Fenestrated endovascular repair for juxtarenal aortic pathology

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Objective: **To evaluate the outcomes after fenestrated endovascular aortic repair (f-EVAR) in a tertiary European referral center.**

Methods: **All patients treated with commercially available custom-made f-EVAR between September 2002 and June 2007 were prospectively enrolled in a computerized database including co-morbidities and aneurysm morphology. Patients were retrospectively analyzed. Follow-up consisted of clinical examinations and computed tomography (CT) scanning.**

Results: **A total of 54 patients were included in this study. Median age was 72 (interquartile range [IQR] 68-76) years and 85% were men. Median preoperative aneurysm diameter was 60 (53-66) mm. One hundred thirty-four vessels were targeted (43 scallops, 91 fenestrations) and 96 stents were placed (69 bare, 27 covered). Target vessel catheterization was achieved in 98% of cases. Two patients (3.7%) died within 30 days, 1 from trash embolization and multiorgan failure and 1 from retroperitoneal bleeding caused by a renal artery perforation. Three type I endoleaks occurred intraoperatively, two sealed pre-discharge and one was treated with a Palmaz stent (Cordis, Miami Lakes, Fla) on postoperative day 4. Thirteen patients had type II endoleaks, and 2 required treatment. The median clinical follow-up was 25 (12-32) months with median CT follow-up of 22 (4-26) months. Aneurysm diameter decreased ≥5 mm in 47%, was unchanged in 50%, and increased ≥5 mm in 3% of patients at 1 year. There were three type II endoleaks at 1-year follow-up, one of which was successfully treated after 19 months due to aneurysm growth. Ninety-six percent of target vessels remained patent during the study period and all occlusions occurred within the first year of follow-up. Five target vessels occluded (2 renal arteries [RAs] and 3 superior mesenteric arteries [SMAs]) without symptoms during follow-up and successful reinterventions were done on 2 stenosed RAs. Three patients suffered creatinine increase but none needed dialysis. One late aneurysm-related death occurred due to massive bleeding during redo surgery for infection.**

Conclusion: **Despite complex anatomy or severe comorbidities in these patients f-EVAR has acceptable short- and midterm results in this series which includes a learning curve and offers a valid treatment alternative to patients unsuitable for standard EVAR or open repair. (J Vasc Surg 2009;■■:■■■.)**

Randomized trials have shown endovascular aneurysm repair (EVAR) to be a valid treatment option in patients with asymptomatic abdominal aortic aneurysms (AAA). This minimally invasive option offers patients a treatment with less morbidity and mortality than conventional open aneurysm surgery.[1-3] The technique is, however, usable only in patients with suitable proximal and distal sealing zones. This is true in 50-70% of patients, the remaining patients have inadequate fixation and seal in the proximal aortic neck or iliac vessels.[4,5] In order to treat patients with inadequate proximal necks, the sealing zone of the stent graft must be moved proximal to a healthier portion of the aorta. The aortic visceral side branches can be incorporated into the repair with the aid of fenestrations in the graft that allow continued blood flow into the viscera. Since the initial report in 1999,[6] fenestrated EVAR (f-EVAR) devices have been implanted in over 1500 patients worldwide and are now commercially available. Limited data are published, however, and data skewed due to most patients originating from one single center series.[7] The aim of this study is to analyze the results in a single center experience of patients treated with f-EVAR, with the main focus on target vessel patency and short-term outcome.

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METHODS

All patients treated with f-EVAR were prospectively enrolled in a computerized database incorporating multiple variables such as co-morbidities, aneurysm size, neck morphology, indication for treatment, total number of fenestrations, and total number of stents/covered stents in target vessels. Workup consisted of clinical exam and high-resolution spiral computed tomography (CT) scan from the distal thoracic aorta through the deep femoral arteries. Preoperative cardiopulmonary workup consisted of spirometry, echocardiography, and 12 lead electrocardiogram (EKG) in all cases.

