Fenestrated and Branched Stent-grafting After Previous Surgery Provides a Good Alternative to Open Redo Surgery

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Objective. To present our experience using fenestrated and branched endoluminal grafts for Para-anastomotic aneurysms (PAA) following prior open aneurysm surgery, and after previous endovascular aneurysm repair (EVAR) complicated by proximal type I endoleak.
Methods. Fenestrated and/or branched EVAR was performed on eleven patients. Indications included proximal type I endoleak after EVAR and short infrarenal neck (n = 4), suprarenal aneurysm after open AAA (n = 4), distal type I endoleak after endovascular TAA (n = 1), proximal anastomotic aneurysm after open AAA (n = 1), and an aborted open AAA repair due to bleeding around a short infrarenal neck.
Results. The operative target vessel success rate was 100% (28/28) with aneurysm exclusion in all patients. Mean hospital stay was 6.0 days (range 2–12 days, SD 3.5 days). Thirty day mortality was 0%. All cause mortality during 18 months mean follow-up (range 5–44 months, SD 16.7 months) was 18% (2/11) with no deaths from aneurysm rupture. Cumulative visceral branch patency was 96% (27/28) at 42 months. Average renal function remained unchanged during the follow-up period.
Conclusions. Our report highlights the potential of fenestrated and branched technology to improve re-operative aortic surgical outcomes. The unique difficulties of increased graft on graft friction hindering placement, short working distance, and increased patient co-morbidities should be recognized.

Keywords: Fenestrated; Branched; Juxtarenal; Suprarenal; Fenestrated endograft; Branched endograft; EVAR; Aneurysm; Abdominal aortic aneurysm; Salvage surgery; Open aneurysm repair; Open surgery.

Introduction

Long-term proximal complications following endovascular aneurysm repair (EVAR) and open infrarenal abdominal aortic aneurysm (AAA) repair has been reported in the literature to range from 2.4 to 5.2%.[1–5] These complications include true juxta-anastomotic aneurysms and pseudo-aneurysms following open repair and type I endoleaks following EVAR.[3,5,6] Left untreated, these problems carry a significant risk of rupture and thereafter little opportunity for survival.[4]

Traditional open surgical repair, the historical mainstay of treatment, is difficult. In one large series reporting on open repair of proximal anastomotic failure following open infrarenal AAA repair, renal artery re-implantation or bypass was required in 45% with significant surgical morbidity in 27%.[1] In another series of patients with para-anastomotic aneurysms (PAA), emergency repair resulted in a 24% mortality, repair after rupture in 67% mortality, and elective repair carried an 11% mortality.[7]

Endovascular repair has been proposed as an alternative in properly selected patients with PAA as a means to reduce the relatively poor results following open repair.[8–11] In one series endovascular treatment reduced mortality to 3.6% and significant morbidity to 14.2%.[12] However, the long-term durability of endografts placed within a prior surgical prosthesis has been questioned.[11] In one series, tube grafts placed for the treatment of PAA required later revision in most of the cases.[11]

Endovascular repair of type I endoleaks are common, but often the anatomic limitation that resulted in failure of the initial endograft prevents successful

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standard treatment with the placement of an endovascular cuff or a new device. A juxta-renal aortic complications following EVAR or open surgery cannot be treated with standard endovascular grafts.

Fenestrated and branched techniques have been applied to this subset of patients who have not undergone prior surgery with good technical and short-term results.[13–16] Recently, there has been a technical report utilizing fenestrated and branched techniques to increase the percentage of patients with PAAs after open surgery who could be offered an endovascular treatment option.[17] This report presents our experience using fenestrated and branched endovascular stent-grafts both for the treatment of PAA following prior aneurysm repair by open surgery, and also after previous endovascular repair complicated by type I endoleaks.

