Management of endoleak after endovascular aneurysm repair: Cuffs, coils, and conversion

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Objective: The effectiveness of endovascular treatment of abdominal aortic aneurysm (AAA) may be limited by persistent perfusion of the aneurysm sac (endoleak). Endoleak that results in persistent systemic pressurization of the aneurysm or in continued AAA expansion is believed to require treatment to prevent rupture. This report describes the results of three techniques used to treat endoleak.

Method: Endovascular repair of AAA was performed in 897 patients between January 1996 and September 2002. Seventy-three endoleaks that required treatment developed in 70 patients (11.7%). These involved the graft attachment site (type I) or the graft junction site (type III) or originated from collateral side-branch vessels (type II) and were associated with an increase in aneurysm size. Endoleak type was confirmed at angiography in all cases. Average time between the initial endovascular procedure and endoleak treatment was 14.5 ± 5.7 months. The techniques used for endoleak treatment were deployment of an endovascular extension graft or cuff (n = 44), coil embolization (n = 24), and conversion to conventional open repair (n = 5). Configurations of endovascular grafts in which endoleak developed were bifurcated (n = 44), aortouniiliac (n = 15), and aortoaoartc-tube (n = 11). Mean follow-up after endoleak treatment was 24.5 ± 12.2 months (range, 1-60 months).

Results: Endovascular extension grafts or cuffs were used to treat 41 attachment site endoleaks and 3 graft junction endoleaks, with overall technical success rate of 97%. Embolic coils were used to treat 16 retrograde side-branch endoleaks and 8 attachment site endoleaks, with overall technical success rate of 87%. Conversion to open surgery was performed in 4 patients with attachment site endoleaks and 1 patient with a graft junction site endoleak, and was successful in all cases. After endoleak treatment, aneurysm size decreased (>5 mm) in 38% of patients, stabilized in 58% of patients, and increased (>5 mm) in 4% of patients. Major morbidity occurred in 7.0%, with no perioperative deaths.

Conclusions: Endovascular extension grafts, coil embolization, and conversion to open surgery each may be used to effectively repair endoleak. Selection of the treatment method used is determined by the anatomic characteristics of the endoleak and the patient’s ability to tolerate conventional repair. Conversion to open repair was uniformly successful. Deployment of an extension cuff was successful when complete closure of the endoleak was achieved. Embolic coils were effective for retrograde endoleaks and provided stabilization of AAA size in selected patients with attachment site endoleaks in limited follow-up. (J Vasc Surg 2003;37:1155-61.)

The use of endovascular stent grafts to prevent rupture of abdominal aortic aneurysm (AAA) is predicated on elimination of arterial perfusion from the aneurysm sac. Exclusion of the AAA from the arterial circulation eliminates arterial pressure and thereby prevents aneurysm growth and rupture. Continued arterial perfusion of the aneurysm sac may occur, however, after endovascular AAA repair. This persistent perfusion has been termed “endoleak” and has been observed in 15% to 21% of clinical trials involving commercially produced endovascular stent grafts.

Endoleaks have been classified into types on the basis of the etiology or site of origin. Endoleaks that result in direct antegrade flow into the aneurysm sac may occur at the endovascular stent graft attachment site (type I) or at the junction point between graft components (type III). These direct antegrade endoleaks are associated with considerable risk for aneurysm rupture and therefore necessitate prompt and definitive treatment. Endoleaks may also originate through retrograde flow in the collateral side-branch arteries of the aneurysm (type II). The most common vessels involved are the lumbar and inferior mesenteric arteries. The force generated by this retrograde collateral perfusion has been difficult to quantify. However, aneurysm rupture has been reported to result from type II endoleak. Many investigators therefore recommend treatment, particularly when type II endoleak is associated with AAA expansion. Management of both direct (type I and III) and collateral (type II) endoleaks is an essential element of endovascular treatment of AAA. This report describes results of three techniques used to treat endoleak.

