**PREDICTING FEATURES OF VISCERAL STENTS FAILURE IN FENESTRATED ENDOVASCULAR AORTIC ANEURYSM REPAIR**

**PURPOSE
Visceral stents in Fenestrated Endovascular Aortic Repair (FEVAR) have a significant risk of complications and carry a considerable burden of reinterventions. The aim of this study is to identify pre and intra-operative predictors of visceral stent failure.

MATERIALS
A retrospective review of 75 consecutive FEVARs in a single center from 2013 – 2021 was undertaken. Mortality, stent failure and reintervention pertaining to 226 visceral stents were collected.**

**METHODS**

**Anatomical features including aortic neck angulation, aneurysm diameter and angulation of target viscerals were obtained from pre-operative CT scans. Stent oversizing and intraprocedural complications were recorded. Post-operative CT scans were analyzed to determine length of cover of target vessels.

RESULTS
Only bridging stents through fenestrations to visceral vessels were considered; 28 (37%) cases had 4 visceral stents, 24 (32%) had 3, 19 (25%) had 2, 4 (5%) had 1. 30-day mortality was 8%, a third of which was related to visceral stent complications. Intraprocedural complexity was documented during the cannulation of 8 (3.5%) target vessels with a technical success rate of 98.7%.**

**Post-operatively a significant endoleak or visceral stent failure was identified in 22 stents (9.8%), of which 7 (3%) had in-patient re-intervention within 30 days. Further reinterventions at 1, 2 and 3 years were 12 (5.4%), 2 (1%) and 1 (0.4%) respectively. The majority of re-interventions were for renal stents (n=19, 86%).**

**Smaller stent diameter as well as shorter length of visceral stent were significant predictors of failure. No other anatomical feature or stent choice was found to be a significant predictor of failure.**

**CONCLUSIONS
The modality of visceral stent failures varies, but renal stents with smaller diameter and/or shorter length are more likely to fail over time. Their complications and reinterventions are common and carry a significant burden, therefore, close surveillance must be continued long term.

Keywords: Abdominal Aortic Aneurysm, Fenestrated Stent-Graft, Balloon-expandable stents, Fenestration, Juxtarenal Aneurysm, Reintervention, Stent-graft, Endoleak, Stent thrombosis, Target artery/vessel/branch**

# **Introduction**

The challenge of complex abdominal aortic aneurysm (AAA) unsuitable for conventional endovascular aortic repair (EVAR) found a resolution after the introduction in 1999 of fenestrated endovascular aneurysm repairs (FEVAR)1. By extending the proximal sealing zone from the infrarenal to the supra-renal aorta, FEVARs are able to overcome the lack of adequate sealing zone in the infrarenal aorta whilst maintaining antegrade perfusion of the visceral vessels with the placement of bridging stents through the fenestrations.

For the treatment of juxta and suprarenal aneurysms, the effectiveness of FEVAR is comparable to open AAA repair with particular regards to high risk-patients unfit for open repair2. The main disadvantage affecting the outcome of FEVARs is the higher rate of reinterventions mainly due to the failure of visceral stents3. Adequate placement of visceral stents is key to achieve aortic aneurysm sealing, but their failure can cause significant complications. Visceral stent thrombosis can lead to acute bowel ischemia or kidney infarction and their failure or malposition can compromise aneurysm sealing with an endoleak4.
Fractures, dislodgments, stenosis and occlusions, generally defined as “stent failure” or “stent instability” are the typical presentations of bridging stent complications. In accordance with these clinical findings, Oderich et al.5 reported a new classification of endoleaks for these procedures.
Although FEVAR was originally designed to facilitate proximal sealing being limited to fenestrations just for the renal arteries, there has been a paradigm shift towards planning 4 fenestrations for renal arteries, superior mesenteric artery (SMA) and coeliac artery (CA). Landing the main stent graft higher in a healthier and smaller aorta has reduced the incidence of type Ia endoleak, but has introduced more complexity and a higher incidence of complications related to viscerals stenting8.
The GLOBALSTAR registry highlighted visceral stent reintervention rates of 7% at 30 days and 30% at 3 years after FEVAR6. A systematic review of 2,796 patients identified reintervention rates following FEVAR and Branched-EVAR (BEVAR) of 12% a 1 year, rising to 31% at 3 years7.
The aim of this study is to identify anatomical and pre-operative features as well as visceral stent characteristics that can predispose to visceral stent failure.

