Benefits and harms of screening men for abdominal aortic aneurysm in Sweden: a registry-based cohort study

Minna Johansson, Per Henrik Zahl, Volkert Siersma, Karsten Juhl Jørgensen, Bertil Marklund, John Brodersen

Summary

Background Large reductions in the incidence of abdominal aortic aneurysm (AAA) and AAA-related mortality mean that results from randomised trials of screening for the disorder might be out-dated. The aim of this study was to estimate the effect of AAA screening in Sweden on disease-specific mortality, incidence, and surgery.

Methods Individual data on the incidence of AAA, AAA mortality, and surgery for AAA in a cohort of men aged 65 years who were invited to screening between 2006 and 2009, were compared with data from an age-matched contemporaneous cohort of men who were not invited for AAA screening. We also analysed national data for all men aged 40–99 years between Jan 1, 1987, and Dec 31, 2015, to explore background trends. Adjustment for confounding was done by weighting the analyses with a propensity score obtained from a logistic regression model on cohort year, marital status, educational level, income, and whether the patient already had an AAA diagnosis at baseline. Adjustment for differential attrition was also done by weighting the analyses with the inverse probability of still being in the cohort 6 years after screening. Generalised estimating equations were used to adjust the variance for repeated measurement and in response to the weighting.

Findings AAA mortality in Swedish men has decreased from 36 to ten deaths per 100 000 men aged 65–74 years between the early 2000s and 2015. Mortality decreased at similar rates in all Swedish counties, irrespective of whether AAA screening was offered. After 6 years with screening, we found a non-significant reduction in AAA mortality associated with screening (adjusted odds ratio [aOR] 0·76, 95% CI 0·38–1·51), which means that two men (95% CI –3 to 7) avoid death from AAA for every 10 000 men offered screening. Screening was associated with increased odds of AAA diagnosis (aOR 1·52, 95% CI 1·16–1·99; p=0·002) and an increased risk of elective surgery (aOR 1·59, 95% CI 1·20–2·10; p=0·001), such that for every 10 000 men offered screening, 49 men (95% CI 25–73) were likely to be overdiagnosed, 19 of whom (95% CI 1–37) had avoidable surgery that increased their risk of mortality and morbidity.

Interpretation AAA screening in Sweden did not contribute substantially to the large observed reductions in AAA mortality. The reductions were mostly caused by other factors, probably reduced smoking. The small benefit and substantially less favourable benefit-to-harm balance call the continued justification of the intervention into question.

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See **Comment** page 2394

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Introduction

Screening for abdominal aortic aneurysm (AAA) has been implemented in the UK,[1] the USA,[2] and Sweden[3] on the basis of outcomes from four randomised trials in the 1980s and 1990s.[4–7] The most recent trial results showed a 34% relative risk reduction in AAA mortality, or a 0·3 percentage point absolute risk reduction (appendix). However, the trials displayed great heterogeneity; screening had no effect in two trials[6,7] and the confidence intervals were non-overlapping. Since these trials, the incidence of AAA has decreased by more than 70% in the UK[8,9] and Sweden,[10] probably because of reduced smoking. Reduced incidence of the disease that is screened for reduces the absolute benefit and probably results in a less favourable benefit-to-harm balance.[11] An important harm of AAA screening is overdiagnosis, which means detection of aneurysms that would not have caused symptoms during the person's life or caused their death.[12,13] Overdiagnosis might result in avoidable surgery (overtreatment), leading to iatrogenic mortality or morbidity and psychosocial harm from being diagnosed with a life-threatening disease.[14,15]

The balance between benefits and harms of existing screening programmes for AAA is therefore unknown.[12,13] The AAA screening programme in Sweden was introduced step-wise by county between 2006 and 2015. Together with the well developed population registries in Sweden, this presents a unique possibility to assess a contemporary, public AAA screening programme.

