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Original Article

Outcomes of elective open surgical repair or fenestrated endovascular aneurysm repair for juxtarenal abdominal aortic aneurysms in Sweden

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Abstract

Background: A juxtarenal abdominal aortic aneurysm is defined as a short (less than 4 mm) or no-neck aneurysm, which is often treated with open or complex endovascular repair. The evidence to support the best treatment strategy is scarce. The aim of this study was to assess the short- and mid-term outcomes of elective open surgical repair or fenestrated endovascular aneurysm repair for juxtarenal abdominal aortic aneurysms in Sweden.

Methods: Patients who underwent elective open surgical repair or fenestrated endovascular aneurysm repair for juxtarenal abdominal aortic aneurysms between 2018 and 2021 were identified in the Swedish Vascular Registry. Demographics, practice patterns, and operative details were assessed. The primary outcome was 30-day mortality. Secondary outcomes included perioperative complications and mid-term survival.

Results: Among 3777 aortic aneurysm repairs performed, 418 involved juxtarenal abdominal aortic aneurysms (open surgical repair 228 (54.5%), fenestrated endovascular aneurysm repair 176 (42.1%), chimney endovascular aneurysm repair 6 (1.4%), and branched endovascular aneurysm repair 8 (1.9%)). Some 25 centres performed juxtarenal abdominal aortic aneurysm repairs with open surgical repair and fenestrated endovascular aneurysm repair. The caseload varied from 2 to 54 repairs per centre. The mean aneurysm diameter was 61 mm. Endovascularly treated patients were older and had more pulmonary co-morbidities. The 30-day mortality rate was 2.2% (open surgical repair 2.6% and fenestrated endovascular aneurysm repair 1.7%; $P = 0.397$). Perioperative major complications occurred in 14.1% of patients (open surgical repair 19.3% and fenestrated endovascular aneurysm repair 7.4%; $P < 0.001$) and perioperative vascular complications occurred in 12.1% of patients (open surgical repair 8.8% and fenestrated endovascular aneurysm repair 11.9%; $P = 0.190$). The survival rate (estimated using Kaplan–Meier analysis) at 1 year and 3 years was 93.1% and 85.9% respectively for open surgical repair and 95.2% and 80.9% respectively for fenestrated endovascular aneurysm repair ($P = 0.477$).

Conclusion: This nationwide study reveals considerable variations in volume and treatment strategy between Swedish centres performing juxtarenal abdominal aortic aneurysm repairs. Survival is comparable for open surgical repair and fenestrated endovascular aneurysm repair, although there are significant baseline demographic differences between patients selected for the two treatment modalities.

Introduction

Repair of juxtarenal abdominal aortic aneurysms (JRAAA), that is aneurysms extending up to the renal arteries (defined as neck length less than 4 mm), is more challenging than standard infrarenal abdominal aortic aneurysm (AAA) repair[1]. Traditionally, elective JRAAA repair is performed using open surgery, which may require suprarenal clamping and reconstruction of visceral arteries.

Endovascular aneurysm repair (EVAR) has been implemented worldwide due to its minimally invasive approach and lower perioperative complication rates when compared with open surgical repair (OSR). Whilst evidence for the treatment of infrarenal AAA is based on multiple RCTs[2–4], the actual evidence on the treatment options for JRAAA relies on national registries and observational studies.

Several endovascular treatment strategies for JRAAA have been developed. Custom-made endografts, including those in fenestrated EVAR (fEVAR) or branched EVAR (bEVAR), were developed to treat complex aortic aneurysms. Other options, including parallel grafts (chimneys/snorkels), as well as standard EVAR used in combination with endo-anchors, have been advocated. Guidelines suggest that surgical repair may be considered for JRAAA greater than or equal to 55 mm in diameter in high-volume centres with an annual caseload greater than or equal to 20. In patients with standard surgical risk, the choice for

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surgical treatment technique should be based on patient fitness and anatomy, whereas, in patients with high surgical risk, fEVAR should be considered as first-line treatment. fEVAR should be the preferred endovascular technique for elective repair, with the other endovascular solutions only being considered for emergency situations or as a bail out[1].