CT protocol. All preoperative CT scans were performed on a 16 or 64 slice multidetector spiral CT scanner. CT scans were reconstructed with 0.75-3 mm axial slices. In the early experience, planning was performed on axial and multiplanar reconstructions. In the later phase (since 2005), post-processing reconstructions and center-line-of-flow measurements were performed on a dedicated vascular three dimensional (3D) workstation (www.terarecon.com) and done to define the circumferential as well as longitudinal relationship of target vessels. Neck diameter and morphology including presence of thrombus, calcifications,

Fig 1. Maximum intensity projection reconstruction of an aortic aneurysm with very short infrarenal neck.

Fig 2. Fenestrated stent graft deployed with both renal arteries catheterized and renal sheaths in place.

and angulations were assessed. Multiplanar and maximal intensity projection reconstructions were used when necessary, particularly in the presence of aortic neck angulation.

Inclusion criteria. All patients considered unfit or at high risk for open aneurysm repair (old age, severe comorbidities, previous aortic reconstruction, or need for suprarenal aortic clamping)[8] with inadequate infrarenal aortic necks were considered for f-EVAR. Necks ≤8 mm, conical in shape (>15% diameter change/10 mm) or heavily thrombus lined (circumferential thrombus abutting the renal arteries) were common indications for fenestrated repair. Stent graft apposition at the level of the renal arteries was mandatory (thus excluding suprarenal and thoracoabdominal aneurysms). In light of our previous experience, patients with juxtarenal aneurysms unfit for infrarenal EVAR, constitute a high risk for open surgery. Over the study period (when we saw the good results of f-EVAR compared to open surgery), a shift towards the endovascular approach occurred. Severe neck angulation (<90°) was the only absolute exclusion criteria. Only asymptomatic aneurysms were included in this study.

Stent graft. The Zenith device (www.cookmedical.com) formed the foundation of the fenestrated graft in all cases. This is a modular stent graft where the fenestrations are located on the most proximal tubular portion of the stent graft. Fenestrations were designed to match the locations of the target vessel ostia and come in three basic types: small fenestrations (6 × 8 mm, intended for use in conjunction with a stent/covered stent in the target vessel), large fenestrations (>8 mm, with and without crossing stent struts) and scallop fenestrations located at the most proximal portion of the fabric. The target vessels are catheterized through the fenestrations after partial deployment of the proximal tubular graft using access from the contralateral common femoral artery. The stent graft repair is then completed by extension with a bifurcated main body overlapping into the tubular graft and extension limbs into the iliac arteries bilaterally (Figs 1-3). The device description and implantation technique has been described in detail earlier[7,9,10] and has undergone various modifications over time. Initially small fenestrations were stented selectively and scallops not at all. This has now progressed to that all small fenestrations and large fenestrations that do not have crossing stent struts are routinely stented and scallops are stented selectively depending on the target vessel incorporated and the "fit" of the graft. Technical success was defined as exclusion of the aneurysm without signs of type I or III endoleak at the completion angiography and correct placement of the fenestrations according to the preoperative plan.

Follow-up. Routine follow-up consisted of clinical exam at 1 month and yearly thereafter. Multislice CT scan and plain abdominal films were performed after 1 year and yearly thereafter. Additional CT scans during the follow-up period were done after 1 and 6 months on the first few patients and thereafter on clinical indication only. Endpoints were target vessel stenosis or occlusion, secondary intervention, or death. Endoleaks (early and late), change in aneurysm size, and change in serum creatinine over time were also registered. Aneurysm diameter changes were considered significant when ≥5 mm.

Statistics. Continuous data are presented as median with interquartile range. The Wilcoxon signed rank test was

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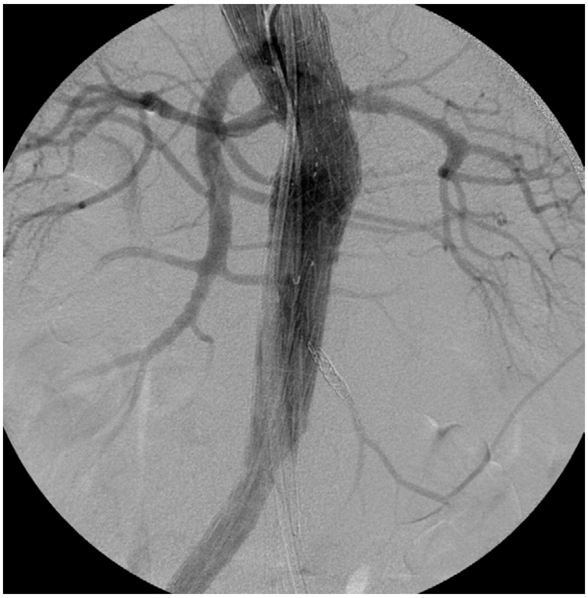


