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Selecting subjects for ultrasonographic screening for aneurysms of the abdominal aorta: four different strategies

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Background We studied whether the effectiveness of ultrasound screening for abdominal aortic aneurysms could be increased by preselecting high-risk subjects, based on the presence of risk indicators for the disease.

Methods In a population-based screening programme for abdominal aortic aneurysms among 5328 subjects living in Rotterdam, The Netherlands, we studied four different strategies to select subjects for ultrasound screening of the abdominal aorta, based on risk indicators for abdominal aortic aneurysm disease. Risk indicators used in each strategy were entered in a logistic regression model to predict the probability of an individual having an abdominal aortic aneurysm. Using several cutoff values for the probability of a subject having an aneurysm for each strategy, we estimated the proportion of subjects that should be referred for ultrasound screening and the proportion of aneurysms that would be diagnosed by each strategy (sensitivity).

Results When a probability of 1.5% of having an aneurysm is chosen as the cutoff point above which ultrasound screening is indicated, the proportion of subjects that would be referred for screening ranged from 36% (first strategy) to approximately 50% (other strategies), while 80% (first strategy) to approximately 94% (other three strategies) of all aneurysms would be detected.

Conclusion Effectiveness in screening for abdominal aortic aneurysms can be increased by selecting subjects by means of a short medical questionnaire, filled out by the screening candidates, including questions on medical history.

Keywords Abdominal aortic aneurysm, elderly, screening, risk function, risk indicators

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Early detection and surgical treatment of subjects with an abdominal aortic aneurysm is important to prevent death from rupture.[1,2] Ultrasonographic assessment of the abdominal aortic diameter is considered an accurate method to detect abdominal aortic aneurysms, but the effectiveness of population based ultrasonographic screening for abdominal aortic aneurysms is thought to be low.[3]

The effectiveness of ultrasound screening for abdominal aortic aneurysms can be increased by preselecting high-risk subjects.[4] Several strategies to select subjects with an increased risk of an abdominal aortic aneurysm have been advocated.[5–9] However, in most screening programmes selection is based on age and gender characteristics alone and in consequence, older men (e.g. 65–74 years) are mostly selected for ultrasound screening. However, it is unclear what the consequence of this selection procedure may be in terms of the reduction in population mortality from abdominal aortic aneurysms and the proportion of aneurysms that will be missed since only a part of those at risk will be screened.

Several risk indicators for abdominal aortic aneurysms, apart from age and gender, have been identified.[10] Selection of subjects with an increased risk based on these indicators, including blood pressure and serum cholesterol levels, or selection based on manifestations of clinical cardiovascular disease can be of value in reducing the number of subjects that have to be referred for ultrasound examination. Additionally, palpation and auscultation of the abdomen may also be of further value to reduce the number of subjects that require ultrasonographic screening.

Strategies to preselect subjects at increased risk of abdominal aortic aneurysms may increase screening effectiveness if they are easily performed, reduce the number of subjects requiring

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screening and identify the vast majority of subjects with an aneurysm. On these premises we studied the value of four different strategies in a population-based study among 5283 men and women aged ⩾55 years.

Subjects and Methods

This study is part of the Rotterdam Study, a population-based study, which aims to investigate determinants of disease occurrence and progression in older subjects. The cohort includes 7983 subjects aged ⩾55 years living in Ommoord, a suburb of Rotterdam in the Netherlands. The rationale and design of the study have been described elsewhere.[11] All subjects were interviewed at home and invited to visit the research centre twice for extensive clinical measurements.

At the interview several factors potentially associated with the occurrence of abdominal aortic aneurysms were recorded. Smoking behaviour was coded as 'never', 'former' and 'current'. The presence of intermittent claudication and a history of angina was assessed using the Rose cardiovascular questionnaire.[12] A history of myocardial infarction was considered positive if the subject reported having been hospitalized for the condition. The use of blood pressure lowering drugs for the indication hypertension was registered.

