

# Abdominal Aortic Aneurysm: Populations at Risk and How to Screen

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Abdominal aortic aneurysms (AAAs) account for significant morbidity and mortality in adults. Because they are most often asymptomatic until rupture occurs, screening that allows early detection and management has been advocated. In this review, the authors examine evidence to support screening at-risk populations for AAAs and evaluate various screening methods.

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Abbreviations: AAA = abdominal aortic aneurysm, CI = confidence interval, MASS = Multicentre Aneurysm Screening Study, OR = odds ratio, US = ultrasound

THE past decade has witnessed significant focus on screening for the detection and early management of abdominal aortic aneurysm (AAA) in an effort to reduce overall mortality and mortality related to ruptured AAA. Much of our contemporary understanding of the value of AAA screening draws from four large randomized trials (1–4), data from which were subsequently combined in a metaanalysis (5) and recently reexamined in a Cochrane systematic review (6). Based on these data, routine screening for AAA has been recommended by several organizations, including the United States Preventive Services Task Force (5), American Heart Association/American College of Cardiology (7), the Society for Vascular Surgery and Society for Vascular Medicine in the United States (8), and the Canadian Society for Vascular Surgery (9). However, individual guidelines are inconsistent as to which specific at-risk pop-

ulations are most likely to benefit. The current data suggest benefit of screening in older men and those with atherosclerotic risk factors, but the role of screening in women remains undefined.

## EPIDEMIOLOGY: THE SCOPE OF THE PROBLEM

AAA is defined as a dilation of the abdominal aorta to a size 50% greater than the proximal normal segment or to a maximum aortic diameter greater than 3 cm. The epidemiology of AAA is derived mainly from population-based ultrasound (US) screening studies and autopsy studies. Overall prevalence estimates range from 4% to 8% in men and are reported at 1% in women (1,3,10–12). Among the 126,196 patients—predominantly men aged 50–79 years—who underwent US screening in the Veterans Affairs Cooperative Study (13), AAA (>3 cm) was diagnosed in 3.6%, and 1.2% had an aneurysm measuring 4.0 cm or greater. The annual incidence of AAA ranges from 40.6 to 49.3 per 100,000 men and from 6.8 to 12 per 100,000 women.

## Risk Factors for AAA

The four leading risk factors for development of AAA include increasing age, smoking, male sex, and family

history (13). Secondary risk factors include other cardiovascular risk factors (eg, hypertension and hyperlipidemia) and established cardiovascular disease. Diabetes, black race, and female sex are all associated with reduced risk of AAA (13), although women with a family history of aneurysm or those with multiple cardiovascular risk factors continue to have a two- to threefold increased risk of aneurysm compared with women without these risk factors.

Several population-based studies (14,15) have shown increasing prevalence of AAA with increasing age. Among 6,386 men and women screened in the Tromsø, Norway, population-based study (14), the prevalence of AAA increased from 1.9% at 45–54 years to 6.0% at 55–64 years, 12.8% at 65–74 years, and 18.5% at 75–84 years among men, and from 0% at 45–54 years to 1.1% at 55–64 years, 4.1% at 65–74 years, and 8.6% at 75–84 years among women. The peak prevalence in women occurs at an older age than in men (15).

The prevalence of AAA is also significantly greater among smokers (5.1%) than in nonsmokers (1.5%), with some studies demonstrating a more than fivefold increased risk of AAA (13), an association more than twice as strong as that between smoking and coronary artery disease (16). The association between smoking and

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AAA exhibits a dose-dependent relationship that increases according to number of years of smoking and number of cigarettes smoked daily and decreases significantly according to the number of years after quitting (17). In the Veterans Administration Aneurysm Detection And Management study reported by Lederle et al (13), the excess prevalence associated with smoking accounted for 75% of AAAs larger than 4.0 cm detected by screening US.

