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Midterm Outcomes and Aneurysm Sac Dynamics Following Fenestrated Endovascular Aneurysm Repair after Previous Endovascular Aneurysm Repair☆

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WHAT THIS PAPER ADDS

Evaluating the durability of fenestrated endovascular aneurysm repair (FEVAR) after endovascular aneurysm repair (EVAR), the results were compared with a control group, primary FEVAR. Patients with FEVAR after EVAR showed higher rates of five year aortic related procedures; however, this did not affect mortality. Furthermore, patients with FEVAR after EVAR showed significantly more aneurysm sac growth at one year (48%; $n = 21/44$) *vs.* 8% ($n = 9/110$), $p < .001$). Further studies will have to evaluate whether FEVAR is a valid intervention after failed infrarenal EVAR, and to determine the effectiveness of fenestrated cuffs or total relining.

Objective: Fenestrated endovascular aneurysm repair (FEVAR) is a feasible option for aortic repair after endovascular aneurysm repair (EVAR), due to improved peri-operative outcomes compared with open conversion. However, little is known regarding the durability of FEVAR as a treatment for failed EVAR. Since aneurysm sac evolution is an important marker for success after aneurysm repair, the aim of the study was to examine midterm outcomes and aneurysm sac dynamics of FEVAR after prior EVAR.

Methods: Patients undergoing FEVAR for complex abdominal aortic aneurysms from 2008 to 2021 at two hospitals in The Netherlands were included. Patients were categorised into primary FEVAR and FEVAR after EVAR. Outcomes included five year mortality rate, one year aneurysm sac dynamics (regression, stable, expansion), sac dynamics over time, and five year aortic related procedures. Analyses were done using Kaplan—Meier methods, multivariable Cox regression analysis, chi square tests, and linear mixed effect models.

Results: One hundred and ninety-six patients with FEVAR were identified, of whom 27% ($n = 53$) had had a prior EVAR. Patients with prior EVAR were significantly older (78 ± 6.7 years *vs.* 73 ± 5.9 years, $p < .001$). There were no significant differences in mortality rate. FEVAR after EVAR was associated with a higher risk of aortic related procedures within five years (hazard ratio [HR] 2.6; 95% confidence interval [CI] 1.1 − 6.5, $p = .037$). Sac dynamics were assessed in 154 patients with available imaging. Patients with a prior EVAR showed lower rates of sac regression and higher rates of sac expansion at one year compared with primary FEVAR (sac expansion 48%, $n = 21/44$, *vs.* 8%, $n = 9/110$, $p < .001$). Sac dynamics over time showed similar results, sac growth for FEVAR after EVAR, and sac shrinkage for primary FEVAR ($p < .001$).

Conclusion: There were high rates of sac expansion and a need for more secondary procedures in FEVAR after EVAR than primary FEVAR patients, although this did not affect midterm survival. Future studies will have to assess whether FEVAR after EVAR is a valid intervention, and the underlying process that drives aneurysm sac growth following successful FEVAR after EVAR.

Keywords: Failed endovascular aneurysm repair, Failure to rescue, Fenestrated endovascular aneurysm repair, Five year aortic related procedures, Sac dynamics

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INTRODUCTION

In the last decade, endovascular aneurysm repair (EVAR) has become the preferred treatment for infrarenal abdominal aortic aneurysms (AAAs). Nevertheless, high rates of re-intervention after EVAR remains a concern.[1,2] Failure of sealing due to progression of disease causes the most complications over time and can result in type 1 endoleaks and rupture.[3,4] For that reason, an intervention to treat inadequate sealing is highly recommended. Fenestrated endovascular aneurysm repair (FEVAR) allows extension of the proximal sealing zone towards the visceral aortic segment, while maintaining blood flow to the mesenteric and renal arteries.[5,6] Additionally, FEVAR has been used to treat inadequate sealing after EVAR, due to better peri-operative outcomes and lower mortality rates compared with open repair and conversion.[7–13]

In the literature, low peri-operative morbidity and mortality rates are reported for FEVAR as salvage treatment for prior EVAR, despite the technical challenges of implantation due to the previous endograft.[12,14] Moreover, low rates of midterm aneurysm related mortality are described.[8,15–17] Still, there is a paucity of evidence for the durability of FEVAR as a re-intervention method.