Overall, there is a general trend of wider use of the endovascular technique for JRAAA, partly due to increasing knowledge, increasing experience, and the availability of complex endografts[5,6]. However, concerns have been raised regarding the long-term outcomes of endovascular solutions for JRAAA, as the results of the UK COMplex AneurySm Study (COMPASS) suggest a higher mid-to-long-term overall mortality in patients with complex AAA treated endovascularly[7,8]. Comparative nationwide outcomes are lacking, especially with the availability of newer devices.

The aim of this study was to assess the outcomes of elective OSR or fEVAR for JRAAA for patients treated between June 2018 and May 2021 identified in the Swedish Vascular Registry (Swedvasc). The primary aim was to evaluate the short-term outcome of OSR or fEVAR for JRAAA and the secondary aim was to assess differences in centre practice patterns, patient characteristics, and mid-term outcomes.

Methods

This was a retrospective study of prospectively collected data from the Swedvasc Registry. It adhered to the STROBE guidelines[9]. Ethics approval was obtained (Dnr 2021-04449), with the need for individual informed consent waived for this retrospective analysis. The study complied with the Declaration of Helsinki.

Data source

The Swedvasc Registry was created in 1987 and achieved national coverage in 1994. It is a validated prospective registry with greater than 95% coverage for aortic procedures[10]. In 2018, the registration module for aortic disease was updated to include data entry for JRAAA repair. The registry includes data on patient characteristics and co-morbidities, aneurysm extent, surgical technique, clamp position for OSR, endograft extent, and management of visceral arteries, as well as perioperative complications. Furthermore, by cross-matching with the population registry, survival is continuously obtained.

Data screening and reclassification of aneurysm types

All patients registered for elective treatment for JRAAA between June 2018 and May 2021 were identified in the Swedvasc Registry. Whilst the majority of patients included in this study were correctly registered as having JRAAA, it was noted that some patients classified as having infrarenal AAA should be reclassified as having JRAAA due to suprarenal clamp position in OSR or incorporation of fenestrations with renal arteries, and vice versa. As the aim of this study was to analyse the results of elective JRAAA repair in Sweden, correct classification of aneurysm type was important. By reviewing actual anatomical and intraoperative data from the database, the misclassified patients were identified and reclassified based on the following rules:

- Patients who underwent OSR with proximal clamping above the renal artery: reclassified as having JRAAA when the proximal aortic clamp was placed above at least one main renal artery.
- Patients who underwent EVAR with fenestration to renal and/or visceral arteries: reclassified as having JRAAA when treated with fenestration to at least one main renal artery.
- Patients originally classified as having infrarenal AAA in the registry, but who underwent OSR with a proximal clamp position above the renal arteries or incorporation of the superior mesenteric artery and/or the coeliac artery during fEVAR, were classified as having pararenal or suprarenal aneurysms, depending on the extent of repair, and excluded from the present analysis. However, patients classified as having juxtarenal AAA in the registry with incorporation of several visceral arteries in the repair remained in the analysis.
- Patients registered as having juxtarenal/pararenal/suprarenal AAA treated with infrarenal EVAR were reclassified as having infrarenal AAA. Patients registered as having juxtarenal/pararenal/suprarenal AAA treated with OSR were left unchanged, even when the proximal aortic clamp was placed below the lowest renal artery, as it is technically possible to perform a repair of a JRAAA with a very short neck with an infrarenal clamp.

Study cohort

All patients who underwent elective treatment for asymptomatic JRAAA between June 2018 and May 2021 were identified in the Swedvasc Registry based on the above-mentioned criteria. The primary aim of this study was to analyse OSR *versus* fEVAR. Other endovascular options (bEVAR and chimney EVAR) were excluded from the main analysis and reported separately.

Clinical and outcome variables

Baseline characteristics, including patient demographics and co-morbid conditions, and pathology characteristics were analysed.

