Beyond Standard EVAR

With the progressive nature of aortic disease, fenestrated EVAR might be the best option for treating infrarenal AAAs with marginal short necks.

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The fundamental tenet of successful long-term endovascular aortic aneurysm repair (EVAR) is adequate proximal and distal fixation and seal. Because aortic aneurysmal disease is progressive in nature, compromising the initial repair in patients with a marginal neck can lead to secondary interventions and eventual failure. Fenestrated EVAR is a less-invasive alternative to open repair that improves proximal fixation by raising the proximal neck to the normal suprarenal and paravisceral aorta.

BACKGROUND

To understand the benefits of fenestrated EVAR, it is key to identify patients at risk of failure after standard EVAR. With infrarenal abdominal aortic aneurysms (AAAs), the proximal neck is the most common site of endovascular repair failure. The length, diameter, and angulation of the proximal neck, as well as the presence of a reverse taper, all influence proximal fixation.[1] An inadequate proximal neck hinders EVAR in up to 40% of patients with infrarenal AAAs.[2] Advances in device designs and techniques have not improved the outcomes of EVAR for marginal necks. In a study by Moise et al, anatomical barriers to EVAR were investigated during two time periods, before and after the year 2000. Interestingly, even with the progress in EVAR technology and some progress in dealing with anatomical factors such as arterial access, an inadequate proximal neck remained the main exclusion criterion for EVAR during both time periods.[3]

Many adjuncts have been introduced to improve fixation in unfavorable necks. Active fixation prevents migration and is available in the majority of the currently approved devices. Suprarenal fixation extends the site of actual fixation to an area above the renal arteries where the aorta may be healthier. Sealing, however, still occurs in the infrarenal aorta. Although intuitive, suprarenal fixation has not consistently been effective in limiting migration compared to infrarenal devices.[4]

Appropriate positioning of the C-arm with craniocaudal and lateral projections may remove parallax and allows deployment of the covered portion of the device just below the renal arteries. This, in theory, may optimize fixation and seal throughout the entire length of a marginal neck. The use of repositionable endografts may allow a few attempts to optimize deployment and utilize all of the available neck below the renal vessels. Although these adjuncts may temporarily aid in achieving proximal fixation, they cannot prevent future aortic degenerative changes, which are frequently seen after aneurysm repair where there are unfavorable aortic necks.

EVAR AND THE INSTRUCTIONS FOR USE

In an attempt to identify and standardize guidelines for patients at risk for EVAR failure, the Ad Hoc Committee of Standardized Reporting Practices for the Society for Vascular Surgery defined a marginal neck as having a length < 15 mm, diameter > 28 mm, angle > 60°, and presence of significant calcification or thrombus.[5] These guidelines predominantly coincide with the instructions for use (IFU) for the majority of EVAR devices. The Zenith Flex device (Cook Medical, Bloomington, IN) requires a neck size of 18 to 32 mm with a length ≥ 15 mm, ≤ 60° neck angle, and iliac diameter of 10 to 20 mm for a length ≥ 15 mm.

The Endurant stent graft (Medtronic, Inc., Minneapolis, MN) requires a neck size of 19 to 32 mm and is the only device that requires a length ≥ 10 mm, ≤ 60° neck angle, and iliac diameter of 8 to 25 mm for a length ≥ 10 mm. The Excluder device (Gore & Associates, Flagstaff, AZ) requires a proximal neck of 19 to 32 mm in neck size with a length ≥ 15 mm, ≤ 60° neck angle, and iliac diameter of 10 to 27 mm for a length ≥ 15 mm. The Ovation (TriVascular, Inc., Santa Rosa, CA) and Powerlink (Endologix, Inc., Irvine, CA) devices have similar requirements in their IFUs. The Aorfix device (Lombard Medical Technologies, Oxfordshire, UK) was recently approved by the US Food and Drug Administration (FDA) and allows treatment of angulated necks up to 60°; in Europe, angulated necks up to 90° can be treated.

