Open surgical repair after failed endovascular aneurysm repair: Is endograft removal necessary?

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Introduction: Open surgical repair after failed endovascular aneurysm repair (EVAR) usually involves complete endograft removal and replacement with a prosthetic surgical graft. This is associated with significant morbidity and mortality. We have used an alternative strategy focused on limiting the magnitude of surgical repair by preserving the functioning portion of the endograft and avoiding aortic cross-clamping, when possible.

Methods: Between January 2000 and 2008, patients requiring delayed conversion after EVAR at our institution were managed with (1) complete endograft preservation and external wrap of the aortic neck to secure a proximal seal, or (2) partial endograft removal with interposition grafting from the infrarenal aortic neck to the remaining endograft. Records of all patients were retrospectively reviewed for demographics, operative details, and outcomes.

Results: During this time, 12 patients were treated with delayed open surgical conversion. The indication for conversion in all patients was a type I endoleak with aneurysm enlargement not amendable to percutaneous intervention. Mean age was 81 ± 6.2 years (range, 61-90 years). Average time to conversion was 44.7 months (range, 7-80 months). Complete endograft preservation was attempted in eight patients and was successful in six (75%). The two patients that failed this approach, as well as four additional patients who were not candidates for this approach, underwent partial endograft excision and replacement with an interposition graft sutured to the remaining portion of the stent graft. Complete endograft removal was not required in any patients. There was one post-operative mortality (8.3%) and one significant post-operative morbidity (8.3%). Mean intensive care unit and hospital stays were 2.8 ± 3.9 days (range, 1-15 days) and 8.4 ± 5.8 days (range, 3-26 days), respectively.

Conclusions: Open surgical repair of failed EVAR can be accomplished with preservation of all or a significant portion of the endograft in most patients. This may limit the magnitude of the repair procedure and may reduce morbidity and mortality. (J Vasc Surg 2009;50:714-21.)

Endovascular aortic aneurysm repair (EVAR) is associated with improved early and late outcomes compared with open repair, including lower perioperative morbidity and mortality and reduced late aneurysm-related death.1-4 This difference in outcome has resulted in EVAR replacing open repair as the procedure of choice for most patients with infrarenal abdominal aortic aneurysms (AAA) and suitable anatomy. However, concerns over long-term endograft durability remain.5-9 Reintervention after EVAR is reported in up to 35% of patients independent of the type of endograft implanted.8,9,12 Lifelong surveillance is recommended to identify potential late complications of device failure, endoleak, and endograft migration that may lead to aneurysm rupture. Secondary intervention may be required when such complications are associated with new-onset endoleaks, significant aneurysm enlargement, or symptoms of rupture.

The standard technique of conversion to open repair after failed EVAR involves surgical exposure of the aneurysm, proximal and distal vascular control, complete re-

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Competition of interest: none.

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any open abdominal surgical procedure to repair the aneurysm >30 days after initial endograft implantation. The patient population included those initially treated and followed up at Stanford as well as patients treated with EVAR elsewhere and referred to Stanford for conversion after failed EVAR. Data reviewed included patient demographics, preoperative imaging studies, details of the original EVAR procedure, postoperative clinical and imaging follow-up, secondary interventions, indications and details of the conversion procedure, and late follow-up.

**Surgical approach.** Preoperative surgical planning included evaluation of aneurysm morphology, neck length and diameter, position of the endograft, source of the endoleak, and adequacy of proximal and distal endograft fixation. All patients were evaluated for endovascular treatment options before conversion. The surgical approach for patients requiring conversion was individualized and focused on securing proximal fixation and seal of the endograft with preservation of the endograft, if possible. This was approached in one of two ways: (1) complete endograft preservation with external wrap of the aortic neck to secure a proximal seal and eliminate type I endoleak, or (2) partial endograft removal with interposition of a surgical prosthetic graft from the infrarenal aortic neck to the remaining endograft or iliac limbs.