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**Table I. Treatment for endoleaks**

<table>
<thead>
<tr>
<th>Endoleak treatment</th>
<th>Type I: Proximal attachment</th>
<th>Type I: Distal attachment</th>
<th>Type II: Collateral branch</th>
<th>Type III: Graft junction</th>
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<tr>
<td>Extension endograft</td>
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<td>11</td>
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<td>3</td>
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<tr>
<td>Coil embolization</td>
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<td>1</td>
<td>16</td>
<td>0</td>
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<tr>
<td>Conversion to open repair</td>
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**Table II. Patient demographic data and comorbid illnesses**

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<td>Coronary artery disease</td>
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<td>Chronic obstructive pulmonary disease</td>
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<td>10</td>
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<tr>
<td>Hypercholesterolemia</td>
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<td>10</td>
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<tr>
<td>Renal insufficiency (creatinine &gt;1.4)</td>
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<td>6</td>
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<tr>
<td>Diabetes (type I and II)</td>
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<td>Stroke or transient ischemic attack</td>
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</tr>
<tr>
<td>History of recent (within 3 months) smoking</td>
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<td>59</td>
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<tr>
<td>Average age (y)</td>
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</table>

**MATERIAL AND METHODS**

**Patient demographics and database.** Five hundred ninety-seven patients underwent endovascular repair of AAA between January 1996 and September 2002 under protocol approved by the Institutional Review Board of Mount Sinai Medical Center and Weill-Cornell Medical School. Seventy-three endoleaks that required treatment developed in 70 patients (11.4%). The endoleaks were localized to the proximal attachment site in 41 cases and the distal attachment site in 12 cases. The endovascular stent graft junction was the source of the endoleak in four cases. Endoleaks originated from collateral lumbar or inferior mesenteric arteries or both in 16 cases (Table I). Maximum aortic diameter at endoleak treatment ranged from 5.9 to 8.2 cm (mean, 6.4 cm).

Endovascular stent grafts used for the initial AAA repair that developed endoleaks were Talent (Medtronic World Medical, Sunrise, Fla; n = 51), physician-made (n = 6), AneuRx (Medtronic/AVE, Santa Rosa, Calif; n = 6), Vanguard (Meditech/Boston Scientific, Natick, Mass; n = 3), Excluder (WL Gore, Flagstaff, Ariz; n = 2), Lifepath (Baxter, Deerfield, Ill; n = 1), and Ancure (Guidant, Menlo Park, Calif; n = 1). There was no significant relationship between type of graft used and incidence of endoleak. The configurations of these grafts were bifurcated (n = 44), aortouniiliac (n = 15), and aortoaortic (n = 11). Grafts that developed distal attachment site endoleaks were Talent (n = 6), physician-made (n = 3), and Vanguard (n = 2). Average time between primary endovascular AAA repair and the procedure to treat the endoleak was 14.5 ± 5.7 months. Time between initial AAA repair and endoleak treatment was significantly longer for type II endoleaks than for type I and III endoleaks (12.8 ± 4.2 vs 5.79 ± 7.8; P < 0.01). All data for each patient, procedure, and follow-up were entered prospectively in a computerized vascular registry. Each of the 68 patients had concomitant comorbid medical conditions (average, 2.7 per patient) (Table II). The incidence of comorbid medical conditions was similar to that for the overall patient population undergoing endovascular procedures.

**Preoperative management.** Preoperative assessment included helical computed tomography angiography (CTA) with intravenous contrast medium, with images acquired at 3 mm intervals. The scans were used to determine the presence of an endoleak and to measure aneurysm size. Video image analysis software (Fiesta; General Electric Medical Systems, Milwaukee, Wis) was used to calculate change in AAA size. CTA was also used to direct subsequent angiography for endoleak localization. Site of origin of the endoleak was confirmed with digital subtraction angiography in all 73 cases.