If devices are used according to IFU criteria, results are generally excellent and comparable between devices, with < 1% type IA endoleaks. However, a large number of patients who undergo standard EVAR have anatomies that are outside the IFU. Schanzer et al[6] demonstrated the
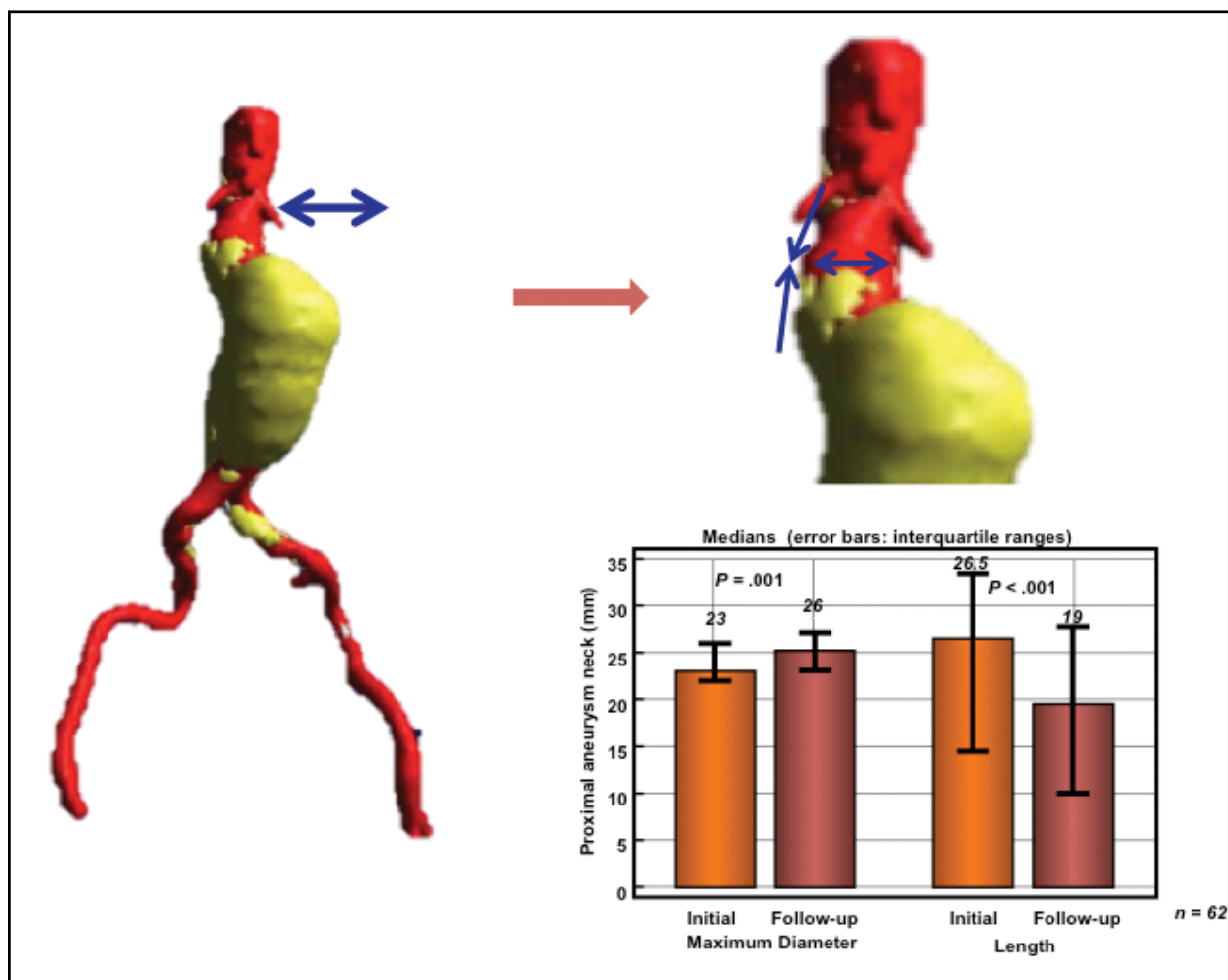
Figure 1. Significant neck changes were observed during surveillance in aortic neck length and diameter during mid- and long-term follow-up.

frequent use of EVAR outside the IFU in 10,228 patients undergoing EVAR. Patients were separated into either a conservative (neck length > 15 mm, neck size < 28 mm, and angle < 45°) or liberal (neck length > 10 mm, neck size < 32 mm, and angle < 60°) group. Interestingly, in the entire cohort, 58.5% of all patients were outside the conservative group requirements, and 31.1% were additionally outside the liberal group requirements.