Fig 3. Final angiogram showing good flow through renal stents and in superior mesenteric artery (SMA) which was incorporated into the graft with a non stented, reinforced scallop.

used for analyzing changes in aortic diameter during follow-up. All cause mortality, aneurysm-related mortality, and intervention-free survival was estimated by Kaplan-Meier and life table analysis. SPSS for windows version 13.0 (SPSS Inc, Chicago, Ill, www.spss.com) was used for all statistical analysis. A $P < .05$ was considered statistically significant.

RESULTS

A total of 54 patients were treated with custom ordered fenestrated stent grafts between September 2002 and June 2007. During the same period, 47 asymptomatic patients underwent open repair for juxtarenal aortic aneurysms. The present series consisted of 46 men and 8 women with a median age of 72 (68-76) years. The preoperative risk factors are listed in Table I. The indication for treatment was AAA in 44 patients, residual AAA after open aneurysm surgery in 3 patients, aortic ulceration in 3 patients, residual AAA after conventional infrarenal EVAR in 2 patients, and aortic dissection with a secondary aneurysm in 2 patients. All patients included in the study were asymptomatic, deemed unsuitable for open surgery, and had either a short aneurysm neck (≤8 mm), were anatomically unsuitable for a traditional infrarenal EVAR due to poor proximal necks, or considered at increased risk for open repair. Median aortic diameter was 60 (53-66) mm on the preoperative CT scan, 54 (46-64) mm after 12 months, and 53 (43-66) mm after 24 months. The reduction of the aortic diameter at 12 months was statistically significant ($P = .001$). The aneurysm diameter decreased ≥5 mm in 47% of patients at 1 year, increased ≥5 mm in 3%, and remained stable in 50%.

A total of 134 fenestrations/scallops (91 fenestrations, 43 scallops) were incorporated in the prosthesis design

Table I. Pre-operative co-morbidities and risk factors

	Patients (n)	*%*
Diabetes	7	13
Previous MI	19	35
Angina	13	27
Congestive heart failure	7	13
Arterial hypertension	34	62
COPD	21	38
Renal insufficiency (creatinaemia >105 μmol/L)	24	44

MI, Myocardial infarction; *COPD,* chronic obstructive pulmonary disease.

Table II. Distribution of vessels incorporated into the fenestrated devices

	Number of renal fenestrations			
Mesenteric fenestrations/Scallops	*0*	*1*	*2*	*3*
None		8	9	
SMA	1	3	29	1
SMA + Celiac	**1**		**2**	

SMA, Superior mesenteric artery.
Majority of patients (54%) had devices involving the two main renal arteries and the SMA (94 renal arteries with 62 stents and 25 covered stents placed, 37 SMAs with 7 stents and 2 covered stents placed and 3 celiac arteries with no stents or covered stents placed). Two patients had devices incorporating all four visceral vessels.

(mean 2.5 per patient) with a total of 96 stents/covered stents placed into target vessels. Table II shows the distribution of renal, superior mesenteric, and celiac arteries involved.