In each instance, the anterior wall of the aneurysm and aortic neck were exposed through an upper abdominal transperitoneal or retroperitoneal approach under general endotracheal anesthesia. The inferior mesenteric artery was ligated and the aortic neck was encircled. The iliac arteries were not dissected or exposed. In some cases, a transfemoral wire and sheath were introduced and an aortic occlusion balloon was positioned in the suprarenal aorta for proximal aortic control.

**Complete endograft preservation.** Selection for the procedure required a satisfactory aortic neck length, good juxtarenal endograft position, and a type I endoleak as a result of poor proximal seal of the endograft (whether due to neck enlargement or severe neck angulation). A 2-cm wide band of Dacron or Teflon fabric was passed around the aortic neck. The ends of the band were grasped with clamps, pulled together, and secured with interrupted polypropylene sutures. Additional sutures were placed, each sequentially tightening the circumferential band and compressing the aortic neck against the endograft, until apposition and seal of the type I endoleak was achieved (Fig 1A). Pulsatility of the aneurysm sac or direct measurements of intrasac pressure were used as clinical indicators of progressive sealing of the type I endoleak. The aneurysm sac was then opened and mural thrombus was evacuated.

Successful elimination of the type I endoleak was confirmed by direct observation of the endograft and its proximal seal from within the aneurysm sac. If there was evidence of an incomplete seal with a persistent type IA endoleak, interrupted polypropylene sutures were used to attach the proximal endograft to the external aortic cuff to eliminate the endoleak. Back-bleeding lumbar vessels were suture-ligated from within the aneurysm sac. The distal end of the aneurysm was inspected to ensure that there was no distal type IB endoleak, and the endograft was inspected to rule out the possibility of a fabric tear or type III endoleak. These procedures did not require aortic or iliac cross-clamping or systemic heparinization. After confirmation of endoleak resolution, the aneurysm sac was tightly closed over the endograft, thus greatly reducing aneurysm sac diameter.

**Partial endograft preservation.** Patients with intact distal fixation but with failed proximal fixation, who were not candidates for complete endograft preservation, were candidates for partial endograft preservation. A patient was not a candidate for complete endograft preservation when preoperative imaging demonstrated a short, angulated aortic neck with low position of the endograft in the neck and endograft migration or severe angulation of the endograft within the aneurysm sac.

In these patients, the infrarenal aorta was cross-clamped just below the renal arteries after systemic heparinization. The aneurysm sac was opened and mural thrombus was removed, exposing the endograft. Back-bleeding from the iliac arteries was controlled by using padded vascular clamps on the iliac limbs of the endograft within the aneurysm sac. The proximal portion of the endograft was then removed by dividing either the body of the endograft.
endograft or the two iliac limbs of the endograft. Wire cutters were used to divide the metallic stent components of the endograft. Back-bleeding lumbar arteries were suture-ligated when encountered.

A prosthetic Dacron graft of appropriate size was selected, and the proximal portion was sutured end-to-end to the infrarenal aorta (buttressed with an external Teflon felt strip). This graft could be in a tube or bifurcated configuration, depending on the level at which the endograft was divided. The distal anastomosis of the surgical graft to the endograft was performed within the aneurysm sac and was facilitated by collapsing the distal endograft into a short segment of the Dacron graft, which acted as a sleeve, equalizing the diameter of the endograft and the surgical graft. The aneurysm sac was closed tightly over the aortic graft (Figs 2 and 3).

**Follow-up.** Postoperatively, patients were observed in the intensive care unit, with transfer to the standard surgical unit when appropriate. Patients were seen and imaged at 1, 6, and 12 months after discharge and annually thereafter. Postoperative imaging consisted of ultrasound imaging and computed tomography (CT) angiography. Noncontrast, fine-cut CT and abdominal ultrasound imaging were used in patients with chronic renal insufficiency (Fig 2).
RESULTS

The prospective vascular database included >600 patients treated with EVAR by the senior author (C. Z.) between January 2000 and January 2008. During this time, 12 patients were treated with delayed open surgical conversion, including eight patients initially treated at our own institution and four initially treated elsewhere with subsequent referral for the treatment of persistent proximal type I endoleaks with aneurysm enlargement after EVAR. All patients were treated elective; no emergency or other surgical conversions were performed during the study period. Patient demographics are summarized in Table I. Nine of the 12 patients were men and 11 patients were octogenarians. All patients had significant multiple medical comorbidities.

