted hazard ratio 6.7, 99% confidence interval 3.4 to 13.2) and this increased risk became apparent two years after screening.

Conclusions Men with abdominal aortic aneurysm and those with aortic diameters measuring 25-29 mm have an increased risk of mortality and subsequent hospital admissions compared with men with an aorta diameter of ≤24 mm. Consideration should be given to control of risk factors and to rescreening men with aortas measuring 25-29 mm at index scanning.

Introduction

Screening for abdominal aortic aneurysm in men over 65 years of age has been recommended on the basis of several randomised controlled trials and meta-analyses.[1 2] These studies have shown that a single screening examination using ultrasound with follow-up intervention as appropriate can reduce aneurysm related mortality, with benefits extending to at least 10 years.[3] Screening has been shown to be cost effective[4] and has already been, or is being, introduced in the United Kingdom.[5 6] Patients with an abdominal aortic aneurysm, however, have also been shown to have an increased mortality from other vascular disease,[4 7 8] which in some part may be responsible for the failure of screening for abdominal aortic aneurysm to reduce all cause mortality in most studies.[7]

Most screening protocols use a threshold aortic diameter of 30 mm. Men with an aorta at or above this diameter are entered into a follow-up programme and those below are reassured and no follow-up planned. Among those without an aneurysm, however, there is some evidence of a possible association between aortic diameter and mortality, raising the possibility of a significantly increased risk among those whose aortic diameter is just below the threshold for aneurysm.[9]

We used record linkage to investigate the health outcomes of a group of 8146 men who attended the Highland aortic aneurysm screening programme between 2001 and 2004 and were followed until mid 2010, and to determine how these outcomes related

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Codes for outcomes (international classification of diseases, ninth and 10th revisions) to aortic diameter. We examined morbidity and mortality for men who had an aortic aneurysm (aortic diameter ≥30 mm), and those who had an ectatic aorta (25-29 mm) compared with those whose aorta was ≤24 mm at initial screening.

Methods

Between April 2001 and March 2004 we invited men in Highland and Western Isles aged 65-74 to attend the Highland aortic aneurysm screening programme. At the time of the initial scan, men completed a questionnaire about their general health and provided personal details. The programme's dataset contains age at screening, self rated assessment of health, smoking history (in pack years), medical history, family history of cardiovascular disease and diabetes, place of birth, postcode, duration of time living in the region, and the outcome of the abdominal aortic aneurysm screening.

The aortic diameter was defined as the maximum antero-posterior diameter, measured to the nearest millimetre. Failure to image in the community was followed through with hospital based ultrasound. We defined abdominal aortic aneurysm as an aorta measuring 30 mm or more; men with aortas of this size were followed up using the protocol from the Multicentre Aneurysm Screening Study.[10] Men with abdominal aortic aneurysms measuring 30-44 mm were rescanned annually and those with aortas measuring 45-54 mm were rescanned every three months. Men with aneurysms measuring 55 mm or more were considered for surgery. Men with aneurysms were offered lifestyle advice, and correspondence to their general practitioner suggested treatment with aspirin and a statin. Those men with a "normal" scan (aortic diameter ≤29 mm) had no further intervention or screening.

By linking the questionnaire data from the Highland aortic aneurysm screening programme to the Scottish Morbidity Record linked dataset held by the Information Services Division at the Scottish government health department we obtained longer term outcomes (aneurysm related morbidity and mortality in relation to aortic diameter at screening). Using probability matching, the Information Services Division linked the Highland aortic aneurysm screening programme dataset to the national Scottish Morbidity Record database (comprised of general acute inpatient and day case discharges SMR01, cancer registrations SMR06, and the General Registrar Office-Scotland death registrations) and provided an anonymous linked dataset for analysis. Appendix 1 shows the outcome codes (international classification of diseases, ninth and 10th revisions). Deprivation was expressed in fifths and 10ths according to the Scottish index of multiple deprivation,[11] and rurality by the Scottish government urban-rural classification[12]; both were derived from postcodes.