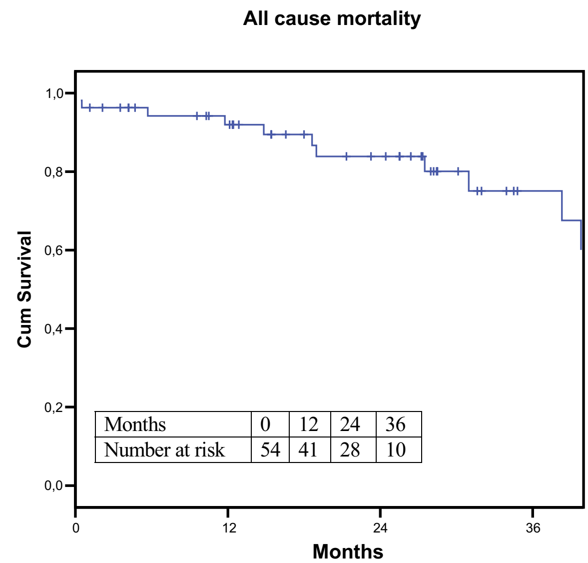
Primary technical success was achieved in 49 patients. Median procedure time was 250 (210-333) minutes with a median fluoroscopy time of 78 (59-108) minutes. The median volume of contrast utilized was 270 mL with a median iodine dose of 53 g/patient. Percutaneous approach to the common femoral artery was used in 88 groins (44 patients) with failure in 12 groins (9 patients) requiring conversion to open surgery in order to secure hemostasis or adequate lower extremity circulation. Median blood loss was 600 (400-1000) mL with median volume of transfused blood products of one unit per patient (0-3).

Endoleaks. The use of large balloon-expandable stents (Palmaz) to treat type I (n = 11) or type III (n = 3) endoleak (at the overlap between the first and second graft component) was required in 13 patients. Completion angiography showed type I endoleaks in 3 patients, 2 proximal and 1 distal. In the 2 cases with proximal leaks, these had resolved on pre-discharge CT scans at 2 and 5 days postoperatively. In the third case, a distal endoleak was treated with a Giant Palmaz stent in the right iliac artery on postoperative day 4. Type II endoleaks were observed in 13 patients on completion angiography and persisted in 3 patients at 1 year. One patient was successfully treated with coil embolization of the inferior mesenteric artery after 44 days (endoleak on 1-month CT scan) and another with glue embolization of lumbar arteries after 553 days (expanding aneurysm sac). No other type II endoleaks were treated. One patient had a type III endoleak on the completion angiography but died from complications due to bowel ischemia prior to any control angiography.

Target vessel patency. Patency during the follow-up period was achieved in 129 of 134 target vessels. Those vessels which stenosed or occluded during follow-up did so within the first 12 postoperative months. Two unstented renal arteries early in the series became partially covered by the stent graft fabric without causing a hemodynamically significant stenos or occlusion during the follow-up period. Five target vessels occluded either during surgery or follow-up. In one case, a Giant Palmaz stent was placed over the left renal artery during the primary procedure in order to seal a proximal type I endoleak where the renal artery already had a reduced blood flow secondary to a guidewire-induced dissection. One dissection distal to a stent in a renal artery was left untreated. The artery was stented primarily but the completion angiography showed a short dissection distal to the stent (into a renal artery branch) without affecting the blood flow to the rest of the kidney. The vessel occluded prior to the 12-month CT scan. Three superior mesenteric arteries (SMAs) occluded during the follow-up period. All had a scallop and were unstented primarily. Two were found to be occluded on a 12-month CT scan and one 6 month's postoperatively. In all cases, the patients were asymptomatic and no further intervention was necessary. Redo percutaneous transluminal angioplasty (PTA) was performed on two stented renal arteries which showed stenoses on the 1-year CT scan with successful assisted primary patency in both cases. Two other stented renal arteries had significant stenosis on 1-year CT follow-up and were not treated. In one case, the patient had disseminated malignant disease and in the other case the kidney had shrunken and was non-functional at the time of diagnosis.

Renal function. The median preoperative creatinine level in the female group was 94 (67-98) μmol/L (normal level 45-90 μmol/L) and in the male group 103 (88-141) μmol/L (normal level 60-105 μmol/L). Nineteen patients (35%) developed at least a transient increase in serum creatinine >30% in the immediate postoperative period. All improved during follow-up with a decrease below the 30% barrier in 16 cases (84%). Five patients with normal postoperative creatinine levels developed an increase >30% later during follow-up without any signs of reduced renal blood flow or stenoses on their CT scans. Two renal arteries were treated for stenoses (see previous section) without measurable signs of decreased renal function. Two patients died within 30 days from the procedure and both showed a significant elevation of serum creatinine (252-505 μmol/L) as part of multiorgan failure. One patient was on dialysis prior to endografting and no other patient became dialysis-dependent during follow-up.