Other significant risk factors for AAA ( $\geq 4.0$  cm) include family history of AAA (odds ratio [OR], 1.94 [95% CI, 1.6–2.3]), coronary artery disease (OR, 1.52 [95% CI, 1.4–1.7]), and hypercholesterolemia (OR, 1.44 [95% CI, 1.3–1.6]) (13). The risk of AAA is lower in women (OR, 0.18 vs that in men), black persons (OR, 0.53 [95% CI, 0.45–0.6]), and individuals with diabetes (OR, 0.52) (13).

### Clinical Presentation and Natural History

The clinical consequences of AAA can be dire, with death resulting from aneurysm rupture. However, aneurysms are asymptomatic in the majority of individuals. Although some patients present with back pain, abdominal pain, or an abdominal pulsation, aneurysms more commonly remain undetected and manifest with unheralded rupture and death. Indeed, autopsy series have shown that as many as 25% of large aneurysms (4–7 cm) are found to have ruptured. Risk of aneurysm rupture is directly related to the initial aneurysm size. In the Small Aneurysm Study in the United Kingdom (18), the rates of rupture per 100 person-years were 0.9 in aneurysms 3.0–3.9 cm in size, 2.7 in aneurysms 4.0–5.5 cm in size, and 27.8 in aneurysms 5.6 cm or larger (18). Data from the National Center for Health Statistics in the United States (19) show that aneurysms accounted for nearly 17,000 deaths annually, half of which were attributable to AAAs. Ruptured AAAs are the 13th leading cause of death in the United States.

The prognosis after AAA rupture is grim, with community-based mortality rates as high as 79% (20). As many as 59%–83% of patients with AAA die before reaching the hospital or under-

going surgery (21). For those individuals who do survive to hospitalization and surgery, operative mortality rates for ruptured AAAs are approximately 40% (22), leaving at most 10%–25% of individuals with ruptured AAAs who survive to hospital discharge (5). In contrast, the short-term mortality rate for elective surgical repair of nonruptured AAAs is approximately 5% (20). Because the prognosis after rupture is so poor and few individuals with ruptured aneurysm survive to hospital discharge, research has focused on reducing AAA-related mortality with screening to facilitate elective AAA repair.

### DIAGNOSTIC TESTING MODALITIES

Duplex US, a simple, safe, and inexpensive tool, is the most common diagnostic modality used for detection of AAA. US has a 95% sensitivity and 100% specificity to detect aneurysms greater than 3.0 cm (20), can delineate aneurysm dimensions (ie, anteroposterior, transverse, and longitudinal), and can be used for aneurysm characterization, identifying additional features such as thrombus, intramural hematoma, and the relationship to major arterial branches. Because eccentricity and tortuosity of the aorta might lead to overestimation of the true aortic dimensions, it is essential to carefully image the aorta perpendicular to the longitudinal axis.

Computed tomography (CT) and magnetic resonance (MR) imaging are being used more frequently for aortic imaging given recent advances in these technologies. Both modalities provide high-resolution imaging of the aorta, accurately identifying the presence of aortic aneurysms, delineating the relationship of the aneurysm to branch arteries of the aorta, and determining the aneurysm's proximal and distal boundaries. CT and MR imaging allow visualization of vessel wall characteristics, such as inflammation, mural thrombus, and vascular calcification. Clinicians typically reserve CT and MR imaging for anatomic characterization of aneurysms before percutaneous or surgical repair. They are not recommended for screening purposes, given the increased cost and risks of contrast agent and radiation exposure.

Routine physical examination is of moderate value in the diagnosis of AAA. In a pooled analysis of 15 studies of abdominal palpation for AAA detection, the sensitivity rates ranged from 29% to 76%, with increasing accuracy for larger aneurysms, and the positive predictive value neared 43% (23). Although large aneurysms may be detected, abdominal palpation cannot be relied on to rule out AAA with certainty.

