Eur J Vasc Endovasc Surg (2019) 58, 698—707

Effect of Endovascular Treatment Rate on Population Level Outcomes and Survival After Intact Abdominal Aortic Aneurysm Repair☆

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WHAT THIS PAPER ADDS

This study compared four geographically adjacent populations with identical demographics, similar patient characteristics, and similar indications for the treatment of intact abdominal aortic aneurysms. Endovascular repair was adopted with significantly variable rates between these populations ranging from 38% to 74%. However, despite these disparities between the regions, there were no significant differences in early or late outcomes such as mortality, complications, and re-interventions. Thus, the remarkably different enthusiasm for the use of endovascular repair between these health care districts did not seem to affect the overall outcomes of these otherwise comparable patient populations.

Objectives: The aim was to study outcomes of endovascular aneurysm repair (EVAR) and open surgical repair (OSR) of abdominal aortic aneurysms (AAAs) in four geographically adjacent populations with identical demographics and variable EVAR rates.

Methods: This was a multicentre cohort study based on local and national registry data from an area of 815 000 inhabitants. The study involved 527 consecutive patients with an intact AAA treated with EVAR ($n = 327$) or OSR ($n = 200$) between 2010 and 2016. The catchment area was divided into four health care districts (populations A, B, C, and D) with one central hospital in each district. Each hospital decided independently between OSR and EVAR for patients within their population; OSR was performed in all hospitals while EVAR was centralised in one of them. Patient demographics and treatment outcomes were extracted from local registries. Population demographics, overall AAA incidence, and mortality data were retrieved from a national database.

Results: The rate of new intact AAA diagnosis varied between 20 and 29 per 100 000 inhabitants/year with the highest incidence in population D ($p < .001$). The intact AAA repair rates were 9.8, 8.9, 9.9, and 8.7 per 100 000 inhabitants/year for populations A, B, C, and D, respectively ($p = .64$). There were no significant differences in mean age (73.6 $\pm$ 8.0 years) or mean aortic diameter (62 $\pm$ 13 mm) between the treated patient populations. Groups A and B had high EVAR rates (74% and 72%, respectively) whereas the EVAR rates were lower in groups C and D (50% and 38%, respectively) ($p < .001$). The 30 day mortality rates were 2%, 2%, 4%, and 1% ($p = .55$), and complication rates were 17%, 12%, 15%, and 11% ($p = .39$) for A, B, C and D, respectively. There were no significant differences in mortality, complication or re-intervention rates between the groups during the mean follow up of 3.3 $\pm$ 2.0 years.

Conclusions: At population level, high EVAR rates had no measurable effect compared with lower EVAR rates on the outcomes in patients with intact AAA.

Keywords: Abdominal aortic aneurysm, EVAR, Endovascular aortic repair, Open surgical repair, Endovascular repair rate, Endovascular repair frequency
Article history: Received 4 October 2018, Accepted 24 April 2019, Available online 20 September 2019

INTRODUCTION

The surgical treatment options for abdominal aortic aneurysms (AAAs) are traditional open surgical repair (OSR) or the less invasive endovascular aneurysm repair (EVAR). In

☆ Abstract presented as oral presentation at the annual European Society for Vascular Surgery congress in Lyon, France, 2017.

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https://doi.org/10.1016/j.ejvs.2019.04.027

the past two decades, the trend for intact AAA treatment has shifted towards EVAR. Several randomised controlled trials (RCTs) such as The UK EndoVascular Aneurysm Repair-1 (EVAR-1), Dutch Randomised Endovascular Aneurysm Management (DREAM), Standard Open Surgery Versus Endovascular Repair of AAA (OVER), and Anevrysme de l'aorte abdominale, Chirurgie versus Endoprothese (ACE) showed that EVAR is associated with lower 30 day mortality, shorter length of hospital stay, lower initial costs, and fewer complications than OSR.[1–6] However, no long term survival benefit has been shown for AAA patients who have undergone EVAR compared with OSR.[6–8] A meta-analysis of the randomised controlled trials RCTs showed that the marginal early survival benefit associated with EVAR was lost after five years of follow up.[9] Furthermore, EVAR is associated with a higher frequency of re-interventions warranting lifelong surveillance, which may lead to higher overall costs than OSR in the long term.[10]

The proportion of intact AAA patients treated with the endovascular approach over open and endovascular surgery combined (hereafter referred to as the EVAR rate) varies from country to country between 28% and 79%.[11] It is not clear if higher EVAR rates result in lower mortality and complication rates at a population level, as would be expected based on the RCTs. The patient demographics vary significantly between clinical trials and registries, which makes the comparison of these study populations difficult. To overcome this potential bias early and long term outcomes of intact AAA treatment were investigated in four geographically adjacent populations with variable EVAR rates but identical demographics in terms of age, sex, ethnicity, and burden of cardiovascular risk factors. Secondary aims were to compare results between EVAR and OSR, and to assess population level aneurysm related mortality and AAA rupture rates.

PATIENTS AND METHODS

This multicentre cohort study was approved by the Institutional Review Board and an organisational authorization was obtained from all four participating centres. Individual patient consent forms were not required for this type of study. The study was based on both a national statistics registry and local vascular quality registry data from each participating centre from an area of 815 000 inhabitants. All institutions that provide vascular surgical services in this area participated in the study. Each hospital maintained a local database of treated AAA patients. An independent investigator verified all outcome endpoints (mortality, re-interventions, complications) in a retrospective and standardised fashion, and extracted all missing data from the patients' electronic medical records. The national registry (Statistics Finland and Population Register Centre) includes data on population demographics in Finland, diagnoses made in public health care, health care visits, and deaths based on the International Classification of Disease (ICD)-10 codes.

