Low Prevalence of Abdominal Aortic Aneurysm Among 65-Year-Old Swedish Men Indicates a Change in the Epidemiology of the Disease

Sverker Svensjö, MD; Martin Björck, MD, PhD; Mikael Gürtelschmid, MD; Khatereh Djavani Gidlund, MD; Anders Hellberg, MD, PhD; Anders Wanhainen, MD, PhD

Epidemiology and Prevention

Background—Screening elderly men with ultrasound is an established method to reduce mortality from ruptured abdominal aortic aneurysm (AAA; Evidence Level 1a). Such programs are being implemented and generally consist of a single scan at 65 years of age. We report the results from screening 65-year-old men for AAA in middle Sweden.

Methods and Results—All 65-year-old men (n=26 256), identified through the National Population Registry, were invited to an ultrasound examination. An AAA was defined as a maximum infrarenal aortic diameter of ≥30 mm. In total, 22 187 (85%) accepted, and 373 AAAs were detected (1.7%; 95% confidence interval, 1.5 to 1.9). With 127 previously known AAAs (repaired/under surveillance) included, the total prevalence of the disease in the population was 2.2% (95% confidence interval, 2.0 to 2.4). Self-reported smoking (odds ratio, 3.4; P<0.001), coronary artery disease (odds ratio, 2.0; P<0.001), and hypertension (odds ratio, 1.6; P=0.001) were independently associated with AAA in a multivariate logistic regression model. Thirteen percent of the entire population reported to be current smokers, one third of the frequency reported in the 1980s. The observed low prevalence of AAA was explained mainly by this change in smoking habits.

Conclusions—On the basis of the observed reduced exposure to risk factors, lower-than-expected prevalence of AAA among 65-year-old men, unchanged AAA repair rate, and significantly improved longevity of the elderly population, the current generally agreed-on AAA screening model can be questioned. Important issues to address are the threshold diameter for follow-up, the possible need for rescreening at a higher age, and selective screening among smokers. (Circulation. 2011;124:1118-1123.)

Key Words: abdominal aortic aneurysm ■ risk factors ■ screening ■ smoking ■ ultrasound

Ruptured abdominal aortic aneurysm (AAA) is a common cause of death among elderly men. Several randomized controlled trials have established early detection by screening with ultrasound and prophylactic surgery in appropriately selected individuals as the most effective method to reduce the high mortality.1–4 Although not explicitly evaluated in the randomized controlled trials, a prevailing recommendation is a screening model in which 65-year-old men are invited to a 1-time ultrasound screening of the infrarenal aorta.5–9 Over the past 5 years, Sweden has experienced a rapid introduction of such a screening program, with practically nationwide coverage achieved today.10 In the United Kingdom, a similar program has recently been launched,11 and in the United States, a single scan is offered to men 65 to 75 years of age who have ever smoked.12

Methods

After the introduction of a general AAA screening program for 65-year-old men in the county of Uppsala in 2006, the neighboring counties of Dalarna, Södermanland, Gävleborg, and Västmanland consecutively launched similar programs in a stepwise fashion (Figure 1). In 2009, screening programs had been implemented in all 5 counties, and 65-year-old men, consecutively identified through the National Population Registry updated every third month, were invited to a 1-time ultrasound examination of the abdominal aorta. In 2009, the 5 counties had a total population of 1,404,978 (15% of Sweden’s population). With the exception of 1 county (Västmanland), where men with a history of AAA repair or surveillance of a known AAA were identified and excluded from the local screening program before invitation, no exclusion criteria were used. The examination fee was 140 SEK (US $25), equal to that of breast cancer screening. Travel expenses were not reimbursed.

All ultrasound examinations were carried out at the local hospitals by ultrasound technicians or registered nurses with specific ultrasound proficiency. The baseline examination included a single ultrasound scan in which the maximum infrarenal anteroposterior diameter is measured according to the leading edge to leading edge principle with the ultrasound transducer longitudinal to the aorta13 (Figure 2). An AAA was defined as a maximum infrarenal aortic diameter ≥30 mm.