### CLINICAL TRIALS OF SCREENING FOR AAA

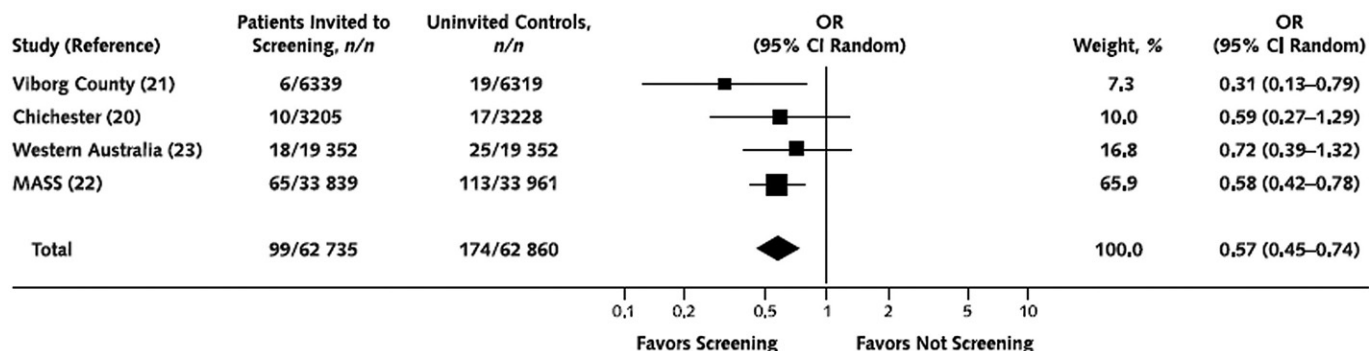
Duplex US has been employed in four major population-based, randomized trials (1–4) to evaluate the value of screening for the early detection and management of AAA (Table 1): the Multicentre Aneurysm Screening Study (MASS) (1); the Chichester (United Kingdom), screening study of Scott et al (4); the Viborg County (Denmark) screening study of Lindholt et al (2); and the Western Australia screening study of Norman et al (3). All studies' participants were 65 years of age or older and had an average risk for AAA. Women were included in only one study, that of Scott et al (4).

The MASS (1) studied the utility of screening for AAA in 67,800 participants—all men 65–74 years of age—who were randomized to receive a screening abdominal US examination. Nearly 80% of invited individuals accepted the invitation to undergo screening US, and participants were followed for a mean of 4.1 years. Subjects with initial aortic diameters of 3.0–5.4 cm underwent periodic repeat scanning, and those with aortic diameters 5.5 cm or greater or an increase of 1.0 cm in 1 year were referred to a vascular consultant. In the invited group, there were 65 AAA-related deaths (absolute risk, 0.19%), compared with 113 deaths (0.33%) in the control group, resulting in a 42% relative risk reduction (53% in those who actually underwent screening). There was no significant reduction in all-cause mortality. Seven-year follow-up data from the MASS (1) demonstrated sustained reduction in AAA-related mortality in the group invited for screening, with a hazard ratio of 0.53 (95% CI, 0.42–0.68) (24) and borderline benefits in all-cause mortality (hazard ratio, 0.96 [95% CI, 0.93–1.0]). In the

**Table 1**  
Overview of Randomized Controlled Trials of AAA Screening (1–4)

Study	Sex	Age (y)	No. of Pts.			AAA-related Mortality
			Randomized	Invited for Screening	Screened	
MASS (1)	Men only	65–74	67,800	33,839	27,147 (80%)	0.58 (0.42–0.78)
Scott et al (4)	Men and women	65–80	15,775 (6,433 men, 9,342 women)	7,887 (3,205 men, 4,682 women)	2,342 men (73%), 3,052 women (65%)	0.59 (0.27–1.29)
Lindholt et al (2)	Men only	65–73	12,658	6,333	4,852 (77%)	0.33 (0.16–0.71)
Norman et al (3)	Men only	65–83	38,704	19,352	12,203 (63%)	0.61 (0.33–1.11)*; 0.19 (0.04–0.89) in men aged 65–74 y

\* Age-standardized mortality rate ratio.



