The chimney procedure is an emergently available endovascular solution for visceral aortic aneurysm rupture

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A 79-year-old woman presented with a ruptured saccular thoracoabdominal aortic aneurysm involving the celiac and mesenteric artery. The patient was unfit for open surgical repair. A "chimney" procedure was performed, which involved placement of stents in the aortic side branches alongside the endograft. The patient underwent another chimney procedure 2 weeks later for a type I endoleak. Computed tomography angiography (CTA) at 1 and 6 months showed a good result with no endoleaks or graft migration. The chimney procedure provides an alternative for emergency patients unfit for open repair and has the advantage that stents can be used that are already available in most institutions. (J Vasc Surg 2011;53:1386-90.)

Endovascular repair of infrarenal abdominal aortic aneurysms (AAAs) has developed into a less invasive treatment with good results compared with open surgery.[1-5] Endovascular AAA repair (EVAR) with current devices is, however, only safe and effective if the anatomical characteristics of the aneurysm fulfill strict criteria. Approximately 20% to 50% of all patients with AAA have no suitable anatomy for EVAR.[6-8]

To expand the applicability to patients with challenging anatomy, fenestrated or branched endografts can be used. However, the fenestrated stent graft procedures are relatively complex and are performed only in a small number of institutions with extensive experience. Additionally, these grafts are custom-made, which prevents use in emergency settings.

An alternative that can be used in patients with challenging anatomy is the "chimney graft" technique,[9] also described as the "double barrel"[10] or "snorkel" technique.[11] This procedure involves placement of adjunctive stents in the side branches of the aorta alongside the endovascular stent graft. Only a few cases have been described so far in literature. We report the feasibility of chimney graft repair of a ruptured saccular thoracoabdominal aortic aneurysm involving the celiac and mesenteric artery in a female patient.

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CASE REPORT

A 79-year-old female was transferred to the Yale New Haven Hospital in December 2009. She had been hemodynamically unstable and complaining of abdominal and back pain. Computed tomography angiography (CTA) revealed a contained ruptured saccular aortic aneurysm between the celiac and superior mesenteric artery (Fig 1, *A* and *B*). Her past medical history included end-stage renal disease requiring hemodialysis, coronary artery stenting, hypothyroidism, gastroesophageal reflux disease, partial colectomy with colostomy for colon carcinoma, and hysterectomy for endometrial carcinoma. The patient had not undergone previous abdominal aortic surgery.

Because of the presence of rupture of her aneurysm, emergent repair was indicated. Due to her comorbidities, she was deemed unfit for open surgical repair. No "on-the-shelf" endovascular solution was possible. The emergent nature did not allow time to construct a homemade fenestrated or branched graft. Because the mesenteric artery and celiac artery were involved in the part of the aorta that had to be crossed with an endograft, the only endovascular solution would be the chimney procedure. Coverage of the renal arteries had no adverse effects since the patient was already on hemodialysis. The chimney procedure involved deployment of covered stents into the aortic visceral branches in addition to deployment of an aortic endograft, while making sure that the proximal ends of the visceral stents were located above the aortic endograft to ensure perfusion.

After induction of general anesthesia, a sheath was placed in the right common femoral artery and the aortic dimensions were measured with intravascular ultrasound (Volcano Corporation, San Diego, Calif). Another purpose of application of intravascular ultrasound was to minimize the contrast and radiation exposure during the procedure. The celiac artery was subsequently accessed through a sheath in the left brachial artery and the superior mesenteric artery (SMA) through the right brachial artery. Polytetrafluoroethylene (PTFE)-covered balloon expandable iCAST stents (Atrium Medical Corporation, Hudson, NH) were de-