We obtained descriptive statistics for the cohort as a whole and categorised participants by their baseline aortic diameter into three groups: ≤24 mm, 25-29 mm, and ≥30 mm. To compare categorical variables between the three groups we used χ^2 tests for trend, with analysis of variance and the Kruskal-Wallis tests used to compare normally and non-normally distributed data across the groups.

The end of follow-up was 26 June 2010. Cox proportional hazards regression was used to calculate crude hazard ratios (99% confidence intervals) for events of interest. We compared each of the 25-29 mm and 30 mm or more groups with the 24 mm or less group. Subsequently we simultaneously adjusted the estimates for a range of personal characteristics, indicators of medical history, and markers of general health. The potential covariates included those identified from a review of published literature, together with those deemed clinically important when examining the association between aortic diameter and morbidity and mortality. Into the models we entered the number of pack years smoked, with a value of zero for non-smokers, and deprivation 10th, rather than fifth, but otherwise the variables remained in their original format (categorical or continuous). Smoking status was the only variable that was initially considered for entry into the models but not subsequently used, owing to collinearity with pack years. To avoid competing risks, in the survival analyses of each non-fatal event of interest we excluded those men who had had one of the other listed non-fatal events. The models for mortality included all the men. For the hospital admission outcomes we produced separate Kaplan-Meier survival curves for each aortic diameter group. Tests for interactions between deprivation 10th and aortic diameter group were done for all hospital admission outcomes. For those outcomes with a test for interaction P<0.10, we carried out further survival analyses stratified by deprivation fifth.

The proportion of missing values among the personal and health related factors was low (<9%) and seemed to be missing at random. Therefore we excluded missing values from the analysis. Owing to multiple outcomes, we regarded a more stringent P value of ≤0.01 as statistically significant for the main analyses. All analyses were carried out using the software package PASW Statistics 18.0.2 (SPSS, Chicago, IL).

Results

Of the 8355 men who attended for screening,[13] 8146 (97.5%) completed the questionnaire and so were available for record linkage. The uptake of screening in the original cohort was 89.6% (3.8% declined an appointment and 6.6% did not attend). The figure of 8146 therefore represents 86% of the men aged 65-74 living in the region between 2001 and 2004. The median duration of follow-up was 7.4 (interquartile range 6.9-8.2) years. Of the 8146 men, 414 (5.1%) had an aortic aneurysm (aortic diameter ≥30 mm), 669 (8.2%) had an aortic diameter 25-29 mm, and 7063 (86.7%) a diameter of 24 mm or less. Table 1⇓ shows the personal and health related data obtained from the questionnaire. A larger aortic diameter at screening was associated with older age (although the differences in age were small); current smoking; higher pack years (among ever smokers); poorer self assessed health; reported previous heart attack, hypertension, or stroke; and a family history of aneurysm.

Of the 8146 men, 654 (8.0%) died within the follow-up period. Table 2⇓ shows the primary cause of death. Mortality was associated with aortic diameter at screening: 512 (7.2%) men with an aortic diameter of 24 mm or less died compared with 69 (10.3%) with a diameter of 25-29 mm and 73 (17.6%) with a diameter of 30 mm or more. Aneurysm accounted for only 11 deaths (1.7% of all deaths). Of the nine aneurysm related deaths in men with an initial aortic diameter of 30 mm or more, five were caused by ruptured abdominal aortic aneurysm and the rest were postoperative deaths. Deaths in only two men with an aortic diameter less than 30 mm were attributed to aneurysm during follow-up, neither associated with rupture. Most of the excess mortality risk associated with aortic diameter was due to hypertension and vascular disease or cancer, relations that persisted in the 30 mm or more group even after adjustment for potential confounders. Men with an aortic diameter of 30 mm or more were over three times as likely to die from cancer (adjusted hazard ratio 3.03, 99% confidence interval 1.41 to 6.53) and nearly twice as likely to die from hypertensive and vascular disease (1.90, 1.17 to 3.08) than men with an aortic diameter of 24 mm or less.