The aim of this study was to estimate the effects of organised AAA screening in Sweden on AAA mortality, the incidence and level of overdiagnosis, and rates of surgery for AAA and to thereby estimate the level of overtreatment.

See **Online** for appendix

Research in context

Evidence before this study

We updated the search from a systematic review on screening for abdominal aortic aneurysm (AAA) by the US Preventive Services Task Force (USPSTF) in 2014. The USPSTF found four randomised trials of AAA screening from the 1980s and 1990s and concluded that screening was associated with a 50% relative reduction in AAA mortality. Since the USPSTF review, extended follow-up data from one of the included trials (Western Australia) have been published. The results of our updated meta-analysis of the four trials showed a 34% relative risk reduction for AAA mortality (95% CI 7–53), corresponding to a 0·3 percentage point absolute risk reduction. This means that 30 men avoided death from AAA for every 10 000 men invited to once-only screening given the disease prevalence at the time. However, the data from the individual trials were heterogeneous (I^2=80%, ranging from a large beneficial effect in two of the trials to no effect in the other two trials) and did not have overlapping confidence intervals. Thus, the certainty of the estimate is very low.

We have previously estimated overdiagnosis from AAA screening primarily on the basis of data from the MASS trial (the largest of the randomised trials). We found that for every 10 000 men invited to once-only AAA screening, 176 men were overdiagnosed (95% CI 150–202), and 37 of these men were overtreated and had avoidable preventive surgery (95% CI 15–60) at 13 year follow-up.

Since these randomised trials, the incidence of AAA has decreased by more than 70% in the UK, and similar trends have been observed in Sweden. This is probably due to reduced smoking. Smoking increases both growth and the risk of rupture of the AAA, and about 80% of deaths from AAA affect smokers; decreased smoking has therefore probably decreased the absolute benefit of AAA screening, resulting in a less favourable benefit-to-harm balance because overdiagnosis might have been reduced less than the benefit.

The substantial changes in incidence and mortality for reasons other than screening motivate contemporary estimates of effects of the intervention. The gradual implementation of AAA screening in Sweden and the availability of reliable population data present a unique possibility.

Added value of this study

In this registry-based cohort study, we estimated the effect of screening in age-matched screened and non-screened cohorts of men in a population with contemporary substantial decreases in AAA incidence and mortality. We used the stepwise introduction of AAA screening in Swedish counties to create two comparable cohorts. Only 7% of the effect of screening on mortality in the MASS trial was observed in our study when expressed in absolute numbers (two *vs* 27 men avoided deaths per 10 000 of those offered screening). The rate of overdiagnosis was 28% of that estimated in the MASS trial (49 *vs* 176 per 10 000 men offered screening), and the rate of overtreatment was 51% of that estimated in the MASS trial (19 *vs* 37 per 10 000 men offered screening).

Implications of all the available evidence

The small benefit and substantially less favourable benefit-to-harm balance of AAA screening at present means that the continued justification of the intervention should be revisited.

Methods

Study design

Individual, anonymised data on AAA mortality, incidence of AAA, and use of elective and acute surgery for AAA were obtained from a Swedish national cohort of 25 265 men who were invited to join the AAA screening programme between 2006 and 2009. These data were compared with data from a contemporaneous cohort of 106 087 age-matched men who were not invited to screening. To take background trends into account, we also analysed national trends for the same outcomes in all Swedish men aged 40–99 years in the period 1987 to 2015, continuously excluding counties once screening became implemented. This study was approved by the Regional Ethical Committee in Gothenburg, reference number 008-16.