At the research centre, blood pressure was calculated from the mean of two consecutive measurements with a random-zero sphygmomanometer at the right brachial artery in the sitting position. Diastolic blood pressure was registered at Korotkoff V. The systolic blood pressure was also measured at the posterior tibial artery using a 8 MHz continuous wave Doppler probe (Huntleigh 500D, Huntleigh Technology, Bedfordshire, UK) and a random-zero sphygmomanometer. The ankle-arm systolic blood pressure index was calculated as the ratio of the systolic blood pressure at the ankle and the arm. The lowest ankle-arm index in either leg was used in the analysis. Peripheral vascular disease was considered present when the ankle-arm index was less then 0.9.[13] Serum total cholesterol was determined by an automated enzymatic procedure[14] in a non-fasting blood sample. Serum high density lipoprotein (HDL)-cholesterol was measured after precipitation of the non-HDL fraction with phosphotungstate-magnesium.

At physical examination, a palpable dilation of the abdominal aorta according to the physician was scored as a positive palpation. If the abdominal aorta could not be palpated because of obesity or if the investigating physician judged the diameter of the abdominal aorta to be normal, palpation was scored negative. All bruits registered over the abdominal aorta, irrespective of their possible origin, were scored as a positive auscultation.

After physical examination, ultrasound scanning of the abdominal aorta was performed using a 3.5 MHz linear-array transducer (Toshiba SSH 60A). The distance between the most anterior and the most posterior wall echo was measured. The diameters of the widest part of the abdominal aorta (distal aorta) and the diameter at the level of the superior mesenteric artery (proximal aorta) were recorded. An aneurysm was considered present when the distal aortic diameter was ⩾35 mm or when the ratio between the distal and proximal aorta was ⩾1.5.[15]

Subjects living in nursing homes (n = 1056) were excluded from ultrasound examination because of technical limitations in the transport of the ultrasound equipment. Subjects with a history of abdominal aortic repair were also excluded (n = 27). In 173 subjects (3.2%) it was technically impossible to visualize the abdominal aorta. In total, 5283 subjects with available ultrasound measurements of the abdominal aorta were included in the analyses.

Four different strategies, based on different ways information on risk indicators can be collected, were evaluated, leading to four different risk functions to identify subjects with an increased risk of an abdominal aortic aneurysm. The first risk function was based on information easily available from a population register and included age and gender. In a second risk function information obtained during the interview (which could easily be collected in a questionnaire) was evaluated. Besides age and gender, this risk function included information assessed during the Rotterdam Study interview on smoking behaviour, the use of antihypertensive drugs for the indication hypertension, Rose questionnaire for intermittent claudication or angina pectoris, and a history of myocardial infarction and stroke. In the third risk function variables that were assessed during the visit to the research centre were used in addition to the information considered in risk function two including age, gender, diastolic and systolic blood pressure, the ankle-arm blood pressure index, serum cholesterol and HDL-cholesterol levels. Finally, a fourth risk function was derived, adding the results of palpation and auscultation of the abdominal aorta by a physician to the variables considered in risk function three.

For all risk indicators considered for inclusion in the risk functions, positive predictive value, sensitivity, specificity and univariate odds ratios (OR) were calculated. Next, age- and gender-adjusted OR with standard errors were calculated using a logistic regression model with the presence of an aneurysm as the dependent variable. Risk indicators with an age- and gender-adjusted coefficient/standard error ratio of ⩾1.3 or ⩽–1.3, corresponding with a *P*-value of ⩽0.19 were entered in a multivariate logistic regression model together with the other variables selected for that risk function.

The general formula of the risk function is: P(aneurysm) = $1/[1 + \exp(-(b_0 + b_{1...n}X_{1...n}))]$ where P(aneurysm) is the probability of an individual having an abdominal aortic aneurysm, b_0 is the intercept in the logistic equation, $b_{1...n}$ stands for the logistic coefficients of the variables X1 to Xn. $X_{1...n}$ represents the value of the variable $X_{1...n}$ in a particular individual. In case of a dichotomous variable the value is 1 in the presence and 0 in the absence of the risk indicator. The accuracy of either risk function in selecting subjects for ultrasound screening was determined by calculating the proportion of those aged ⩾55 years that would require ultrasonographic evaluation based on the probability of having an abdominal aortic aneurysm estimated by applying the risk function to each individual (proportion selected). Further, we calculated the proportion of all subjects with an abdominal aneurysm that would be detected by either risk function (sensitivity) and the proportion of subjects without an abdominal aneurysm that was not referred for ultrasound screening (specificity). These parameters were calculated for all four risk functions using a 1.5%, 2% and 3% estimated probability of an individual having an abdominal aortic aneurysm as cutoff points above which ultrasonographic screening of the abdominal aorta was judged necessary.