The primary outcome was measured as sac enlargement > 5 mm within 5 years, and for the entire cohort, that rate was a staggering 40.9%. Significant sac enlargement was observed in 39% of patients in the conservative group, 40.9% in the liberal group, and 43% in those outside both groups ($P < .001$). Of note, 60% of the AAAs were smaller than 55 mm preoperatively. Predictors of sac enlargement included endoleak, age 80 years or older, aortic neck diameter ≥ 28 mm, aortic

neck angle > 60°, and common iliac diameter > 20 mm.[6] These findings are echoed in multiple studies that reveal increased rates of type I endoleak, reinterventions, and decreased freedom from graft-related adverse events in those with proximal neck criteria outside the IFU.[7-11]

As experience with EVAR has increased, surgeons are treating increasingly complex aneurysms with devices that were never tested nor designed for such adverse anatomy. In addition to marginal neck characteristics, the progressive nature of aortic disease leaves these patients at high risk for failure.

CHANGES IN THE AORTIC NECK AS EVIDENCE OF PROXIMAL DISEASE PROGRESSION

Aortic aneurysmal disease is a truly progressive disease. Prior to intervention, there is evidence of changes in the

Figure 2. The Zenith Fenestrated endovascular AAA graft (Cook Medical) was approved for use in the US by the FDA in April 2012.

Figure 3. The Zenith p-Branch device (Cook Medical) is an off-the-shelf fenestrated device that is under investigation for endovascular repair of juxtarenal AAAs.

proximal aortic neck with aneurysm growth. Wellborn et al found that the increasing diameter of an aneurysm is associated with a loss of suitability for EVAR. More than 80% of patients with 3- to 4-cm aneurysms were EVAR candidates, which dropped to 60% to 62% for 4- to 6-cm aneurysms, 46% for 6- to 7-cm aneurysms, and 21% of those larger than 7 cm.[12] In a follow-up study in patients with aneurysms from 4 to 5.4 cm, a significant increase in median neck diameter and decrease in median neck length were observed during 2 years of follow-up, although there was no major loss of suitability for EVAR.[13] This study, however, did not focus on those with marginal neck characteristics (length < 15 mm and diameter > 28 mm) and only followed patients for 2 years. A later study with longer follow-up of patients with marginal neck characteristics revealed a significant decrease in median neck length, increase in median neck size, and a loss of suitability for EVAR (Figure 1).[14]

Changes in the aortic neck do not only occur prior to repair. It is well documented that the aortic neck dilates after endograft placement, which is thought to be in part related to the oversizing often associated with repair.

Besides preoperative marginal neck characteristics, disease progression is another likely cause and contributes to the failure of endograft repairs. Ouriel et al compared outcomes of EVAR for smaller (< 5.5 cm) versus larger aneurysms (> 5.5 cm). A higher rate of type I endoleak, migration, conversion to open procedures, and lower patient survival was evident in the larger aneurysm group.[15] In a substudy of the EVAR trial cohorts, an increase in the aortic neck diameter was greater after EVAR compared to open repair at 2 years.[16] Additionally, that progression of disease and neck enlargement has been seen after EVAR with both infrarenal and suprarenal fixation.[17] Given the evidence of progression of aortic disease, patients with marginal neck characteristics are at particularly high risk for loss of fixation and likely require a treatment that avoids sealing and fixation in the diseased neck altogether.