**Figure 1.** Metaanalysis data of mortality associated with AAAs in screening trials. Reproduced with permission from Fleming et al (5).

MASS (1), as in other screening trials, aneurysm-related deaths accounted for only a small percentage of total mortalities (approximately 3%), with the majority of deaths related to cancer (34%) and ischemic heart disease (28%).

In the screening study of Scott et al (4), 15,775 men and women 65–80 years of age were randomized to undergo US screening. Nearly 70% ( $n = 5,394$ ) of those invited for screening accepted the invitation, and aneurysms were detected in 4% ( $n = 218$ ). Male participants exhibited a 55% reduction in aneurysm rupture (2.8 vs 6.2 per 1,000 participants) and a 42% reduction in AAA-related mortality at 1 year. No significant differences related to aneurysm screening were detected in the women included in the trial.

The screening trial of Lindholt et al (2) studied 12,639 men aged 65–74 years, half of whom were invited for screening. Of more than 4,800 subjects (77% of those invited) who underwent

screening US, AAA was detected in 191 (4%). Individuals with AAAs of 5 cm or larger were referred to a vascular surgeon and those with initial AAA diameters larger than 3 cm returned for annual follow-up US examinations. The AAA-related mortality rate was significantly lower in the screened group after nearly 5 years of follow-up (9 deaths vs 27 deaths in the control group; hazard ratio of 0.33 [95% CI, 0.16–0.71]), although there was no difference in all-cause mortality.

In the study of Scott et al (4), 41,000 men aged 65–83 years were randomized to undergo AAA screening. The prevalence of AAA was 7.2% in the approximately 12,000 individuals who were screened. Further management of aneurysms in these individuals in regard to referral for intervention or the type of repair was left to the discretion of the primary care physician and the patient. Overall, including men older than 75 years, 18 AAA-related deaths were reported in the

screened group, compared with 25 in the control group, corresponding to a nonsignificant mortality rate ratio of 0.61 (95% CI, 0.33–1.1). However, analysis of men 65–74 years of age did show a significant reduction in AAA-related mortality (OR, 0.19 [95% CI, 0.04–0.89]).

In a pooled metaanalysis of these studies, including more than 125,000 study participants, Fleming et al (5) demonstrated that screening for AAA results in an overall reduction in AAA-related mortality in men (OR, 0.57 [95% CI, 0.45–0.74]; **Fig 1**). In contrast, the pooled analysis showed no reduction in all-cause mortality (OR, 0.98 [95% CI, 0.95–1.02]; **Fig 2**). A recent Cochrane systematic review (6) confirmed these findings and demonstrated a reduction in AAA-related mortality among men (OR, 0.60 [95% CI, 0.47–0.78]) but no benefit among women (OR, 1.99 [95% CI, 0.36–10.9]). No differences in all-cause mortality were seen in men or women (6). However, neither of these studies incorpo-

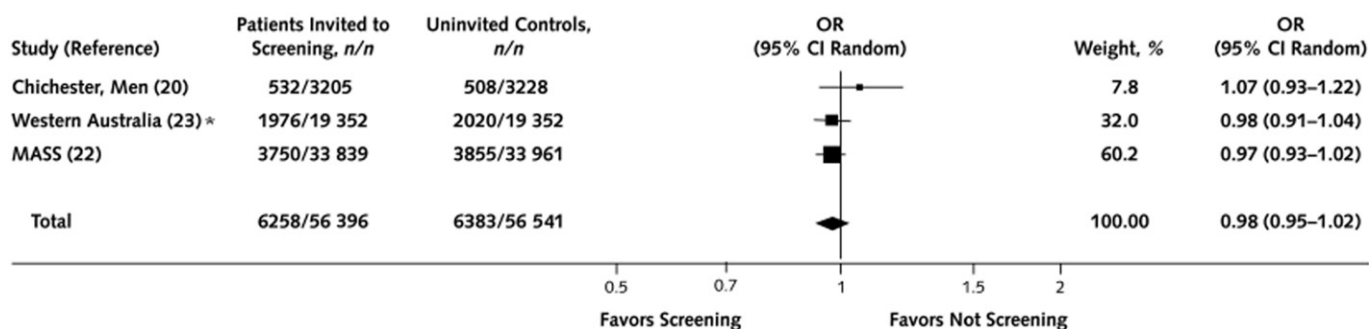


Figure 2. Metaanalysis data of all-cause mortality in AAA screening trials. Reproduced with permission from Fleming et al (5).

rated the 7-year follow-up data from MASS (24).