# **Methods**

This is a retrospective review of 75 consecutive patients who underwent FEVAR in a single center between January 2013 and December 2021.

## *Inclusion and exclusion criteria*

All patients who underwent FEVAR from 1 to 4 fenestrations were included in the study. Patients who underwent previous or simultaneous endovascular or open procedures were also included in the series.

For the detailed analysis of visceral stents, only stents between fenestration and visceral vessels were considered, stents placed to stabilize FEVAR scallops were excluded from the analysis.
Any other complex repair such as BEVAR and Chimney EVAR were also excluded.

## *Unit Patient management*

All patients with juxtarenal AAA with a diameter above 55mm were discussed at multidisciplinary team (MDT) meetings to explore the best treatment option.

Following MDT patients were reviewed in the vascular and anesthetic clinics to assess fitness for surgery.
All main custom-made devices (CMD) used in our cohort were tailored AnacondaTM FEVAR stents from Terumo Aortic (Vascutek Ltd., Renfrewshire, UK). This is a repositionable graft with combined hooks and ring stents for proximal sealing and fixation. Pre-operative CT angiograms were shared with the manufacturer to shape the CMD and its fenestrations following their dedicated instruction for use (IFU). To accommodate the visceral vessels anatomy, the configuration of the fenestrations follows standard measurements to meet minimum distances and diameters provided by the manufacturer in the IFU.

The number and configuration of the fenestrations were agreed between surgeons, interventional radiologists and manufacturer according with the length of sealing neck needed. Each device was supplied with a plastic 3D model used to practice under fluoroscopy to confirm procedure feasibility and possible challenges represented by difficult angulations, with device modifications made following practice deployment when necessary.
Urgent cases were provided with an expedited CMD delivery in 3 to 6 weeks, as opposed to the standard 8 weeks. This was decided on a case by case basis after discussion with the manufacturer.

A combination of Atrium (Getinge, Goteborg, Sweden), BeGraft and BeGraft+ (Bentley InnoMed, Hechingen, Germany) and LifeStream (Becton, Dickinson and Company – BD, Franklin Lakes, NJ, USA) stents were used.
Standardised flaring with 12mm balloon for all Atriums, 7 and 8mm Bentleys, while smaller 5 and 6 mm Bentleys a 10 mm balloon was used.
Cases were performed in a hybrid theatre with open surgical access to common femoral arteries (CFA) and the axillary artery, either left or right according to patient anatomy and theatre set-up.
All fenestrations and visceral vessels were sequentially cannulated “from the top” via open axillary artery puncture with progressive deployment of CMD. This is an institutional decision to facilitate the stenting of target vessels with steep angulations. Cannulating the CA and SMA first, prior to fully unsheath the CMD, also allows to easily correct any rotation without the risk of twisting the graft. It is also possible to deploy the iliac limbs and close CFA arteriotomies while completing visceral vessels stenting to minimize lower limbs and spinal cord ischaemia.

Post-operatively patients spent at least one night in a High Dependency Unit (HDU) for intensive monitoring and observations. Post-procedure every patient was ensured to be on single antiplatelet and statin if no contraindications. If operative or post-operative concerns, an inpatient Computer Tomography Angiography (CTA) was arranged prior to discharge. As part of the follow-up protocol, CTAs were arranged at 1 month, 6 months, and 12 months and then yearly.

## *Data Collection*

## Data Collection

Patient notes, investigations, operation notes, critical care notes, out-patient clinic notes, imaging reports and CT scan imaging were reviewed with data extracted onto a standardized template.

A standard protocol to review pre and post operative imaging was agreed between 3 independent physicians: an interventional radiology consultant, a vascular surgeon and a trainee vascular surgeon.

SYNAPSE PACS software was used to obtain 3D reconstructions.
All the collected anatomical, clinical and peri-operative data are listed in Table 1.

Long term follow-up data were collected from clinic letters, CT imaging and re-interventions.

Death rate and cause of death were also investigated. Follow-up was considered to be any CTA focused on FEVAR surveillance. Patients were considered alive to the date of last hospital encounter.