CURRENT STATUS OF FENESTRATED ENDOGRAFTS IN THE US

In April 2012, approval for the Zenith Fenestrated device was received from the FDA (Figure 2). Outside

of the initial clinical trial[18] and investigational device exemptions, experience with fenestrated endografts originated outside the US. In fact, the Zenith Fenestrated endograft has been used extensively worldwide, with excellent midterm results.[19-21] In three large European studies, a total of 552 patients underwent fenestrated EVAR, the vast majority for short-necked and juxtarenal aneurysms. All cases were elective in asymptomatic patients. Cumulative technical success was 99%, between the three studies, for 986 of 996 fenestrations. Intraoperative conversion to open repair was needed in two patients (0.4%) due to an inability to remove the top cap and distal aortic occlusion. Thirty-day mortality was 2.9%. No deaths were noted in patient follow-up to be aneurysm related. The UK GLOBALSTAR registry showed survival rates of 94%, 91%, and 89% at 1, 2, and 3 years, respectively.[20] Verhoeven et al reported survival rates of 90.3%, 84.4%, and 58.5% at 1, 2, and 5 years, respectively, and visceral vessel patency of 93.3% at 5 years.[21]

In the data reported from the US multicenter trial with the Zenith Fenestrated endograft, 30 patients were followed for 24 months. Seventy-seven visceral vessels were fenestrated, with 100% technical success. During the 2-year follow-up, no aneurysm-related deaths, aneurysm ruptures, or conversions were noted. Additionally, no type I or III endoleaks were observed. Aneurysm size decreased in 16 of 23 patients who were followed to 24 months (69.6%), was stable in seven patients (30.4%), and there were no patients who underwent aneurysm growth > 5 mm. Eight patients were identified to have renal events, five requiring reintervention; however, none required dialysis.[18]

Based on European and early US experience with fenestrated EVAR, it is clear that improved outcomes are achieved in patients with marginal short necks. The Zenith Fenestrated device is currently approved by the FDA for juxtarenal aneurysms with proximal neck lengths between 4 to 14 mm. Fenestrated EVAR, therefore, allows endovascular repair for many AAAs that do not meet standard EVAR criteria according to the IFU. As with standard EVAR, optimal fixation and seal is mandatory in normal proximal aorta, which, in fenestrated EVAR, can extend well above the level of the renal arteries.

The customizable graft may actually allow seal up to the level of the superior mesenteric artery (SMA) with either a scallop or fenestration. Customization usually requires planning and manufacturing of devices specific for each patient's anatomy, which takes several weeks. Such a delay may not be acceptable in patients with symptomatic or very large aneurysms. The need for off-the-shelf fenestrated devices is self-evident. The Zenith p-Branch is an off-the-shelf device that is currently under investigation (Figure 3).[22] This device allows endovascular repair of an aneurysm that extends to the level of the SMA, providing pivot fenestrations for the renal vessels, a fenestration for the SMA, and a scallop for the celiac artery.

An alternative to fenestrated EVAR in patients with an inadequate neck is the use of chimneys and snorkels (ie, visceral stents that are placed alongside the aortic graft to allow proximal extension of the aortic graft while preserving flow to the visceral vessel). Good immediate success has been reported.[23-25] Unfortunately, no long-term data exist to support their use. A higher rate of type IA endoleak has been reported, given the lack of complete graft apposition to the aortic wall due to the visceral stents alongside the aortic graft and the complexity in using more than two visceral vessels.[25] Bilateral and multiple upper extremity accesses are also required, which has been associated with an increased risk of stroke in the range of 3% to 9.5%.[23-25] The progressive nature of aortic aneurysmal disease suggests that chimney and snorkel grafts are prone to failure due to inadequate sealing when several grafts are placed alongside each other, the added radial force associated with each endograft, the limitation to extend proximal fixation above the SMA, and the ongoing neck dilatation after suboptimal fixation.

FENESTRATED EVAR FOR FAILED STANDARD EVAR REPAIRS

In addition to primary repair of short-neck and juxtarenal aneurysms, fenestrated EVAR has been used for endovascular salvage of failed EVAR. These patients usually present with type IA endoleaks, migration, sac enlargement, or dilation of the proximal aortic neck. They typically don't respond to reballooning, cuff placement, or other adjunct measures. Such failures occur in patients with progressive disease and those who did not meet IFU criteria and therefore didn't have an adequate initial repair, or a combination of both. Typically, fenestrated cuff placement with a combination of fenestrations and/or scallop allows extension into normal aorta without compromising the visceral vessels.