The following preoperative co-morbidities are recorded in the Swedvasc Registry and were assessed in this study: any medically treated hypertension; diabetes mellitus treated by diet, oral hypoglycaemic agents, or insulin; any diagnosed pulmonary disease; cerebrovascular disease, including stroke, transient ischaemic attack, and cerebral haemorrhage; chronic kidney disease, defined as serum creatinine greater than 150 mmol/l; active renal replacement therapy; and heart disease, defined as history of angina, myocardial infarction, heart failure, coronary artery bypass surgery, or percutaneous transluminal coronary angioplasty. The Glasgow aneurysm score (GAS; score = age in years + 7 for heart disease + 10 for cerebrovascular disease + 14 for chronic renal disease) was calculated to adjust for individual risk profile[11].

Perioperative complications (that is complications within 30 days) were classified as major complications and vascular complications. Major complications included intraoperative blood loss greater than 5000 ml, prolonged ICU stay (greater than 5 days), stroke, myocardial infarction, paraparesis, renal impairment with need of renal replacement therapy at 30 days, multiorgan failure, abdominal compartment syndrome, bowel ischaemia, bowel resection, and reoperation due to bleeding. Vascular complications included extremity ischaemia, iatrogenic vessel damage, occlusion of revascularized branch, graft occlusion, graft infection, major amputation, and distal embolism. The incidence of type I/III endoleaks in the fEVAR group was also captured. Severe complications, defined as Clavien–Dindo classification[12] grade IV or above (that is life-threatening complication, organ failure, or patient demise), were captured in the Swedvasc Registry, including stroke, myocardial infarction, spinal ischaemia, renal replacement therapy at 30 days, multiorgan failure, bowel ischaemia, prolonged ICU stay greater than 5 days, extremity ischaemia, major amputation, and mortality within 30 days.

Statistical analysis

Categorical and dichotomous variables are presented as *n* (%), whereas continuous variables are presented as mean(s.d.). Differences in demographics and outcome variables were tested for significance using Fisher's exact test for categorical variables and Student's *t* test for continuous variables. A binary logistic regression model was constructed to identify independent factors associated with early mortality and Cox regression was employed for assessment of factors associated with death during follow-up. Survival was estimated using Kaplan–Meier analysis. All tests were two-sided. $P < 0.050$ was considered statistically significant. Statistical analysis was performed using SPSS® (IBM, Armonk, NY, USA; Statistics, version 28).

Results

A total of 3770 aortic operations performed at 28 Swedish centres were recorded in the Swedvasc Registry during the study interval. Of these, 495 were classified as involving JRAAA at initial assessment. A total of 21 patients having JRAAA who underwent standard EVAR were reclassified as having infrarenal AAA and 73 patients having infrarenal AAA, with use of renal artery revascularization or a suprarenal clamp, were reclassified as having JRAAA, resulting in a total of 547 JRAAA patients post-reclassification. A total of 129 emergency cases were excluded.

Of the remaining 418 patients who underwent elective treatment for JRAAA, 228 patients (56%) were treated with OSR and 190 patients (44%) were treated with endovascular repair. Overall, the 30-day mortality rate after JRAAA repair in this cohort was 2.2% (OSR 2.6% and endovascular repair 1.6%; $P = 0.352$). A total of 14 of the endovascular cases were treated with bEVAR or chimney EVAR and are thus excluded from the main analysis and reported separately. The 404 remaining procedures of OSR and fEVAR were performed at 25 centres (out of 28 centres performing aortic repair overall), with a total volume of JRAAA over the study interval varying from 2 to 54 cases per centre (median of 18 (interquartile range (i.q.r.) 10.75–25.75) cases per centre) (*Fig. S1*).