Survival. The median clinical follow-up was 25 (12-32) months with a median CT follow-up of 22 (4-26) months. Twelve patients died during the follow-up period and 2 of those within 30 days of the initial procedure (3.7%). One patient developed bowel ischemia secondary to mesenteric artery embolization and died after 13 days from multiorgan failure. One patient died after 15 days from complications secondary to retroperitoneal bleeding. The patient had extremely difficult renal access during the operation due to neck angulation thus necessitating the use of an extra stiff wire in the renal artery for sheath placement. On sheath advancement, the stiff wire caused a renal perforation. This was unfortunately missed intraoperatively. Postoperative hemodynamic instability prompted a CT scan that revealed a retroperitoneal bleed. The patient died despite an effort to control the bleeding. One patient died from massive bleeding at an outside hospital 6 months after the primary procedure during surgery of the groin related to infection. No other deaths were aneurysm related. Figs 4 and 5 show the survival function for all cause mortality and intervention-free survival.



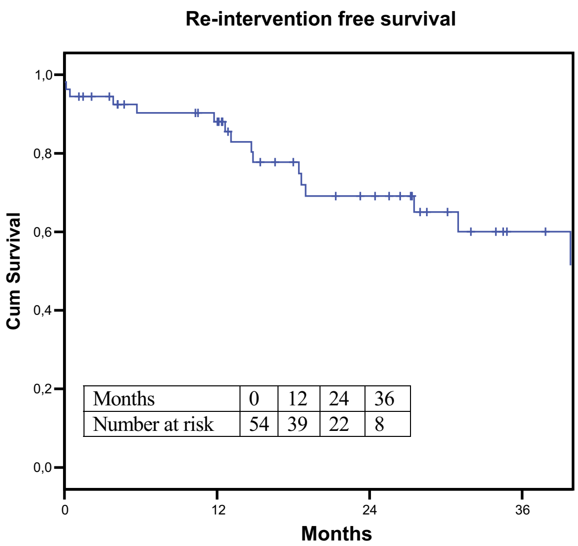
Months	0	12	24	36
Number at risk	54	41	28	10

Fig 4. Kaplan-Meier estimate of the survival function for all cause mortality with numbers at risk inside the box. Twelve patients died during the follow-up period and 2 of those within 30 days of the initial procedure (3.7%). In total, three deaths were aneurysm-related.

DISCUSSION

Infrarenal EVAR is a valid option to open surgical repair (OR) with many benefits for the patients.[2,3] However, anatomical limitations in the proximal aneurysm neck exclude EVAR in 20-30% of patients. In contrast to OR, where a clamp can be placed suprarenally but the repair performed infrarenally, EVAR requires a good infrarenal neck for durable fixation and seal. In patients with unsuitable infrarenal necks, the concept of f-EVAR has been shown to be feasible.[11] By customizing a stent graft with fenestrations for the mesenteric arteries, one can utilize a healthier more proximal portion of the aorta as a sealing and fixation zone.

Previous published series of fenestrated stent grafting are limited except for the vast experience from the Cleve-



Months	0	12	24	36
Number at risk	54	39	22	8

Fig 5. Kaplan-Meier estimate of the re-intervention free survival with numbers at risk inside the box. During the first year of follow-up, two endoleaks (type I and II, respectively) were treated. One renal artery was embolized secondary to a massive bleeding on the first postoperative day. The patient died of complications. One patient developed acute ischemia in the right leg and was treated with thrombectomy and patch in the common femoral artery on postoperative day 115. The reason was stenos secondary to a Perclose suture. During the second year, one type II endoleak was treated and percutaneous transluminal angioplasty (PTA) was done on two stenosed renal arteries.