## Data review, endpoints and analysis

The primary endpoint was development of any visceral stent failure (described as occlusion, fracture, kink, visceral type Ic and type III endoleaks), including related re-intervention and mortality.

All the above mentioned imaging characteristics were collected from all visceral stent placements to compare features of complication and reintervention vs successful placements.

Patients were censored at the point of last data collection (1st July 2022) and considered alive at the time of their last hospital encounter. Date of deaths were collected from community electronic records.

# **Statistical analysis**

Comparisons were made between successful procedures and reinterventions. To avoid the assumption that our data followed normal distributions, the Mann-Whitney U test was used to compare all the numerical variables and the deduced z-scores were applied to acquire *p* values.
Due to the absence of values for some nominal variables (stent type and vessel directions) in the re-intervention group, comparisons were simplified to 2 x 2 contingency tables and compared using a chi-square calculator to find *p* values (atrium stents against other stents and downwards target vessel angulation against other angulations).

# **Results**

## *Patient cohort and overall mortality*

75 patients underwent FEVAR. 69 (92%) were male and the median age at time of procedure was 76.2 (Q1, Q3: 72, 81). Most patients presented with at least one cardiovascular risk factor (Table 1).
A symptomatic aneurysm was present in 5 (6,6%) urgent cases: 3 tender aneurysms, 1 contained ruptures and 1 aorto-enteric fistula following previous open AAA.

FEVAR was used as a proximal cuff for 6 (8%) cases with type 1a Endoleaks of previous EVAR. For 2 (2.6%) cases FEVAR was used to address complications post open abdominal aortic aneurysm (AAA) repair: 1 aorto-enteric fistula and 1 anastomotic aneurysm.

In-hospital mortality occurred in 6 (8%) patients, whilst the 30 day mortality rate was 9.3%.

The overall survival rate at 1 year was 85%, at 2 years 78% and at 3 years 71% (Figure 1). Median follow-up was 35 months (Q1, Q3: 10, 63).

## *FEVAR device configurations and stent choices*

The median number of CMD fenestrations was 3 (Q1, Q3: 2, 4). 4 fenestrations were planned for 28 (37%) cases, 24 (32%) cases had 3 fenestrations, 19 (25%) cases had 2 fenestrations and 4 (5%) cases had 1 fenestration (Figure 2).

Respecting the general principle of having 2 cm of straight aortic sealing neck of healthy arterial wall without thrombus or dilation, the department moved towards more 4 fenestration grafts over the duration of the study (Figure 2). Approximately, 65% of FEVARs had 4 fenestrations in the last 3 years.
A total of 226 fenestrations and a total of 241 covered stents were used to bridge the fenestration to the target visceral vessels. Fenestrations for renal arteries were 141 (62%), for superior mesenteric artery 53 (24%), and for coeliac axis 32 (14%).
16 visceral vessels (7%) required the deployment of 2 stents and for 1 fenestration (0.4%) it was necessary to deploy 3 stents.
All bridging stents were balloon mounted expandable covered stents; 208 (86%) Atrium (Getinge), 16 (7%) BeGraft and 14 (6%) BeGraft+ (Bentley) and 3 (1%) LifeStream (BD – Becton, Dickinson and Company).

## *Intraprocedural difficulties*

8 target vessels (3.5% of all the fenestrations) had significant intraprocedural difficulties. The most common intraprocedural complication affecting correct stent deployment was related to difficult cannulation and 3 (1.3%) visceral vessels could not be stented due to a failed cannulation (98.7% technical success rate). Of these, 1 coeliac artery stent needed embolisation after deployment due to persistent large 1c endoleak and inability to re-cannulate the target vessel whilst 2 right renal arteries could not be cannulated.

1 renal artery was inadvertently cannulated via the SMA fenestration , needing successful re-cannulation and re-stenting of both target vessels. 1 stent kinked shortly after deployment and relining with a further stent was necessary during the procedure. 1 stent dislodged and slipped into the aorta, requiring replacement with a similar stent. 1 stent fractured after flaring and was subsequentially relined. 1 stent dislodged back from the balloon onto the shaft when passing through the fenestration.