Table 1 General characteristics of the 5283 participants of the Rotterdam Study in whom ultrasound measurements of the abdominal aorta were obtained

	Mean or %	SD[a]
Male sex (%)	42.0	
Age (years)	67.7	7.9
Current smoking (%)	23.5	
Angina pectoris (%)	6.8	
Intermittent claudication (%)	1.5	
History of myocardial infarction (%)	22.0	
History of stroke (%)	3.1	
Hypertension (%)	21.1	
Serum cholesterol (Mmol/l)	6.7	1.2
Serum HDL[b]-cholesterol (Mmol/l)	1.4	0.4
Systolic blood pressure (mmHg)	139.2	22.2
Diastolic blood pressure (mmHg)	73.9	11.3
Distal aortic diameter (mm)	17.6	4.9
Proximal aortic diameter (mm)	19.6	3.2
Abdominal aortic aneurysm (%)	2.1	

[a] Standard deviation.

[b] High density lipoprotein.

Results

In 112 subjects (2.1%, 95% CI : 1.7–2.5) an abdominal aortic aneurysm was diagnosed by ultrasound. The mean distal aortic diameter in subjects with an abdominal aortic aneurysm was 41.5 mm (SD 11.8) and ranged from 25 to 92 mm (Table 1).

In Table 2, positive predictive value, sensitivity, specificity and adjusted OR for diagnosing abdominal aortic aneurysms are presented for the most important risk indicators. Although the prevalence of abdominal aortic aneurysms increased with age, about 60% of all aneurysms were detected in subjects aged 55–75 years old. Only in 13.4% of the subjects with an apparently enlarged aorta during palpation, was an aneurysm diagnosed by ultrasound. Of those aneurysms that were diagnosed by palpation the mean distal aortic diameter was 47 mm (range 32–92 mm).

The variables and logistic coefficients ultimately included in the four risk functions to select subjects with an increased risk for abdominal aortic aneurysms are given in Table 3.

In Table 4, the proportion of subjects selected for ultrasound screening, the sensitivity (i.e. the proportion of subjects with an aneurysm that is detected) and the specificity (i.e. the proportion of subjects without an aneurysm that is not referred for screening), are given for the four risk functions. When an estimated risk of $\geqslant$1.5% is chosen to be selected for ultrasonographic screening, 80% of the aneurysms will be diagnosed by applying the first risk function while the sensitivity for the other three risk functions is approximately 94%. This would require 36% (first risk function) to approximately 49% (other three risk functions) of the population of $\geqslant$55 years to be referred for ultrasonography. When a higher cutoff point for the estimated risk of an abdominal aortic aneurysm is used to select subjects for ultrasonography, the proportion of subjects requiring ultrasound assessment decreases to less then 10% but at the expense of a decreasing sensitivity to less then 40%.

Discussion

Our analyses suggest that preselection of high-risk subjects is feasible using a simple structured medical questionnaire based on age, gender, drug use for the indication of hypertension, smoking status and complaints of intermittent claudication.

Several preselection criteria for ultrasound screening for abdominal aortic aneurysms have been proposed earlier. Collin *et al.*[16] recommended selective screening of men aged 65–74 years and several screening programmes for abdominal aortic aneurysms are based on this suggestion.[17–21] These criteria are based on the results of autopsy studies and on the assumption that subjects in this age group will benefit most from surgery if an aneurysm is diagnosed. However, no information on the

Table 2 Positive predictive value (PPV), sensitivity, specificity, odds ratio (OR) and (95% CI) of selected risk indicators for abdominal aortic aneurysms in older adults

Risk indicator	N[a] %	PPV %	Sensitivity %	Specificity	Adjusted OR[b] (95% CI)	*P*-value
Male sex	2217	4.1	81	59	6.5 (3.8–11.2)	<0.001
Age 55–65 years	2455	1.1	22	43	1.0[c]	
Age 66–75 years	1931	2.1	38	62	1.4 (1.1–1.9)	0.02
Age >75 years	897	4.2	39	81	2.7 (1.8–4.1)	<0.001
Current smoking	1231	3.7	38	79	3.1 (1.7–5.1)	<0.001
Anti-hypertensive drug use	774	2.5	36	70	1.8 (1.1–3.0)	0.03
Angina pectoris	356	3.5	11	94	1.7 (0.9–3.3)	0.11
Intermittent claudication	78	8.1	5	99	1.9 (0.7–5.0)	0.19
History of myocardial infarction	1152	5.2	17	94	1.5 (10.9–2.6)	0.16
Cholesterol $\geqslant$6.5 Mmol/l	2785	2.2	57	46	1.8 (1.2–2.7)	0.01
Ankle-arm index $\leqslant$0.9	617	5.0	29	89	2.1 (1.3–3.3)	<0.001
Enlarged aorta on palpation	148	13.4	19	97	7.0 (3.7–13.2)	<0.001
Bruit over abdominal aorta	213	6.7	14	96	1.9 (0.9–3.8)	0.07

[a] Number of subjects with the risk indicator.