This study set out to investigate the durability of FEVAR after prior EVAR. The aim was to explore midterm outcomes and aneurysm sac dynamics of FEVAR after prior EVAR compared with primary FEVAR.

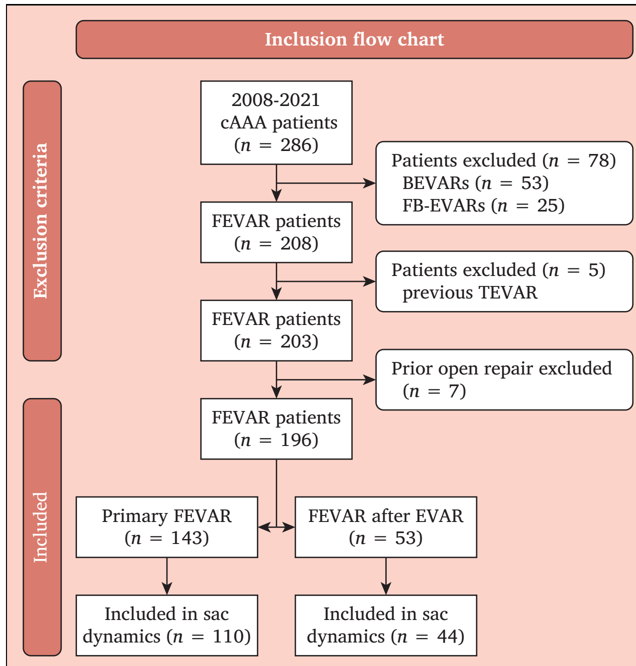


Figure 1. Inclusion flow chart for patients undergoing fenestrated endovascular aneurysm repair (FEVAR) and FEVAR after prior endovascular aneurysm repair (EVAR). cAAA = complex abdominal aortic aneurysms; BEVAR = branched endovascular aneurysm repair; TEVAR = thoracic endovascular aneurysm repair.

MATERIALS AND METHODS

Design and population

All consecutive patients undergoing FEVAR between 2008 and 2021 at two large hospitals in The Netherlands (Erasmus University Medical Centre, Rotterdam, and Maasstad Hospital Rotterdam) were included in this retrospective cohort study. Exclusion criteria were patients with a history of previous thoracic endovascular aortic repair (TEVAR) or open AAA repair (Fig. 1). The study complied with the Declaration of Helsinki in research ethics and was approved by the institutional and ethical review board of both hospitals.[18]

Data collection and definitions

To determine outcomes of patients with a FEVAR after a previous EVAR, a reference group consisting of patients who underwent primary FEVAR was used. The two groups were assessed independently. Scallops were not included as fenestrations. Patient demographics, comorbidities medication, and aneurysm related death were reported according to the Society for Vascular Surgery reporting standards for complex abdominal aortic aneurysm repair.[19] The maximum peri-operative aneurysm diameter was determined using computed tomography angiography (CTA) within 30 days of the surgery. For aneurysm sac dynamics, patients were required to have both a 30 day and one year CTA (to allow a grace period, the CT image between six and 18 months was used). One year CTAs were compared with 30 day CTAs for one year aneurysm sac dynamics, defined as: sac regression $\geq$ 5% volume decrease; stable sac $<$ 5% volume change; sac expansion $\geq$ 5% volume increase. For the aneurysm sac dynamics over time, all available follow up CTA of the patients were used. All aneurysm sac measurements were obtained using image processing software (3-mensio Medical Imaging, Bilthoven, The Netherlands). The group has previously validated a study on aneurysm volumes for both intra-and interobserver variability in infrarenal AAA.[20] The measurement protocol was made depending on the anatomical variants of complex aneurysmal aortic disease to maximise detection of proportional aneurysm sac volume change over time. The study included complex abdominal aortic aneurysms. The volumes were measured between 10 mm proximal to the upper renal artery to 10 mm proximal to the aortic bifurcation.[21] The outcome five year aortic related procedures, included use of proximal cuff, limb extension, iliac percutaneous transluminal angioplasty, conversion to aorto-uni-iliac configuration, coiling, glueing, embolisation, endoleak treatment, open or laparoscopic ligation of collateral and other surgical intervention. Finally, the type of treatment for patients with prior EVAR was categorised as either total relining (fenestrated cuff and bifurcated graft), or proximal fenestrated cuff alone. All were custom made devices.