## *Visceral stents performance*

Visceral stent failure was determined after occlusion, stenosis, kink, fracture, crush, dislocation or endoleak (type Ic, IIIb or IIIc).
Early mortality related to acute visceral stent thrombosis was registered in 2 (2.6%) cases.
On the day following FEVAR, one patient had kidney infarction that eventually led to multiorgan failure and one patient had acute SMA stent thrombosis with consequent bowel ischemia and death.

Overall 22 (9.8%) visceral stents required a second endovascular procedure of which 1 stent was revised twice within 30 days and at 3 years. 7 (3%) were revised within 30 days, 12 (5.4%) at 1 year, 2 (1%) at 2 years and 1 (0.4%) at 3 years.
5 (6.6%) of these cases had a small endoleak related to visceral stenting at completion angiogram that eventually required re-intervention.

Of all the visceral stent failures that required re-intervention, 7 (3%) cases presented with a type 3c endoleak, 6 (2.7%) cases had a type 1c endoleak, 4 (1.8%) cases had in-stent thrombosis, 2 (0.9%) cases had stenosis, 1 (0.4%) case had migration and related 1c endoleak, 1 (0.4%) case had stent kink and 1 (0.4%) case had a stent fracture.

19 renal stents (8.4%; 86% of all the reinterventions) required re-intervention and one of these was relined twice, 3 SMA stents needed reintervention (1.3%; 14% of all the reinterventions) and no visceral stenting of the coeliac axis was involved in any reintervention (Table 3). Overall renal artery bridging stents were more prone to failure if compared against coeliac and SMA stenting (p=0.13).

## *Anatomical features and visceral stent characteristics as predictors of failure*

When comparing successful stentings with re-interventions, a smaller stent diameter (6.9 ± 1.3mm vs 6.4 ± 1.3mm; p=0.03) and a shorter stent (29.6 ± 7mm vs 25.8 ± 6mm; p = 0,01) are significant predictors of stent failure (Table 4).
No other significant predictor of stent failure was demonstrated for any considered anatomical feature when comparing successful cases with those that required re-intervention: Aneurysm diameter (64.1 ± 9.2 mm vs 62.5 ± 7.5 mm; p=0.24); neck angulation (29.8 ± 19 ° vs 31.3 ± 14 °; p=0.41); target vessel diameter (6.0 ± 1.3 mm vs 5.7 ± 1.3 mm; p=0.37); Distance between target vessel origin and its first branch (35.4 ± 14.3 mm vs 36.3 ± 1.3 mm; p=0.25); and target vessel angulation (p=0.17).
No coeliac axis stent needed reintervention, so the presence of median arcuate ligament compression of more than 50% (19% of stented CA) did not seem to influence stent performance.

Outcomes were not significantly affected by stent type (p=0.18). Out of the 223 successful stented fenestrations, an Atrium stent was used as bridging stent for 191 (86%) fenestrations, of these 21 (9.4%) required intervention. BeGraft+ stents were used for 15 (6.7%) fenestrations and only one required reintervention. Conventional BeGraft stents were used for 13 (6%) fenestrations and Lifestream stents for 3 (1.3%) fenestrations and none of these required re-intervention.
Different stent oversize (15 ± 14% vs 14 ± 10 %; p=0.4) and length of covered target vessel (18.5 ± 6.1 mm vs 17.3 ± 7.3 mm; p = 0.3) were not significantly different when comparing between successful stenting and those requiring re-interventions.