## SCREENING

### The Role of Screening in Women

There is considerable controversy regarding the role of AAA screening in women. Only one large study, the Chichester study of Scott et al (4), evaluated screening for AAA in women, studying 9,342 women aged 65–80 years, of whom only 3,052 actually underwent screening. The prevalence of AAA in women (1.3%) was significantly lower than in men (7.6%), and the prevalence of AAAs larger than 5 cm was 0.1%. Screening did not result in any differences in AAA-related mortality (relative risk, 1.0 [95% CI, 0.14–7.1]) or all-cause mortality (relative risk, 1.05 [95% CI, 0.92–1.19]) (4). However, although these data would suggest no benefit to screening in women, several additional issues must be considered. Although the prevalence is lower in women, those women diagnosed with AAA tend to fare worse than their male counterparts, with a fourfold greater risk of rupture, a reduced likelihood of being hospitalized or undergoing surgery, and greater risk of in-hospital mortality (15,25,26). Moreover, like men, women with certain risk factors continue to have an increased probability of AAA. In the Veterans Administration Aneurysm Detection And Management study (17), although female sex was a negative risk factor overall compared with male sex, female smokers had a nearly fourfold greater risk of AAA compared with female nonsmokers (OR, 3.8 [95% CI, 1.57–9.2]), and the risk of AAA was increased among women older than 70 years of age (OR,

1.8 [95% CI, 1.2–2.6], women with a family history of AAA (OR, 2.6 [95% CI, 1.1–6.0]), and women with cerebrovascular disease (OR, 3.2 [95% CI, 1.48–6.9]). Therefore, it remains unclear whether screening for AAA in a selective population of women with high-risk features may prove beneficial.

### The Role of Screening in Smokers

Smokers have a significantly greater risk of aneurysm development and constitute a group likely to benefit from AAA screening. At all ages, the prevalence of AAAs larger than 3.0 cm is greater among smokers than among never-smokers (5), and smoking accounted for nearly three fourths of the excess prevalence of AAA in a large United States cohort (13). Smoking is also strongly associated with increased AAA-associated mortality (16). The US Preventive Services Task Force (5) modeled the potential benefits of screening based on smoking status and determined that screening a hypothetical cohort of men aged 65 years with a history of smoking would detect 89% of aneurysms prevalent in this subpopulation, suggesting that AAA-related mortality could be reduced in this group.

### The Role of Screening in Other High-risk Populations

Several groups with significantly increased risk for aneurysm formation might benefit from AAA screening, including patients with a family history of aneurysms and patients with connective tissue disorders (eg, Marfan syndrome) or vasculitides (eg, Takayasu arteritis and giant-cell arteritis).

In the Aneurysm Detection And Management study (17), a family history of AAA was associated with a twofold increased risk of having an AAA (OR, 1.9 [95% CI, 1.6–2.3]). However, prospective data on the role of AAA screening in these subpopulations are lacking.

### Impact of Age on AAA Screening

Individuals older than 75 years were included in two of the four studies, those of Norman et al (3) and Scott et al (4). In the study of Norman et al (3), subgroup analysis showed no reduction in AAA-related mortality with screening among men older than 75 years (OR, 1.13 [95% CI, 0.56–2.29]), compared with a significant benefit in men aged 65–74 years (OR, 0.19 [95% CI, 0.04–0.89]). Although the incidence of AAA is greater in this age group, the higher prevalence of comorbidities and the reduced life expectancy seemingly negate any advantages of AAA screening in this older population.