Aortic diameter at screening was also associated with hospital admissions (table 3⇓). The proportion of men with no subsequent hospital admission was 34.8% (n=2459) in the 24 mm or less group compared with 29.6% (n=198) in the 25-29 mm group and 16.9% (n=70) in the 30 mm or more group. Increasing aortic diameter at screening was associated with increased subsequent risk of admission for all circulatory disease (table 3 and fig 1⇓). After adjustment for potential confounders, men with aortic diameters or more than 25 mm were at increased risk of hypertensive disease, ischaemic heart disease, and chronic obstructive pulmonary disease, whereas the increased risk of cerebrovascular disease, atherosclerosis, peripheral arterial disease, and diseases of the respiratory system was significant only in the 30 mm or more group. Compared with men with an aortic diameter of 24 mm or less, those with an aortic diameter of 25-29 mm had an increased risk of diabetes mellitus and of heart failure, but these risks were not found in men with an aneurysm. Lung cancer remained more common in the aneurysm group after adjustment. Men with an aneurysm at screening were over seven times more likely to have abdominal wall hernia or conditions such as intraperitoneal adhesions (table 3). Increasing aortic diameter at screening was associated with increasing risk of subsequent admission for aneurysm. For those in the 25-29 mm category, this became evident from two years after screening (fig 2⇓).

Discussion

In this study, baseline screening identified 5.1% of men with an aneurysm (≥30 mm) and 8.2% with an aortic diameter of 25-29 mm, which has been termed ectatic aorta. A previous study found a prevalence of 7.5% of ectatic aorta in a similar aged cohort using similar criteria for diameter, but included a distal renal/aortic antero-posterior diameter ratio of more than 1.2 as an alternative definition.[14] A key issue dealt with by our study is whether men with an ectatic aorta have an excess risk of poor outcomes. The mortality rate in our cohort during follow-up was low and deaths due to aneurysm were rare. However, increasing aortic diameter at screening was associated with increased mortality from vascular disease or cancer and increased risk of hospital admissions, mainly related to circulatory and respiratory diseases and certain forms of cancer. The increased morbidity was noted not only in those with aortic aneurysm at initial screening but also in those with ectatic aortas, a small proportion of whom were also discharged from hospital with a diagnosis of aneurysm during follow-up. These relations held after adjustment for several potential confounders.

Comparison with other studies

Mortality in this cohort—8% after a median of 7.4 (interquartile range 6.9-8.2) years follow-up—was low compared with previously published series. In the Multicentre Aneurysm Screening Study cohort, who were of similar age to ours, mortality in the invited group was 11.4% after a median follow-up of 4.1 years[10] and total mortality was 30% at 10 years.[3] In the Tromso study,[15] which included a wider age range of men and women (25-84 years), mortality in men at 10 years was 19.9%, and in the American Cardiovascular Health study, which included men and women with an average age of 75 at screening,[9] mortality at 10 years was 38.6%. The reasons for our lower mortality, apart from differences in age, are unclear, although may reflect improving cardiovascular risk prevention and the relatively rural nature of our cohort.[13 16] The risk of death from aneurysm in our cohort was low. In total, 11 deaths were reported as being due to aneurysm, representing 0.14% of the cohort and 1.7% of all deaths. Most of these deaths were in men who had aneurysm at initial screening. Only two deaths occurred among those with an aortic diameter of less than 30 mm, representing 0.03% of that group. In the Multicentre Aneurysm Screening Study, the death rate from aneurysm at 10 years among those who attended screening was 0.33% (91/27 201), whereas 19 deaths (0.08%) were reported in 25 541 men with an index scan showing an aortic diameter of less than 30 mm. The follow-up was 10.1 years, making the risk of a ruptured aneurysm 1:10 216 life years compared with 1:12 454 life years for this study. In the Multicentre Aneurysm Screening Study cohort, however, the rate of rupture increased noticeably in years 8-10 of follow-up. In the Tromso study,[15] the death rate from aneurysm for the whole cohort at 10 years was 0.41% (27/6640), whereas for those with normal scans it was 0.1% (7/6295).