Study endpoints

The primary outcome was the five year mortality rate. Secondary outcomes included five year aortic related procedures, one year aneurysm sac dynamics, and sac dynamics over time.

Statistical analysis

Categorical variables were presented as number (%) and were compared using Pearson's χ^2 test or Fisher's exact test. Continuous variables were tested for normal distribution using Q-Q plots, histograms, and Shapiro—Wilk test and presented as mean ± standard deviation (SD) if normally distributed. If not normally distributed, they were presented as median (interquartile range [IQR]). *T* tests and Mann—Whitney U tests were used to test continuous variables based on whether parametric or non-parametric.

For five year mortality rate and five year aortic related procedures, multivariable Cox regression analyses and Kaplan—Meier were used. Furthermore, age, sex, and supracoeliac sealing zone were adjusted for. To investigate the aneurysm sac volume over time, two longitudinal mixed effects models were made for primary FEVAR and FEVAR after EVAR. In these models, time was entered as the independent variable and aneurysm volume as the dependent variable, assuming random intercepts and slopes to allow individual variation per patient (fixed: time + [$time^2$]; random: ∼time). To compare the time sensitivity of the models, the models were run with and without different polynomial terms for time and the difference in likelihood ratios calculated.[22] To adjust for peri-operative aneurysm diameter in one year sac dynamics, logistic regression was used. Confidence intervals (CIs) of 95% were used, and statistical significance was defined as $p < .050$.

All statistical analyses were performed using RStudio (version 4.2.2. Foundation for Statistical Computing, Institute for Statistics and Mathematics, Vienna, Austria).

RESULTS

Patient characteristics

One hundred and ninety-six patients treated with FEVAR between 2008 and 2021 were included, with a median follow up time of 27 months (IQR 12, 54). Fifty-three patients had had a prior EVAR in their medical history (27%) (female, 15%, $n = 8/5$, and 143 patients underwent primary FEVAR (73%) (female, 20%, $n = 28/143$) (Table 1). Indications for FEVAR after EVAR were type 1a endoleaks, accounting for 80% of the cases, while 20% had dilatation of the infrarenal aorta with virtually no proximal seal left. The median follow up was 27 months (IQR 13, 55) for the primary FEVAR group and 26 months (IQR 10, 54) for the FEVAR after EVAR group. Patients in the prior EVAR group were significantly older (78 ± 5.9 *vs.* 73 ± 6.7, $p < .001$). The proportion of current smokers was lower in the FEVAR after prior EVAR group compared with the primary FEVAR group (11%, $n = 6/53$, *vs.* 35%, $n = 50/143$, $p = .002$). In the FEVAR after prior EVAR group, most patients were treated with four fenestrations (47%, $n = 25/53$), followed by three fenestrations (42%, $n = 22/53$), and two fenestrations (11%, $n = 6/53$). In the primary FEVAR group, most patients were treated with three fenestrations (45%, $n = 65/143$), followed by four fenestrations (34%, $n = 48/143$), two fenestrations (17%, $n = 24/143$), one fenestration (4%, $n = 5/143$), and five fenestrations (1% $n = 1/143$). However, none of these differences in the number of fenestrations was found to be statistically significant. In the FEVAR after EVAR group, 36 patients underwent complete relining, while 17 patients received only a proximal cuff. Finally, the maximum peri-operative aneurysm diameter was significantly larger in the FEVAR after prior EVAR group compared with the primary FEVAR group (67 ± 10 mm *vs.* 62 ± 10 mm, $p = .003$). The median duration after failed EVAR to FEVAR intervention was 70 months (IQR 47, 98). Further

Table 1. Baseline clinical, anatomical, and device related variables for primary fenestrated endovascular aneurysm repair (FEVAR) and FEVAR after prior endovascular aneurysm repair (EVAR)