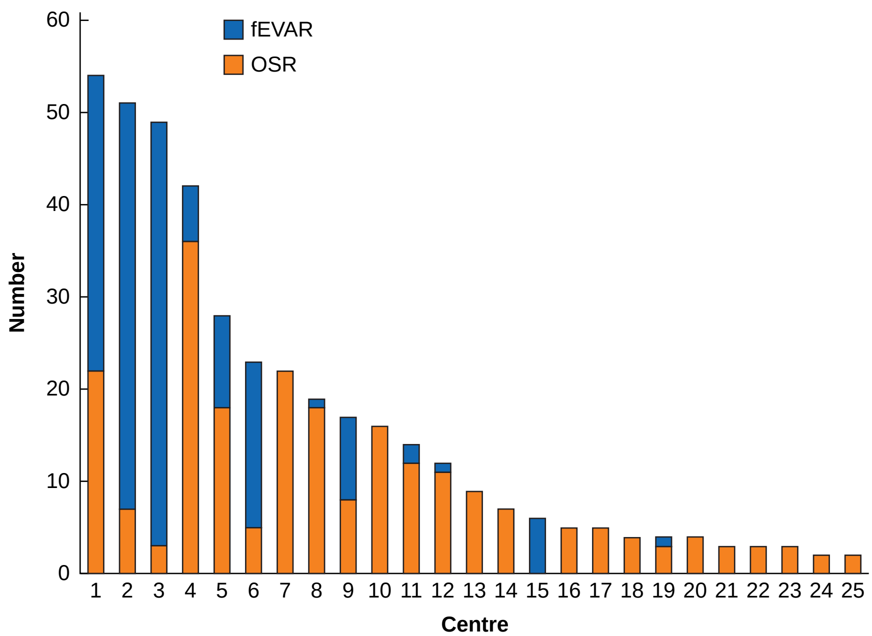
Practice of JRAAA repair varied, with 15 centres performing less than 10% of repairs with fEVAR and 2 centres performing over 90% of repairs with fEVAR (*Fig. 1*). A total of 24 centres performed OSR, with the three highest-volume centres performing 36, 22, and 22 procedures, representing 35% of the cases. A total of 12 centres performed fEVAR, with the three highest-volume centres performing 46, 44, and 32 procedures, representing 69% of the cases.

Patient characteristics are presented in *Table 1*. In patients who underwent OSR, proximal clamp position was infrarenal in 17%, above one main renal artery in 57%, and above both renal arteries in 26%. In the fEVAR group, 95% had fenestrations to two renal arteries and 78% had three or four fenestrations.

Overall, the 30-day mortality rate was 2.2% (OSR 2.6% and fEVAR 1.7%; $P = 0.397$). At 90 days, the overall mortality rate was 3.0% (OSR 3.5% and fEVAR 2.3%; $P = 0.346$).

Analysis by logistic regression did not identify co-morbidity factors as predictors for 30-day mortality (*Table S1*).

Among the 404 patients included in this analysis, 55 (13.5%) were octogenarians (OSR 34 and fEVAR 21). No deaths were observed in this subgroup of patients at 30 and 90 days after surgery.



No. at risk

fEVAR	32	44	46	6	10	18	0	1	9	0	2	1	0	0	6	0	0	0	1	0	0	0	0	0	0
OSR	22	7	3	36	18	5	22	18	8	16	12	11	9	7	0	5	5	4	3	4	3	3	3	2	2

Fig. 1 Numbers of elective open surgical repairs and fenestrated endovascular aneurysm repairs for juxtarenal abdominal aortic aneurysms by each centre in Sweden over a 3-year interval, 2018–2021

fEVAR, fenestrated endovascular aneurysm repair; OSR, open surgical repair.

Table 1 Baseline demographics of patients who underwent elective open surgical repair or fenestrated endovascular aneurysm repair for juxtarenal abdominal aortic aneurysms in Sweden over a 3-year interval, 2018–2021