Population catchment areas

The catchment area was divided into four geographically adjacent health care districts (defined as populations A, B, C, and D) with one central hospital in each district (Fig. 1). Hospital A is a tertiary referral centre for the region and serves as a university teaching hospital with five or six vascular surgeons. Hospitals B, C, and D are secondary referral centres with two or three vascular surgeons in each of them. The distance between any of these hospitals is between 140 and 160 km (90—100 miles). Based on previous studies, the characteristics of populations A—D were well defined; the four populations were identical in terms of age and sex distribution, ethnicity, and burden of cardiovascular risk factors (such as hypertension, hypercholesterolaemia, and smoking), and incidence of cardiovascular events.[12—14] The mean population age, sex distribution, overall intact AAA (ICD-10 code I71.4) and ruptured AAA (ICD-10 code I71.3) incidence, and AAA related mortality within each area were retrieved from the national database. The total intact AAA repair rates and EVAR rates were calculated for each population. As a surrogate for cardiovascular disease burden within the catchment areas, the incidence rates of acute coronary events for each population were extracted from The Finnish Cardiovascular Disease Register, which included inhabitants aged 35—79 years and coronary events occurring between 2013 and 2015.

Patients and outcome measures

Each hospital was responsible for the treatment of AAA patients of the corresponding population districts. OSR was performed in all four hospitals, while all EVARs were referred to one centre located in population area (A). Each hospital decided independently which patients they would treat with OSR and whom to refer for EVAR. There were 715 consecutive patients recorded in the local registries of the four hospitals between 2010 and 2016. Patients with ruptured AAA were excluded ($n = 157$). Twenty patients with isolated iliac aneurysm, nine patients with thoraco-abdominal aortic aneurysm, and two patients living outside the study population were excluded. Thus, a total of 527 patients with intact infrarenal or juxtarenal AAA treated by EVAR ($n = 327$) or OSR ($n = 200$) were included in the study.

All data including patient demographics, comorbidities, aneurysm diameter and morphology, length of stay at primary hospital, and any early complication or re-intervention occurring within 30 days post-operatively or during the index hospitalisation were prospectively collected and inserted into a standardised form for analysis. In addition, re-interventions and late complications occurring during the follow up period were registered and reviewed retrospectively from the medical records. Late complications included surgical wound infection, prosthetic graft infection, incisional hernia requiring intervention, access site complications, endograft complications (migration, type I/III

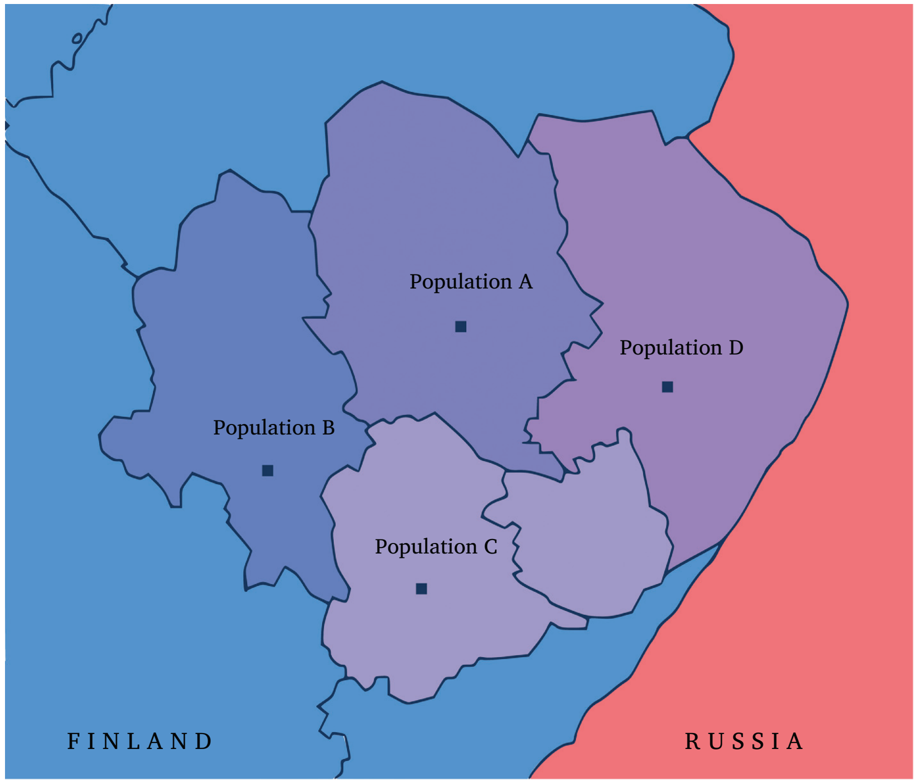

Figure 1. Map of the catchment area divided into four study populations. The locations of their respective central hospitals are marked with squares. Open surgical repair is performed in all four hospitals while population A hospital serves as the only tertiary referral centre for endovascular aortic repair in the area.

endoleak, branch stenosis, or occlusion), late rupture, gastrointestinal complications, and limb ischaemia or other vascular complications associated with the AAA repair. Re-interventions included any secondary intervention related to the AAA repair or late complication. Survival status and causes of deaths were extracted from the national registry. AAA related mortality was defined as peri-operative mortality, late rupture or death related to the AAA treatment. Patients were followed until the end of year 2017. The mean follow up time was 3.3 $\pm$ 2.0 years.