# **Discussion**

To our knowledge, this is the first study looking at detailed anatomical features and bridging stent specifics when utilizing FEVAR for treating juxta-renal abdominal aneurysms with the aim of identifying predictors of visceral stent failures. Patients requiring shorter stents with reduced diameter have an increased risk of stent failure, however re-intervention had high success rates.
Most series described in international literature6,7,9 included both bare metal stents and covered stents, confirming the superiority of balloon mounted covered stents. If there is wall apposition of the main body between the fenestration and the target vessel, the visceral stent should not provide extra seal, but only preserve patency and add graft stability. This explains why non covered stents were initially used as bridging stents10. However, they showed a high rate of complications, failures, endoleaks and reintervention9, so current practice has now moved to the exclusive use of balloon mounted covered stents. They can provide extra sealing, precise placement and flaring around the fenestration. In our study cohort, only balloon mounted covered stents were used.
In branched endovascular aortic repairs (BEVARs), visceral stents failure and reintervention have a much higher incidence than in FEVARs7, this being largely related to the longer distance they need to cover and the adverse anatomy they need to support11. Lack of FEVAR graft apposition to the aortic wall (>5mm) is a significant risk factor for visceral stenting failure and reintervention, suggesting that visceral stents in FEVARs are likely be subjected to similar stress forces of BEVARs bridging stents12.
The presented patient cohort is comparable with those described in international literature for mortality, complications and reintervention rate6,13. Of note, 8 cases (10%) were performed for emergency symptomatic unruptured aneurysms or for revision surgery following historic EVARs or open repairs. Such indications are inherently associated with higher morbidity and mortality rates. Target vessel complications and endoleaks remain the two most important common cause of reintervention, but these are internationally under-reported due to the focus on mortality and overall complications14.
As described in other series9,12, in our cohort there was a clear trend towards the use of CMD with 4 fenestrations (Figure 2). Although this has reduced the incidence of type Ia endoleak, it has increased the rate of visceral stents related complications and reintervention8. These results confirm that visceral stents failures in FEVARs are common, requiring reintervention in 23% of the patients who underwent FEVAR, in line with international literature4,7,9,15. It is important to adopt a strict and comprehensive long term FEVAR surveillance since visceral stent failures can lead to catastrophic consequences such as endoleak, renal failure, bowel ischemia and eventually death. Considering the high number of stents used, their overall performance is very good with an overall initial patency rate of >99% and technical success rate of 98.7%.
Overall 9.8% of the visceral stents used in our cohort needed reintervention. Only in one case was it necessary to re-intervene on the same stent, suggesting that visceral stent reintervention is a safe option with good long-term outcome able to preserve FEVAR function.
Some stents characteristics seem to contribute as predictor of failure. In this cohort, smaller stent diameters were more likely to require reintervention. A plausible explanation is that stents with smaller diameters are stiffer and produce more turbulence. Smaller and stiffer stents can also affect the fine balance between FEVAR stability and stent flexibility10.
Unsurprisingly shorter stents have also been found to require more re-interventions. This finding supports the need of more length options for balloon mounted covered stent. This study suggests that renal stents are more liable to re-intervention if compared to SMA or CA, a finding that has been described in similar studies7,9. In addition, the presence of median arcuate ligament compression on the CA did not result in bridging stent failure or reinterventions. None of the other considered anatomical features was a significant predictor of stent failure.
There are several limitations of this study. It remains a single center cohort, and validating these results in a larger group would increase the power an accuracy of these results. In addition, unit treatment decisions changed over the duration of the study, with a preference for more 4 fenestrated cases as time progressed. Nonetheless caution regarding stent diameter and length should be taken into consideration when planning FEVAR.

# **Conclusions**

Visceral stent complications are common and their modalities of failure vary and remain largely unpredictable. We recommend caution when using shorter stents with smaller diameters. Our findings support the role of industries in developing new technologies and widening the range of available stent lengths.
The high success rate of re-intervention and the late finding of some visceral stent failure (up to 3 years of follow-up) support long term surveillance after FEVAR.

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# **Table 1**

|  |  |  |
| --- | --- | --- |
| **Pre-operative CT** | **Intraoperative details** | **Post-procedure CT and outcome** |
| Neck anglea | Number of Fenestrations | Visceral vessel coverage |
| Size of the aneurysm | Bridging stent diameter | Early and long term complications |
| Visceral vessel angulationb | Stent length | Early or late stent failure |
| Arcuate ligament compressionc | Stent oversizing | Re-intervention |
| Visceral vessel diameterd | Multiple bridging stents |  |
| Visceral vessel stenosis | Intraprocedural difficulties |  |
| Distance of the first branch from ostium | Perioperative complications |  |