	Overall (n = 404)	Open surgical repair (n = 228)	Fenestrated endovascular aneurysm repair (n = 176)	P
Male	344 (85.1)	195 (85.5)	149 (84.7)	0.458
Age (years), mean(s.d.)	73.0(6.4)	71.6(6.7)	74.7(5.4)	<0.001
Hypertension	310 (76.7)	187 (82)	123 (69.9)	<0.001
Heart disease	167 (41.3)	89 (39.0)	78 (44.3)	0.280
Diabetes	63 (15.6)	34 (14.9)	29 (16.5)	0.384
Smoking				0.843*
Never	39 (9.7)	23 (10.1)	16 (9.1)	
Ex-smoker	226 (55.9)	138 (61.1)	88 (50.0)	
Active	86 (21.3)	55 (24.1)	31 (17.6)	
Unknown	53 (13.1)	12 (5.3)	41 (23.3)	
Lung disease	119 (29.5)	56 (24.6)	63 (35.8)	0.045
Stroke	42 (10.4)	20 (8.8)	22 (12.5)	0.146
Chronic kidney disease	52 (12.9)	26 (11.5)	26 (14.8)	0.206
Renal replacement therapy	2 (0.5)	2 (0.9)	0 (0)	0.318
Previous aortic surgery	44 (10.9)	14 (6.1)	30 (17.0)	0.002
Glasgow aneurysm score, mean(s.d.)	76.90(8.04)	75.21(8.22)	79.08(7.27)	0.068

Values are n (%) unless otherwise indicated. *Unknown smoking status excluded.

Table 2 Perioperative major complications after elective open surgical repair or fenestrated endovascular aneurysm repair for juxtarenal abdominal aortic aneurysms in Sweden over a 3-year interval, 2018–2021

	Overall (n = 404)	Open surgical repair (n = 228)	Fenestrated endovascular aneurysm repair (n = 176)	P
Intraoperative blood loss >5000 ml	26 (6.8)	25 (11)	1 (0.7)	<0.001
Stroke	2 (0.5)	0 (0)	2 (1.2)	0.153
Myocardial infarction	6 (1.6)	4 (1.9)	2 (1.2)	0.449
Paraparesis	5 (1.4)	2 (1)	3 (1.8)	0.315
Renal impairment with need of renal replacement therapy at 30 days	18 (4.7)	11 (5.2)	7 (4.1)	0.402
Multiorgan failure	8 (2.1)	5 (2.4)	3 (1.8)	0.486
Bowel ischaemia	10 (2.6)	9 (4.3)	1 (0.6)	0.023
Bowel resection, n	5	4	1	
Abdominal compartment syndrome	1 (0.3)	0 (0)	1 (0.6)	0.446
Prolonged ICU stay (>5 days)	21 (5.5)	16 (7.6)	5 (3.0)	0.038
Reoperation due to bleeding	7 (1.8)	2 (1.0)	5 (2.9)	0.147

Values are n (%) unless otherwise indicated.

Table 3 Perioperative vascular complications after elective open surgical repair or fenestrated endovascular aneurysm repair for juxtarenal abdominal aortic aneurysms in Sweden over a 3-year interval, 2018–2021

	Overall (n = 404)	Open surgical repair (n = 228)	Fenestrated endovascular aneurysm repair (n = 176)	P
Type I/III endoleaks	NA	NA	8 (4.5)	NA
Extremity ischaemia	8 (2)	7 (3.1)	1 (0.6)	0.072
Iatrogenic vessel damage	23 (5.7)	16 (9.1)	7 (3.1)	0.009
Occlusion of revascularized branch	2 (0.5)	1 (0.5)	1 (0.5)	0.530
Graft occlusion	3 (0.8)	1 (0.5)	2 (1.2)	0.419
Graft infection	3 (0.8)	3 (1.4)	0 (0)	0.169
Major amputation	1 (0.3)	1 (0.5)	0 (0)	0.554
Distal embolism	6 (1.6)	3 (1.4)	3 (1.8)	0.645

Values are n (%) unless otherwise indicated. NA, not applicable.

A total of 60 patients (14.9%) were women (OSR 33 and fEVAR 27). Overall, sex did not influence rates of 30-day mortality (female 3.3% and male 2%; $P = 0.397$) and 90-day mortality (female 3.3% and male 2.9%; $P = 0.557$).

No significant difference in mortality rate was found when comparing the three highest-volume centres with the remaining centres for both OSR (30-day mortality rate: highest-volume centres 2.5% and remaining centres 2.7% ($P = 0.646$); 90-day mortality rate: highest-volume centres 5% and remaining centres 2.7% ($P = 0.293$)) and fEVAR (30-day mortality rate: highest-volume centres 1.4% and remaining centres 2.8% ($P = 0.501$); 90-day mortality rate: highest-volume centres 2.2% and remaining centres 2.8% ($P = 0.608$)).