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diameter of $\geq 30\text{ mm.}^{14}$ The scan result was communicated to the participant by the ultrasound technician at the time of screening, and for subjects with a screening-detected AAA, an appointment was scheduled with a vascular surgeon or a nurse for further information.

Between 2006 and 2009, all screened men in 4 of the 5 counties (Uppsala, Dalarna, Sörmland, and Gävleborg) were asked to complete a standardized health questionnaire containing information on smoking habits and family and medical history. Coronary artery disease was defined as a history of angina pectoris or myocardial infarction, cerebrovascular disease as a history of stroke or transient ischemic attack, and diabetes mellitus as a history of diabetes mellitus treated through diet or medication.

All 65-year-old men with a history of previous AAA repair who were alive at the time of invitation to screening were identified in the Swedish Vascular Registry (Swedvasc), a nationwide registry with a documented high external validity. From the National Causes of Death Register, men in the designated cohort who had died of an AAA before 65 years of age were identified.

Data evaluation was carried out with computer software packages (statistical analysis: SPSS PC version 19.0, SPSS, Chicago, IL). Proportions are presented with 95% confidence intervals (CIs). An independent-sample $t$ test was used for comparison of continuous data. For comparison of 2 proportions, an uncorrected $\chi^2$ test was used. To estimate the odds ratio for factors associated with AAA, all variables with a value of $P<0.1$ in the univariate analyses were explored in a multivariate logistic regression model. The different smoking variables were entered separately into the same multivariate analysis. A value of $P<0.01$ was considered significant. The estimated etiologic fraction (EF), ie, the excess prevalence associated with a risk factor, was calculated according to the following formula: $EF=(\text{odds ratio}-1)/\text{odds ratio}$. The study was approved by the Ethics Committee of the Uppsala/Orebro Region.

Results

The study profile is displayed in Figure 3. Between 2006 and 2010, 26 256 men were invited to screening, of whom 22 187 accepted (85%; 95% CI, 84 to 85). A total of 80 living 65-year-old men had a history of AAA repair, and 47 men were under surveillance for a known AAA. Nine men in the designated cohort were reported to have died of an AAA before the 65 years of age. Of 14 678 health questionnaires distributed, 14 620 were completed (99.6%).

Among 22 139 men with a valid ultrasound measurement, 373 AAAs were detected (1.7%; 95% CI, 1.5 to 1.9). The prevalence of previously known AAA (repaired or under surveillance) in the total population eligible for screening was 0.5% (95% CI, 0.4 to 0.6). Thus, the estimated total prevalence of the disease in the population was 2.2% (95% CI, 2.0 to 2.4). Seventy percent of all screening-detected AAAs were $<40\text{ mm}$; the size distribution is presented in Table 1. An aortic diameter between 25 and 29 mm was observed in 395...
men (1.8%; 95% CI, 1.6 to 2.0). Both the mean and median maximum infrarenal aortic diameters were 19 mm (95% CI, 19 to 19 mm; range, 9 to 88 mm; Figure 4).

The risk factor distribution is displayed in Table 2. Smoking, coronary artery disease, and hypertension were independently associated with AAA in a multivariate logistic regression model, in which smoking yielded the highest odds ratios (Table 3). The EF for smoking was 71%.

**Discussion**

In this contemporary population-based AAA screening study, the commonly suggested screening design, ie, a 1-time screening of men with ultrasound at 65 years of age, was used. The compliance was high (85%), which, together with the population-based study design, makes the results generalizable. Regarding socioeconomic status and health parameters such as prevalence of cardiovascular disease, the study population is highly representative of the general Swedish population.17

The majority of the screening-detected AAAs were small; 70% were <40 mm, similar to previous reports from Gloucestershire (62% were <40 mm)18 and the Aneurysm Detection and Management (ADAM) screening program (69% were <40 mm).19 The observed mean nonaneurysmal infrarenal aortic diameter (19 mm) was slightly inferior to that reported from the ADAM cohort (20 mm). In the ADAM trial, however, the outer diameter to outer diameter was measured as opposed to the leading edge to leading edge diameter in the present report. Considering that the aortic wall is 1 to 2 mm thick, the results were almost identical in this respect.