Although the risk of aneurysm related mortality is small, previous studies have shown a significant risk of developing an aneurysm in men with an aortic diameter of 25-29 mm.[14 17] One study, in a UK programme, found an expansion rate of 0.9 mm yearly in men with ectatic aortas, resulting in 2.4% of these men exceeding an aortic diameter of 55 mm or requiring surgery within five years of initial screening.[17] A Danish study found that 29% of men with an initial aortic diameter of 25-29 mm went on to develop aneurysms, with expansion rates varying from 1-4.7 mm annually.[14] Both studies concluded that men with ectatic aortas should be screened every five years. In our study, men whose initial aortic diameter was less than 30 mm were not rescanned, so we cannot report rates of expansion or the development of aneurysm. However, 4.5% of men with an aortic diameter of 25-29 mm had a hospital admission with an aneurysm diagnosis during follow-up, such presentations becoming noticeable from two years after screening, supporting the concept of repeat screening in the 25-29 mm group. The association between aneurysm and cardiovascular disease that we observed has been shown in several studies.[16 18 19] In the Tromso study,[15] an abdominal aortic aneurysm at baseline conferred a 2.5-fold increase in cardiovascular mortality over 10 years, compared with a 1.88-fold increased risk in our study. One study followed up 4734 men and women aged over 65 for 10 years.[9] They found an increased risk of mortality associated with aneurysm, but the increased risk of cardiovascular events in men with aortic diameters of 20-29 mm did not reach statistical significance. However, the criteria for a diagnosis of abdominal aortic aneurysm and the follow-up periods differed between the studies. The UK Small Aneurysm Trial also showed that aortic aneurysm was a marker for cardiovascular disease, with increased cardiovascular mortality not related to aneurysm.[20]

Men with abdominal aortic aneurysm therefore have an increased risk of cardiovascular disease, suggesting that secondary prevention interventions for cardiovascular disease are appropriate. Men with an aortic diameter of 25-29 mm have an increased risk of cardiovascular disease, which disappears when confounders such as smoking, deprivation, and hypertension are taken into account. The Tromso study compared participants with an aortic diameter of 27-29 mm with a reference group measuring 21-23 mm and found a twofold increase in cardiovascular mortality in the higher diameter group.[15] In our study, the increased risk of mortality from all causes for the 25-29 mm category became non-significant after adjustment for confounding variables, perhaps reflecting the differing diameter criteria used. However, there was a significantly increased risk of subsequent hospital admission due to hypertensive and ischaemic heart disease, heart failure, diabetes mellitus, and chronic obstructive pulmonary disease. It could be argued that interventions known to reduce the impact of these factors, such as smoking cessation, antihypertensive treatment, statins, and aspirin, might reduce that risk.

Screening for abdominal aortic aneurysm is being implemented throughout the United Kingdom. According to current proposed protocols, men with an aortic diameter less than 30 mm would receive no further intervention and no follow-up screening. In the Tromso study, it was recommended that those participants with an aortic diameter greater than 27 mm should be followed up for subsequent development of an aneurysm and for cardiovascular risk reduction, although specifics of a follow-up regimen were not given.[15] Another study was even more tentative, concluding that it remains unclear whether screening for abdominal aortic aneurysm could be used to identify people at risk of cardiovascular disease.[9]

Strengths and weaknesses of the study

Our study has several strengths. The cohort comprised 86% of men aged 65-74 in Highland and Western Isles at the time of enrolment. We obtained outcome data by linking to national hospital admissions and cancer and death registrations, with no loss to follow-up. Data were available on a wide range of potential confounders, including smoking, health status, family medical history, and socioeconomic status, enabling these to be taken into account. An obvious limitation is that no women were included in the cohort. Most screening programmes for aortic aneurysm to date have not included women as they are less likely to have aortic aneurysm[21] and are likely to have them later in life than men.[22] Furthermore, although the cohort was large, relatively few men died, so the study may have lacked power to detect differences for some of the specific causes of mortality.

Conclusions and policy implications

In conclusion, men can benefit from undergoing abdominal aortic aneurysm screening. The problem that remains for men with an enlarged, but non-aneurysmal aorta, is whether they should be rescreened and whether they should be offered interventions aimed at reducing their cardiovascular risk.