Statistical analysis

Data were presented as numbers and percentages or mean $\pm$ standard deviation (SD) when appropriate. Incidence rates were expressed as *n*/100 000 inhabitants/year with 95% confidence intervals (CIs). Pearson chi-square or Fisher exact test was used for nominal variables and Mann—Whitney U test or Kruskal—Wallis test for non-parametric data. The statistical differences between the incidence rates were calculated using Poisson regression model. The Kaplan—Meier method was used to calculate survival, freedom from re-intervention, and freedom from late complications; the log rank test was performed to compare differences between the study groups. The multivariable Cox regression model was used to identify risk factors for long term mortality and to adjust the survival statistics for age, gender, comorbidities, and aortic diameter. A p value $< .05$ was considered significant. All statistical analyses were performed using SPSS version 24.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Population catchment area characteristics

Population catchment area characteristics for districts A, B, C, and D are presented in Table 1. The age distributions of the catchment area populations were similar (Fig. S1). The proportions of males in the overall populations in hospital districts A, B, C, and D were 49.6%, 49.9%, 49.7%, and 49.9%, respectively. Reflecting cardiovascular morbidity in these four population catchment areas, the incidence of acute coronary events was statistically lower in population B than in the other populations. The respective annual acute coronary event rates (with 95% CIs) were 573 (551—596), 437 (417—458), 546 (510—584), and 515 (490—542) per 100 000 inhabitants for populations A, B, C, and D, respectively.

Districts A and B had high EVAR rates (74% and 73%, respectively) whereas the EVAR rate was lower in districts C and D (50% and 38%, respectively) ($p < .001$). The incidence of new intact AAAs observed ranged from 19.6 to 28.7 per

Table 1. Population catchment area characteristics

Variable	Hospital districts and catchment area populations between 2010 and 2016				*p* value
	A	B	C	D	
Mean population − *n**	248150	250662	148701	168992	
New intact AAA cases*	364	379	275	335	
New intact AAA incidence − *n*/100 000/year*	21.0 (18.9−23.2)	19.6 (17.7−21.7)	25.8 (22.9−28.9)	28.7 (25.8−32.0)	< .001
AAA related hospital visits − *n**	1318	908	909	1135	
AAA related hospital visits − *n*/100 000/year (95% CI)*	75.9 (71.9−80.1)	51.8 (48.5−55.2)	87.3 (81.2−93.2)	96.0 (90.5−101.7)	< .001
RAAA cases − *n**	83	112	98	81	
RAAA incidence − *n*/100 000/year (95% CI)*	4.8 (3.6−5.9)	6.4 (5.3−7.7)	9.4 (7.7−11.3)	6.9 (5.5−8.5)	< .001
RAAA repairs − *n*†	28	54	39	36	
AAA related mortality (intact + ruptured) − *n**	78	82	66	59	
AAA related mortality − *n*/100 000/year (95% CI) *	4.5 (3.6−5.6)	4.7 (3.8−5.8)	6.3 (5.0−8.1)	5.0 (3.9−6.4)	0.17
Intact AAA procedures − n†	169	153	102	103	
EVAR − *n* (%)	125 (74%)	112 (73%)	51 (50%)	39 (38%)	< .001
OSR − *n* (%)	44 (26%)	41 (27%)	51 (50%)	64 (62%)	< .001
Intact AAA repair rate, *n*/100 000/year (95% CI) †	9.8 (8.3−11.3)	8.9 (7.5−10.3)	9.9 (8.0−11.8)	8.7 (7.0−10.4)	.64

AAA = abdominal aortic aneurysm; RAAA = ruptured abdominal aortic aneurysm; SD = standard deviation; CI = confidence interval; EVAR = endovascular aneurysm repair; OSR = open surgical repair.
* Data extracted from the national registry (Statistics Finland and Population Registry Centre, Helsinki, Finland).
† Data extracted from the vascular quality registries and electronic medical records of the four participating hospitals.

100 000 inhabitants; the incidence of new AAA diagnosis was higher in populations C and D than in A and B ($p < .001$). There were no differences in AAA related mortality between the populations. However, the incidence of ruptured AAA during the study period was significantly higher in population C (9.4 per 100 000 inhabitants/year) than in A, B, and D (4.8—6.9 per 100 000 inhabitants/year, $p = .001$). A combined AAA rupture rate for populations C and D with low EVAR rates was higher (8.0/100 000/year, 95% CI 6.9—9.3) than in populations A and B with higher EVAR rates (5.6/100 000/year, 95% CI 4.8—6.4, $p < .001$). There were no statistically significant differences in intact AAA repair rates between the populations; the respective rates were 9.8, 8.9, 9.9, and 8.7 per 100 000 inhabitants/year.