Characteristic	Primary FEVAR ($n = 143$)	Prior EVAR ($n = 53$)	*p* value
Age, at surgery – y	73 ± 6.7	78 ± 5.9	<.001
Sex, female	28 (20)	8 (15)	.61
Cardiovascular risk factors			
Hypertension	112 (78)	47 (89)	.30
DM	20 (14)	10 (19)	.54
Current smoking	50 (35)	6 (11)	.002
PAOD	53 (37)	20 (38)	1.0
Myocardial infarct	43 (30)	18 (34)	.82
COPD	48 (34)	14 (26)	.42
*Pre-operative eGFR**			.088
eGFR > 60 mL/min/1.73 m^2	91 (64)	32 (60)	
eGFR 30–60 mL/min/1.73 m^2	46 (32)	16 (30)	
eGFR < 30 mL/min/1.73 m^2	2 (1.4)	4 (7.5)	
ASA III or IV	87 (61)	43 (81)	.012
Medication			
Beta blockers	73 (51)	31 (58)	.53
Statins	117 (82)	46 (87)	.67
Antiplatelets	101 (71)	38 (72)	1.0
Anticoagulants	25 (17)	14 (26)	.25
Antihypertensives	103 (72)	42 (79)	.58
Device			.042
Cook	128 (90)	40 (75)	
Anaconda	12 (8.4)	11 (21)	
Other	3 (2.1)	2 (3.8)	
No. of fenestrations			.76
1	5 (3.5)	0 (0)	
2	24 (17)	6 (11)	
3	65 (45)	22 (42)	
4	48 (34)	25 (47)	
5	1 (0.7)	0 (0)	
Sealing zone			.22
Supracoeliac	68 (48)	38 (72)	
Infracoeliac	75 (52)	15 (28)	
Aneurysm type			.55
TAAA IV	8 (5.6)	1 (1.9)	
Supra- or pararenal	8 (5.6)	3 (5.7)	
Juxtarenal	127 (89)	49 (92)	
Maximum peri-operative aneurysm diameter – mm	62 ± 10	67 ± 10	.003

Data are presented as *n* (%) or mean ± SD. Due to rounding numbers may not add up. SD = standard deviation; DM = diabetes mellitus; PAOD = peripheral arterial occlusive disease; COPD = chronic obstructive pulmonary disease; eGFR = estimated glomerular filtration rate; ASA = American Society of Anesthesiologists; TAAA = thoraco-abdominal aortic aneurysm.
* Pre-operative eGFR if available.

Table 2. Specification of graft related events and one year sac dynamics following primary fenestrated endovascular aneurysm repair (FEVAR) and FEVAR after prior endovascular aneurysm repair (EVAR)

Characteristic	Primary FEVAR (n = 143)	FEVAR after EVAR (n =53)
Median follow up – mo	27 (13, 55)	26 (10, 54)
Peri-operative death	5 (3.5)	0
Aneurysm related death	6 (4.2)	0
Graft related events, no. of patients	25 (18)	13 (25)
Proximal graft related events	4 (2.8)	2 (3.8)
Type 1a endoleaks	2 (1.4)	2 (3.8)
Migration	0	0
Proximal cuff	2 (1.4)	0
Bridging stent related events	22 (15)	15 (28)
Type 3a endoleaks	8 (5.6)	7 (13)
Visceral PTA	3 (2.1)	4 (7.5)
Visceral occlusion	4 (2.8)	2 (3.8)
Visceral re-stenting	7 (4.9)	2 (3.8)
Distal graft related events	4 (2.8)	5 (9.4)
Type 1b endoleaks	1 (0.7)	1 (1.9)
Distal extension	3 (2.1)	4 (7.5)
Type 2 endoleaks	20 (14)	10 (19)
Conservative management	16 (11)	9 (17)
Coiling, gluing, or embolisation	4 (2.8)	0
Open or laparoscopic ligation of collaterals	0	1 (1.9)
*One year sac dynamics**,†		
Sac regression, ≥ 5% volume decrease	85 (77)	10 (23)
Stable sac, < 5% volume change	16 (15)	13 (29)
Sac expansion, ≥ 5% volume increase	9 (8.2)	21 (48)

Data are presented as n (%) or median (interquartile range). Due to rounding, numbers may not add up. Patients included for aneurysm sac dynamics were required to have 30 day CTA and one year CTA included. PTA = percutaneous transluminal angioplasty.
* $p \leq .001$.
† Primary FEVAR (n = 110); FEVAR after EVAR (n = 44).

demographic information, comorbidities, medication, and anatomic characteristics are reported in Table 1.

Peri-operative mortality

There were no peri-operative deaths in the FEVAR after EVAR group. However, five patients in the primary FEVAR group died within 30 days after surgery ($p = .48$) (Table 2).