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Ethical approval: This study was approved by the Scottish Government Privacy Advisory Committee and the relevant Caldicott Guardian.

Data sharing: No additional data available.

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What is already known on this topic

Screening for abdominal aortic aneurysm is effective in reducing aneurysm related mortality

Men with an aneurysm have a higher mortality from other vascular diseases than men without an aneurysm

What this study adds

Men with an ectatic aorta (25-29 mm) at time of screening for abdominal aortic aneurysm have a significantly higher risk of mortality and of admission to hospital than men with a normal sized aorta (≤24 mm)

The increased risk of death was associated with higher rates of circulatory disease

The increased risk of admission to hospital was due to circulatory disease and chronic obstructive pulmonary disease

Tables

Table 1| **Baseline personal and health related characteristics of all men by aortic diameter group. Values are numbers (percentages) of participants unless stated otherwise**

Characteristic	Aortic diameter (mm)			Total (n=8146)	P value
	≤24 (n=7063)	25-29 (n=669)	≥30 (n=414)		
Mean (SD) age (years)	70.3 (2.9)	70.6 (2.9)	70.8 (2.8)	70.3 (2.9)	<0.001
Place of birth:					
Western Isles	745 (10.5)	69 (10.3)	50 (12.1)	864 (10.6)	0.760
Highland	2957 (41.9)	295 (44.1)	179 (43.2)	3431 (42.1)	
Rest of Scotland	1944 (27.5)	184 (27.5)	107 (25.8)	2235 (27.4)	
Rest of United Kingdom	1182 (16.7)	100 (14.9)	60 (14.5)	1342 (16.5)	
Other	192 (2.7)	15 (2.2)	12 (2.9)	219 (2.7)	
Missing	43 (0.6)	6 (0.9)	6 (1.4)	55 (0.7)	
Years lived in Highland:					
Median (interquartile range)	50 (26-69)	55 (27-70)	55 (27-70)	50 (26-69)	0.078
Missing	221 (3.1)	23 (3.4)	14 (3.4)	258 (3.2)	
Deprivation fifth*:					
1 (most deprived)	221 (3.1)	24 (3.6)	5 (1.2)	250 (3.1)	0.183
2	1650 (23.4)	153 (22.9)	105 (25.4)	1908 (23.4)	
3	2532 (35.8)	269 (40.2)	147 (35.5)	2948 (36.2)	
4	1543 (21.8)	138 (20.6)	94 (22.7)	1775 (21.8)	
5 (least deprived)	614 (8.7)	49 (7.3)	21 (5.1)	684 (8.4)	
Missing	503 (7.1)	36 (5.4)	42 (10.1)	581 (7.1)	
Urban-rural status†:					
Other urban areas	1224 (17.3)	84 (12.6)	63 (15.2)	1371 (16.8)	<0.001
Accessible small towns and rural	1144 (16.2)	92 (13.8)	58 (14.0)	1294 (15.9)	
Remote small towns and rural	1030 (14.6)	81 (12.1)	60 (14.5)	1171 (14.4)	
Very remote small towns and rural	3169 (44.9)	377 (56.4)	191 (46.1)	3737 (45.9)	
Missing	496 (7.0)	35 (5.2)	42 (10.1)	573 (7.0)	
Smoking status:					
Never smoked	2283 (32.3)	145 (21.7)	59 (14.3)	2487 (30.5)	<0.001
Former smoker	3562 (50.4)	356 (53.2)	224 (54.1)	4142 (50.8)	
Current smoker	1218 (17.2)	168 (25.1)	131 (31.6)	1517 (18.6)	
Median No (interquartile range) pack years‡	24 (12-40)	30 (18-50)	36 (20-50)	25 (13-40)	<0.001
General health:					
Excellent	906 (12.8)	73 (10.9)	26 (6.3)	1005 (12.3)	<0.001
Very good	2595 (36.7)	218 (32.6)	136 (32.9)	2949 (36.2)	
Good	2286 (32.4)	231 (34.5)	154 (37.2)	2671 (32.8)	
Fair	1044 (14.8)	118 (17.6)	74 (17.9)	1236 (15.2)	