The screening programme

The public health-care system in Sweden is organised in 21 counties. AAA screening was first introduced in Uppsala County in 2006,[3] and subsequently in other counties until reaching nationwide coverage in 2015. All men aged 65 years in the national population-based registry were invited to a once-only screening of the abdominal aorta by ultrasound.[3] Some counties also invited men aged 70 years.[16] Participation has been reported at 85%.[3] AAA was defined as an aortic diameter of at least 30 mm, although some counties offered to rescreen men with an aortic diameter of 25–29 mm after 5 years.[3] Men with a screen-detected AAA were followed-up at local vascular surgery clinics.[16] Guidelines recommend that men with an aortic diameter less than 55 mm are monitored with ultrasound at regular intervals.[17] Preventive surgery is considered for men with an aortic diameter of 55 mm or more.[17]

The cohorts

The screening cohort included men from Uppsala who were born between 1941 and 1944, men from Dalarna and Södermanland who were born between 1943 and 1944, and men from the region of Västra Götaland who were born in 1944. These counties introduced screening between 2006 and 2009. All men in these age cohorts who were registered as residents of the respective counties by Jan 1 in the year of their 65th birthday were included in the screening cohort.

The control cohort included all men who were born between 1941 and 1944, and registered as residents of Stockholm, Kalmar, Blekinge, Skåne, Halland, Jämtland/Härjedalen, Västernorrland, Norrbotten, and Gotland counties by Jan 1 of the year of their 65th birthday. These counties introduced screening between Jan 1, 2010, and Dec 31, 2015.

Counties where screening was introduced in various age groups simultaneously (Västmanland and Östergötland) and counties where screening was introduced in 2009 (Örebro, Gävleborg, Jönköping, Värmland, and Västerbotten) were not included in the cohorts to avoid contamination and to ensure necessary length of follow-up.

The registries

Individual, anonymised data on the incidence of AAA, AAA mortality, and surgery for AAA were retrieved for all men aged 40–99 years who were registered as residents of Sweden between Jan 1, 1987, and Dec 31, 2015. We used the Swedish cause of death registry, which has full national coverage and 98% complete mortality data.[18] Data on all AAA diagnoses registered in the same cohort of men were retrieved from the Swedish inpatient and outpatient registries.[19] The inpatient registry has nationwide coverage of all hospital admissions since 1987, with less than 1% of data missing.[19] The outpatient registry has nationwide coverage for policlinic visits since 2001, but does not cover primary health care. Although 25–30% of visits did not have registered diagnoses in the first years, this gradually decreased to about 4% of visits in 2016.[19] Data on all surgical procedures for AAA, both acute and elective, were retrieved from the Swedish national registry for vascular surgery (Swedvasc).[20] Swedvasc has nationwide coverage and includes 99% of all surgeries for AAA.[20]

In the analyses of AAA mortality and incidence, we used ICD-10 codes I71.3 (AAA, ruptured) and I71.4 (AAA, not ruptured) and the corresponding ICD-9 codes (441.3 and 441.4) when classified as causal or contributing to death or when registered as diagnoses in the outpatient or inpatient registries. Our analyses of surgery for AAA were based on data from the module for surgery of infrarenal aortic aneurysms (ie, those aneurysms targeted by screening) in Swedvasc (or coded as surgery for AAA in earlier versions of the registry). Individual data on socioeconomic status (marital status, educational level, and income) and emigration for the men included in the cohorts were retrieved from Statistics Sweden.

Definition of overdiagnosis and overtreatment

Overdiagnosis was defined as the excess risk or probability of having an AAA diagnosis in the screening cohort relative to the control cohort at 6 year follow-up to take account of incidence increases due to advancement of time of diagnosis (lead time).[21] Our estimate of overdiagnosis thus includes excess cases irrespective of whether the men had elective surgery or were assigned to active monitoring.

Overtreatment refers to overdiagnosed men who had elective surgery. Because patients who are overtreated fulfil the criteria for preventive surgery, the surgeon cannot know which individuals are being overtreated, and overtreatment is therefore an inevitable consequence of overdiagnosis. Overtreatment was defined as the excess of men who had elective surgery for AAA in the screening cohort (compared with the control cohort) minus the excess of men who had rupture of the AAA in the control cohort (compared with the screening cohort) 6 years after screening. We defined AAA rupture as deaths from AAA or acute surgery for AAA. This would include both survivors and non-survivors of acute surgery for AAA.