Five year mortality rate

After risk adjusted analysis there were no significant differences in the five year mortality rate between groups (hazard ratio [HR] 0.7, 95% CI 0.3 – 1.5, $p = .33$) (Fig. 2).

One year aneurysm sac dynamics

One year sac regression, expansion, and stability data are presented in Table 2. The analysis included 78% (n = 154/196) of all the patients. Patients who underwent prior EVAR had a considerably lower rate of sac regression at one year compared with those who had primary FEVAR (23%, n = 10/44, *vs.* 77%, n = 85/110, $p < .001$). In fact, the prior EVAR group showed higher rates of sac expansion than the primary FEVAR group (48%, n = 21/44, *vs.* 8%, n = 9/110, $p < .001$). After adjusting for peri-operative aneurysm diameter, patients with prior EVAR had a significantly lower odds of sac regression, with an odds ratio of 0.01 (95% CI 0.1 – 0.3, $p < .001$). In Supplementary Table S1, an overview of patients who underwent FEVAR after EVAR shows that those who received total relining and those who received only a proximal fenestrated cuff, had similar sac expansion results after one year, which were not statistically significant (48%, n = 14/29, *vs.* 47%, n = 7/15, $p = .89$).

Five year aortic related procedures

After risk adjusted analysis, prior EVAR was associated with a higher risk of needing aortic related procedures within five years (HR 2.6; 95% CI 1.1 – 6.5, $p = .037$) (Fig. 3). For FEVAR after prior EVAR and primary FEVAR, most five year aortic related procedures were related to bridging stent events (28%, n = 15/53, and 15%, n = 22/143) and type 2 endoleaks (19%, n = 10/53, and 14%, n = 20/143). More details on graft related complications and procedures are listed in Table 2.

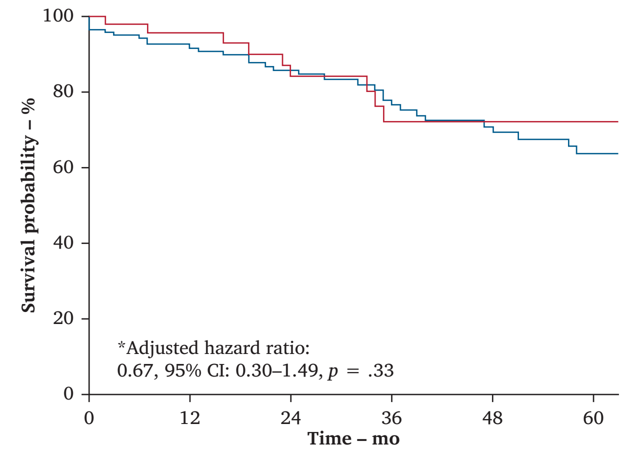
Aneurysm sac dynamics over time

In Figure 4, the longitudinal mixed effect models show aneurysm sac volumes since FEVAR as function of time (in months), for both the FEVAR after EVAR group and the primary FEVAR group. The model demonstrates that FEVAR after EVAR was associated with an increased aneurysm sac volume over time, where primary FEVAR was associated with a decreased aneurysm sac volume ($p < .001$). The occurrence of endoleaks did not differ significantly between groups. Details are shown in Table 2.

DISCUSSION

The aim of the present study was to examine the durability of FEVAR as rescue treatment for failed EVAR. The risk of five year mortality was similar between the two groups (HR 0.7; 95% CI 0.3 – 1.5, $p = .33$). Furthermore, FEVAR after EVAR had lower rates of sac regression at one year compared with primary FEVAR (23%, n = 10/44, *vs.* 77%, n = 85/110) and higher rates of sac expansion (48%, n = 21/44, *vs.* 8%, n = 9/110). The same trend was observed in the linear mixed effect models, where patients treated with FEVAR after prior EVAR showed an increase in aneurysm sac volume over time, and patients treated with primary FEVAR showed a decrease in aneurysm sac volume over time. Finally, FEVAR after EVAR was associated with a higher risk of aortic related procedures after five years (HR 2.6; 95% CI 1.1 – 6.5, $p = .037$).