Patient and procedural characteristics

The mean age of the patients was 74 ± 8 years; 88% were male and 26% were octogenarians with no differences between the four populations (Table 2). However, patients treated by EVAR were significantly older (76 ± 7 years) than those who underwent OSR (70 ± 8 years, $p < .001$). The proportion of octogenarians was 37% in the EVAR group and 9% in the OSR group ($p < .001$). There were no major differences in the comorbidity rates between the treated patient population groups, although patients in population C had a higher frequency of pulmonary disease than population B (37% *vs.* 20%, $p = .006$). Patients treated with EVAR had significantly higher cardiac comorbidity (63% *vs.* 49%, $p = .001$) and chronic kidney disease rates (31% *vs.* 14%, $p < .001$) than OSR patients. The mean aortic diameter of the treated patients was 62 ± 13 mm with no statistically significant differences between the population groups or between EVAR and OSR patients. The proportion of patients undergoing intact AAA repair below the common treatment threshold (aneurysm diameter < 55 mm for men and < 50 mm in women) was highest (25%) in group A and lowest (13%) in group D ($p = .04$); however, there were no differences in this regard between patients treated by EVAR *vs.* OSR (19% in both groups). In year 2010, 98% of the EVAR procedures were done using surgical femoral access, whereas in year 2016 up to 80% of the endovascular procedures were performed using fully percutaneous access. Regarding OSRs, 18% were aorto-aortic, 65% aorto-iliac, and 17% aorto-femoral reconstructions. Suprarenal clamping was employed in 14% of the OSRs.

Outcomes

There were no significant differences for in hospital, 30 day, or 90 day mortality rates between the four populations (Table 3). The 30 day mortality was 2% for EVAR and 4% for OSR patients ($p = .14$). Regarding peri-operative complications, there were no significant differences in overall complication rates between the population groups. Complication rates were 12% for EVAR and 16% for OSR ($p = .44$). New onset dialysis, bowel ischaemia, and respiratory failure were significantly more common in the OSR than EVAR group. The

Table 2. Demographics and comorbidities of the 527 patients undergoing intact AAA repair

Variable	Population A (n = 169)	Population B (n = 153)	Population C (n = 102)	Population D (n = 103)	p value*	OSR (n = 200)	EVAR (n = 327)	p value †
Age − mean±SD, years	73 ± 8	74 ± 7	75 ± 7	73 ± 9	.50	70 ± 8	76 ± 7	< .001
Octogenarians − n (%)	39 (23)	37 (24)	33 (32)	30 (29)	.31	17 (9)	122 (37)	< .001
Male − n (%)	148 (87)	138 (90)	90 (87)	89 (84)	.80	181 (91)	284 (87)	.21
Comorbidities − n (%)								
Diabetes	40 (24)	30 (20)	17 (17)	22 (21)	.56	41 (21)	68 (21)	.94
Cardiac disease	99 (59)	89 (58)	60 (59)	56 (54)	.90	97 (49)	207 (63)	.001
Cerebrovascular disease	17 (10)	16 (10)	9 (9)	13 (13)	.84	26 (13)	29 (9)	.13
Pulmonary disease	34 (30)	31 (20)	38 (37)	28 (27)	.006	52 (26)	79 (24)	.64
Chronic kidney disease (stage 3−5)	44 (26)	33 (22)	25 (24)	25 (24)	.83	27 (14)	100 (31)	< .001
Baseline creatinine	97.5 ± 77.5	93.9 ± 49.6	93.4 ± 23.8	86.3 ± 29.0	.03	84.9 ± 25.7	98.7 ± 65.0	< .001
Baseline GFR	71.8 ± 2.7	73.1 ± 2.0	69.1 ± 16.6	75.3 ± 21.2	.07	79.8 ± 18.6	68.1 ± 19.5	< .001
Maximum aortic diameter − mm						62.0 ± 13.6	61.8 ± 12.2	.79
In OSR patients	61.4 ± 12.0	65.4 ± 14.2	62.6 ± 14.4	60.0 ± 13.3	.21			
In EVAR patients‡	6.0 ± 11.7	62.4 ± 11.8	63.9 ± 14.3	63.1 ± 11.5	.18			
Aortic diameter below treatment threshold − n (%)§	42 (25)	28 (18)	14 (14)	13 (13)	.04	37 (19)	60 (19)	1.0

Data are presented as n (%) or mean ± standard deviation.
AAA = abdominal aortic aneurysm; OSR = open surgical repair; EVAR = endovascular aortic repair; GFR = glomerular filtration rate; SD = standard deviation.
* p value for difference between groups A, B, C, and D.
† p value for difference between OSR *vs.* EVAR group.
‡ Data missing for five patients.
§ Patients undergoing intact AAA repair at an aneurysm diameter < 55 mm for men and < 50 mm in women.

length of stay at the primary hospital was significantly longer in population D with the highest OSR rate; the mean length of stay was 10 ± 8 days in the OSR group *vs.* 3 ± 4 days in the EVAR group (p < .001). After EVAR, 181 patients (55%) were transferred from hospital A to their referring hospital (B, C, or D) before discharge whereas 89 (27%) went home directly; 54 (17%) were discharged to another ward or institution

Table 3. Early treatment outcomes (30 day or in hospital) and AAA related mortality during the follow up