land Clinic. Operative mortality in these and other published reports vary from 0.4-2.6%.[7,12-17] The mortality in our series is higher at 3.7%, the reason for this is unclear and might be due to patient selection and the small number of patients in the series. In addition, during the learning curve of our experience, patients with quite severe neck angulation were accepted and this increases the level of difficulty both with regard to accurate planning of the graft as well as the actual implant. Furthermore, the introduction of a dedicated 3D workstation using center line of flow (CLF) reconstructions, has greatly improved the accuracy of stent graft planning. The patients that died in our series did so of seemingly technical causes. One patient displayed massive embolization that caused multiorgan failure and death. The second patient suffered a retroperitoneal bleed due to a renal perforation and succumbed from this despite attempts to control the bleeding. These cases indicate that the addition of fenestrations to the stent graft procedure adds a level of complexity, which incurs an additional risk for the patient. In particularly complex cases, a multitude of catheters and wires may be left inside the patient for an extended period of time increasing the risk of embolization occurring. Target vessels that are hard to catheterize sometimes require the use of stiff guidewires to achieve stable positions for stent delivery. These circumstances add to the difficulty and higher risk of the procedure. Given this, the results are still comparable to those achieved from open infrarenal repair in randomized trials.[2,18] In addition, a number of the patients treated in ours and the other reported series would probably have needed a more proximal open repair, due to the lack of infrarenal neck, which would likely affect the outcome negatively. Like previous studies have shown, the survival benefit after endovascular repair in patients unfit for open surgery is still questionable. This is also reflected in the 22% mortality at 2 years in our series, which is similar to the mortality rate of an unselected cohort of infrarenal aneurysm patients not receiving treatment.

Despite that, there are indications that patients not anatomically suitable for standard EVAR carry a higher rupture risk than those who are.[19] This may justify fenestrated repair in high-risk patients as in our series. We also believe that with increasing experience with fenestrated endografting, we will be able to identify those patients that are less likely to benefit from the repair and subsequently improve the results further.

Despite the increased complexity compared to standard EVAR, and considering that this and other reports include the learning curve of f-EVAR, the procedural and fluoro times are not prohibitive. The vast majority of target vessels are successfully catheterized during the procedure without any damage occurring. The target vessel patency in our series was 96% with a mean follow-up approaching 2 years and this is similar to other reports.[11] The need of excellent preoperative planning for these procedures cannot be overemphasized. High-quality multidetector CT scans with thin slice reconstructions are mandatory to provide adequate preoperative information. As stated, we now routinely plan these cases in a 3D workstation. This allows for very precise determination of relationships between fenestrations both longitudinally and rotationally. Planning using only axial CT reconstructions is tedious and imprecise and is not recommended. With correct preoperative planning these procedures are made significantly easier and fully automated systems for this are currently being investigated (Personal Communication Dr Roy Greenberg, Cleveland Clinic Foundation, Cleveland, Ohio). The largest issue is to estimate the interface between the endografts and the aorta, a fact that can significantly affect the relationship between the fenestrations and the target vessels. This takes some experience especially in the setting of very angulated aortas and infrarenal necks.

Like other authors have noted,[7,13,16,20,21] there seems to be increased risk of target vessel occlusion in unstented fenestrations. Previously these have been described mainly for unstented scallops for the renal arteries, but a recent report from the Liverpool group has also noted the phenomenon for the SMA.[21] We had three cases of postoperative asymptomatic SMA occlusions in unstented SMA scallops. The reason for this was probably misalignment of the graft after deployment. During the catheterization process, the graft is constrained by diameter-reducing ties on the posterior aspect of the stent graft. This is to achieve a space between the graft and the aortic wall and to alleviate catheterization of the fenestrations and target vessels. After successful target vessel catheterization and sheath placement, the graft is released and tracks over the sheaths to oppose the aortic wall. Thus, any fenestration that is not secured by sheath access runs the risk of misaligning after deployment. Whereas the positioning of the target vessel craniocaudally within an unstented fenestration is often easy to determine, a rotational misalignment is hard to visualize and detect. A discrete misalignment intraoperatively may lead to partial covering of the target vessel (shuttering), reducing flow, and subsequently leading to an occlusion. We have now adopted a policy of liberal use of stents in deep scallops for the SMA. Fenestrations are always stented. If the planning identifies a high risk of SMA compromise, a safety wire is placed through a brachial approach leaving the option to stent the SMA after deployment, should this be necessary.