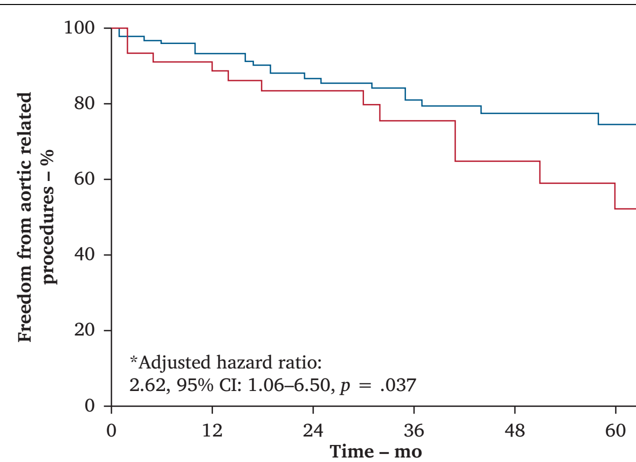
The five year mortality rates were comparable between patients who underwent FEVAR after EVAR and those who underwent primary FEVAR. It is worth noting that the age at



No. at risk						
Primary FEVAR	143	108	78	56	45	33
Kaplan–Meier estimate survival rates – %	100	91.7	85.7	76.6	69.2	63.6
Standard error – %	0	2.4	3.3	4.4	5.1	5.6
Prior EVAR	53	39	28	18	14	13
Kaplan–Meier estimate survival rates – %	100	95.6	84.0	72.2	72.2	72.2
Standard error – %	0	3.1	6.1	8.2	8.2	8.2

Figure 2. Cumulative Kaplan–Meier estimate of five year mortality rate following primary fenestrated endovascular aneurysm repair (FEVAR) and FEVAR after prior endovascular aneurysm repair (EVAR). CI = confidence interval. *Adjusted for prior EVAR *vs.* primary FEVAR, sex (male/female), age at surgery, and supracoeliac sealing *vs.* infracoeliac sealing zone.

surgery was corrected for, as patients with prior EVAR were approximately five years older than patients with primary EVAR. These results are surprising because patients with FEVAR after EVAR showed higher rates of aortic related procedures. Thus, it appears that in the study, aortic related procedures over a five year period do not necessarily have an impact on survival. This finding is consistent with the study of Zettervall and colleagues, in which patients who



No. at risk						
Primary FEVAR	143	103	71	50	38	25
Kaplan–Meier estimate re-intervention rates – %	100	93.4	86.9	81.1	77.5	74.6
Standard error – %	0	2.3	3.3	4.2	4.7	5.3
Prior EVAR	53	37	25	15	11	9
Kaplan–Meier estimate re-intervention rates – %	100	88.9	83.6	75.6	64.8	52.4
Standard error – %	0	4.7	5.7	7.2	9.5	11.0

Figure 3. Cumulative Kaplan–Meier estimate of five year secondary aortic related procedures for primary fenestrated endovascular aneurysm repair (FEVAR) and FEVAR after prior endovascular aneurysm repair (EVAR). *Adjusted for prior EVAR *vs.* primary FEVAR, sex (male/female), age at surgery, and supracoeliac sealing zone *vs.* infracoeliac sealing zone.

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underwent aortic related procedures following FB-EVAR showed improved long term survival.[23] It is likely that patients who underwent aortic related procedures have a lower mortality rate because the interventions are performed in response to certain complications (e.g., endoleaks, stent migration), which can lead to a higher mortality rate if left untreated.

In the literature, low rates of peri-operative mortality were reported for FEVAR after prior EVAR.[12,14] In the study, there were no peri-operative deaths in the FEVAR after EVAR group. However, five patients with primary FEVAR died within 30 days after surgery. It is relevant to highlight that the study included patients treated from 2008 to 2021, and the peri-operative death cases occurred in the earlier years when FEVAR was a novel procedure in the hospitals. Operator experience could be a contributing factor to the higher peri-operative mortality rates observed in the primary FEVAR group and potentially conceal survival differences compared with FEVAR after EVAR.