Variable	Population A (n = 169)	Population B (n = 153)	Population C (n = 102)	Population D (n = 103)	p value*	OSR (n = 200)	EVAR (n = 327)	p value †
Early complications	29 (17)	18 (12)	15 (15)	11 (11)	.39	31 (16)	40 (12)	.44
In hospital death	3 (2)	2 (1)	3 (3)	1 (1)	.70	5 (3)	4 (1)	.27
Re-bleeding requiring intervention	5 (3)	1 (1)	3 (3)	4 (4)	.36	3 (2)	10 (3)	.26
Surgical wound infection	9 (5)	0	0	0	.001	1 (1)	8 (2)	.09
Prosthetic infection	3 (2)	0	0	1 (1)	.23	2 (1)	2 (1)	.62
Myocardial infarction	4 (2)	4 (3)	4 (4)	2 (2)	.83	8 (4)	6 (2)	.13
Stroke	2 (1)	2 (1)	2 (2)	0	.61	2 (1)	4 (1)	.82
New onset dialysis	5 (3)	1 (1)	2 (2)	1 (1)	.40	8 (4)	1 (< 1)	.001
Bowel ischaemia	2 (1)	1 (1)	0	1 (1)	.74	4 (2)	0	.02
Limb ischaemia	14 (8)	8 (5)	6 (6)	3 (3)	.09	11 (6)	20 (6)	.77
Other infection	4 (4)	4 (3)	5 (5)	1 (1)	.66	6 (3)	8 (2)	.26
Respiratory failure	2 (1)	3 (2)	2 (2)	0	.79	6 (3)	1 (< 1)	.001
Other complication	8 (5)	7 (5)	4 (4)	3 (3)	.84	6 (3)	16 (5)	.81
Re-intervention during hospital stay	4 (2)	3 (2)	2 (2)	2 (2)	.69	1 (1)	10 (3)	.53
Length of stay at primary hospital, days	6.0 ± 8.4	4.5 ± 4.6	5.6 ± 4.0	8.3 ± 7.2	< .001	10.4 ± 8.0	3.3 ± 3.5	< .001
30 day mortality	4 (2)	3 (2)	4 (4)	1 (1)	.55	7 (4)	5 (2)	.14
90 day mortality	7 (4)	10 (6)	4 (4)	4 (4)	.67	11 (6)	14 (4)	.52
AAA related mortality ‡	7 (4)	4 (3)	6 (6)	3 (3)	.56	10 (5)	10 (3)	.36
Follow up time − years	3.2 ± 2.1	3.1 ± 1.9	3.2 ± 1.9	3.7 ± 2.1	.31	3.6 ± 2.1	3.0 ± 1.9	.001

Data are presented as n (%) or mean ± standard deviation.
OSR = open surgical repair; EVAR = endovascular aortic repair; AAA = abdominal aortic aneurysm.
* p value for difference between groups A, B, C, and D.
† p value for difference between OSR *vs.* EVAR group.
‡ Defined as peri-operative mortality, late rupture or death related to AAA treatment; p values calculated using log rank method.

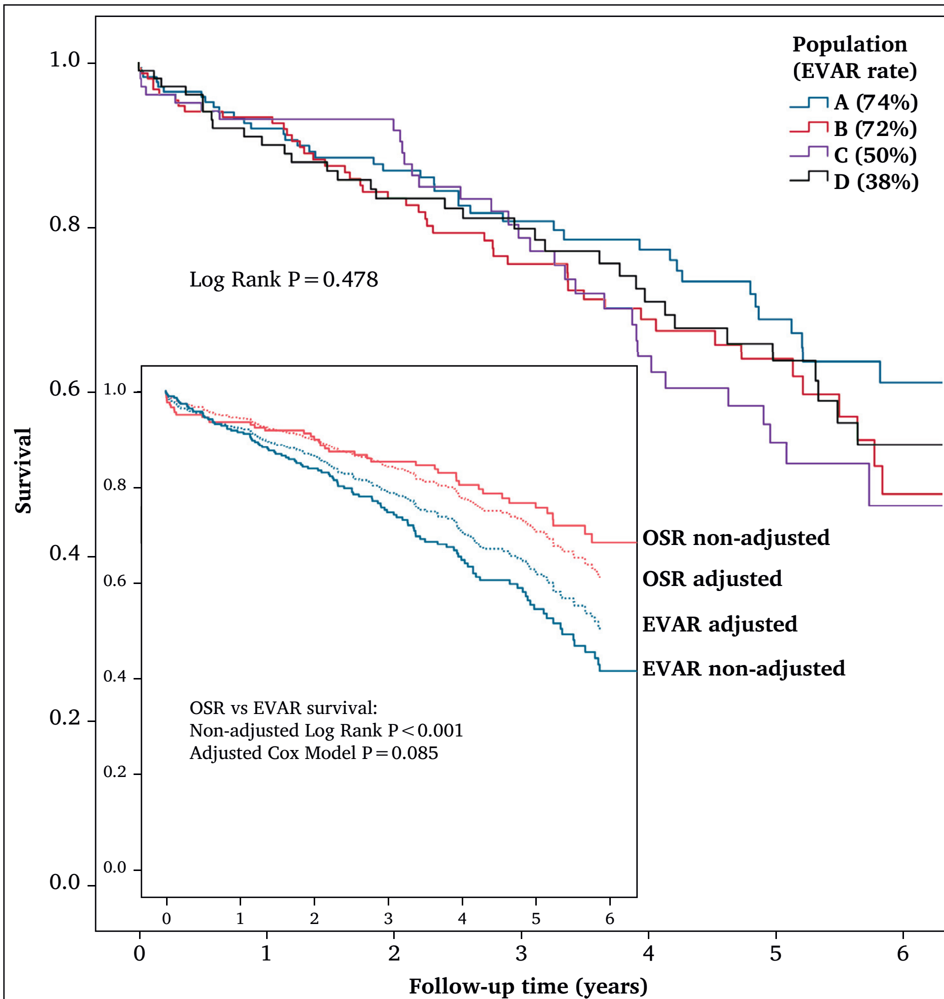

Figure 2. Kaplan–Meier analysis of patient survival showed no significant differences among the population groups A, B, C, and D. Patients treated by EVAR had higher mortality than those treated by OSR. However, Cox regression survival analysis adjusted for age, gender, comorbidities and aortic diameter showed no statistically significant difference between OSR *vs.* EVAR (inset). EVAR = endovascular aortic repair; OSR = open surgical repair.