The observed 1.7% prevalence of screening-detected AAAs in a general population of 65-year-old men is, to the best of our knowledge, the lowest reported in a predominantly white population to date. The observed number of men with a history of previous AAA repair or under surveillance for a known AAA was similar to previous reports4 and does not change the fact that a lower-than-expected prevalence of the disease was found.

In a comparative study20 of the 4 randomized controlled trials, the age-specific prevalence for 65-year-old men was

![Figure 3. Trial profile. AAA indicates abdominal aortic aneurysm; US, ultrasound.](image)

**Table 1. Prevalence of Abdominal Aortic Aneurysm at Different Cutoff Values for Maximum Infrarenal Aortic Diameter**

<table>
<thead>
<tr>
<th>Maximum Infrarenal Aortic Diameter, mm</th>
<th>n</th>
<th>Prevalence, % (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥30</td>
<td>373/22 139</td>
<td>1.7 (1.5–1.9)</td>
</tr>
<tr>
<td>≥40</td>
<td>111/22 139</td>
<td>0.5 (0.4–0.6)</td>
</tr>
<tr>
<td>≥50</td>
<td>46/22 139</td>
<td>0.2 (0.2–0.3)</td>
</tr>
<tr>
<td>≥55</td>
<td>31/22 139</td>
<td>0.1 (0.1–0.2)</td>
</tr>
</tbody>
</table>

CI indicates confidence interval.
extrapolated to 3.5% to 4.5%, 2 to 3 times the prevalence in the present study. From Gloucestershire, UK, where there has been an ongoing screening program since 1990 targeting 65-year-old men, a prevalence of 2.7% was reported in 2003.18 Preliminary results from the ongoing English screening program, however, reveal a low prevalence similar to that in the present report.21 In the ADAM screening program from 1992 to 1997, the mean age was 66 years with a prevalence of 4.2%.19 In a cohort of 3.1 million screened men and women, Kent et al22 reported an overall prevalence of AAA of 1.7% among all men and 2.8% for men 65 to 79 years of age.23 The screening program was not population based, however, but consisted of self-referred patients, and many were <65 years of age. In a Swedish necropsy study

Table 2. Smoking Habits, Family History, and Comorbidities of Screened 65-Year-Old Men Stratified by Abdominal Aortic Aneurysm or Normal Aorta

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Normal Aorta (n=14,378), % (95% CI)</th>
<th>AAA (n=233), % (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ever smoked, %</td>
<td>63.4 (62.6–64.1)</td>
<td>87.1 (82.8–91.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Current smoker, %</td>
<td>13.0 (12.5–13.6)</td>
<td>33.1 (27.0–39.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Smoke-years</td>
<td>15.8 (15.6–16.1)</td>
<td>30.6 (28.3–32.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pack-years</td>
<td>10.8 (10.5–11.0)</td>
<td>23.7 (20.9–26.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>First-degree relative with AAA, %</td>
<td>1.4 (1.2–1.6)</td>
<td>1.3 (0–2.8)</td>
<td>0.85</td>
</tr>
<tr>
<td>Coronary artery disease, %</td>
<td>11.0 (10.5–11.6)</td>
<td>25.8 (20.1–31.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hypertension, %</td>
<td>37.0 (36.2–37.8)</td>
<td>55.4 (48.9–61.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hyperlipidemia, %</td>
<td>23.5 (22.8–24.2)</td>
<td>40.0 (33.6–46.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cerebrovascular disease, %</td>
<td>4.6 (4.2–4.9)</td>
<td>9.4 (5.7–13.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Claudication, %</td>
<td>1.3 (1.1–1.5)</td>
<td>3.0 (0.8–5.2)</td>
<td>0.025</td>
</tr>
<tr>
<td>COPD, %</td>
<td>6.4 (6.0–6.8)</td>
<td>9.0 (5.3–12.7)</td>
<td>0.10</td>
</tr>
<tr>
<td>Diabetes mellitus, %</td>
<td>12.2 (11.6–12.7)</td>
<td>10.7 (6.7–14.7)</td>
<td>0.51</td>
</tr>
<tr>
<td>Renal insufficiency, %</td>
<td>0.9 (0.8–1.1)</td>
<td>0</td>
<td>0.28</td>
</tr>
</tbody>
</table>

CI indicates confidence interval; AAA, abdominal aortic aneurysm; and COPD, chronic obstructive pulmonary disease.