Materials, Methods, and Patients

Eleven patients who had undergone previous aneurysm surgery were enrolled in a single institution investigational device protocol database between March 2002 and September 2005. Informed consent was obtained from all patients. Indications for fenestrated or branched EVAR included unfavorable anatomy for traditional endovascular repair, a PAA with maximum diameter of ≥ 5 or 5.5 cm in women and men respectively, or a persistent type I proximal endoleak. Traditional endovascular repair, including placement of a standard endovascular cuff or additional Palmaz stent, was deemed unlikely to result in a durable solution according to a multidisciplinary patient evaluation. Imaging evaluation included thin cut (<3 mm) spiral computerized tomography angiography (CTA) with axial and coronal reconstructions to evaluate anatomy and contrast angiography when deemed necessary for additional anatomic information.

Customized stent-grafts were either fenestrated or branched and based on the Zenith system (William A. Cook Australia., Ltd., Brisbane, Australia) as described previously.[16] Three types of customizable options were utilized: scallops, small fenestrations (6 mm in diameter), and branch sites (pre-made or a fenestration with a stent-graft inserted). Radio-opaque markers identified fenestrations and branch sites to enable accurate alignment. Anterior and posterior markers facilitated rotational orientation during insertion and deployment. Grafts were fitted with diameter reducing ties that allowed for only partial deployment (in terms of diameter) prior to catheterization of side vessels which allowed for small changes in orientation (and positioning) to facilitate proper placement.

Fenestrated and/or branched EVAR proceeded in the operating theatre under general, epidural, or local anesthesia based upon surgeon, anesthesiologist, and patient preference. Patients were pre-hydrated with intravenous solution prior to the procedure and urine output was monitored. Imaging was performed using a mobile C-arm (OEC 9800, General Electric Medical Systems, Salt Lake City, UT, USA). The technique for endograft deployment has been previously described.[13,15] Briefly, the stent-graft was positioned, then deployed but still constrained by the diameter reducing ties, catheterization of the visceral vessels performed, the reducing ties removed, the top cap opened followed by deployment of stents or grafts inside the target vessels. Completion angiography was then performed.

Post-operative evaluation consisted of clinical and laboratory assessment at discharge, 1 month, 6 months, 12 months, and annually thereafter. Helical CTA, duplex evaluation, and abdominal X-rays were performed at 1 month, 6 months, 12 months, and annually thereafter. Contrast angiography was performed for suspected type I endoleak and/or visceral vessel impairment with any required secondary intervention performed at the time of angiography.

Results

The patients included in the study all presented with co-morbidities which placed them at high risk for an open repair. Nine out of the eleven patients were classified as ASA Class III or IV. Indications for fenestrated or branched EVAR procedures included proximal type I endoleak after prior EVAR with a short infrarenal neck (fenestrated, $n = 4$) (Fig. 1), suprarenal aneurysm extension after open infrarenal AAA repair (branched, $n = 4$) (Fig. 2), a distal type I endoleak after prior endovascular TAA repair and less than 10 mm between the distal endograft and the coeliac axis (fenestrated, $n = 1$) (Fig. 3), a proximal anastomotic aneurysm after previous open AAA repair (fenestrated, $n = 1$), and finally one patient who had his open repair aborted due to inflammation and bleeding around a short infrarenal neck (fenestrated, $n = 1$).

Eleven patients (9 men, 2 women) were treated from March 2002 until September 2005 at a single academic institution with expertise in fenestrated and branched procedures (Table 1).

Operative results

Endovascular access was obtained via the common femoral arteries. One patient underwent a planned

Fig. 1. Angiogram demonstrating a large proximal type I endoleak after prior EVAR with a short infrarenal neck.
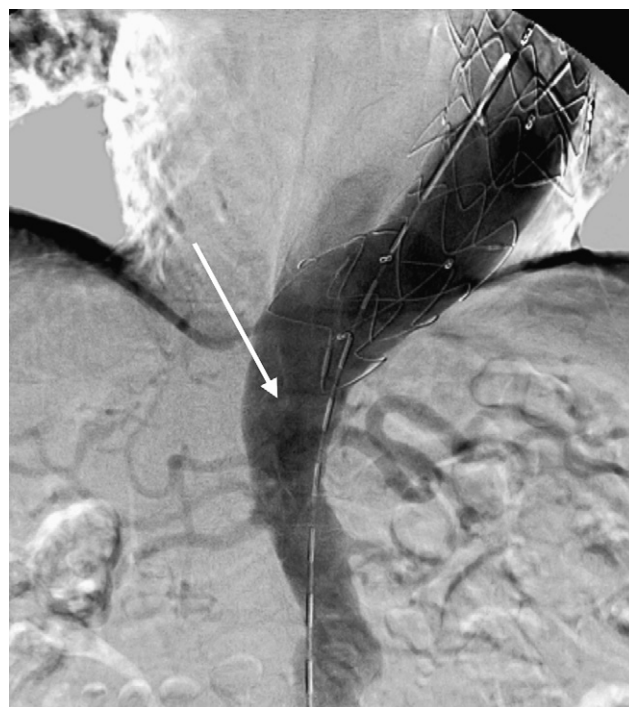