such as a primary level district hospital or a nursing facility; three patients (1%) died in hospital.

There were no significant differences in mortality rates among populations A, B, C, and D during follow up (Fig. 2, Table S1). Non-adjusted long term mortality was higher in EVAR patients ($p = .002$). However, when adjusted for age, gender, comorbidities, and aortic diameter, there was no longer a statistically significant difference between the two groups ($p = .085$). Age, chronic kidney disease, and aortic diameter were independent pre-operative risk factors for long term mortality in the multivariable analysis (Table S2). A total of 152 patients died during follow up. The cause of death was AAA related in 20 patients and non-AAA related in 122 patients; the cause of death was unknown in 10 patients. No statistically significant differences in AAA related mortality were observed between the study groups (Table 3). There were no differences in freedom from re-intervention between the population groups, but patients treated by EVAR had a significantly higher rate of re-interventions than those treated by OSR ($p < .001$) (Fig. 3, Table S3). Similarly, freedom from late complications was lower for the EVAR *vs.* OSR group ($p = .01$), although there were no significant differences between the population groups (Fig. 4, Table S4).

DISCUSSION

In this multicentre study, the goal was to examine whether the variable enthusiasm for the use of EVAR among the centres would make a difference to the outcomes of intact AAA treatment. The EVAR rates varied between 38% and 74% in four adjacent health care districts with similar populations in terms of demographics, cardiovascular risk factors, and indications for treatment. Despite these major differences in the EVAR rates, no significant differences were observed in peri-operative mortality, long term mortality, early complications, late complications, or re-interventions among the four patient populations. The incidence of new intact AAA diagnosis and AAA rupture was higher in populations C and D with their lower EVAR rates. None of the hospital districts had a screening programme

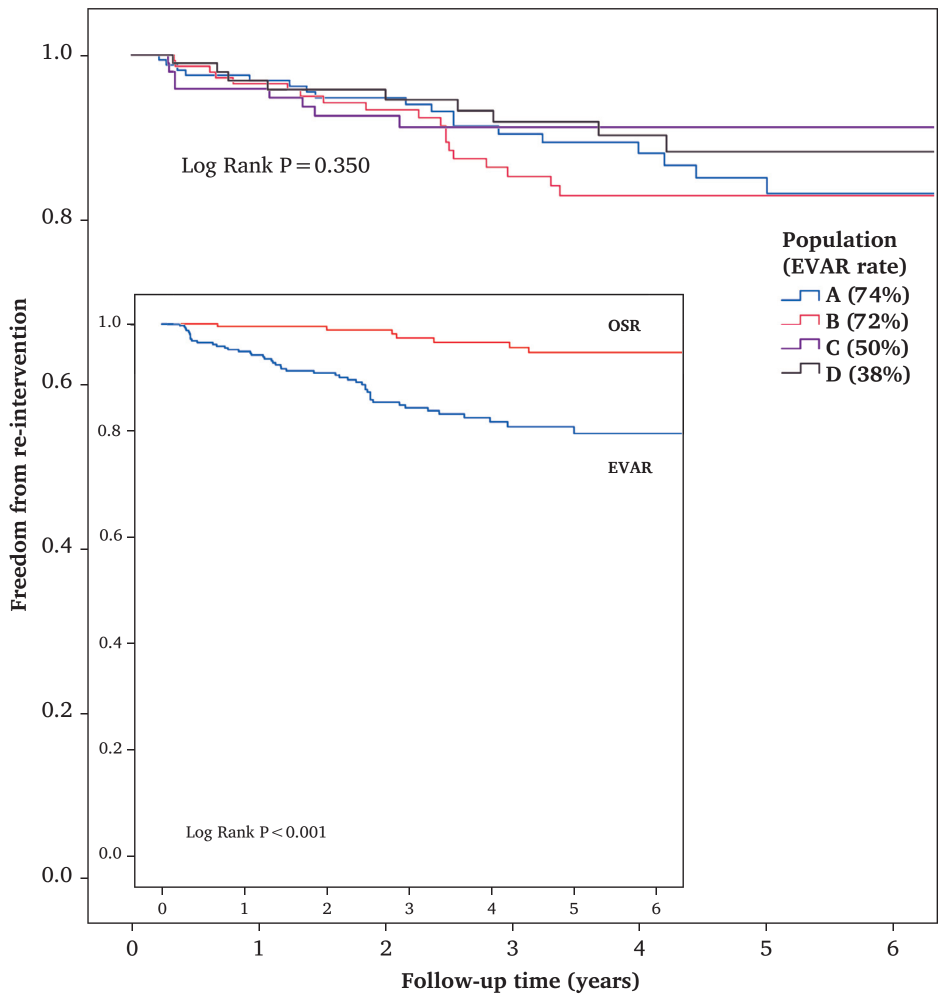

Figure 3. Kaplan–Meier analysis showed no significant differences in freedom from re-intervention among the population groups A, B, C, and D. Patients treated with EVAR had a significantly higher re-intervention rate than those treated by OSR (inset). EVAR = endovascular aortic repair; OSR = open surgical repair.