Patients treated with FEVAR after EVAR showed significantly less sac regression after one year, and higher rates of sac expansion compared with primary FEVAR. To account for the potential confounding effect of peri-operative aneurysm diameter, which was larger in patients with prior EVAR, it was included as a covariable in the logistic regression model, as larger aneurysm sacs could have a lower rate of sac regression at one year. Despite this adjustment, the results remained significant. One year sac dynamics were stratified for patients who had undergone FEVAR after EVAR using two different techniques: total relining and the use of a fenestrated proximal cuff only. The findings indicate that total relining was associated with similar rates of sac expansion compared with the fenestrated cuff, moreover the differences were not statistically significant. Conceptually, it seems to make more sense to advocate total relining in patients with failed EVAR as other, usually undetectable, potential causes for sac growth like graft porosity, graft sweating or small stich holes bleeding are treated simultaneously. However, the data do not prove this hypothesis. There is a lack of literature on the durability of either total relining or fenestrated cuffs, and the results indicate the need for more research on this topic.

Similar to the one year sac dynamics, an increase in aneurysm sac volume over time in patients treated with FEVAR after EVAR was found. Recent evidence has shown that after EVAR, not only sac expansion but any failure of the sac to regress is associated with a higher long term mortality rate and higher long term re-intervention risk.[24,25] A more recent study has suggested that non-regression at one year imaging is associated with a higher five year all cause mortality risk and graft related events after FB-EVAR.[21] For that reason, it may be assumed that FEVAR after EVAR is a less durable treatment. Nonetheless, the limited literature on aneurysm sac regression after FEVAR for complex abdominal aortic aneurysms emphasises the significance of the findings. In low risk patients, explantation of the graft can be considered; however, this is associated with a higher mortality rate in older high risk patients.[16] Therefore, such patients might benefit from relining with FEVAR. Whether this holds true in longer term follow up remains to be elucidated, especially given that half of the aneurysm sacs keep growing.

It is important to mention that failure of the aneurysm sac to regress in the prior EVAR group could be attributed to the presence of type 2 endoleaks (19%, $n = 10/53$). It is unlikely to be the sole reason, as their presence was not more common than in the primary FEVAR group, nor is it known why patients with prior EVAR would develop more frequent or severe type 2 endoleaks compared with patients with primary FEVAR. Primary FEVAR treatment, however, is showing good results and high rates of aneurysm sac regression both after one year and over time despite presence of type 2 endoleaks in 14% ($n = 20/143$) of the patients, indicating successful aneurysm sac exclusion. Furthermore, treating type 2 endoleaks to stop aneurysm sac growth after EVAR has been shown to be highly ineffective with 93% of patients showing continuing sac growth after so called successful treatment.[26] Ultimately, there may be other underlying reasons for non-sac regression after infrarenal EVAR, such as unknown familial or genetically triggered aneurysm disease or unknown

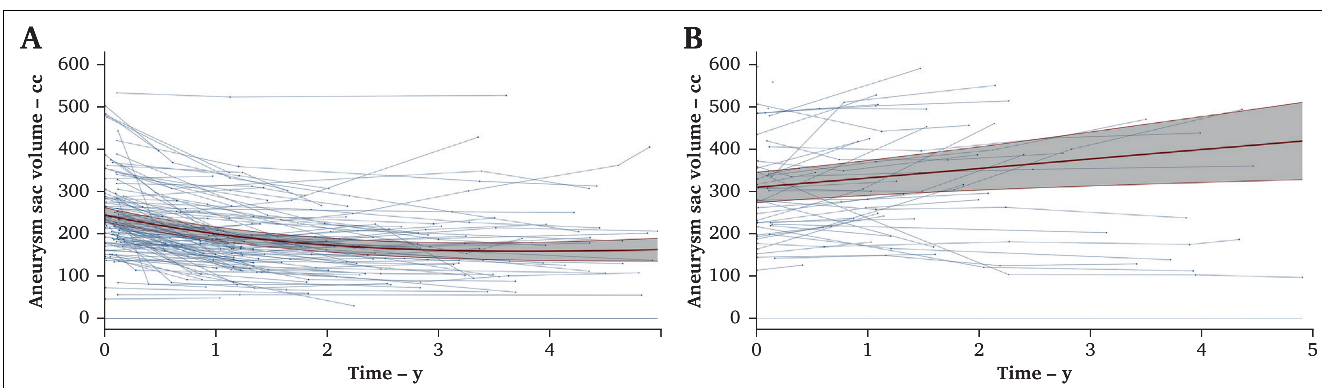

Figure 4. Linear mixed effects models for aneurysm sac dynamics following (A) primary fenestrated endovascular aneurysm repair (FEVAR) and (B) FEVAR after prior endovascular aneurysm repair (EVAR). $p < .001$ between panels A and B.