Primary EVAR procedures were performed with a variety of endografts, including six infrarenal (50%) and six suprarenal (50%) devices. One infrarenal device with hooks at the proximal attachment site was placed; all other endografts lacked hooks or barbs. Preoperative CT imaging in each patient demonstrated good distal fixation of the endograft to the iliac arteries with evidence of inadequate proximal fixation or seal with type I endoleak. Before surgical conversion, eight patients underwent one or more secondary endovascular procedures, consisting of proximal cuff placement (9 cuff procedures) in six patients, conversion to aortouniiliac configuration in two patients, and IMA embolization in one patient. All eight patients continued to experience aneurysm sac enlargement after the secondary interventions. The remaining four patients were not candidates for endovascular intervention due to the initial endograft being too close to the renal arteries in two patients, excessive distance from the renal arteries due to migration in one, or excessive neck dilatation in one. Average time to surgical conversion was 44.7 months (range, 7-80 months). Mean aneurysm size increased by 1.2 cm (range, -1.2 to 4.5 cm) between the time of initial EVAR and the time of surgical conversion ($P = .01$; Table II). One patient had an apparent decrease in aneurysm size of 7 to 5.8 cm between the initial EVAR and subsequent conversion. A new-onset type I endoleak developed 10 months after EVAR, which was treated with two proximal extender cuffs, with resultant endoleak resolution. However, her type I endoleak recurred 18 months later with subsequent aneurysm enlargement to 6.2 cm, prompting surgical conversion when endovascular options were no longer feasible.

Surgical exposure was achieved through a transperitoneal approach in eight patients and through a retroperitoneal approach in four. External wrap of the aortic neck with endograft preservation was attempted in eight patients without aortic cross-clamping (Fig 1) and was successful (confirmed by opening the aneurysm sac and demonstrating complete absence of endoleak) in six (75%; Fig 4). In three of these patients, additional sutures were placed within the aneurysm sac to control small type IA or type II endoleaks. In two patients, external wrap of the aortic neck was not successful in controlling the endoleak. Both patients had persistent proximal endoleaks that could not be controlled with additional sutures at the aortic neck. The first patient had a severely angulated aortic neck that prevented the external wrap from eliminating the type I endoleak and achieving proximal seal. The second patient had a proximal type II endoleak from a proximal posterior lumbar artery that could only be identified after aortic cross-clamping and proximal endograft removal.

The total endograft preserving technique failed in two patients, and they were converted to a partial endograft preserving procedure during the same operative setting. This technique was also used in four other patients who were primarily excluded from complete endograft preservation because of short aortic neck ($n = 2$), steeply angulated and excessively long neck ($n = 1$), and inferior vena cava injury during the initial aortic dissection ($n = 1$). In patients undergoing partial endograft preservation, the proximal endograft was excised and replaced with a surgical interposition graft, leaving the distal endograft intact. The distal anastomosis was sewn to the distal main body of the stent graft in two patients or to the limbs of the bifurcated device in four. Partial endograft excision successfully eliminated the proximal endoleak in all six patients (100%). Complete endograft removal was not required in any of our patients.

Operative outcomes are summarized in Table III. Ex- trubation was possible in 83% patients immediately after operation or ≤24 hours. The average length of stay in the intensive care unit (ICU) was 2.8 days, and 92% were discharged <10 days. One patient with periatrial inflammation sustained an intraoperative vena cava injury during aortic neck dissection. This patient required a massive intraoperative blood transfusion and died 3 days after surgery from multisystem organ failure, for a morality rate of 8.3%. A significant morbidity (8.3%) occurred in a patient with excessive intraoperative blood loss from a type II endoleak. Postoperative respiratory failure developed, and the patient required an ICU stay of 15 days.