**Endovascular extension graft and cuff procedure.** All endovascular extension graft procedures were performed in the operating room on a radiolucent table with fluoroscopic guidance. Epidural or spinal anesthetic was used in all patients. Exposure of the common femoral and distal external iliac arteries was performed through an oblique groin incision. The Talent endovascular stent graft was used for correction of all but 2 of the proximal attachment site endoleaks that were treated with placement of an extension graft or cuff (Fig 1); the remaining two endoleaks were treated with AneuRx proximal cuff extensions. This allowed for transrenal fixation in patients who received Talent grafts. The aortoiliac or cuff configuration was used most commonly for treatment of proximal endoleaks (n = 24), whereas aortouniiliac grafts were required infrequently (n = 6). Endovascular extension grafts used for repair of distal attachment site and graft junction site endoleaks were Talent (n = 11), Vanguard (n = 2), and AneuRx (n = 1). The aortouniiliac configuration was used to treat 9 distal endoleaks, and the bifurcated configuration was used to treat 2 endoleaks. Two graft junction endoleaks were repaired with ilioiliac grafts, and 1 was repaired with an aortouniiliac graft.

**Coil embolization procedure.** Coil embolization was performed transluminally through percutaneous arterial access in all 24 patients. Embolic coils (Cook Vascular, Bloomington, Ind) were deployed in the collateral vessel at...
Fig 1. Digital subtraction angiogram of proximal attachment site endoleak treatment. 

A, On lateral projection, extensive proximal attachment site endoleak is seen originating along the posterior aortic wall (arrow). B, Selective interrogation confirms location from which the endoleak originates. C, After deployment, extension cuff (arrow) is visualized proximal to the original stent graft. D, Completion angiogram confirms elimination of perfusion of the aneurysm with deployment of the proximal extension graft. Marker on the extension cuff (arrow) indicates that the proximal extent of the graft material has been positioned immediately distal to the renal arteries.
its origin from the aneurysm sac in all cases. Endoleaks emanating from the inferior mesenteric artery were accessed through collateral vessels originating from the superior mesenteric artery. Lumbar artery endoleaks were embolized through collateral vessels accessed from the iliolumbar or circumflex iliac arteries (Fig 2). Endoleaks were found to have 2 contributing collateral vessels in 6 of the 16 patients with type II endoleaks. Coil embolization of both vessels was performed in these six cases. In the remaining 10 patients only a single collateral feeding vessel was visualized. In the eight patients who underwent coil embolization of attachment site endoleaks, adequate length of undilated artery that would allow deployment of an endovascular extension graft was not present. In addition, these patients were at high risk for conventional open repair. In these patients the origin of the endoleak at the attachment site was interrogated directly from the aortic lumen. Embolic coils were then placed into the aneurysm sac until cessation of flow into the aneurysm was obtained.

Conversion to standard open repair. Conversion to open repair was performed in five patients in whom the anatomy of the attachment site endoleak or graft junction endoleak precluded placement of an endovascular extension graft. Conversion was delayed in 4 patients and immediately at the initial endovascular procedure in 1 patient. All patients had limited comorbid medical conditions and were determined by medical evaluation to be adequate candidates for conventional surgery. Conversion was performed
follow-up protocol that included of a pair of the endoleak, all patients were enrolled in a standard infrarenal position. Graft, with subsequent replacement of the clamp in the infrarenal position.

**Postoperative monitoring and follow-up.** After repair of the endoleak, all patients were enrolled in a standard follow-up protocol that included office visits within 1 month of surgery, at 6 and 12 months postoperatively, and annually thereafter. During the visit a detailed history was obtained and physical examination was performed. Plain radiographs of the abdomen and a contrast-enhanced helical computed tomography scan were also obtained at these follow-up visits. Mean follow-up was 24.5 ± 12.2 months after endoleak repair.

**Definitions and statistical analysis.** Definitions used are those outlined by the Ad Hoc Committee on Reporting Standards, Society for Vascular Surgery/American Association for Vascular Surgery. All values represent mean ± SD. The Student t test was used to compare continuous variables. Significance was assumed at P < .05.