One concern regarding fenestrated stent graft is the potential effect on renal function. This has been well described by the group at the Cleveland Clinic and they noted some effect on renal function in about a fifth of their patients postoperatively.[7,9,22] Reports on conventional EVAR also report a deterioration in renal function after EVAR regardless of whether bare fixation stents across the renal arteries are used or not.[23-25] It is well known after open repair that renal function is affected negatively in the immediate postoperative period in a large number of patients. Series that have compared open and endovascular repair report conflicting results, most likely due to selection bias. Renal status is also negatively correlated to longer time and more proximal clamp positioning.[26,27] Logically the same phenomenon is seen after EVAR. In this series, 30% of patients had transient creatinine increase postoperatively but only 16% of these had permanent increase in creatinine, which was still within normal limits. No patient required dialysis. In a small number of patients, renal function deteriorated during follow-up without signs of renal artery stenosis. This might very well be the result of natural progression of disease in these patients.

Like most endovascular treatments, f-EVAR has the appeal of the minimally invasive approach and data until now seem to confirm that this technology works in the short- to midterm. Obviously further long-term follow-up is needed and the ultimate answer to find the right treatment for these patients depends on continued close observation and technological development. To be able to achieve good results with this technology, however, certain prerequisites must be met: (1) the quality of the preoperative imaging needs to be significantly better than for standard EVAR or open repair, including appropriate 3D imaging capabilities. The importance of good preoperative graft planning cannot be emphasized enough. (2) Even though the skills required for fenestrated endografting are no different from other complex endovascular interventions, these procedures require a wider range of endovascular tools than standard EVAR and, in most cases, also intraoperative imaging of higher standard than most mobile C-arms can offer. (3) The volume of patients that qualify for f-EVAR might be in the range of 10-20% of a total standard AAA practice. Thus the numbers will, in most centers, be fairly low and this might affect results negatively.

Certain patient characteristics should be identified as they might increase the difficulty of the procedure. In our experience, the presence of much angulated necks, very tortuous, narrow or calcified iliacs, and especially any combination of these features increases the difficulty substantially. The reason is that stent graft orientation during the procedure is crucial and these features severely inhibit stent graft manipulation within the aorta. If one or several of these features are present, other treatment options should be considered and fenestrated endografting should only be undertaken by very experienced operators.

CONCLUSION

f-EVAR is a procedure with good short- and midterm results that offer a valid treatment alternative to patients unsuitable for standard EVAR or open repair. Further development of procedure specific devices, improved preoperative planning, and better understanding of the stent graft to native aorta interaction might improve results in the future.

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AUTHOR CONTRIBUTIONS

Conception and design: TK, BS, TR
Analysis and interpretation: TK, MM, BS, KB, ND, TR
Data collection: TK
Writing the article: TK, TR
Critical revision of the article: TK, MM, BS, KB, ND, TR
Final approval of the article: TK, MM, BS, KB, ND, TR
Statistical analysis: TK, KB, TR
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DISCUSSION

Dr Hasan Dosluoglu (*Buffalo, NY*). In light of the previous paper, it will be interesting to see what percent of your patients were in the high-risk category. So could you please break down those who were physiologically high risk vs those who weren't? What was your mortality in each group? I understand that it was 20% for the entire cohort. Was there a difference between groups and could you identify a subgroup that you, in retrospect, would have preferred not to have done anything?

Dr Thorarinn Kristmundsson. The definition of high risk is a little bit complicated, but that's a definition by the surgeon and the anesthesiologist. Many of these patients have had previous aortic surgery or severe comorbidities and the need for suprarenal clamping was also considered high risk. We haven't done any subgroup analysis to identify risk factors.

Dr Peter Gloviczki (*Rochester, Minn*). Your group should be congratulated for pushing the envelope and developing this procedure in patients who are really high risk or unfit for surgery repair.

My question is somewhat related to the previous one, because you said that these were all high-risk patients or unfit for surgery. Dr West, from our group, reported in 2006 in the Journal of Vascular Surgery about his 10 year Mayo Clinic experience with 247 patients with a perioperative mortality of 2.8% who had supraceliac clamping and required aortic aneurysm repair because of juxtarenal and suprarenal aneurysms. So there are quite a large number of patients who can undergo open surgery with a very decent mortality.