Previous repair with an infrarenal device allows easier endovascular salvage. The bare suprarenal stents may create difficulties in cannulating the renal and visceral vessels through the bare stent, although several failed EVARs with suprarenal fixation have been successfully repaired with fenestrated cuffs. In our experience, six patients presented with proximal type IA endoleaks and aneurysm enlargement, and one developed a pseudoaneurysm with a suprarenal stent fracture. There was a 100% technical success rate for retreatment and no

reduction in renal function. An important addition is the use of staging angiography and intravascular ultrasound with possible renal angioplasty/stenting to aid in cannulation during the subsequent fenestrated repair.

Recently, Katsargyris et al published their experience with 26 patients who underwent fenestrated EVAR for complications after standard EVAR. Of the 26 patients (21 had previously been repaired with suprarenal fixation), 23% were repaired for disease extension, and 19% were repaired for a < 10-mm neck. Other indications for treatment included low initial stent graft placement (27%) and migration (23%). Almost 90% were repaired with a fenestrated proximal cuff. Catheterization difficulties due to the previous stent were reported in 42% of cases, although the target vessel perfusion success rate was 95%. There was no patient mortality; however, one conversion was required due to an inability to retrieve a top cap. There were no type IA endoleaks after repair.[26] In comparison, open conversion and explantation is associated with a significant mortality risk of 20%.[27,28] These results favorably support the use of fenestrated EVAR for the repair of failed initial EVAR.

CONCLUSION

EVAR continues to be the primary technique used for treating infrarenal aneurysms, although it is rampantly being performed outside the IFU. A significant risk of failure after standard EVAR for aneurysms with an inadequate neck exists, which may manifest as endoleak, migration, sac enlargement, and possibly rupture. Such failures impose further interventions, morbidity, and mortality. Additionally, the progressive nature of aortic disease renders initial treatments inadequate, as they are prone to failure in the long-term. Among patients with marginal necks and juxtarenal AAAs, fenestrated EVAR offers excellent results when adequate proximal fixation and seal are achieved and should be the first-line treatment in patients with neck characteristics outside the IFU for standard devices. ∎