for aneurysms. Overall, peri-operative mortality was low in all districts with no statistically significant differences between the four populations, and there was no major difference in 30 day mortality rates between the OSR and EVAR groups either. The long term mortality was higher in the EVAR group in this study. However, the adjusted comparison showed that this was mostly due to a higher prevalence of comorbidities and the greater age of the EVAR compared with OSR patients. Late complication and re-intervention rates were significantly higher in the EVAR group, but even so, there were no remarkable differences when these events were compared among the four patient populations.

There are a few previous publications comparing EVAR rates and early outcomes between patient populations.[1,11,15] However, none of these studies compared the results within the same country with similar patient demographics. Furthermore, late outcomes or long term mortality were not investigated in those studies. In the previous study by Beck and colleagues,[11] the EVAR rates varied between 28% and 79% within 11 countries during nearly the same time period as the current study (2010–2013). In their study, the mean diameter for intact AAA was between 5.9 and 6.5 cm, whereas in the current study the mean diameter ranged between 6.0 and 6.3 cm suggesting that the indications for intervention were within the average range. In another study by Mani and colleagues comparing EVAR rates among six countries, the variation was from 14.7% to 56.0%, and peri-operative mortality rates ranged from 0.3% to 3.0% in the EVAR groups and from 1.8% to 5.6% in the OSR groups.[1] For example, the rate of EVAR in the UK was 49.4% and the peri-operative mortality was 4.0%, whereas in Denmark, the EVAR rate was 23.8% and peri-operative mortality was 3.4%. In study population A, the EVAR rate was 74% and the peri-operative mortality was 2%. In population group D, the EVAR rate was 38% and peri-operative mortality was the same, 2%. Thus, the results are in line with the findings of Mani and colleagues. Moreover, the results of the study comparing EVAR and OSR are similar to those published previously in four

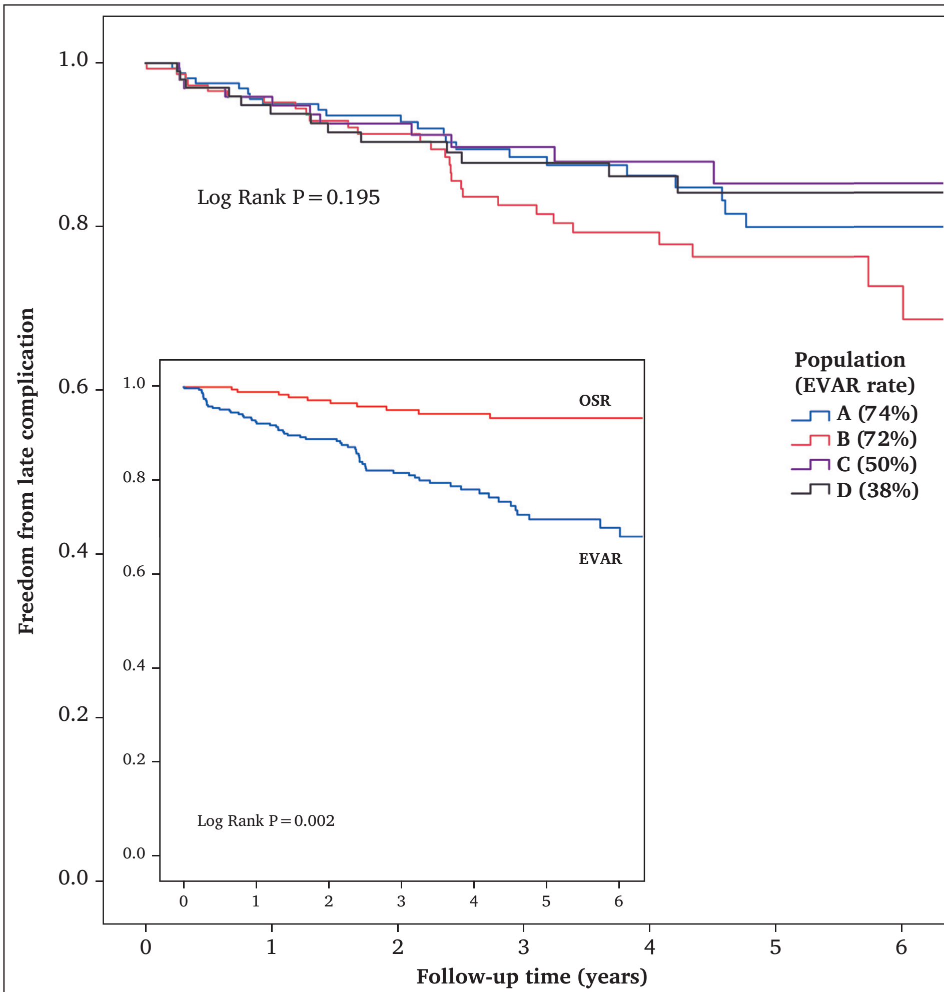

Figure 4. Kaplan–Meier analysis showed no significant differences in freedom from any late complications (including also endograft complications, i.e. migration, type I/III endoleak, stenosis or occlusion) among the population groups A, B, C, and D. Patients treated with EVAR had significantly higher late complication rate compared with those treated by OSR (inset). EVAR = endovascular aortic repair; OSR = open surgical repair.