Fig. 3. Angiogram demonstrating a distal type I endoleak after prior endovascular TAA repair and less than 10 mm between the distal endograft and the celiac axis precluding proper sealing with a standard non-fenestrated endovascular extension. The celiac axis is identified by the arrow.

Fig. 2. Contrast CT scan demonstrating suprarenal aneurysm extension ten years after open infrarenal AAA repair with a bifurcated prosthesis. The patient represented by this CT scan has only one patent renal artery (right). Although not evident in this image, the SMA is also thrombosed.

Table 1. Prior surgery, post-operative problem, endovascular solution, and number of branch vessels involved are listed for all patients included in this series

Patient	Prior surgery	Post-op problem	Endo solution	Vessels involved
1	Aorto-bifem	Suprarenal extension	Branched device	2
2	Endo TAA	Distal type I endoleak	Fenestrated device	1
3	Endo AAA	Prox type I endoleak	Fenestrated device	3
4	Endo AAA	Prox type I endoleak	Fenestrated device	1
5	Endo AAA	Prox type I endoleak	Fenestrated device	2
6	Endo AAA	Prox type I endoleak	Fenestrated device	3
7	Aorto-bifem	Suprarenal extension	Branched device	3
8	Aorto-bifem	Suprarenal extension	Branched device	4
9	Open tube AAA	Suprarenal extension	Branched device	3
10	Aortic tube	Anastomotic aneurysm	Fenestrated device	3
11	Open surgery (aborted)	–	Fenestrated device	3

laparotomy for left renal artery endovascular access. In this particular patient the origin of both renal arteries was difficult to access (angulation; lifted by the aneurysm). We were unable to catheterize the left renal artery. Therefore we performed a laparotomy and accessed the renal artery by puncture and catheterized the fenestration in a retrograde manner. The mean procedure time was 243 min. (range 110–420 min., SD 117 min.), and the mean blood loss was 889 ml (range 200–1500 ml, SD 635 ml). The mean fluoroscopy time was 40 min. (range 5–88 min., SD 28 min.) and 198 ml of iodinated contrast was used per procedure (range 100–400 ml, SD 85 ml). Branched endografts were defined as either a premade branched device ($n = 1$) or an endograft in which covered stent-grafts (Jomed International AB, Helsingborg, Sweden; Atrium, Hudson, NH, USA) were placed through the fenestrations creating a branched endograft ($n = 3$). Twenty-eight branch visceral vessels were cannulated successfully. The overall operative target vessels success rate was 100% (28/28).

All endovascular procedures were considered initially successful defined by successful perfusion of the target branch vessels. One patient had the endograft placed a little low, but the aneurysm was successfully excluded, with well perfused side vessels. Completion angiography demonstrated successful sealing with aneurysm exclusion in all patients. In one patient a type II endoleak was diagnosed which was not treated at the time of the initial intervention. There were no type I, III, or IV endoleaks observed.

Three intra-operative complications were noted: in one patient repositioning of the graft proved very difficult and we had to force the graft down a few cm inside a previous surgical graft, but crushed the lower two stents of the tube. This required a bridging body extension to achieve sealing between the tubular first part and the bifurcated second part. In a second patient, after previous stentgrafting, insertion of the contralateral limb of the fenestrated graft dislocated the old Vanguard limb, which required a bridging stentgraft to seal distally. In a third patient, the insertion of the contralateral limb proved difficult and finally dislocated a stent inside the right renal artery. This stent had to be recovered and a new one had to be repositioned.