Postoperative follow-up imaging has confirmed successful elimination of endoleak in all patients (Fig 4 and 5). There have been no recurrent endoleaks or aneurysm en-
largements at a mean follow-up of 14.3 ± 8.5 months (range, 6-29 months). Follow-up for patients managed with the proximal banding and partial endograft preserving techniques was similar at 15.2 ± 8.2 months (range, 6-29 months) and 13.0 ± 10 months (range, 0-28 months), respectively. Only one patient was lost to follow-up after conversion with partial endograft preservation.

**DISCUSSION**

Late surgical conversion may be an emergency for aneurysm rupture or an elective procedure for graft infection or aneurysm enlargement in the presence of an endoleak, aortic neck dilatation, or endograft migration not amenable to endovascular interventions. Despite advances in endograft design, increased clinical experience, and close patient surveillance, conversion to open surgical repair may be required in 0.6% to 4.5% of patients after EVAR.13-21 This is similar to the 3% to 10% reported incidence of reintervention after open AAA repair.24-27 It is our practice to pursue endovascular interventions as first-line treatment for patients with endograft failure and suitable anatomy, reserving open conversion for patients who have exhausted these options. In this series, 67% of patients had endovascular interventions after EVAR, before consideration for open conversion, with subsequent failure. The remaining patients were not candidates for endovascular interventions.

All patients had a type I endoleak with loss of proximal endograft seal, with aneurysm enlargement and aortic neck dilatation or stent graft migration. Notably, these are the most commonly reported indications for surgical conversion.13-21 Further, all patients in this series had intact distal iliac fixation with adequate distal seal.

The traditional approach for late surgical conversion entails complete endograft removal, followed by aortic replacement with a standard surgical prosthetic graft, and is generally associated with high morbidity and mortality. May et al15 reported a 17% mortality rate and a 17% incidence of renal failure requiring hemodialysis in 18 patients undergoing delayed conversion to open surgery. Lyden et al16 reported a 24% mortality rate after delayed surgical conversion among patients enrolled in the European Collaborators on Stent-Graft Techniques for Aortic Aneurysm Repair (EUROSTAR) registry, a large multicenter experience with 2464 patients monitored for up to 5 years. Terramani et al18 reviewed all available reports of delayed conversion up until 2002 and calculated an average mortality rate of 23% (158 of 8304) when all trials were collated.

The high morbidity and mortality rates associated with delayed conversion, as reported by most authors, is likely

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**Table II. Aneurysm characteristics and interventions performed before conversion**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Initial aneurysm size, cm</th>
<th>Endograft type</th>
<th>Secondary interventions, No.</th>
<th>Aneurysm size at conversion, cm</th>
<th>Time to conversion, mon</th>
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</thead>
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<tr>
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</tr>
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</tr>
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</tr>
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</tr>
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</tr>
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<td>Infrarenal w/hooks</td>
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<td>8.2</td>
<td>98.4</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>5.9 ± 8.9</td>
<td></td>
<td>1.0 ± 0.95</td>
<td>7.9 ± 1.3</td>
<td>44.7 ± 25</td>
</tr>
<tr>
<td>Range</td>
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<td></td>
<td>0-3</td>
<td>5.5-9.7</td>
<td>7.6-80.5</td>
</tr>
</tbody>
</table>

* AUI, Aortouniiliac; SD, standard deviation.

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**Fig 4. A,** Preoperative image of the patient from Fig 1 shows a proximal type I endoleak (blue arrow) unamenable to endovascular intervention. The patient underwent conversion with creation of a proximal aortic wrap allowing complete endograft preservation. **B,** The postoperative image demonstrates recreation of the proximal endograft seal by the aortic wrap (yellow arrow) and elimination of endoleak.
attributable to several factors including advanced age and patient comorbidities, advanced aortic disease with larger aneurysms which increases technical demand, the presence of the endograft which makes dissection difficult, and the need for suprarenal and occasionally supraceliac aortic cross-clamping for those devices with suprarenal fixation.

The physiologic stress of suprarenal aortic cross-clamping, in particular, has been well described and previously associated with significant increases in operative morbidity and mortality. Prolonged aortic cross-clamp times, occasionally necessary in prior EVAR patients with well-incorporated proximal graft attachments, result in even more pronounced renal ischemia, aortic clamp injury, and metabolic derangements. Furthermore, older patients requiring delayed conversions are less likely to tolerate the physiologic effects of aortic cross-clamping and long operative times.