**RESULTS**

**Technical success.** Endovascular extension grafts or cuffs were successfully deployed in all 44 patients. In 1 patient a proximal attachment site endoleak (type I) persisted after endograft deployment (98% initial technical success), and ultimately conversion to conventional open repair was required. Two of 16 patients who had undergone coil embolization of type II collateral branch endoleaks had persistent type II endoleaks (87% initial technical success). Repeat angiography was successful in localizing the newly visualized collateral vessel from which the endoleak originated, and a second coil embolization procedure was performed in each case. Conversion to open surgical repair was successful in all 5 cases in which it was performed. Coils were also successfully deployed into the aneurysm sac in 8 of 8 patients with attachment site endoleaks treated with coil embolization.

**Aneurysm size.** Maximum aortic diameter decreased by 5 mm or more in 38% of patients after repair of the endoleak (42% of cuff extension procedures, 31% of type II endoleaks). Maximum aortic diameter remained stable (change < 5 mm) in 58% of patients after endoleak treatment, and maximum aneurysm size increased by 5 mm or more in 4% of patients. Overall mean reduction in maximum aortic diameter was 5.1 mm in patients who received an endovascular extension cuff. Mean maximum diameter decreased by 3.3 mm in patients who underwent coil embolization. Reduction in maximum aortic diameter was noted in only 1 of 8 patients with type I endoleaks treated with coil embolization, although stabilization was observed in the remaining 7 patients.

**Secondary procedures.** One patient underwent conversion to open surgical repair 1 month after deployment of an endovascular extension graft and cuff failed to seal a proximal attachment site endoleak. Repeated coil embolization was performed in 2 patients, 6 and 12 months, respectively, after initial type II endoleak treatment, because of newly visualized type II endoleaks. In 2 patients the iliac endovascular graft limb became occluded after secondary repair and required extraanatomic revascularization.

**Morbidity and mortality.** There were no 30-day perioperative deaths (0%) after endoleak repair procedures. Total 30-day major morbidity rate was 6.8% (Table III), and total 30-day minor morbidity rate was 5.5% (Table IV). No significant difference in perioperative morbidity and mortality was present between open conversion and endovascular repair groups.

**DISCUSSION**

Clinical trials using endovascular stent grafts for treatment of AAA consistently demonstrate a significant incidence of endoleak. These endoleaks compromise overall effectiveness of aneurysm repair. While the precise parameters that define the need for intervention to correct endoleak have not been definitively established, occurrence of aneurysm expansion and rupture associated with untreated endoleak confirms the need for correction in certain cases.

A variety of techniques have been used to treat endoleak. Early reports describe conversion from endovascular to conventional open aneurysm repair. Conversion has been performed both during endovascular surgery and later in a relatively elective fashion. Conversion to conventional open repair is associated with significant complications. Some have related to the need for urgent conversion. In addition, endovascular repair is frequently selected for patients with significant comorbid medical illnesses. These patients are often less well able to tolerate open surgical repair. As a result, morbidity and mortality that exceed rates typically reported for elective conventional repair have been observed. Difficulties associ-
ated with the presence of a stent graft within the aneurysm itself have also been noted. In particular, problems obtaining proximal aortic control and in removing devices with transmural fixation barbs have been described. Additional techniques more recently used to treat endoleak include placement of a secondary endovascular stent graft extension or cuff, and coil embolization of either collateral arteries feeding the aneurysm sac or of the sac itself. Other techniques that have been proposed include direct induction of aneurysm thrombosis with injection of thrombin-polymer, placement of a thrombogenic sponge, laparoscopic ligation of the feeding lumbar artery, and deployment of a Palmaz stent at the proximal implantation site.

In this study the technique selected for treatment was determined primarily by the cause of the endoleak or its anatomic site. Placement of a secondary endovascular extension graft for treatment of an attachment site or graft junction leak was performed whenever technically feasible. Use of an endovascular extension graft required that an adequate length of undilated artery be present in the region adjoining the attachment site endoleak. Proximal neck anatomy was of particular significance in endoleaks originating at the proximal aortic attachment site, where the level of the renal artery ostia may be a significantly limiting factor. In the current study transrenal fixation with a custom-fabricated Talent extension graft was used for all proximal site failures, to provide increased fixation of the endovascular extension graft. As a result, no difficulty was encountered with limited space between the renal arteries and the graft flow divider. Proximal extension cuffs or grafts were routinely oversized by 2 to 4 mm.