## Table 1.

Description of the anatomical features and procedural details collected for the review.
a. Defined as the angle of aortic central line between the aneurysm and the visceral segment

b. Angulation between the visceral vessel and the aortic axis orientations, this being judged as downwards, horizontal or upward

c. Defined as at least 50% stenosis of the coeliac axis from compression by the median arcuate ligament

d. As the diameter of the first segment of 1cm straight vessel

# **Table 2**

|  |
| --- |
| **CASES CHARACTERISTICS** |
| Total cases | 75 |
| Age | 76.2 ± 6.5 |
| Male | 69 (92%) |
| Aneurysm size (mm) | 64 ± 9.6 |
| Hypertension | 51 (68%) |
| Chronic Lung Disease | 20 (27%) |
| Ischemic heart disease | 37 (49%) |
| Chronic cardiac failure | 5 (7%) |
| Chronic renal failure | 14 (19%) |
| Cerebral vascular accident | 15 (20%) |
| Cancer | 14 (19%) |
| Peripheral arterial disease  | 10 (13%) |
| Smoking history | 51 (68%) |
| Emergency | 5 (6.6%) |
| Previous EVAR | 6 (8%) |
| Previous open AAA repair | 2 (2.6%) |
| 1 Fenestration | 4 (5%) |
| 2 Fenestrations | 19 (25%) |
| 3 Fenestrations | 24 (32%) |
| 4 Fenestrations | 28 (37%) |
| Hospital stay (days) | 8.7 ± 6.7 |
| Intensive care stay (days) | 2.24 ± 2.8 |
| 30 days mortality | 7 (9.3%) |

## Table 2.

Patients and cases characteristics summary.
Continuous data are presented as the median and Interquartile Q1,Q3 or means ± standard deviation. Categorical data are given as the counts (percentage).
EVAR: Endovascular Aortic Repair
AAA: Abdominal Aortic Aneurysm

# Table 3

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Target Vessel | AAA Size (mm) | Devicefen | Neck angle | Diameter target vessel | LengthOstium to first branch | Direction | Stenosis | Stent | Stent diameter | Oversize (%) | StentLength | length of target vessel covered | Number of Stents to target vessel | Failure type | Time of reintervention |
| 1 | LRA | 85 | 1 | 55 | 6 | 40 | Downward  | No | Atrium | 6 | 0% | 22 | 30 | 2 | Kink | 2 year |
| 2 | RRA | 55 | 2 | 30 | 5 | 14 | Downward  | No | Atrium | 5 | 0% | 22 | 15 | 1 | Ic endoleak | 1 year |
| 3 | LRA | 55 | 2 | 30 | 4,9 | 38 | Downward  | No | Atrium | 5 | 2% | 22 | 19 | 2 | Ic endoleak | 1 year |
| 4 | LRA | 63 | 2 | 30 | 3,7 | 44 | Downward  | No | Atrium | 5 | 35% | 22 | 15,5 | 1 | Thrombosis | 1 year |
| 5 | LRA | 65 | 2 | 35 | 5,3 | 48,4 | horizontal | Yes | Atrium | 6 | 13% | 22 | 11,3 | 1 | IIIc endoleak | 30 days |
| 6 | RRA | 65 | 2 | 35 | 5,4 | 58,3 | downward | No | Atrium | 6 | 11% | 22 | 14 | 1 | Ic endoleak | 1 year |
| 7 | LRA | 60 | 4 | 40 | 6,5 | 36 | downward | No | Atrium | 7 | 8% | 22 | 10 | 1 | IIIc endoleak | 1 year |
| 8 | LRA | 53 | 3 | 10 | 6 | 31 | downward | No | Atrium | 7 | 17% | 32 | 9,7 | 1 | Stenosis | 1 year |
| 9 | LRA | 60 | 3 | 15 | 5,6 | 13 | horizontal | No | Atrium | 7 | 25% | 22 | 3 | 1 | Thrombosis | 30 days and 3 years |
| 10 | RRA | 60 | 3 | 15 | 5,4 | 31 | horizontal | No | Atrium | 6 | 11% | 22 | 13 | 1 | Ic endoleak | 30 days |
| 11 | SMA | 58 | 3 | 40 | 9 | 47 | downward | No | Atrium | 10 | 11% | 38 | 33 | 1 | Fracture | 1 year |
| 12 | RRA | 72 | 2 | 45 | 6,8 | 56 | Downward | Yes | Atrium | 7 | 3% | 22 | 14 | 1 | Migration | 3 years |
| 13 | LRA | 61 | 3 | 35 | 4,1 | 41 | Downward | No | Atrium | 5 | 22% | 22 | 16,5 | 1 | Thrombosis | 30 days |
| 14 | LRA | 55 | 3 | 60 | 5,7 | 36,5 | Downward | No | Atrium | 7 | 23% | 22 | 10 | 1 | IIIc endoleak | 1 year |
| 15 | LRA | 56 | 4 | 30 | 5,5 | 36,6 | Downward | No | Atrium | 6 | 9% | 22 | 11,3 | 1 | IIIc endoleak | 30 days |
| 16 | LRA | 63 | 4 | 20 | 5,6 | 39 | Downward | No | Atrium | 6 | 7% | 32 | 19 | 1 | Ic endoleak | 1 year |
| 17 | LRA | 60 | 4 | 60 | 5,2 | 26,5 | Downward | No | Atrium | 6 | 15% | 22 | 29 | 1 | Ic endoleak | 30 days |
| 18 | SMA | 70 | 4 | 15 | 6,7 | 34,5 | Downward | No | Atrium | 8 | 19% | 38 | 27 | 1 | IIIc endoleak | 2 year |
| 19 | RRA | 70 | 4 | 15 | 4,4 | 27 | Downward | No | Atrium | 5 | 14% | 32 | 21 | 1 | IIIc endoleak | 1 year |
| 20 | LRA | 70 | 4 | 15 | 3,5 | 20 | Downward | No | Atrium | 5 | 43% | 22 | 22,5 | 1 | IIIc endoleak | 1 year |
| 21 | SMA | 53 | 3 | 45 | 8,3 | 56,3 | Downward | No | Atrium | 9 | 8% | 38 | 21 | 1 | Thrombosis | 30 days |
| 22 | LRA | 67 | 4 | 25 | 5,9 | 23,3 | Downward | No | Begraft | 6 | 2% | 28 | 17 | 1 | Stenosis | 1 year |