Perioperative results

No patient died during the operation. Mean hospital stay was 6.0 days (range 2–12 days, SD 3.5 days). Thirty day mortality was 0%. Perioperative morbidity included a significant retroperitoneal bleed which did not require surgical intervention, one patient developed urinary retention requiring a urinary catheter for 48 hours, and one patient experienced lower extremity paralysis after the procedure. The patient who experienced paralysis underwent a branched endovascular repair for the treatment of a suprarenal extension after open infrarenal AAA repair. The branched device contained a full branch for the right renal artery and a small fenestration fitted with a covered stent for the celiac trunk. The SMA and the left renal artery were chronically occluded. On the first post-operative day, the patient experienced lower extremity paralysis. A lumbar drain was placed and the symptoms resolved over the next three days. The neurologist who followed the patient during admission concluded that there was a slight muscular weakness at discharge. At out-patient follow-up, the patient had regained normal muscle strength. However this was not confirmed by neurological investigation.

Follow-up

The mean follow-up was 18 months (range 5–44 months, SD 16.7 months) with no patients lost to follow-up. All cause mortality was 18% (2/11) with no deaths from aneurysm rupture. The two patients who died both suffered a myocardial infarction, respectively 9 and 42 months after their fenestrated endovascular surgery. Analyzed on an intention to treat basis, cumulative visceral branch patency was 96% (27/28) at 42 months. In our early experience with fenestrated stent-grafting one unstented renal artery scallop occluded within six months.

One patient experienced mesenteric ischemia and was found to have a kinked stent-graft in the coeliac artery (Fig. 4). This patient's symptoms included abdominal pain following meals. Angiography confirmed a significant stenosis of the coeliac trunk and the presence of a kink between two short side stentgrafts. At the primary procedure, we positioned two short covered stents inside the coeliac trunk, but they started tilting and created a kink. Due to the fact that the coeliac artery was the patient's only mesenteric vessel, the patient developed symptomatic mesenteric ischemia. He was successfully treated with interventional retrieval of the most proximal covered stent and placement of a new, longer covered stent (Atrium) (Fig. 4). Following this intervention, the patient remained asymptomatic. A second patient was converted to open surgery after 6 months. In this patient, a three-branch graft was never positioned correctly to begin with: the final position of the graft ended too low and tilted to the right. CTA showed a crushed stent in the superior
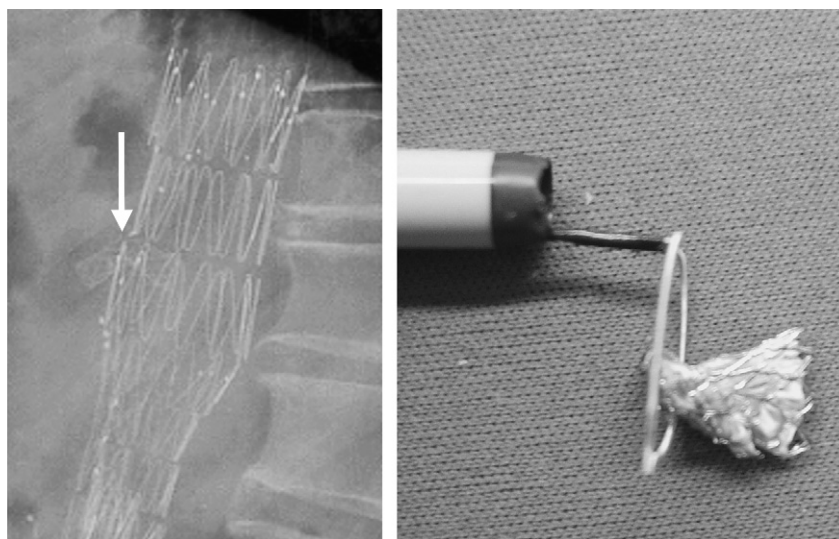
Fig. 4. A. Post-operative (6 month) fluoroscopic view of the branched endograft in a patient who experienced mesenteric ischemia and was found to have a kinked stent-graft in the celiac artery (arrow). B. He was successfully treated with interventional retrieval of the most proximal covered stent and placement of a new, longer covered stent. This image shows the proximal covered stent after it was retrieved by snare and removed from the patient.

mesenteric artery. We elected to convert him to open repair. He recovered well from this procedure. Finally, one patient underwent open lumbar artery clipping for a persistent type II endoleak with an enlarging aneurysm sac.