Endoleaks originating at the distal aortic attachment site occurred in 11 study patients who had undergone primary AAA repair with an aortoaoic tube graft. Graft migration in these cases occurred; however, it appeared to be a consequence of aortic neck dilatation, as was the case for proximal attachment site endoleaks. Extension to the iliac artery with an aortouniliac or bifurcated stent graft was required in these patients. Bifurcated grafts were used when sufficient space was present to allow the contralateral limb of a bifurcated device to be cannulated and deployed. The aortouniliac configuration was used in the remaining cases. Oversizing of the iliac implantation site by 2 mm likely accounts for the absence of iliac endoleaks. In treating endoleaks that originated from a defect at the graft junction site, it was first necessary to cross the defect with an angiographic wire. This allowed the endovascular graft to traverse the defect, sealing the endoleak. In 1 patient in whom the defect could not be crossed with the angiographic wire, conversion to open surgical repair was required.

Transcatheter coil embolization was used preferentially to treat endoleaks originating from collateral branches of the aneurysm sac. Translumbar coil embolization was not used. In 6 of 16 patients with type II endoleaks, two arteries combined to generate the endoleak. It is possible that the presence of two patent collateral arteries that allow both inflow and outflow from the aneurysm sac contributed to the persistence of the type II endoleaks in these cases. Coil embolization was successful in eliminating aneurysm perfusion in most cases. However, the durability of this technique for endoleak repair has been questioned. In the current study, development or unmasking of a second type II endoleak occurred in two patients at subsequent follow-up, and repeated embolization was necessary. Further follow-up will be necessary to accurately assess the long-term effectiveness of coil embolization for treatment of collateral branch endoleaks.

In eight highly selected patients, coil embolization was also used to treat attachment site endoleaks. In each case no adequate site for implantation was present that would allow use of an extension graft or cuff. All eight patients also had extensive comorbid medical conditions that precluded conversion to conventional repair. Direct coil embolization of the aneurysm sac has been reported to be successful in treatment of type II endoleaks. After coil embolization, aneurysm size has not increased in any patients in the current study, which may suggest stabilization. However, reduction in aneurysm diameter has been observed in only 1 of 8 patients. In addition, studies conducted in animal models of AAA suggest that coil embolization of type I endoleak does not effectively reduce intra-aneurysmal pressure. Follow-up has been 1 year or less in 7 of 8 of these patients. In this study the use of coil embolization to treat attachment site endoleaks was limited to patients in whom no alternative treatment was available.

Localization of the source of the endoleak is essential for successful treatment. In this study CTA was effective as a screening method, providing accurate information regarding change in aneurysm size and suggesting the likely source of the endoleak. However, definitive determination of the source of the endoleak required angiography in several cases. Once the source of the endoleak was confirmed, the treatment method was selected. Cuff extension was used preferentially for attachment site and graft junction endoleaks; coil embolization was selected for type II endoleaks. Endoleaks were determined to originate from a combination of type I and II endoleaks in 3 patients at angiography. Spontaneous resolution of the type II endoleak occurred after treatment of the type I endoleak with an endovascular extension graft in these patients. These findings suggest that ongoing follow-up of these patients is important.

**CONCLUSION**

In repairing endoleaks, endovascular cuff extension, coil embolization, and conversion to conventional surgery each may be used effectively. Selection of the treatment method used for correction is determined by the anatomic characteristics of the endoleak and overall patient health. Deployment of an extension cuff was successful when complete closure of the endoleak was achieved. Embolic coils were effective for retrograde endoleaks, and they provided stabilization of AAA size in selected patients with attachment site endoleaks in limited follow-up. Conversion to open repair was uniformly successful in treating endoleaks, but was used only in patients without extensive comorbid conditions. Careful continued
follow-up will be necessary to determine the long-term effectiveness of each of these techniques.

REFERENCES