Table 1 (continued)

Characteristic	Aortic diameter (mm) ≤24 (n=7063)	25-29 (n=669)	≥30 (n=414)	Total (n=8146)	P value
Poor	184 (2.6)	21 (3.1)	18 (4.3)	223 (2.7)	
Missing	48 (0.7)	8 (1.2)	6 (1.4)	62 (0.8)	
Ever had a heart attack	927 (13.1)	117 (17.5)	88 (21.3)	1132 (13.9)	<0.001
Ever had high blood pressure	2672 (37.8)	280 (41.9)	188 (45.4)	3140 (38.5)	<0.001
Ever had a stroke	382 (5.4)	63 (9.4)	42 (10.1)	487 (6.0)	<0.001
Ever had diabetes	755 (10.7)	98 (14.6)	43 (10.4)	896 (11.0)	0.172
Ever had a different condition	1791 (25.4)	174 (26.0)	121 (29.2)	2086 (25.6)	0.098
Close relative ever had a heart attack:					
Yes	2306 (32.6)	242 (36.2)	138 (33.3)	2686 (33.0)	0.175
No	4408 (62.4)	399 (59.6)	247 (59.7)	5054 (62.0)	
Missing	349 (4.9)	28 (4.2)	29 (7.0)	406 (5.0)	
Close relative ever had high blood pressure:					
Yes	1543 (21.8)	153 (22.9)	95 (22.9)	1791 (22.0)	0.342
No	5043 (71.4)	472 (70.6)	282 (68.1)	5797 (71.2)	
Missing	477 (6.8)	44 (6.6)	37 (8.9)	558 (6.8)	
Close relative ever had a stroke:					
Yes	1378 (19.5)	132 (19.7)	67 (16.2)	1577 (19.4)	0.198
No	5205 (73.7)	496 (74.1)	314 (75.8)	6015 (73.8)	
Missing	480 (6.8)	41 (6.1)	33 (8.0)	554 (6.8)	
Close relative ever had diabetes:					
Yes	882 (12.5)	98 (14.6)	45 (10.9)	1025 (12.6)	0.984
No	5646 (79.9)	530 (79.2)	333 (80.4)	6509 (79.9)	
Missing	535 (7.6)	41 (6.1)	36 (8.7)	612 (7.5)	
Close relative ever had an aortic aneurysm:					
Yes	217 (3.1)	25 (3.7)	24 (5.8)	266 (3.3)	0.002
No	6233 (88.2)	593 (88.6)	347 (83.8)	7173 (88.1)	
Missing	613 (8.7)	51 (7.6)	43 (10.4)	707 (8.7)	

*Based on Scottish index of multiple deprivation 2004.
†Based on Scottish Executive eightfold urban-rural classification.
‡Current and former smokers only.

Table 2| Primary cause of death by aortic diameter group. Values are numbers (percentages) of participants unless stated otherwise

	Aortic diameter (mm)			Crude hazard ratio (99% CI)		Adjusted hazard ratio* (99% CI)	
Cause of death	≤24 (n=7063)	25-29 (n=669)	≥30 (n=414)	25-29 mm	≥30 mm	25-29 mm	≥30 mm
Cancer	91 (1.3)	9 (1.3)	16 (3.9)	1.05 (0.43 to 2.59)	3.02 (1.50 to 6.06)	0.92 (0.33 to 2.57)	3.03 (1.41 to 6.53)
Diabetes	10 (0.1)	1 (0.1)	1 (0.2)	1.06 (0.07 to 15.75)	1.71 (0.12 to 25.47)	—	—
Central nervous system disease	18 (0.3)	2 (0.3)	1 (0.2)	1.17 (0.17 to 8.00)	0.95 (0.07 to 13.38)	—	—
Hypertensive and vascular disease	305 (4.3)	50 (7.5)	43 (10.4)	1.77 (1.20 to 2.63)	2.49 (1.63 to 3.78)	1.20 (0.75 to 1.94)	1.90 (1.17 to 3.08)
Aneurysm	1 (<0.1)	1 (0.1)	9 (2.2)	—	—	—	—
Chronic obstructive pulmonary disease	32 (0.5)	3 (0.4)	2 (0.5)	0.99 (0.21 to 4.70)	1.06 (0.16 to 6.95)	1.04 (0.21 to 5.10)	0.53 (0.04 to 7.44)
Gastrointestinal disease	15 (0.2)	0 (0.0)	0 (0.0)	—	—	—	—
Other external causes, unintentional injuries, and suicide	9 (0.1)	0 (0.0)	1 (0.2)	—	—	—	—
Other	31 (0.4)	3 (0.4)	0 (0.0)	—	—	—	—
All causes	512 (7.2)	69 (10.3)	73 (17.6)	1.46 (1.05 to 2.02)	2.57 (1.86 to 3.55)	1.08 (0.73 to 1.59)	2.03 (1.40 to 2.94)