Mean serum creatinine remained unchanged during the follow-up period. No patient required dialysis. Except for the patient with the renal artery occlusion (creatinine rising from 84 to 114), no patient experienced a decline in renal function (increase in creatinine of more than 30%). Limb perfusion as assessed by the ankle-brachial index was not affected by the presence of a fenestrated or branched endograft.

Discussion

Re-operative aortic surgery is difficult with substantially increased morbidity and mortality when compared to operating on primary aortic aneurysms. Early reports on PAA have recommended an endovascular approach to these patients in an effort to improve quality of life and survival. Patients requiring re-operative aortic surgery, whether after EVAR or open surgery, are often older with more co-morbidities than patients presenting with their first aortic aneurysms. In our series, most of the patients were deemed unfit for open surgical repair. In these high risk patients, re-operative fenestrated and branched salvage procedures are often the only realistic chance for successful aneurysm exclusion and subsequent long-term survival.

Operative difficulties

Inadequate working distance (i.e. length from renal arteries to neo-bifurcation) in re-operative endovascular surgery increases the complexity of many procedures and requires imagination and flexibility in the design and deployment of these devices. Indeed, previously inserted surgical grafts or endovascular grafts usually present with a rather short body and long limbs. This problem is illustrated in the patient shown in Fig. 2. The patient developed a suprarenal aneurysm ten years after an open surgical infrarenal repair; there was very little working distance in which to place a composite device (i.e. standard three part fenestrated graft). This case was further complicated by the previous open repair in which the left renal artery and SMA were both lost. In summary the aneurysm had a short working distance from the renal arteries to the bifurcation of the previously implanted aortic prosthesis, two of four visceral vessels were already occluded, and he was facing a very difficult re-operative open procedure. The branched endovascular solution included a single premade device with a fenestration for the coeliac artery, a branch for the solitary right renal artery, and a contralateral iliac limb with the gate positioned inside the body instead of outside (Fig. 5). The use of double diameter-reducing ties improved maneuverability and allowed the device to be placed within the confines of the short working distance.

Besides the length issue, repositioning of the graft can prove very difficult due to previous surgical or
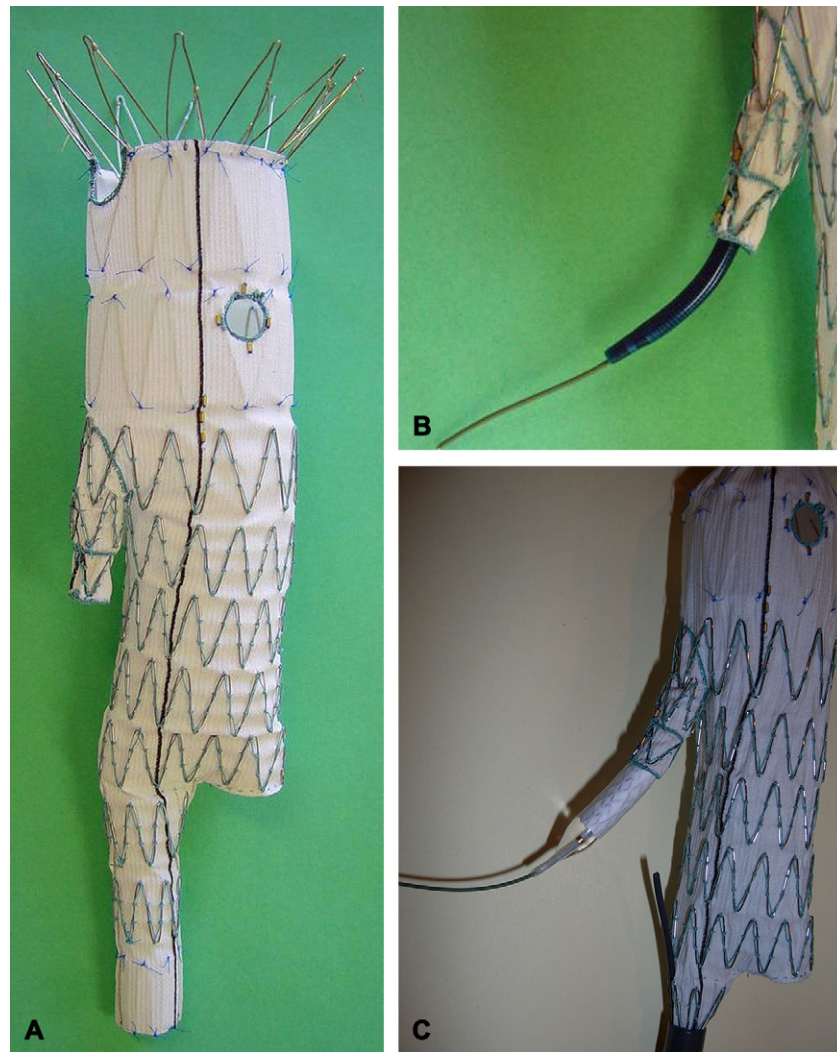
Fig. 5. A. Photograph demonstrating a branched endovascular solution consisting of a single premade device with a fenestration for the celiac artery, a branch for the solitary right renal artery, and a contralateral iliac limb with the gate positioned inside the body instead of outside. B. A guidewire and guiding sheath have been placed through the branch destined for the solitary right renal artery. C. A covered stentgraft has been deployed in the right renal artery branch, extending the sealing zone. The endograft has been partially deployed in this photograph. The contralateral gate is open, but the endograft continues to be attached to the main delivery system.