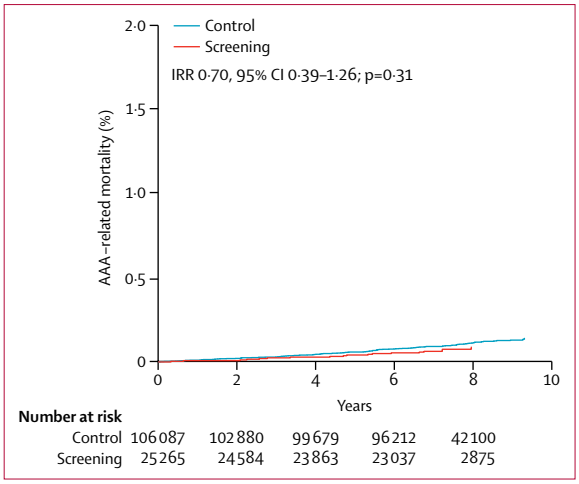

Figure 1: **Mortality from abdominal aortic aneurysm (AAA)**
Unadjusted cumulative mortality from AAA for men in the screened and the non-screened cohorts. Year 0 designates the year of the 65th birthday. The bulk of the screening cohort is censored from the years 7–10 after screening, which is why our data is limited by few events and susceptible to random variation in this time period and the graphical presentation of data beyond this timepoint should be interpreted with caution. IRR=incidence rate ratio.

	Adjusted odds ratio (95% CI)	Risk difference, percentage points (95% CI)
Mortality	0·76 (0·38 to 1·51)	–0·02 (–0·07 to 0·03)
Incidence	1·52 (1·16 to 1·99)	0·49 (0·25 to 0·73)
Elective surgery	1·59 (1·20 to 2·10)	0·30 (0·14 to 0·45)
Rupture	0·66 (0·44 to 1·00)	–0·10 (–0·19 to –0·02)
Overtreatment	..	0·19 (0·01 to 0·37)

Estimates of the excess probability (both as a relative and an absolute measure) in the screening cohort compared to the control cohort of having had the corresponding outcome at 6-year follow-up. Adjustment for cohort year, marital status, educational level, income, and diagnosis of abdominal aortic aneurysm at baseline was done by propensity score weighting. Adjustment for differential attrition was also done by weighting the analyses with the inverse probability of still being in the cohort 6 years after screening. Generalised estimating equations were used to adjust the variance for repeated measurement and in response to the weighting.

Table: **Abdominal aortic aneurysm mortality, incidence, elective surgery, rupture, and overtreatment**

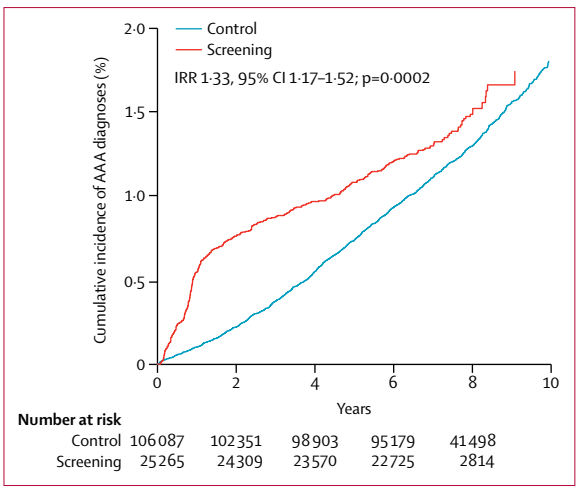

Figure 2: **Incidence of abdominal aortic aneurysm (AAA)**
Unadjusted cumulative rates of incidence of AAA for men in the screened and the non-screened cohorts. Year 0 designates the year of the 65th birthday. The bulk of the screening cohort is censored from the years 7–10 after screening, which is why our data are limited by few events and susceptible to random variation in this time period and the graphical presentation of data beyond this timepoint should be interpreted with caution. IRR=incidence rate ratio.