Table 3. Multivariable Logistic Regression Analysis of Variables* Associated With the Presence of an Abdominal Aortic Aneurysm

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ever smoked†</td>
<td>3.5</td>
<td>2.4–5.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Current smoker†</td>
<td>3.4</td>
<td>2.6–4.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>10 smoke-y†</td>
<td>1.6</td>
<td>1.5–1.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>10 pack-y†</td>
<td>1.3</td>
<td>1.3–1.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>2.0</td>
<td>1.4–2.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hypertension</td>
<td>1.6</td>
<td>1.2–2.1</td>
<td>0.001</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>1.4</td>
<td>1.0–1.9</td>
<td>0.034</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>1.5</td>
<td>0.9–2.4</td>
<td>0.088</td>
</tr>
<tr>
<td>Claudication</td>
<td>1.1</td>
<td>0.5–2.4</td>
<td>0.86</td>
</tr>
<tr>
<td>COPD</td>
<td>1.2</td>
<td>0.8–1.9</td>
<td>0.44</td>
</tr>
</tbody>
</table>

CI indicates confidence interval; COPD, chronic obstructive pulmonary disease.
*Variables with values of P<0.1 in the univariate analysis were included in the analysis.
†Smoking variables were entered separately into the same analysis.
encompassing the years 1958 to 1986,24 the AAA prevalence among 65-year-old men was extrapolated to 3.5%.

Over the past decades, the average life expectancy of a 65-year-old man in Sweden has increased significantly, from 14 years in 1975 to 18 years in 2009.17 The improved longevity may be caused by various factors such as differences in exposure to known risk factors. This implies that the current target population differs from the populations examined in previous investigations of AAA prevalence among 65-year-old men, often dating 10 to 30 years back. In the ADAM cohort, the reported rate of ever smokers among men was 75% compared with 64% in the present report, and similar differences exist for other risk factors such as hypertension rates of 54% versus 37% and coronary artery disease rates of 37% versus 11%. In Sweden as a whole, coronary artery disease mortality rates decreased by 53% in men between 1986 and 2002.25

Smoking is undoubtedly the single most important risk factor for AAA, consistently associated with AAA in the literature. This was confirmed by the present report with a close to 4-fold additional risk observed for ever smokers. The EF of smoking was 71% in the present investigation, similar to previous reports.19 Assuming the same EF on the 3.5% (95% CI, 3.0 to 4.0) prevalence of AAA among 65-year-old men in the 1958 to 1986 Swedish necropsy study24 indicates that 2.5% (0.71 × 3.5%) could be explained mainly by smoking and the remainder 1.0% by other factors. According to data from Statistics Sweden,17 daily smoking among 65-year-old men in Sweden has decreased from 32% in 1980 to 11% in 2007 (compared with 13% in the present report). Thus, the contemporary frequency of smoking is about one third the 1980 rate. Applying the contemporary frequency of current smoking to the 1958 to 1986 Swedish necropsy cohort would result in a total prevalence of 1.8% (one third of 2.5%+1.0%), approximately the same prevalence found in this study. Today’s changing smoking habits may therefore largely explain the lower-than-expected prevalence of AAA in the present report, and a further decline in prevalence could be expected over time as the rate of daily smoking among men continues to drop in Sweden. Although smoking is the most important risk factor for AAA, it is likely that the impact of smoking on the prevalence of AAA would be slightly lower than indicated by our estimated EF if other less well-characterized contributors were to be included in the equation.

The current AAA repair rate among men ≥65 years of age in middle Sweden26 exceeds the total number of screening-detected AAs eventually needing repair. In the present report, the average annual screening detection rate was 133, whereas the current average annual number of AAA repairs in men ≥65 years of age in the catchment area is 177. With about one third of screening-detected AAs eventually undergoing repair27 and only a small number of AAs detected before screening, it is difficult to explain the current workload. The number of AAs requiring surgery among nonattenders is unlikely to explain this observed discrepancy. Thus, a significant proportion of today’s caseload must emanate from other sources. A conceivable explanation may be the development of new clinically relevant AAs after 65 years of age. An altered risk factor exposure may result in a delayed presentation of the disease among genetically predisposed individuals. The longer life expectancy also results in a longer lifespan at risk to develop the disease.