Group with aortic diameter ≤24 mm was reference category for both crude and adjusted hazard ratios.

*Adjusted for age; number of years lived in the Highlands; urban-rural status; number of pack years smoked; deprivation 10th; general health; ever had a heart attack, high blood pressure, stroke, or different condition; and a close relative ever had an aortic aneurysm.

Table 3| Risk of first admission to hospital for specific conditions by aortic diameter group. Values are numbers (percentages) of participants unless stated otherwise

Discharge diagnosis	Aortic diameter (mm)			Crude hazard ratio (99% CI)		Adjusted hazard ratio* (99% CI)	
	≤24 (n=7063)	25-29 (n=669)	≥30 (n=414)	25-29 mm	≥30 mm	25-29 mm	≥30 mm
All circulatory disease:	3796 (53.7)	406 (60.7)	329 (79.5)	1.24 (1.09 to 1.42)†	1.92 (1.65 to 2.22)†	1.20 (1.04 to 1.39)†	1.51 (1.27 to 1.79)†
Hypertensive disease	2385 (33.8)	270 (40.4)	198 (47.8)	1.31 (1.11 to 1.54)†	2.10 (1.74 to 2.55)†	1.29 (1.08 to 1.54)†	1.60 (1.29 to 1.99)†
Acute myocardial infarction	363 (5.1)	48 (7.2)	35 (8.5)	1.60 (1.07 to 2.37)†	2.91 (1.85 to 4.60)†	1.43 (0.93 to 2.21)	1.66 (0.97 to 2.85)
Ischaemic heart disease	1633 (23.1)	201 (30.0)	159 (38.4)	1.41 (1.16 to 1.71)†	2.39 (1.93 to 2.96)†	1.33 (1.08 to 1.64)†	1.52 (1.18 to 1.94)†
Heart failure	587 (8.3)	95 (14.2)	46 (11.1)	1.85 (1.39 to 2.46)†	2.40 (1.62 to 3.56)†	1.55 (1.12 to 2.14)†	1.25 (0.78 to 2.01)
Cerebral vascular disease	559 (7.9)	76 (11.4)	46 (11.1)	1.59 (1.16 to 2.18†)	2.58 (1.74 to 3.83)†	1.35 (0.95 to 1.91)	1.58 (1.02 to 2.45)†
Atherosclerosis	51 (0.7)	7 (1.0)	10 (2.4)	1.69 (0.60 to 4.77)	6.55 (2.69 to 15.96)†	1.56 (0.50 to 4.86)	3.84 (1.39 to 10.63)†
Aneurysm	44 (0.6)	30 (4.5)	263 (63.5)	7.92 (4.30 to 14.57)†	88.82 (58.14 to 135.70)†	6.75 (3.44 to 13.23)†	66.67 (41.59 to 106.88)†
Peripheral arterial disease	350 (5.0)	43 (6.4)	58 (14.0)	1.49 (0.99 to 2.27)	4.67 (3.24 to 6.73)†	1.33 (0.84 to 2.09)	2.33 (1.49 to 3.62)†
Diabetes mellitus	829 (11.7)	111 (16.6)	49 (11.8)	1.55 (1.19 to 2.00)†	1.87 (1.28 to 2.72)†	1.46 (1.10 to 1.94)†	1.21 (0.79 to 1.86)
Diseases of the respiratory system:	1630 (23.1)	188 (28.1)	131 (31.6)	1.33 (1.09 to 1.63)†	1.98 (1.57 to 2.50)†	1.21 (0.98 to 1.51)	1.38 (1.05 to 1.80)†
Chronic obstructive pulmonary disease	623 (8.8)	90 (13.5)	73 (17.6)	1.68 (1.25 to 2.24)†	3.13(2.28 to 4.30)†	1.47 (1.07 to 2.03)†	1.98 (1.37 to 2.86)†
Abdominal wall and peritoneal disease	69 (1.0)	12 (1.8)	16 (3.9)	2.14 (0.96 to 4.79)	7.41 (3.63 to 15.15)†	1.71 (0.60 to 4.88)	7.81 (3.48 to 17.52)†
Neoplasms (all):	1736 (24.6)	169 (25.3)	102 (24.6)	1.19 (0.95 to 1.48)	1.71 (1.30 to 2.26)†	1.17 (0.91 to 1.49)	1.32 (0.96 to 1.81)
Lung	200 (2.8)	20 (3.0)	25 (6.0)	1.25 (0.67 to 2.32)	3.92 (2.24 to 6.84)†	1.29 (0.67 to 2.45)	2.85 (1.50 to 5.40)†
Digestive organs and peritoneum	399 (5.6)	42 (6.3)	27 (6.5)	1.32 (0.86 to 2.04)	2.31 (1.38 to 3.85)†	1.33 (0.82 to 2.16)	1.83 (1.01 to 3.32)‡
Large bowel and rectum	243 (3.4)	20 (3.0)	11 (2.7)	0.97 (0.51 to 1.86)	1.72 (0.78 to 3.81)	1.02 (0.50 to 2.11)	1.56 (0.63 to 3.84)