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biological processes, which is an important subject for further research.

In addition, there was a higher risk of five year aortic related procedures for patients treated for FEVAR after prior EVAR. This is in line with the results of Hostalrich *et al.* and Martin *et al.* where respectively 33% and 37% of patients treated by fenestrated and branched endovascular aneurysm repair (FB-EVAR) for a failed EVAR required secondary aortic related re-interventions.[10,27] The five year aortic related procedures in the study were mostly related to bridging stent events and type 2 endoleaks. Specifically, the occurrence of type 3a endoleaks was more prevalent in patients with FEVAR after EVAR. Potentially this is because of the placement of proximal cuffs in these patients, as it can be hypothesised that the stent graft did not completely conform to the previous EVAR in the distal region, leading to blood flow between the two components. As mentioned above, further studies are needed to evaluate the durability of proximal cuffs and total relining. Conversely, Hostalrich and colleagues reported predominantly stent related events and distal graft related secondary procedures.[10] A study by Schanzer and colleagues showed that after one year, patients who underwent FB-EVAR after previous EVAR, had slightly lower freedom from re-intervention compared with those who had primary FB-EVAR (83% *vs.* 87%; $p = .09$) even though the technical success rates were similar.[11] Given the prolonged follow up period, it is plausible that re-interventions for prior EVAR patients may occur later during the follow up. Patients who had prior EVAR may have comorbidities or other risk factors that increase the likelihood of complications and re-interventions. A clinical implication could be to conduct more thorough monitoring of patients with failed EVAR during follow up to prevent the need for re-intervention. The low rates of type 1a endoleak indicate that FEVAR after EVAR patients experience sac growth along with satisfactory sealing. Future research will be conducted to investigate the long term outcomes and durability within this study population.

The decision to perform direct FEVAR for infrarenal aneurysms as a more durable treatment is a topic of discussion, as sac regression after infrarenal EVAR occurs in only 50%.[24] FEVAR could probably be suggested for patients who have a marginal proximal sealing zone and a large aneurysm diameter. Although EVAR would be a feasible option in these cases, there is a higher chance of failure over time.[28,29] Performing FEVAR after failed EVAR can be technically challenging, which may be another reason to treat patients with FEVAR directly. However, immediate FEVAR treatment for infrarenal aneurysms does come with potential disadvantages, including technical complexity, higher costs, and longer procedure times leading to increased radiation exposure, and logistical problems. The decision of whether to use FEVAR or EVAR should be evaluated on an individual basis.

The study has certain limitations that should be considered. First, its retrospective nature and the fact that the study only included patients with at least one year of CTA follow up for aneurysm sac dynamics, may potentially result in selection bias as patients with an early death were not captured. When interpreting the results, it is important to consider that there was a grace period of 6 – 18 months for the one year CTA scan. Another aspect related to selection bias pertains to the comparison between patients who underwent FEVAR for failed EVAR and those who had primary FEVAR, as there were probably underlying factors in the prior EVAR group that led to adverse outcomes, e.g., type 3 endoleaks (stich hole bleedings) or type 1 endoleaks (either static or dynamic) not visible as endoleaks on CTA imaging. On average, patients in the FEVAR after EVAR group were five years older and had similar survival outcomes, indicating a strict selection among these patients. However, this suggests a potential selection bias, although it also reflects a real life cohort of patients.

Given that both hospitals involved in this study functioned as referral centres, limitations in accessing original pre-EVAR anatomical data for many patients were encountered. Additionally, the relatively small sample size, especially in the FEVAR after EVAR group, may have resulted in type 2 errors within the study.

Conclusion

Despite successful proximal extension and relining, FEVAR after EVAR patients had higher rates of aneurysm sac expansion and needed more secondary procedures than primary FEVAR patients. However, this did not seem to affect five year survival. Future studies will have to assess whether FEVAR after EVAR is a durable intervention following failed infrarenal EVAR, and if a fenestrated cuff needs to be completed with total relining of the EVAR graft. Furthermore, the underlying process that drives aneurysm sac growth following FEVAR after EVAR needs further clarification.

CONFLICTS OF INTEREST

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APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejvs.2024.01.070.

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