endovascular grafts. Friction with the open fenestrated graft and smaller access can create difficulties, as experienced in 5 out the 11 patients. In three of them the problem was solved without too many difficulties, but in one patient, we had to force down a graft that was positioned about 2 cm too high. This resulted in damaging the lowest two stents of the fenestrated tube and probably the fabric. After insertion of the second bifurcated part, we used a bridging body extension to seal the overlap zone securely. In the last patient, the removal of the sheath after introduction of the third part (i.e. the contralateral limb) displaced an old Vanguard limb distally. This was easily solved by using an extra bridging extension (Hemobahn, W.L. Gore, U.S.A.).

A general problem with fenestrated stentgrafting, not only after previous surgery, is the risk of displacing a stent inside the renal arteries with the introduction of the contralateral limb. This happened once in this patient group, and was solved by retrieving the covered stent (Jomed International AB, Helsingborg, Sweden) and leaving it in the aneurysm sac, and replacing it.

It is clear that these techniques are not easy and require good preparation and execution, as well as sufficient back-up material present, to solve intraoperative complications.

Late re-interventions

Three patients in this series required a secondary procedure. This included the patient with a kinked stent-graft in the coeliac artery which was detailed above. The secondary procedure was an endovascular one to removed the kinked stent-graft and place a new, longer one. The second patient underwent a laparotomy for a persistent type II endoleak in the setting of an enlarging aneurysm sac. The final patient underwent open conversion six months after the fenestrated repair. The conversion was regarded necessary in view of the poor initial placement of the fenestrated graft. In retrospect this stent-graft was positioned too low and also tilted to the right, with resultant severe angulation. This resulted in an acute renal stent-graft takeoff to the left renal artery, and kinking of the stent-graft in the SMA with secondary severe stenosis. The reason for the malpositioning was probably an error in conception: instead of using a three-branch graft with a scallop for the coeliac trunk, we should have used a four-branch graft therefore achieving a better seal proximally (and somewhat higher).

Conclusion

Fenestrated and branched endografts may provide an alternative to open surgical repair for the treatment of difficult re-operative aortic aneurysms. This series on the technical and early results support their continued investigational use as a salvage procedure for secondary aneurysms following previous surgical repair. The unique difficulties of increased graft on graft friction hindering maneuverability, short working distance, and increased patient co-morbidities should be recognized. Our report highlights the potential of fenestrated and branched technology to improve re-operative aortic surgical outcomes.

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