landmark randomised controlled trials.[3–6] In the current study, the 30 day mortality was 2% for EVAR and 4% for OSR, whereas the 30 day mortality rates pooled from the four randomised trials were 1% for EVAR and 3% for OSR.[9]

Several previous studies have shown that the long term mortality may be higher after EVAR than OSR.[9,16] EVAR seems to lose its early survival benefit after 1.8 years, and after five years the survival rate may even be slightly better in patients who undergo OSR.[16] By contrast, in a 15 year follow up of the EVAR 1 trial, mortality was significantly higher beyond eight years after OSR.[10] In light of the current evidence, it remains unclear which approach should be preferred, open or endovascular, when both options are anatomically feasible and the patient is fit for open surgery. It was observed that OSR can be done with very good results for the majority of patients, and no measurable effect was noticed on the primary outcomes of intact AAA treatment at the population level in those districts that preferred OSR compared with centres with high EVAR rates. In this regard, the most important message of this study is that in many cases EVAR and OSR have equal weight and the patient should be offered comprehensive information on the benefits and disadvantages of both options. This should include informing patients of their peri-operative mortality and complication risks based on local outcomes and vascular quality registry.[17] It should be up to the patient to decide which option is preferred; the decision should not be dependent upon the vascular surgeon's personal preferences alone. In addition, when the patient is referred for EVAR, if there are any anatomical or technical issues that could potentially increase the risks and durability of the endovascular repair, consideration of open repair should be carefully revisited. Although the most recent European Society for Vascular Surgery 2019 guidelines recommend EVAR as the preferred treatment modality in most patients,[18] a recent draft of the UK's National Institute for Health and Care Excellence guidelines contradicted this, stating that patients should not be offered EVAR if OSR is suitable. The study results emphasise the individual decision making aspect of the current treatment guidelines.[17,18]

In other countries, the percentage of octogenarians with treated intact AAA varies from 7.1% in Hungary to 28.1% in Australia.[11,15] In the current study, the octogenarian rate varied from 23% to 32% between the treated study populations, and octogenarians constituted a larger proportion of the EVAR group (37%) than the OSR group (9%). This is because EVAR is expected to carry lower pre-operative risk than OSR in high risk patients.[19] Nevertheless, EVAR seems to carry a considerable risk of complications (12% in the study including major and minor complications) and even elderly patients require continuous surveillance after EVAR.[17,18] There is a need for risk stratification of elderly patients to determine who will actually benefit from intact AAA repair.

Populations C and D with low EVAR rates had a higher annual incidence of intact AAAs than populations A and B with high EVAR rates. Even so, the intact AAA repair rates did not differ between the populations. The reason for this remained unknown. Interestingly, the ruptured AAA incidence rates were higher in populations C and D with lower EVAR rates. However, since data on the AAA sizes of the new intact AAAs diagnosed during the study period are not available, the turndown rates of each population could not be assessed. Nevertheless, this observation raises an interesting question of whether low EVAR rates translate into higher turndown rates, and, consequently, contribute to higher rupture rates. In this study, no significant differences were observed in AAA related mortality between the groups at population level or among treated patients.

The annual volume of elective open AAA repair in the region ranged from only six to nine per centre. According to a recent study from the Medicare population, hospital volume is strongly associated with peri-operative mortality.[20] The mortality rate after elective open AAA repair was 6.3% in centres that performed zero to five operations per year (quintile with the lowest volume) whereas those that performed operations on 14–62 patients per year had a mortality rate of 3.8% (quintile with the highest volume, $p < .01$). Despite the low hospital volume in this study, the 4% peri-operative mortality rate after OSR is similar to the results of the high volume hospitals in the Medicare data. Although centralisation of AAA treatment to one hospital in the region might result in some improvement of outcomes, this could lead to loss of vascular surgical services in the other hospitals with widespread consequences. Owing to the long distances between the regional hospitals, it is important to be able to treat patients with vascular diseases, to provide vascular surgical consultation to other specialties, and to take care of vascular emergencies and trauma locally.

The major limitation of this study was that the AAA registries of the participating hospitals were not standardised during the study period. Therefore, the current reporting standards for AAA treatment outcomes could not be fully used.[21] For example, complications such as surgical wound infection is sometimes difficult to define, and, thus, the results for peri-operative complications should be interpreted carefully. Furthermore, the registries were designed for internal quality assessment and were not externally monitored. To overcome these limitations, an independent investigator verified the major outcomes and collected any missing data from the electronic medical records of each participating hospital. Thus, a significant proportion of data were entered retrospectively.

CONCLUSIONS

A high EVAR rate had no measurable effect at the population level on the survival and outcomes in patients treated for intact AAA. In district D with a high OSR rate, immediate outcomes were favourable, although the differences did not reach statistical significance. Between the two treatment options, OSR remains a sensible option in good risk patients, especially those with known anatomical risk factors for long term EVAR failure.

CONFLICT OF INTEREST

None.

FUNDING

None.

APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejvs.2019.04.027.

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