Again, only the first event was used, such that each individual could only be counted once. Elective surgery was not counted for men who had previously undergone acute surgery for AAA.

Statistical analysis

We studied the regional variation in AAA incidence and mortality in the 21 Swedish counties. We also realigned county-specific incidence and mortality data, and studied the trends in the periods before and after screening was introduced.

For the cohorts, the cumulative incidence of AAA diagnoses, mortality, elective surgery, and ruptures over the period from screening start to the end of follow-up were estimated with Nelson-Aalen plots, and differences were calculated after 6 years of follow-up using both incidence rate ratios (IRR) and rate differences.

To adjust for possible differences between the two cohorts that were unrelated to AAA screening, the differences in the probability of having had an AAA diagnosis, death from AAA, elective surgery for AAA, or an AAA rupture between the screening and the control cohort 6 years after screening was assessed both as a relative measure (an odds ratio [OR] from a logistic regression) and as an absolute measure (a risk difference from a linear regression). These regressions explicitly include terms for differences in prevalence of the outcomes at baseline; that is, the effect measures are interpreted as differences beyond those already present between regions at start of screening. Adjustment for confounding was done by weighting the analyses with a propensity score obtained from a logistic regression model on cohort year, marital status, educational level, income, and whether the patient already had an AAA diagnosis at baseline. Adjustment for differential attrition was done by additionally weighting the analyses with the inverse probability of still being in the cohort 6 years after screening, which was obtained from a logistic regression model on cohort year, marital status, educational level, income, and previous AAA diagnosis. Generalised estimating equations were used to adequately adjust the variance for repeated measurement and in response to the weighting.

Statistical analyses were done in SAS version 9.4 and SPSS version 24. The meta-analysis was done using ReviewManager version 5.3.

Deviation from protocol

We received information that screening had not been fully implemented for men who were born in 1943, from Västra Götaland. These men were therefore excluded from the screening cohort before analyses.

Data sharing

We cannot share individual patient data because of restrictions from the registries and ethical committee. Aggregated data are available on request.

Role of the funding source

The funders had no role in study design, data collection, data analysis, data interpretation, or writing of the report. All authors had access to the data and were responsible for the decision to submit for publication.

Results

AAA mortality varied between the 21 Swedish counties in the period 1987 to 2000 (range 19–51 per 100 000 men aged 65–74 years), after which the variation decreased (appendix). For men aged 65–74 years, AAA mortality decreased steadily from about 36 to ten deaths per 100 000 men between the early 2000s and 2015, and for men aged 75–99 years, it decreased from about 90 to 60 deaths per 100 000 men between 2005 and 2015 (appendix). AAA mortality decreased by more than 70% for men aged 65–74 years, and this change was similar in screened and non-screened populations (appendix). AAA mortality began decreasing about 10 years before screening was introduced and continued to decrease by about the same rate after introduction of screening (appendix).

After 6 years of screening, AAA mortality had decreased by 30% in the screening cohort relative to the control cohort (figure 1), and the absolute reduction was 3·7 deaths per 100 000 years (95% CI 1·7–9·1), corresponding to 0·02 percentage points or two men avoiding death from AAA per 10 000 men offered screening. In the adjusted analysis, AAA mortality after 6 years of screening had decreased by 24% in the screening cohort relative to the control cohort, but this change was also non-significant (adjusted OR [aOR] 0·76, 95% CI 0·38–1·51),

corresponding to a 0·02 percentage point absolute reduction in disease-specific mortality (95% CI –0·03 to 0·07) or that two men (95% CI –3 to 7) avoid death from AAA for every 10 000 men offered screening (table).