So I am wondering, when you take all your patients with this anatomy, how many of those did you do open, and how many did you do endo, during this period of time? If you could please give us guidelines on who are the patients suitable for your procedure and if the technology is there to do endovascular repair in good risk patients?

Dr Kristmundsson. During this period of time, we did about 50 patients with an open approach at our clinic. I want to congratulate you on these excellent results that you have at the Mayo Clinic. In our clinic, when we do open surgery with suprarenal clamping of patients that are anatomically unfit for conventional EVAR or infrarenal clamping, we have a mortality of about 10% to 15% in the first 30 days of the procedure. So it's a high risk.

Dr Gloviczki. The operation alone is high risk?

Dr Kristmundsson. Yes.

Dr Timothy Resch. Again, we've published the data from Malmö on our patients. And if you look at standard infrarenal repairs, the results are excellent for the open group with 0% mortality.

But as Dr Kristmundsson pointed out, if you look at the patient cohort included here, and I think that was why we went to this endeavor of doing fenestrated endografts with patients that had physiological high-risk criteria: renal or congestive heart failure, other complicating factors, or the mere risk of having a supraceliac clamp, we were, quite frankly, abhorred with our own experience. We would have liked to send most of our patients to the Mayo Clinic. Unfortunately, it's a fairly long trip. So in light of that, we've used the fenestrated endografts for most of those patients and we think they're doing reasonably well.

Dr Luiz Lanziotti (*Rio de Janeiro, Brazil*). We've been involved with fenestrated endografts for juxtarenal AAA, as well as branched endografts for thoracoabdominal aneurysm in Rio, and I noticed you had three SMA occlusions. One of the worries we have in our series is regarding visceral ischemia after stenting. Have you identified any possible technical issues that might have caused these occlusions? Regarding clinical outcomes on these patients, how have you identified them and did these patients have previous inferior mesenteric or celiac artery occlusion as well? Did that influence? What are your insights on that?

Dr Kristmundsson. I think that the main problem is that when you place the scallop for the SMA, there is a risk for a rotational misalignment. So you can get a portion of the fabric that lies over the ostia. And that has been reported by other groups as well. So what we do now is we use a liberal use of stents in deep scallops for the SMAs, and we tried to avoid this problem that way.

These patients that had SMA occlusions were asymptomatic, and we found them during routine follow-up at 1 year and 6 months.

Dr Lanziotti. So were any of those stented patients or all three SMA occlusions were scallop-related?

Dr Kristmundsson. All three were from scallops and all three were unstented.

Dr Resch. When we use covered stent, we use Atrium Adventa, and for the renal stents we use the Bridge Assurant, but you can use various kinds of stents.

For the SMA, the issue becomes a little bit trickier, as I'm sure others will mention, because of the sharp angle take-off, especially if you're going for the SMA from below. You'll have a very poor angle of approach and you run a fairly high risk of causing a dissection distally in the SMA when you do the procedure, so whether to use the self-expanding or balloon-expandable stent remains to be proven.

Dr Timothy Chuter (*San Francisco, Calif*). To clarify the point about selection of high-risk patients. I was fortunate enough to have the opportunity to see the paper on which this presentation was based. One of the things I noted was that 47 patients underwent open repair with suprarenal clamps during the period of this study, which indicates that roughly half the patients who required a suprarenal clamp underwent endovascular procedures and roughly half underwent open surgical procedures. Assuming that the primary triage criterion between open and endovascular treatment was anesthetic risk, the endovascular group truly were high-risk.

This series covered a long period of time and the insertion of a fenestrated stent graft can be a complex operation. I suspect that your skills evolved during that time. Did you notice any difference between early results and late results?

Dr Kristmundsson. During the time of the study, the first year, we only did 1 patient with one fenestration. The cases are getting more and more complicated every year, as we see as the average number of fenestrations in 2007 is 3.1 per patient. In addition, the patients are getting older and sicker. However, we didn't do any subanalysis on the outcomes between the different time periods.