In fact, lower mortality rates have been consistently described when surgical techniques have been used to reduce or eliminate aortic cross-clamping and limit difficult aortic dissection during delayed conversions. Lipsitz et al demonstrated no deaths in nine patients undergoing partial endograft removal compared with 67% mortality rate in patients requiring complete endograft removal. Improved results with partial endograft preservation were likely attributable to less aortic dissection, made difficult by the presence of the endograft, shorter clamp times, and a lower incidence of supraceliac cross-clamping required in the endograft preservation cohort. In fact, supraceliac cross-clamping was required in both patients who underwent complete endograft excision and subsequently died, while this technique was only used in one of the nine patients in the endograft preservation group.

<table>
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<tr>
<th>Patient</th>
<th>Operation</th>
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<th>Ventilator days</th>
<th>ICU LOS, d</th>
<th>LOS, d</th>
<th>Morbidity</th>
<th>Death</th>
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Percent 8.3
Mean 2.7 ± 3.1
Range 0.1-10

EBL, Estimated blood loss; EG, endograft; ICU, intensive care unit; LOS, length of stay.

Fig 5. Computed tomography (CT) scans of the same patient (A) before initial endovascular aneurysm repair (EVAR) and (B) after initial EVAR. Note on image (B) that while iliac fixation is maintained, there is a persistent type 1 endoleak associated with an angulated, reverse-funnel neck. On the CT scan image to the far right (C), completed after time of delayed conversion to open repair, note the absence of endoleak and preservation of the distal endograft.
Similarly, Jimenez et al reported no deaths in 12 patients, of whom eight underwent partial endograft preservation. Suprarenal cross-clamping was used in one patient, and suprarenal balloon occlusion in an additional three. The remaining patients had transendograft balloon placement after opening the aortic sac exposing the stent graft, without the need for extensive aortic dissection. After proximal graft attachments were removed, infrarenal aortic cross-clamping was used for the remainder of the operation.

We have also experienced good results using a strategy of complete endograft preservation with aortic neck banding or partial endograft preservation when performing delayed conversions for type I endoleaks. Both procedures limit aortic dissection, and aortic neck banding has the additional benefit of eliminating the need for aortic cross-clamping. Despite the advanced age of the patients (92% octogenarians), operative outcomes were excellent and most were discharged home in < 10 days. In addition, there were no occurrences of renal failure in our patients, a known complication with traditional conversion.

The one death in our cohort was the result of excessive blood loss attributable to an iatrogenic vena cava injury in a patient with periaortic inflammation induced by the endograft. This highlights the importance of careful preoperative image analysis that showed close proximity of the inferior vena cava to the aortic neck, along with the need for meticulous periaortic dissection, which is made more difficult due the presence of the endograft.

Blood loss was also a contributing factor in the one morbidity of prolonged respiratory failure. The blood loss in this patient was attributable to the large lumbar arteries that were initially inaccessible due to the overlying endograft. It was not until after the proximal endograft was removed that the sources of the type II endoleak could be visualized. At that point, rapid control of bleeding was obtained. From this case, we would recommend early division of the proximal endograft when encountering significant bleeding that is not controlled with several additional sutures. The cost of preserving the entire endograft may be excessive in this circumstance.

Despite the seemingly low incidence of late surgical conversion, the large number of patients undergoing EVAR, combined with longer follow-up intervals as we treat younger patients, may result in an increasing number of patients needing open surgical treatment over time. Thus, careful attention to improving techniques and minimizing operative risk using the aforementioned techniques is advisable.

**CONCLUSION**

Late surgical conversion after failed EVAR may be performed without complete endograft removal in most patients. Proximal type I endoleaks can be treated in some patients by external banding of the aortic neck without the need for aortic cross-clamping. In others, replacement of the proximal portion of the endograft can be performed with preservation of functioning distal endograft limbs.

**REFERENCES**


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