Between 1987 and 2000, the incidence of AAA in the 21 Swedish counties varied from 97 to 208 per 100 000 men aged 65–74 years (appendix). The variation increased after the introduction of screening. The incidence of AAA in men aged 65–99 years increased between the early 1990s and about 2010, but decreased thereafter (appendix).

In the unadjusted analysis, the incidence of AAA was higher in the screening cohort than in the control cohort (figure 2). The absolute difference in incidence after 6 years of screening was 50 diagnoses per 100 000 years (95% CI 25–73), corresponding to 0·30 percentage points or 30 potentially overdiagnosed men per 10 000 men offered screening. In the adjusted analysis, the odds of having an AAA diagnosis at 6 year follow-up was higher in the screening cohort than in the control cohort (aOR 1·52, 95% CI 1·16–1·99; p=0·002), corresponding to a 0·49 percentage point absolute risk increase (95% CI 0·25–0·73) or 49 potentially overdiagnosed men per 10 000 men offered screening (table).

National trends displayed a steep increase in the number of acute surgeries for AAA in men aged 65–99 years until the mid-1990s, followed by a steady decrease for men aged 65–74 years and a plateau for men aged 75–99 years (appendix). The number of elective surgeries for AAA increased steadily from the early 1990s for men aged 65–99 years; this trend was followed by a plateau for men aged 65–74 years from about 2005, and a decrease for men aged 75–99 years after 2010 (appendix).

In the unadjusted analysis, the incidence of elective surgery for AAA was higher in the screening cohort than in the control cohort (figure 3). The absolute difference after 6 years of screening was 36 elective surgeries per 100 000 years (95% CI 21–51), corresponding to 0·22 percentage points or 22 additional elective surgeries per 10 000 men offered screening. In the adjusted analysis, the odds at 6 years of follow-up of having had elective surgery was also significantly higher in the screening cohort than in the control cohort (aOR 1·59, 95% CI 1·20–2·10; p=0·001), corresponding to an absolute increase of 0·30 percentage points (95% CI 0·14–0·45). This increase in surgery was not fully compensated for by a decrease in ruptures (–0·10 percentage points, 95% CI –0·19 to –0·02), rendering a risk of overtreatment of 0·19 percentage points (95% CI 0·01–0·37), or 19 potentially avoidable elective surgeries per 10 000 men offered screening (table). 63% of all additional elective surgeries for AAA in the screening cohort might therefore have constituted overtreatment.

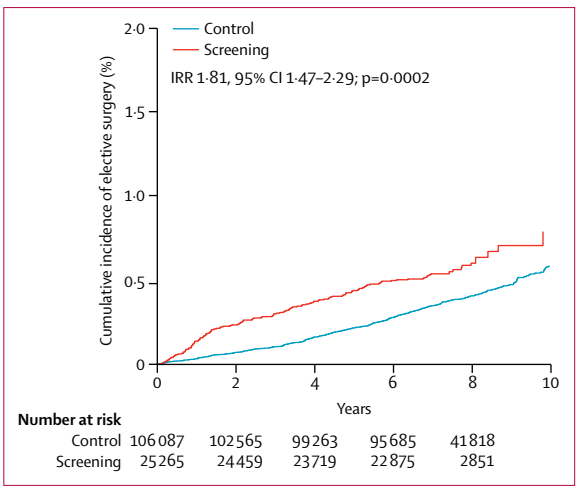

Figure 3: **Elective surgery for abdominal aortic aneurysm**
Unadjusted cumulative rates of elective surgery for abdominal aortic aneurysm for men in the screened and the non-screened cohorts. Year 0 designates the year of the 65th birthday. The bulk of the screening cohort is censored from the years 7–10 after screening, which is why our data are limited by few events and susceptible to random variation in this time period and the graphical presentation of data beyond this timepoint should be interpreted with caution. IRR=incidence rate ratio.