Perioperative complications

Overall, the incidence of perioperative major complications was 14.1% (57 of 404), with patients treated with OSR experiencing a higher rate (19.3%) than those treated with fEVAR (7.4%) ($P < 0.001$) (Table 2). This difference was driven by higher rates of intraoperative blood loss greater than 5000 ml, prolonged ICU stay (greater than 5 days), and bowel ischaemia for OSR cases.

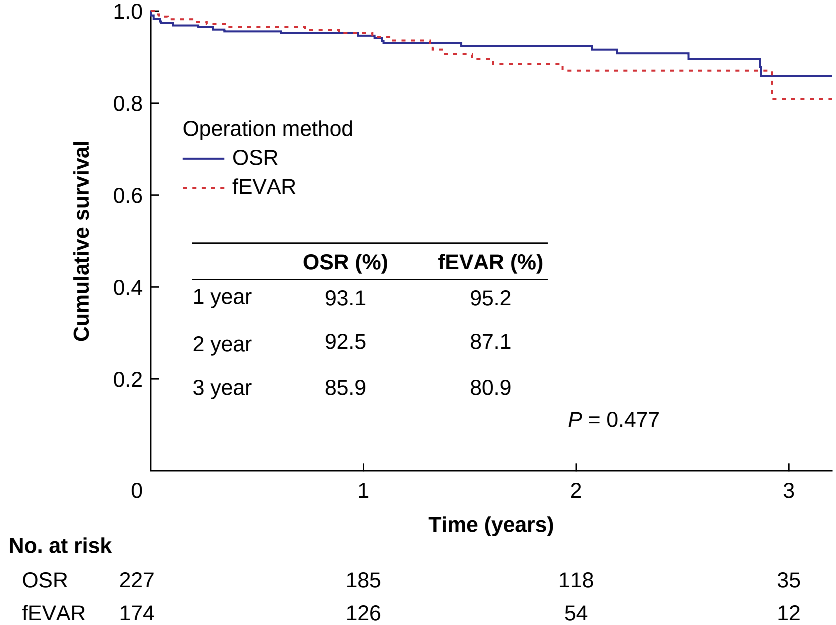


Fig. 2 Survival (estimated using Kaplan–Meier analysis) after elective open surgical repair or fenestrated endovascular aneurysm repair for juxtarenal abdominal aortic aneurysms in Sweden over a 3-year interval, 2018–2021

OSR, open surgical repair; fEVAR, fenestrated endovascular aneurysm repair.

The incidence of perioperative vascular complications was 10.1% (41 of 404), being similar for the two groups (OSR 8.8% and fEVAR = 11.9%; $P = 0.190$) (*Table 3*). A higher incidence of iatrogenic vessel injury was observed in the fEVAR group. In total, two type I and six type III endoleaks were found for fEVAR cases.

The rate of severe complications (Clavien–Dindo grade IV or above) after JRAAA repair was 12.1% overall (OSR 14.0% and fEVAR 9.7%; $P = 0.118$).

Mid-term outcomes

Overall, the median follow-up time was 393 (i.q.r. 365–427) days (OSR median of 393 (i.q.r. 371–433) days and fEVAR median of 392 (i.q.r. 359–426) days). At 1 year, the overall survival rate was 95%, with no statistically significant difference between the two treatment groups (OSR 94.7% and fEVAR 95.4%; $P = 0.475$).

The survival rate (estimated using Kaplan–Meier analysis) at 1 year, 2 years, and 3 years was 93.1%, 92.5%, and 85.9% respectively for OSR and 95.2%, 87.1%, and 80.9% respectively for fEVAR ($P = 0.477$) (*Fig. 2*).

Analysis by Cox regression identified lung disease (HR 3.04; $P = 0.001$), cerebrovascular disease (HR 2.48; $P = 0.023$) and GAS (HR 1.05; $P = 0.035$) as predictors for long-term mortality overall, whereas operative technique was not a predictor (*Table S2*).