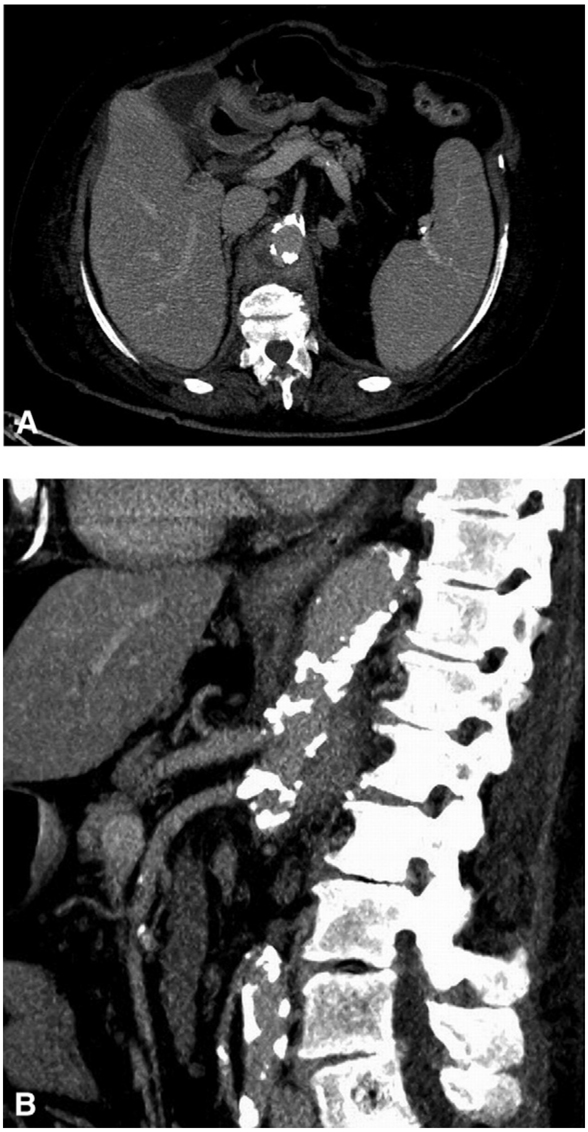

Fig 1. **A** and **B,** Multiplanar computed tomography angiography (CTA) reconstruction of contained saccular thoracoabdominal aortic aneurysm rupture on presentation.

ployed into the celiac (stent diameter 8 mm, length 38 mm) and superior mesenteric artery (stent diameter 6 mm, length 59 mm).

The main body was a Zenith (Cook Medical, Bloomington, Ind) endograft (diameter 30 mm, length 80 mm) and was deployed 10 mm above the celiac artery with 20% oversizing. The complete length of the aortic stent graft was subsequently ballooned, while the atrium stents in the celiac artery and SMA were kept inflated (Fig 2). A completion aortography showed patent celiac artery and SMA without any endoleaks. The patient was transferred from the surgical intensive care to the floor on the second day after surgery. There were no complications or other apparent untoward events. The patient was discharged home 5 days after the procedure.

However, 2 weeks later, the patient presented hemodynamically stable with right groin, abdominal, and back pain. CTA

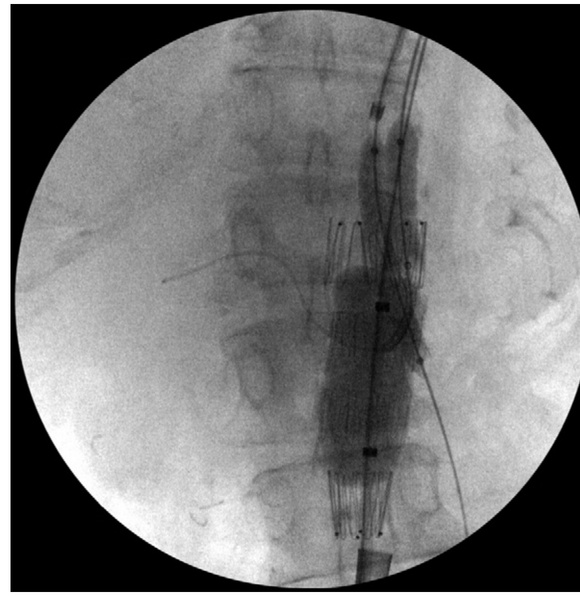

Fig 2. Intraoperative fluoroscopy of the chimney graft: celiac artery stent, superior mesenteric artery stent, and aortic endovascular stent graft. This image shows the two stents in the celiac and superior mesenteric artery and the aortic endograft.