Discussion

We found a small beneficial effect of AAA screening on mortality from AAA. However, the difference was not statistically significant. Reductions in mortality from AAA in Sweden were similar in counties offering screening or not, and we found a 70% reduction in AAA mortality that was unrelated to screening. The clinical significance of the benefit of AAA screening today is therefore questionable. Our results suggest that most of the observed decrease in AAA mortality was caused by other factors, most probably reduced smoking. Indeed, the prevalence of smoking in Sweden decreased from 44% in 1970 to 15% in 2010.[22] Our findings are in line with data from a previous study of the Swedish screening programme that showed a decrease in the incidence of AAA ruptures before the introduction of screening but no reduction of AAA ruptures due to screening.[23]

We estimated that if 10 000 men are invited to AAA screening, two men might avoid death from AAA after 6 years (non-significant). At the same time, 49 men will probably be overdiagnosed, and 19 men will probably be overtreated because of screening. Compared with results at 7 year follow-up of the largest trial of screening for abdominal aortic aneurysm (the MASS trial),[24] we found about half of the benefit in terms of a relative effect and 7% of the estimated benefit in terms of absolute numbers (two *vs* 27 avoided deaths from AAA per 10 000 invited men). Compared with previous estimates of over-diagnosis and overtreatment (based primarily on the MASS trial),[13] we found a lower absolute number of overdiagnosed cases (49 *vs* 176 per 10 000 invited men) and fewer overtreated cases (19 *vs* 37 per 10 000 invited men).[13] However, since the harms of screening decreased less than the benefit, the balance between benefits and harms seem much less appealing in today's setting.

The incidence of AAA increased steadily until about 2010 for all Swedish men aged 65–99 years. Other studies have shown a marked decrease in the rate of screen-detected AAAs in the same time period.[8,10] The increase in incidence before screening that we observed, including in age groups not invited to screening, therefore probably reflects increased use of diagnostic tests (ie, incidental findings with radiological investigations for other purposes) and opportunistic screening rather than a true increase in disease prevalence. In other words, even without organised screening, a large proportion of abdominal aortic aneurysms are identified before rupture. This could partly explain why we found a smaller, non-significant effect on mortality than in the randomised trials. By contrast, this would underestimate the rate of overdiagnosis.

AAA screening might also detect thoraco-abdominal and juxta-renal aortic aneurysms.[25] Surgery to repair these are associated with increased morbidity and mortality[25] and might result in a less favourable benefit-to-harm balance of screening. Furthermore, Swedish men with a screen-detected AAA are routinely screened for popliteal aneurysms; in one study,[26] 24% of all men undergoing surgery for popliteal aneurysms were diagnosed because of AAA screening, a number that is likely to increase in the future. The benefits and harms of such additional screening are not adequately investigated and the potential for harm is appreciable.[26]

This is a retrospective registry-based cohort study including essentially all cases of AAA in Sweden. Although we have a contemporaneous, age-matched control group of non-screened men and we adjusted for differences in socioeconomic factors, it is not a randomised trial. There are important differences in socioeconomic factors and differences in mortality from and incidence of AAA between Swedish counties that predate organised AAA screening. We adjusted for socioeconomic status because it is strongly related to the incidence of AAA,[27] however we cannot exclude residual confounding, most notably related to smoking status.