Non-fenestrated endovascular aneuryrm repair group

After reclassification in the database, 14 endovascular cases were excluded from the main analysis (including six chimney EVAR procedures and eight bEVAR procedures). A total of seven bEVAR procedures were performed in high-volume endovascular centres and one bEVAR procedure was performed in a low-volume centre, and three chimney EVAR procedures were performed in high-volume endovascular centres and three chimney EVAR procedures were performed in low-volume centres. The mean(s.d.) GAS was 79.36(7.62) (range 67–90). One patient had a severe complication (renal replacement therapy at 30 days), that is Clavien–Dindo grade IV or above. No mortality was observed at 1 year.

Patients without history of aortic operations

Excluding 44 patients who had undergone a previous aortic operation (OSR 14 and fEVAR 30), 358 patients underwent primary repair for JRAAA (OSR 213 and fEVAR 145). The mean(s.d.) GAS was 75.20(8.05) for OSR and 78.90(7.23) for fEVAR ($P = 0.106$). Rates of 30-day, 90-day, and 1-year mortality were 2.5% (OSR 2.8% and fEVAR 2.1%; $P = 0.469$), 3.6% (OSR 3.8% and fEVAR 3.4%; $P = 0.560$), and 5.9% (OSR 5.6% and fEVAR 6.2%; $P = 0.496$) respectively. The rate of severe complications was 14.6% in the OSR group and 9.6% in the fEVAR group ($P = 0.108$).

Discussion

Historically, OSR has been considered the first-choice treatment for JRAAA. Regarding early experience, Crawford *et al.*[13] reported a 7% perioperative mortality rate after open complex aortic reconstruction. With the progressive improvement in perioperative monitoring and surgical technique, perioperative mortality rates have significantly improved. Academic institutes reported a 30-day mortality rate after OSR for JRAAA of less than 1%[14,15] and a nationwide database from the USA reported a mortality rate of 4.6%[16]. Comparative studies between open and endovascular repair for treatment of complex AAA are limited. However, three nationwide database comparison studies and three review articles reported lower early mortality and favourable overall complication rates for endovascular options[17–22]. The lack of robust evidence in this field is reflected in the latest ESVS guidelines, which recommend patient-tailored use of both open and endovascular repair for the treatment of complex AAA[1].

JRAAA should be defined as having a neck less than 4 mm from the lowermost renal artery; however, the authors believe that the Swedvasc Registry data might have included aneurysms having a neck less than 10 mm. The reclassification in the present study aims to base findings as close as possible on the correct definition of JRAAA. The authors understand that some of the JRAAA will be reclassified into other types of complex AAA due to different pathologies. Unfortunately, the authors do not have access to preoperative imaging to further confirm the findings.

The results of this national review of elective JRAAA repair performed in Sweden over 3 years reveal heterogeneous treatment preferences and patient volumes across the country. Nevertheless, overall perioperative mortality is low and comparable to the results from other national registries[17–19]. Whilst patients treated with fEVAR are significantly older and more morbid at the time of treatment, the survival at 30 and 90 days, as well as up to 3 years, after surgery is similar to that of the OSR group. This suggests that the selection of the two treatment modalities in the Swedish setting is reasonably sound. Furthermore, treatment tailored to individual patients is shown to be important and the two modalities complement, rather than compete with, each other.

Interestingly, the present analysis does not show an early survival benefit for fEVAR compared with OSR, which was an important finding of the recently published UK-COMPASS[8], a multicentre study of complex aneurysm repair in England based on the National Vascular Registry with core-lab analysis of imaging to include anatomically comparable cases. The UK-COMPASS reported a perioperative mortality rate of 7.4% in the subgroup of patients with an aneurysm neck of 0–4 mm (that is JRAAA), which is markedly higher than the 2.6% observed in the present Swedish report. In contrast, the short-term outcome after endovascular repair in the UK-COMPASS is similar to that of the present study: 30-day mortality rate of 2.2% *versus* 1.7% respectively. The similar survival rate at 3 years for both modalities in the present report mimics the results of the UK-COMPASS JRAAA subgroup of patients. However, direct comparison between the two studies is not possible, due to the presence of multiple confounders. At mid-term, the UK-COMPASS showed conflicting results regarding survival among JRAAA patients treated with fEVAR and OSR, but a lower survival rate in the endovascular group compared with OSR overall. The inclusion of bEVAR and chimney EVAR in the endovascular group does not affect mortality up to 1 year.