Fig 3. Proximal type I endoleak after chimney procedure. Proximal type I endoleak with patent stents in celiac and superior mesenteric artery.

revealed a proximal type I endoleak (Fig 3). The patient was taken to the OR emergently for endovascular repair. Sheaths were placed into the left common femoral and left and right brachial artery. With 15 mm overlap of the previously placed stents, iCAST stents were placed in the celiac (stent diameter 8 mm, length 59 mm) and SMA (stent diameter 6 mm, length 59 mm) and subsequently balloon expanded.

Another aortic Zenith endograft (diameter 32 mm, length 120 mm) was deployed 10 mm below the top of the visceral artery stents. The endograft was ballooned, while both visceral artery stents were

Fig 4. Intraoperative angiography after endovascular repair of proximal type I endoleak with chimney procedure. Good angiographic result after endovascular repair of proximal type I endoleak with the chimney procedure.

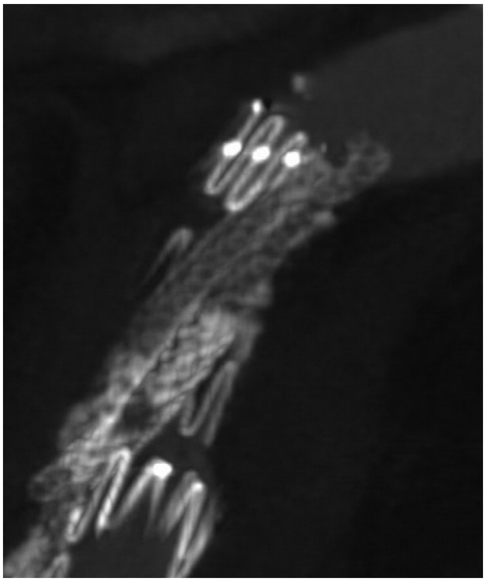

Fig 5. Position of the proximal chimney graft in the aorta and anatomical relationship between the stents. This postoperative computed tomography angiography (CTA) shows the proximal position of the stents in the celiac artery, superior mesenteric artery, and aorta and their relationship with each other and the aortic anatomy.

kept inflated. A completion aortography showed good flow in the aorta, celiac artery, and SMA without any endoleaks (Fig 4).

The patient was extubated and transferred to the vascular surgery step-down unit. There were no complications or untoward events. The patient was transferred to the floor on the second day after surgery and discharged home 6 days after the procedure.

The patient had CTA follow-up after 1 and 6 months which showed no endoleaks and good flow in the aorta and its side branches (Figs 5 and 6).

DISCUSSION

The chimney graft technique serves two purposes: exclusion of the aneurysm sac from blood flow in the aorta and maintenance of sufficient blood flow to aortic side branches that are covered during endovascular repair of an aneurysm.[9,12-15] This procedure provides an alternative for emergency patients who are poor candidates for complex open surgical repair and has the advantage that stents can be used that are currently already available in most institutions.[16] In addition to the advantage of applying available off-the-shelf devices, the procedure is technically less complex than other endovascular solutions. The absence of waiting time for a custom-made fenestrated or branched endograft allows application of the chimney graft in the emergency setting and allows flexibility for variation in patients' anatomy. This procedure can also be used to re-establish blood flow when a renovisceral artery has been inadvertently covered during regular EVAR. Although comparative evidence regarding use of self-expandable and balloon expandable stents in chimney procedures is lacking, balloon expandable stents have several theoretical advantages, including: increased placement accuracy, increased stiffness, less recoil, and absence of continued force acting to expand the vessel as with self-expandable stents which could hypothetically and potentially lead to proximal type I endoleaks during follow-up.[17]

Although the chimney procedure may possibly be associated with higher risks of complications than EVAR, open surgical repair has important drawbacks, including higher risks of complications due to the high level of aortic clamping potentially leading to renovisceral ischemia, longer operative time,[18] and more extensive mobilization of organs and soft tissue.[19]