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1. Sanchez LA. Endovascular AAA repair. Endovasc Today. 2005;6:13-16.
2. Carpenter JP, Baum RA, Barker CF, et al. Impact of exclusion criteria on patient selection for endovascular abdominal aortic aneurysm repair. J Vasc Surg. 2001;34:1050-1054.
3. Moise MA, Woo EY, Velazquez OC, et al. Barriers to endovascular aortic aneurysm repair: past experience and implications for future device development. Vasc Endovascular Surg. 2006;40:197-203.
4. Hager ES, Cho JS, Makaroun MS, et al. Endografts with suprarenal fixation do not perform better than those with infrarenal fixation in the treatment of patients with short straight proximal aortic necks. J Vasc Surg. 2012;55:1242-1246.
5. Chaikof EL, Blankensteijn JD, Harris PL, et al. Reporting standards for endovascular aortic aneurysm repair. J Vasc Sur. 2002;35:1048-1060.
6. Schanzer A, Greenberg RK, Hevelone N, et al. Predictors of abdominal aortic aneurysm sac enlargement after endovascular repair. Circulation. 2011;123:2848-2855.
7. Fulton JJ, Farber MA, Sanchez LA, et al. Effect of challenging neck anatomy on mid-term migration rates in AneuRx endografts. J Vasc Surg. 2006;44:932-937.
8. Abbruzzese TA, Kwolek CJ, Brewster DC, et al. Outcomes following endovascular aortic aneurysm repair (EVAR): an anatomic and device-specific analysis. J Vasc Surg. 2008;48:19-28.
9. AbuRahma AF, Campbell J, Stone PA, et al. The correlation of aortic neck length to early and late outcomes in endovascular aneurysm repair patients. J Vasc Surg. 2009;50:738-748.
10. AbuRahma AF, Campbell JE, Mousa AY, et al. Clinical outcomes for hostile versus favorable aortic neck anatomy in endovascular aortic aneurysm repair using modular devices. J Vasc Surg. 2011;54:13-21.
11. Antoniou GA, Georgiadis GS, Antoniou SA, et al. A meta-analysis of outcomes of endovascular abdominal aortic aneurysm repair in patients with hostile and friendly neck anatomy. J Vasc Surg. 2013;57:527-538.
12. Welborn MB 3rd, Yau FS, Modrall JG, et al. Endovascular repair of small abdominal aortic aneurysms: a paradigm shift? Vasc Endovascular Sur. 2005;39:381-391.
13. Yau FS, Rosero EB, Clagett GP, et al. Surveillance of small aortic aneurysms does not alter anatomic suitability for endovascular repair. J Vasc Surg. 2007;45:96-100.
14. Timaran CH, Veith FJ, Martinez AE, et al. Changes in AAA neck morphology and loss of anatomic suitability for EVAR during surveillance: does the "window of opportunity" close for some small AAAs? J Vasc Surg. 2009;49:S49.
15. Ouriel K, Srivastava SD, Sarac TP, et al. Disparate outcome after endovascular treatment of small versus large abdominal aortic aneurysm. J Vasc Surg. 2003;37:1206-1212.
16. Rodway AD, Powell JT, Brown LC, Greenhalgh RM. Do abdominal aortic aneurysm necks increase in size faster after endovascular than open repair? Eur J Vasc Endovasc Surg. 2008;35:685-693.
17. Oberhuber A, Schwarz A, Hoffmann MH, et al. Influence of different self-expanding stent-graft types on remodeling of the aortic neck after endovascular aneurysm repair. J Endovasc Ther. 2010;17:677-684.
18. Greenberg RK, Sternbergh WC 3rd, Makaroun M, et al. Intermediate results of a United States multicenter trial of fenestrated endograft repair for juxtarenal abdominal aortic aneurysms. J Vasc Surg. 2009;50:730-737.
19. Amiot S, Haulon S, Becquemin JP, et al. Fenestrated endovascular grafting: the French multicentre experience. Eur J Vasc Endovasc Surg. 2010;39:537-544.
20. British Society for Endovascular, Therapy, and Registry the Global Collaborators on Advanced Stent-Graft Techniques for Aneurysm Repair. Early results of fenestrated endovascular repair of juxtarenal aortic aneurysms in the United Kingdom. Circulation. 2012;125:2707-2715.
21. Verhoeven EL, Vourliotakis G, Bos WT, et al. Fenestrated stent grafting for short-necked and juxtarenal abdominal aortic aneurysm: an 8-year single-centre experience. Eur J Vasc Endovasc Surg. 2010;39:529-536.
22. Kitagawa A, Greenberg RK, Eagleton MJ, et al. Zenith p-branch standard fenestrated endovascular graft for juxtarenal abdominal aortic aneurysms. J Vasc Surg. 2013;58:291-300.
23. Bruen KJ, Feezor RJ, Daniels MJ, et al. Endovascular chimney technique versus open repair of juxtarenal and suprarenal aneurysms. J Vasc Surg. 2011;53:895-904.
24. Coscas R, Kobeiter H, Desgranges P, Becquemin JP. Technical aspects, current indications, and results of chimney grafts for juxtarenal aortic aneurysms. J Vasc Surg. 2011;53:1520-1527.
25. Lee JT, Greenberg JI, Dalman RL. Early experience with the snorkel technique for juxtarenal aneurysms. J Vasc Surg. 2012;55:935-946.
26. Katsargyris A, Yazar O, Oikonomou K, et al. Fenestrated stent-grafts for salvage of prior endovascular abdominal aortic aneurysm repair. Eur J Vasc Endovasc Surg. 2013;46:49-56.
27. Kelso RL, Lyden SP, Butler B, et al. Late conversion of aortic stent grafts. J Vasc Surg. 2009;49:589-595.
28. Millon A, Deelchand A, Feugier P, et al. Conversion to open repair after endovascular aneurysm repair: causes and results. A French multicentric study. Eur J Vasc Endovasc Surg. 2009;38:429-434.