### Value of Repeated Screening

Individuals who are found to have an initial aneurysm diameter smaller than 3 cm do not merit follow-up US. Two studies have examined the role of repeated screening in such cases. In the studies of Lindholt et al (2) and Scott et al (27), repeat US was performed 3–5 years after initial examination or at 2-year intervals over a 10-year period, respectively. New aneurysms (>3 cm) were found in 28% and 4.1% of cases in the respective trials (2,27), but none were clinically significant to merit intervention.

**Table 2**  
**Summary of AAA Screening Guidelines**

Group	Year	Men	Women
USPSTF	2005	Recommends for screening in men aged 65–75 years who have ever smoked No recommendation in men aged 65–75 years who have never smoked	Recommends against screening in all women
ACC/AHA	2006	Recommends for screening in men aged $\geq 65$ years who have ever smoked Recommends for screening in men aged $\geq 60$ with family history of AAA	No recommendation
SVMB/SVS/AAVS	2004	Recommends for screening in all men aged 60–85 years	Recommends for screening in women aged 60–85 years with a family history of AAA

Note.—AAVS = American Association of Vascular Surgery; ACC = American College of Cardiology; AHA = American Heart Association; SVMB = Society for Vascular Medicine and Biology; SVS = Society for Vascular Surgery; USPSTF = United States Preventive Services Task Force.

### Harm Associated with Screening and AAA Repair

The benefits of screening need to be weighed against the potential risks resulting from the screening test and the procedure(s) performed as a result of the abnormal findings. Abdominal US is noninvasive and safe without significant physical discomfort. However, surgical repair of AAA is not without risks, including death and perioperative complications (eg, myocardial infarction, respiratory complications, spinal cord ischemia, and prosthetic graft infection). Several studies have demonstrated a perioperative mortality rate associated with open AAA repair of approximately 4%–5% (20). Overall, complications occur in nearly one third of patients, with cardiac complications occurring in as many as 15% of those undergoing surgery (28). Risk factors associated with higher mortality rates include older age (OR, 1.8 [95% CI, 1.4–2.3] for ages 70–79 y and 3.8 [95% CI, 2.9–4.9] for age >79 y), female sex (OR, 1.6 [95% CI, 1.3–1.9]), renal insufficiency (OR, 9.5 [95% CI, 7.7–11.7]), and the presence of multiple cardiovascular comorbidities (OR, 11.2 [95% CI, 3.6–35.4]) (28).

The advent of endovascular repair of AAAs in the early 1990s has led to reduced perioperative mortality and complication rates. In the 2004 trial of Greenhalgh et al (29), the 30-day mortality rate was reduced from 4.7% in subjects receiving open repair to 1.7% in those undergoing endovascular AAA repair (OR, 0.35 [95% CI, 0.16–

0.77]). However, secondary interventions were more common in the endovascular repair group (9.8% vs 5.8% for open repair) (29), and after 4 years of follow-up, the long-term mortality rates (approximately 28%) were no different between the percutaneous and surgical repair groups (HR, 0.90 [95% CI, 0.69–1.18]) (30). In the Dutch Randomized Endovascular Aneurysm Management trial (31), which compared open repair versus endovascular repair in 345 patients with AAAs larger than 5 cm, endovascular repair produced a nonsignificant reduction in short-term operative mortality rate (1.2% vs 4.6%; RR, 3.9 [95% CI, 0.9–32.9] for open repair) (31). However, endovascular repair did significantly reduce the rate of systemic complications in the early perioperative period, but these benefits were not sustained at 2 years (31,32). When weighing these risks against the yearly incidence of AAA rupture in aneurysms larger than 5.5 cm (approximately 16%) and the resultant mortality rate of ruptured AAA (approaching 75%–90%), it becomes evident that patients with large aneurysms benefit from repair.