Age as a risk factor for postoperative complications and increased mortality has been widely studied in the literature, with a reported five-fold increase in 30-day mortality among octogenarians undergoing fEVAR due to complex AAA[23]. The favourable outcomes among octogenarians in the present study, with no fatal complications occurring during the first 90 days after surgery, might be explained by the limited number of octogenarians included in the analysis and be a result of careful patient selection when dealing with older patients.

Even though hospital volume does not affect perioperative or mid-term survival, about 70% of fEVAR procedures were performed in three centres. This observation suggests a trend toward centralization for complex endovascular repair in Sweden, even without formal protocols. On the other hand, there is a more even distribution of open surgical repair among centres.

A clear volume–outcome effect for complex aortic repair has been reported, suggesting that low-volume practice should be avoided[24]. In the present study, 15 centres performed fewer than 5 JRAAA repairs annually. Considering the overall good outcomes of JRAAA repair on a national level, it can be debated whether the low-volume practice of selected centres in the present study can be accepted or further centralization of services of complex aneurysms should be promoted.

In the present study, a higher overall major complication rate after OSR compared with fEVAR was detected and a tendency for more severe complications. In particular, patients undergoing OSR suffered massive intraoperative blood loss (that is greater than 5000 ml), bowel ischaemia, and prolonged ICU stay (greater than 5 days) more often. Notably, 5% of the patients required renal replacement therapy at 30 days after operation, with the treatment method not influencing the occurrence of this complication.

The authors believe that fEVAR is the primary choice of endovascular technique for the treatment of JRAAA. In fact, only 7.4% of endovascular cases were excluded from the main analysis due to a different technique being used (bEVAR or chimney EVAR). The subgroup analysis confirmed that this group has a similar GAS score to the fEVAR group and inclusion of these patients does not significantly affect the mortality outcomes. There are also significantly more patients in the fEVAR group who underwent a previous aortic operation. OSR is likely a less-attractive option, given a higher surgical risk of reoperation. For patients who did not undergo previous aortic repair, their survival rate is comparable between the two groups.

The present study has some important limitations. A head-on comparison between OSR and fEVAR is difficult to conduct, due to clear selection bias. In particular, fEVAR patients are older and sicker in this cohort. The retrospective character of this study should also be seen as a limitation when interpreting its results. There is a lack of information about the anatomical characteristics of treated aneurysms, as well as on the decision-making process during preoperative assessment. Reclassification of aneurysm types aimed to deal with a small number of aneurysms that were classified inappropriately, although there is also a risk of inclusion of infrarenal AAA treated with fEVAR due to hostile neck. Furthermore, data regarding re-intervention rates and centre-specific follow-up algorithms after repair were not available. The decision to exclude patients treated with chimney EVAR or bEVAR was made to be in line with current treatment recommendations[1] and to create comparable groups in terms of treatment options.

Whilst higher-level evidence on treatment of JRAAA is welcome, designing a randomized trial comparing OSR and fEVAR for JRAAA patients is difficult. The high variability in treatment choice based on patients' clinical status, aneurysm morphology, and aortic anatomy, as well as the preference of both patients and clinicians, remains a hard obstacle to overcome. Rapid technological development and disparities in socioeconomic status among different countries further complicate the performance of randomized comparisons. Realistically, high-quality real-world data among different regions is an achievable target, which in aggregate might be used for further analysis, including propensity score matching.

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Disclosure

The authors declare no conflict of interest.

Supplementary material

Supplementary material is available at *BJS* online.

Data availability

The data that support the findings of this study are available upon request from the first author.

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