## Table 3.

Descriptions of visceral stent characteristics and target vessels anatomical features
LRA: Left Renal Artery, RRA: Right Renal Artery, SMA: Superior Mesenteric Artery, AAA: Abdominal Aortic Aneurysm, fen: fenestrations

# **Table 4**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Normal follow-up** | **Re-intervention** | **Significance** |
| **Aneurysm size** | 64.1 ± 9.2 mm | 62.5 ± 7.5 mm | p = 0.24 |
| **Neck angle** | 29.8 ± 19 ° | 31.3 ± 14 ° | p = 0.41 |
| **Target vessel diameter** | 6 ± 1.3 mm | 5.7 ± 1.3 mm | p = 0.37 |
| **Distance from ostiumto first branch** | 35.4 ± 14.3 mm | 36.2 ± 12.3 | p = 0.25 |
| **Direction: DownwardsHorizontalUpwards** | 171 (76.7%)26 (11.7%)4 (1.8%) | 21 (9.4%)1 (0.4%)0 (0%) | p = 0.17 |
| **Stent: AtriumBeGraft+BeGraftLifestream** | 171 (76.7%)14 (6.4%)13 (5.8%)3 (1.3%) | 21 (9.4%)1 (0.4%)0 (0%)0 (0%) | p = 0.18 |
| **Stent diameter** | 6.9 ± 1.3 mm | 6.4 ± 1.3 mm | **p = 0.03** |
| **Oversize** | 15 ± 14 % | 13 ± 10 % | p = 0.4 |
| **Stent length** | 29.6 ± 7 mm | 25.8 ± 6 mm | **p = 0.01** |
| **Length of covered vessel** | 18.5 ± 6.1 mm | 17.3 ± 7.3 | p = 0.3 |

## Table 4.

# Anatomical features and stent configuration comparison between successful stenting and stents that required reintervention. Continuous data are presented as the means ± standard deviation. Nominal data are given as the counts (percentage). To avoid the assumption normal distributions, deduced z-scores from Mann-Whitney U test were applied to acquire p values. For nominal variables, comparisons were simplified to 2 x 2 contingency tables and compared using a chi-square calculator to find p values.

# **Figure 1**

## Figure 1.

Overall mortality following FEVAR (Kaplan-Meier survival curve).

# **Figure 2**

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Figure 2.

Number of FEVAR cases and fenestrations per year. Increasing number of 4 fenestrations is shown by the trend line.
Fen: Fenestrations