### SUMMARY GUIDELINES

Based on these data, routine screening for AAA has been recommended in certain populations by various organizations (Table 2). The US Preventive Services Task Force (5) recommends one-time screening by duplex US in men aged 65–75 years who have ever smoked (B recom-

mendation). Although the benefits in mortality reduction are recognized in men of similar age who have never smoked, the prevalence is lower in this group, leading the Preventive Services Task Force to make no recommendation for AAA screening for men aged 65–75 years who have never smoked. The Preventive Services Task Force specifically recommends against routine screening for AAA in women (5).

In the practice guidelines for patients with peripheral arterial disease, the American Heart Association and American College of Cardiology (7) recommend screening by US in men 60 years of age or older with a family history of AAA (class I indication, evidence level B) and men 65–75 years of age who have ever smoked (Class IIa indication, evidence level B).

Finally, a consensus statement put forth by the Society of Vascular Medicine and Biology, Society for Vascular Surgery, and American Association of Vascular Surgery (8) recommends baseline screening of all men aged 60–85 years, women aged 60–85 years with cardiovascular risk factors, and men and women older than 50 years with a family history of AAA. Patients deemed inappropriate for intervention should not be screened. Periodic surveillance is recommended for aneurysms 3–4 cm in size on an annual basis and for aneurysms 4–5 cm every 6 months; individuals with AAAs larger than 4.5 cm should be referred to a vascular specialist for consideration of repair.

## DISCUSSION

Several conclusions can be drawn from the aggregated data on AAA screening. It is well recognized that aneurysms are more common in men than in women and in those with cardiovascular risk factors, including smoking, hypertension, and established vascular disease. These aneurysms can be accurately identified in a simple, noninvasive manner by duplex US. Data from four large randomized trials (1–4) that used duplex US to screen for AAA show that one-time US screening in an at-risk population—specifically men aged 65–74 years—reduces aneurysm-related mortality but has no impact on all-cause mortality. No established benefit has been seen with screening in men older than 75 years given the reduced life expectancy in this age group and the presence of comorbid diseases. Although the data on aneurysm screening in women show no impact on AAA-related or all-cause mortality, few women have been included in screening trials. Further studies are necessary to determine if women with certain high-risk features (eg, smoking and family history of AAA) might benefit from one-time AAA screening, especially given the lower prevalence in women countered by the higher risk of rupture.

As with any screening program, it is critical to balance the benefits of screening with the potential harms. If an aneurysm is left untreated, the risk of rupture is roughly 27.8 per 100 person-years for aneurysms larger than 5.5 cm (18), and rates of survival after AAA rupture are no higher than 10%–25% (5,18). By comparison, the risks from elective AAA repair include death (in approximately 5%) and surgical complications in one third of patients. However, as evidenced by the four large AAA screening trials (1–4), in certain populations, the benefits of early identification and subsequent repair clearly outweigh the risk of unidentified aneurysm leading to rupture and death.

As a result of the significant reduction in disease-related death in men, the Centers for Medicare and Medicaid Services in the United States agreed to cover a one-time duplex US examination for detection of AAA in (i) men aged 65–75 years who have ever smoked (>100 cigarettes in a life-

time) and (ii) men and women older than 60 years of age with a family history of AAA. Although these are reasonable criteria for screening in a population-based manner, physicians bear the responsibility of determining whether individual patients may indeed benefit from screening based on their individual risk of aneurysm formation. Therefore, although not confirmed by studies at the population level, screening by US may also be justifiable in patients who bear a significantly increased risk of AAA, such as women who smoke or have established vascular disease.

For patients in whom an aneurysm is detected, long-term management is dictated by the initial aneurysm size. Periodic surveillance is required for those with an initial aneurysm diameter smaller than 5 cm: yearly for aneurysms measuring 3–4 cm and every 6 months for those measuring 4–5 cm. Individuals with an AAA larger than 5 cm or those with rapid aneurysm expansion (>1 cm in 1 year) should be referred to a vascular specialist for consideration of repair.

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