Since the aim of AAA screening is earlier detection and subsequent elective surgery to prevent rupture, initial increases in the incidence of AAA and elective surgery is a prerequisite for screening to work as intended. If overdiagnosis or overtreatment did not occur, the initial increase should be fully compensated for by a later decrease in incidence and ruptures.[21] However, increases were not fully compensated for within our observation period, and trends indicate a persistent difference. All analyses of the screened and the non-screened cohort were limited to the initial 6 years after screening; the bulk of the screening cohort is censored from the years 7–10 after screening because our data were limited by few events and thus susceptible to random variation. Since meaningful follow-up was limited to 6 years in our study, the full effect of screening might not have been captured, which might lead to an underestimate of the benefit and overestimates of overdiagnosis and over-treatment. In the MASS trial, most of the effect on AAA mortality was obtained at 7 years (0·27 percentage point reduction in AAA mortality at 7 years;[24] 0·42 percentage point reduction at 10 years;[28] and 0·46 percentage point reduction at 13 years[5]). If applying trends from the MASS trial to our data, the absolute effect of screening on AAA mortality would increase from 0·02 percentage points at 6 years to 0·03 percentage points at 13 years of follow-up. Even if some degree of overestimation of overdiagnosis and overtreatment cannot be excluded, we do not believe that further follow-up would change the overall conclusion of our study.

The cause of death registry, the inpatient registry, and Swedvasc had a very high coverage throughout our study period. But the outpatient registry had a high proportion of visits without registered diagnoses in the early 2000s, before the implementation of organised screening. There are no consistent differences in rate of loss of registration between our screening and control cohorts (available on request), and we see no reason that loss of registration would be associated with the introduction of screening. Indeed, it is not possible to know if, or in what direction, this could introduce bias in our estimates.

In view of the clear definition of the diagnosis (aortic diameter >30 mm) and the objective manner in which AAA is most often diagnosed (by CT or ultrasound), the risk of misclassification of AAA affecting incidence is probably low. Knowledge of an AAA diagnosis probably increases the likelihood of sudden death being ascribed to AAA. That men in the screening cohort are more likely to have an AAA diagnosis could have led to an underestimation of the benefit of screening (sticky diagnosis bias),[29] especially since the proportion of Swedish men aged 65–74 years who had autopsies decreased from 44% to 21% between 1987 and 2015.[30] Furthermore, some deaths caused by screening (eg, suicide after an AAA diagnosis or death from renal failure due to complications of elective surgery for AAA) might not be registered as related to the AAA (slippery linkage bias).[25] This would cause overestimation of the beneficial effect of screening.

A considerable proportion of deaths within 30 days after surgery for AAA were registered as due to aortic aneurysm of unspecified site. These deaths were not included in our analysis because they might include thoracic aortic aneurysms. We also did sensitivity analyses including unspecified diagnoses (ICD-10 codes I71.8, I71.9, I71.5, and I71.6 and ICD-9 codes 441.5, 441.9, 441.6, and 441.7) for both disease-specific mortality and overdiagnosis, but the results were not significantly different (available on request).

Despite thorough attempts, we were unable to obtain basic information about the Swedish AAA screening programme from those responsible. This included precise starting dates and age groups invited. Judging from incidence peaks in our dataset, we found indications

that men born in 1943–44 from Uppsala County might have been screened systematically before their 65th birthday (appendix), leading to underestimates of overdiagnosis and overtreatment in our analyses.

Screening had only a minor effect on AAA mortality; in absolute numbers, only 7% of the benefit estimated in the largest trial of AAA screening was observed. The observed large reductions in AAA mortality were present in both the screened and non-screened cohorts and were thus mainly caused by other factors—probably reduced smoking. The absolute number of overdiagnosed and overtreated cases was also reduced, but we still found 28% and 51% of the absolute number estimated from randomised trials, respectively. Our results call the continued justification of AAA screening into question.

Contributors

MJ and JB contributed to the conception of this study. MJ, JB, KJJ, BM, PHZ, and VS contributed to the study design. MJ, JB, KJJ, PHZ, and VS contributed to the analysis and interpretation of the data. MJ drafted the Article. MJ, JB, KJJ, BM, PHZ, and VS contributed to the critical revision of the Article for important intellectual content. MJ, JB, KJJ, BM, PHZ, and VS gave final approval of the Article for submission. PHZ and VS provided statistical expertise. BM provided administrative, technical, and logistic support. MJ and VS collected and assembled data. All authors have seen and approved the final text.

Declaration of interests

We declare no competing interests.

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