The evidence in literature on the short- and long-term safety and efficacy of the chimney procedure is currently limited to a very few cases. Because the covered stent in the side branch may potentially create a route for leakage between the wall of the aorta and the aortic endograft, the risk of type I endoleak may hypothetically be increased. Our case report described a proximal type I endoleak after the initial procedure, but this was not on the side of the visceral stents, and no endoleaks were noted after the second procedure. Retrospectively, the endoleak was probably caused by limited graft migration that could possibly have been prevented if a larger proximal sealing zone had been chosen during the initial procedure. Although our case report provides only anecdotal evidence, increased proximal sealing may be even more important in chimney procedures to prevent graft migration and endoleak. Hiramoto et al reported the use of the chimney procedure for endovascular repair of abdominal aortic aneu-

Fig 6. Relationship between visceral artery stents and aortic endograft. This postoperative computed tomography angiography (CTA) shows the position of the stents in the celiac artery and superior mesenteric artery and their positional and anatomical relationship to the endovascular grafts in the aorta. The stents in the celiac artery and superior mesenteric artery are patent.

rysms involving the renal arteries in eight patients.[11] The primary assisted patency of the renal artery stents was 100% after a median follow-up of 1 year with no type I endoleaks or graft migrations during follow-up.

The chimney procedure may be especially beneficial in patients with rupture of a saccular aortic aneurysm or other aortic pathology with involvement of only a small segment of the aorta. Because only a small segment of the aorta is involved, better fixation and alignment of the stents within the native aorta may be accomplished with the chimney procedure, while fusiform aortic aneurysms may potentially allow more migration of visceral stents. As our case demonstrated, the proximal sealing zone should not be too short to prevent graft migration and endoleak. Additionally, the risk of graft-related complications after the chimney procedure underscores the importance of follow-up.

Long-term data will be needed to evaluate the safety, efficacy, and durability of the chimney procedure. Future research should provide more insight into the risk of endoleaks and graft migration of the chimney procedure and the patency of the stents in the visceral arteries that run alongside the aortic stent graft.

CONCLUSIONS

The chimney procedure provides an alternative for emergency patients who are poor candidates for complex open surgical aortic aneurysm repair and has the advantage that stents can be used that are currently already available in most institutions. Future research needs to confirm the long-term safety and efficacy.

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INVITED COMMENTARY

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The use of parallel grafts (aka, chimney or snorkel grafts) in the endovascular treatment of aortic pathology remains controversial. There is still much to learn about the applications and limitations of this procedure. Therefore, I find this case report interesting for a number of reasons.

The first reason is that there was an early failure in this case. Although there are several published reports demonstrating the feasibility of success with this procedure, there are surprisingly few reports of failures. Granted, this may be due to publication bias and the fact that long-term follow-up is lacking. Still, failures represent an important learning opportunity to improve our methods of treating disease.

To that end, another interesting facet to this case is the reason for the early failure. There are obvious concerns about the potential for occlusion of the branch vessel or compromise of proximal seal along the gutters of the parallel graft with this technique. It does not appear that either occurred in this case. Rather the loss of seal occurred posteriorly, remote from the visceral stents. The authors have postulated that the endoleak may have occurred secondary to "limited graft migration." However, I have concerns with that hypothesis since Fig 3 in the article shows that the top of the aortic endoprosthesis is still flush with the top of the visceral endoprostheses (although the celiac stent is obscured somewhat by vessel calcifications). Whether parallel grafts are more prone to migration is still unknown, but I hope that this case does not get inappropriately classified as a "migration" when referenced in the future.

So why did the initial procedure fail? My hypothesis is that it was due to another interesting facet to the case; that is, the aortic pathology. The aortic pathology in this case is certainly unusual in both location and morphology. The authors describe the lesion as a saccular aneurysm with rupture, but that is not evident to me in either Fig 1, *A* or *B.* Conversely, the saccular aneurysm is clearly apparent 2 weeks later in Fig 3, and its extent seems to correspond to the initial (intramural?) hematoma seen in Fig 1, *B.* Perhaps, then, the authors have chronicled the early evolution of a penetrating ulcer (that was incompletely excluded by the original procedure). If so, then the learning point is that additional coverage may be necessary in these cases than is apparent on the intraoperative angiograms.

The final interesting facet of this very challenging case is the treatment of the early failure. The authors have demonstrated that endovascular salvage may be feasible in cases of failure after parallel endografting. Hopefully, these instances will remain infrequent.