An alternative explanation may be an overall decrease of the disease in the population. Although, there are no signs of a decrease in AAA repair workload in Sweden,28 this may be an effect of the natural course of the disease with a delay in surgical presentation. The current surgical workload may thus originate from a historical cohort with a higher prevalence of AAA than seen today, a so-called cohort phenomenon.

On the basis of long-term follow-up of the Gloucestershire cohort, Crow et al18 concluded that “a single normal ultrasound scan at age 65 years effectively rules out the risk of clinically significant aneurysm disease for life in men.” Since this report was published in 2001, this has been widely adopted as a suitable and practical screening strategy.5–9 In the most recently published European Society for Vascular Surgery guidelines for the management of AAA,8 a Level 1a recommendation (based on a systematic review of multiple randomized, controlled trials) was made for screening men for AAA with a single scan at 65 years of age. On the basis of the same evidence, the US Preventive Services Task Force (USPSTF) also recommends 1-time AAA screening for men.29 Although the USPSTF recommendation refers to men 65 to 75 of age who have ever smoked, the subsequent Medicare benefit in practice applies only to men 65 years of age. However, no trial has assessed the optimum age for AAA screening. Furthermore, the generally agreed-on threshold diameter of 30 mm to define an AAA may be questioned.30 The definition of a normal aorta in the Gloucestershire report was a diameter of <26 mm, and in a follow-up study within the Chichester cohort, Hafez et al31 concluded that an aortic diameter between 25 and 29 mm should be classified as an “aneurysm in formation” and should be treated as such. Several authors have suggested a follow-up scan after 5 years in this subgroup.2,18,31 In the present report, a threshold diameter of 25 mm would have yielded an additional 1.8% (3.5% total) men for follow-up. It should be emphasized, however, that the randomized trials have not included this group, and there are no data to support that follow-up of persons with an aortic diameter of 25 to 29 mm reduces rupture or improves survival.

The observed low prevalence of AAA, possibly attributed to a reduced smoking rate, may support a more selective screening program such as the USPSTF recommendations to screen only those with a history of smoking. The higher prevalence among smokers may, however, be counterbalanced by the reduced life expectancy among smokers.9 Therefore, the cost-effectiveness of different screening strategies needs to be reevaluated on the basis of modern epidemiological data. According to a Markov simulation model, on the basis of a systematic review of the literature, a prevalence of the disease of 1% was the lower limit of cost-effectiveness of a general population-based screening program,4 indicating that the lower-than-expected prevalence reported in this study may still be associated with cost-effectiveness.

Conclusions

From the observed reduced exposure to risk factors, a lower-than-expected prevalence of AAA among 65-year-old men, an unchanged repair rate, and improved longevity of the elderly
population, we conclude that the current generally agreed-on AAA screening model can be questioned. An evaluation of alternative screening strategies is warranted. Important issues to address are the threshold diameter for follow-up, the possible need for rescreening of the entire population at a higher age, and selective screening among smokers.

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Disclosures
None.

References

CLINICAL PERSPECTIVE
On the basis of results from 4 randomized controlled trials, screening elderly men with ultrasound for abdominal aortic aneurysm (AAA) has emerged as an evidence-based way of reducing mortality from ruptured AAA. Although no trial has assessed the optimum age for AAA screening, current recommendations generally consist of a 1-time ultrasound examination at 65 years of age. In this contemporary population-based AAA screening study of a large cohort of 65-year-old Swedish men, a lower-than-expected AAA prevalence was found. This was attributed mainly to a changed exposure to known risk factors over the past decades, particularly a significant decline in smoking. At the same time, the life expectancy of the target population has increased significantly while the surgical caseload of AAA has remained unchanged. These observed changes in the epidemiology of AAA disease highlight the need to reevaluate different screening strategies on the basis of modern epidemiological data, which may influence the design of future screening programs.
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