[b] Adjusted for all other determinants.

[c] Reference category.

Table 3 Risk indicators for abdominal aortic aneurysms with logistic coefficients included in four different risk functions

	Logistic coefficient (SE)			
	Risk function			
Variable	1	2	3	4
Constant	–10.67	–11.83	–14.86	–15.02
Male gender	1.95 (0.25)	1.70 (0.27)	1.88 (0.27)	1.94 (0.28)
Age (years)	0.08 (0.02)	0.09 (0.01)	0.09 (0.01)	0.09 (0.01)
Former smoker (versus never smoker)		0.52 (0.30)	0.51 (0.30)	0.49 (0.31)
Current smoker (versus never smoker)		1.33 (0.31)	1.26 (0.31)	1.16 (0.32)
Drug use for indication hypertension		0.69 (0.25)		
Intermittent claudication		0.89 (0.46)		
Serum cholesterol level (Mmol/l)			0.20 (0.08)	0.19 (0.08)
Diastolic blood pressure (mmHg)			0.02 (0.01)	0.02 (0.01)
Ankle/Arm index ⩽0.90			0.56 (0.24)	0.46 (0.25)
Enlarged aorta on palpation				1.94 (0.32)
Bruit over abdominal aorta				0.61 (0.35)

Results of multivariate logistic regression.

Table 4 Proportion (%) of subjects selected for ultrasound assessment, sensitivity and specificity in the four risk functions to predict the presence of abdominal aortic aneurysms. All calculations were made by assuming different cutoff points for the individual's risk of an abdominal aortic aneurysm P(AAA) above which referral for ultrasonography is indicated, ranging from 1.5% to 3%

Model	**1**	**2**	**3**	**4**
P(AAA) ⩾1.5%				
Proportion selected	36	49	49	46
Sensitivity	80	94	93	94
Specificity	65	52	52	55
P(AAA) ⩾2%				
Proportion selected	23	21	21	19
Sensitivity	63	63	64	59
Specificity	78	80	80	82
P(AAA) ⩾3%				
Proportion selected	11	10	8	5
Sensitivity	38	40	38	34
Specificity	90	91	93	95

P(AAA) = probability that an aneurysm is present estimated by either risk function. Selected = proportion of subjects that would be selected for ultrasound evaluation of the abdominal aorta, based on the four functions.

sensitivity and cost-effectiveness of this approach is available. If these criteria were applied to our study population, 15% of all participants would be selected for ultrasound assessment of the abdominal aorta, but only 31% of all aneurysms would be identified.

It has also been suggested that high-risk subjects could be identified by using a positive history of cardiovascular disease as the main criterion.[8,17] In our data set, only 5% of those with an abdominal aneurysm had symptoms of intermittent claudication and 17% recalled a history of myocardial infarction (Table 2). If the selection strategy for screening was based on a history of clinical manifest cardiovascular disease, about 25% of those ⩾55 years would be selected for screening, but less then 20% of all aneurysms would be diagnosed.

Less than 20% of abdominal aneurysms was detected by physical examination. This is low compared to the results in some other studies.[7,16,22] Sensitivity in these studies ranges from 30% to 65%. This difference may be explained by the limited experience our study physicians had with palpation and auscultation of the abdominal aorta. However, our approach may well reflect routine screening standards. Lederle *et al.*[9] concluded that, although palpation of the abdomen had a sensitivity of about 50% in experienced hands, all aneurysms palpated during screening were missed by previous routine physical examination of the abdomen.

We conclude that preselection of subjects based on information obtained from a short medical questionnaire can increase effectiveness of screening for abdominal aortic aneurysms. It can be implemented easily and reduces the number of subjects requiring ultrasound screening while detecting the vast majority of subjects with an abdominal aortic aneurysm.

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