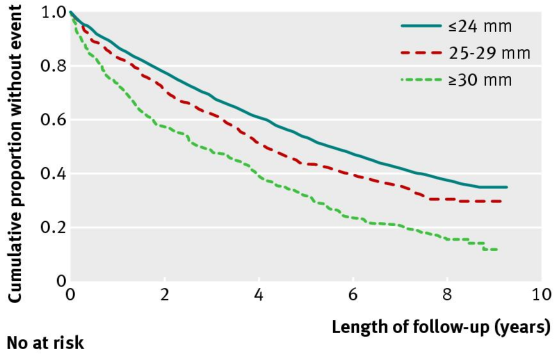
Group with aortic diameter ≤24 mm was reference category for both crude and adjusted hazard ratios.

*Adjusted for age; number of years lived in the Highlands; urban-rural status; number of pack years smoked; deprivation 10th; general health; ever had a heart attack, high blood pressure, stroke, or different condition; and a close relative ever had an aortic aneurysm.

†P≤0.01.

‡P≤0.05.

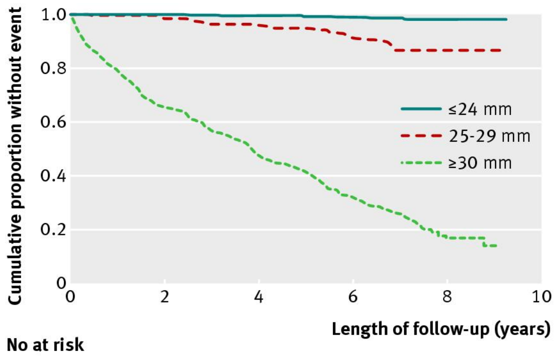
Figures



No at risk

≤24 mm	6252	4831	3780	2951	775
25-29 mm	604	427	307	239	46
≥30 mm	398	226	156	93	20

Fig 1 Time to hospital admission for all circulatory disease by aortic diameter



No at risk

≤24 mm	2503	2498	2486	2470	739
25-29 mm	228	224	218	208	45
≥30 mm	332	216	156	106	19

Fig 2 Time to hospital admission for aortic aneurysm by aortic diameter