Endovascular aortic aneurysm repair techniques have revolutionized the treatment of infrarenal aortic aneurysms and have become the procedures of choice for treatment of abdominal aortic aneurysms (AAA) with superior 30-day and comparable long-term outcomes. However, the various devices currently available are not suitable in approximately half of cases, mainly because of anatomic limitations in which patients with good surgical risk still have the option of open surgery. Vascular surgeons occasionally face the dilemma of possible options to treat a patient with high surgical risk with unfavorable anatomy, especially in the urgent setting of rapidly expanding, symptomatic, or contained ruptured AAA.

An 82-year-old man was airlifted to our hospital after presenting with acute abdominal and left flank pain for 24 hours. The patient was hemodynamically stable, and on computed tomography with intravenous contrast there was a contained rupture of a juxtarenal AAA with left infrarenal extension measuring 11.5 cm (Video 1). The patient was taking clopidogrel and aspirin for recent coronary stents. Current comorbidities included chronic kidney disease with a single left functional kidney, coronary artery disease, severe chronic obstructive pulmonary disease, and congestive heart failure, New York Heart Association, class III. In addition, the patient had 3 previous open abdominal surgeries for complicated acute cholecystitis, ruptured AAA repaired with a tube graft 15 years ago, and sigmoidectomy for diverticulitis. Otherwise, he had a normal white blood cell count and a differential coagulation profile, serum hemoglobin level of 15.1 g/dL, and baseline serum creatinine level of 1.5 mg/dL (to convert to micromoles per liter, multiply by 88.4).

The patient was deemed high risk for open surgery and was not a candidate for conventional endovascular repair. After extensive discussion with the patient and his family, the...
patient wished to proceed with a repair that offered the lowest possible risk of permanent dialysis; therefore, the option of fenestrated endovascular aneurysm repair with a surgeon-modified graft was offered under informed consent for compassionate treatment. Within a few hours, the patient had been transferred to our institution and emergent preoperative workup and renal protection hydration protocols were initiated.

**Methods**

Using advanced 3-dimensional reconstruction imaging software (Aquarius WS), accurate measurements of the relative origins of the visceral arteries were obtained. Based on the preprocedural measurements of relative visceral vessels, clock position, and distance, we selected a 38 × 77 TX2 graft (Cook Medical) that was modified and implanted within a few hours of the patient’s transfer. General anesthesia was administered but no spinal drain was inserted because the patient was taking clopidogrel and the intended length of coverage was limited. To achieve adequate proximal seal over 2 cm of healthy aortic wall, the back-table modification included a scallop for the celiac artery, superior mesenteric artery (SMA), a common trunk, and a fenestration for the left renal artery (Video 1), using the constraining wire technique. The device was introduced via left femoral artery cut down while left renal artery and SMA 7-French flexor sheaths (Cook Medical) were introduced percutaneously via right femoral and left brachial arteries, respectively (Video 2). Once the graft was accurately positioned against respective aortic branches, partial deployment allowed for selective cannulation of the left renal and SMA. The left renal 7-French sheath was introduced over a stiff wire and a 7 × 38 iCAST stent (Atrium Medical) was advanced in position. Following full graft deployment, we removed the constraining wire and deployed the iCAST stent, bridging the left renal artery fenestration with the healthy renal artery. The iCAST stent was flared proximally to improve seal and allow easier access in the future. The distal landing zone of the main body inside the partially compressed, previously placed Dacron tube graft measured 1 Z-stent and was bridged with an additional 36 × 77 TX2 graft. The stent overlap within the partially compressed old tube graft was gently dilated with Coda balloon (Cook Medical) to improve lumen caliber. Completion angiogram demonstrated excellent proximal and distal seal, patent left renal artery, celiac artery, and SMA branches, and an absence of endoleak (Video 2). The contrast used was 95 mL of fluoroscopy, the fluoroscopy time was 42 minutes, the modified graft preparation was 50 minutes, and the surgical procedure length was 4 hours.

**Results**

Postoperatively, the patient recovered uneventfully with immediate abdominal and flank pain resolution and minimal pain medication requirements and was discharged on the fifth hospital day. The patient received a maintenance renal protection hydration protocol during hospitalization; however, he developed transient acute kidney injury with a peak creatinine level of 2.2 mg/dL on the second postoperative day that decreased back to the baseline 1.5 mg/dL on the 4-week follow-up. On 3-month computed tomography angiography, there was no endoleak or graft migration but there were patent left renal, SMA, and celiac arteries, and the excluded ruptured aneurysm sac decreased to 9 cm (Video 3). The patient remained asymptomatic at the 6-month follow-up and had patent vessels and further decrease of the sac on computed tomography.

**Discussion**

Patients with juxtarenal, pararenal, or thoracoabdominal aneurysms in this country are typically offered the standard open repair or hybrid approach with debranching of the visceral arteries. Alternative options for patients with high surgical risk are limited to a few centers that have access to investigational branched devices as well as centers with surgeons trained in fenestrated endograft modification and implantation techniques with good midterm durability reported from limited studies. Several studies have emphasized the need for commercially available devices in the United States to treat high-risk patients with complex aortic aneurysms. More recently, very few case reports have demonstrated the ability to treat high-risk patients with symptomatic or rapidly growing complex aneurysms using surgeon-modified endografts with good short-term results. These patients would have otherwise been left essentially untreated since they could not be submitted to open surgery without significant morbidity or mortality risks and could not wait months before an investigational device became available.

In this study, several physiologic and anatomic considerations made the endovascular procedure challenging. First, the patient’s chronic kidney disease and single functional kidney made it critical to minimize the amount of contrast and wire manipulations to avoid any injury to the renal artery. Second, the presence of a partially collapsed old tube graft could hinder the device advancement and potentially build rotational torque to the device on repositioning, even with the help of a constraining wire. Therefore, we partially unsheathed the graft to flare the fenestrated segment while preserving the ability to make rotational and longitudinal adjustments. The residual device was fully unsheathed only after we ensured optimal alignment with aortic branches. Maintaining the lowest Z-stent within the partially collapsed tube graft was critical since the step-off, present at the level of original anastomosis, would render impossible to pull the unsheathed device back into the tube graft. Third, the presence of intraluminal thrombus flush to the renal artery would increase the risk of embolism; therefore, cannulation of the vessel required tedious wire manipulations. Finally, there was significant tortuosity of the pararenal aorta that could make the apposition of fenestrations against the vessel origins quite challenging, necessitating the acquisition of multiplane views and several position adjustments.
Conclusions

Until the availability of off-the-shelf devices to treat complex aortic or aortoiliac aneurysms, surgeon-modified devices can be lifesaving in the setting of the high-risk patient with acute aortic pathology. Surgeons involved in such procedures need a set of advanced endovascular skills, experience in designing modified devices using sophisticated 3-dimensional reconstructing software, and additional training in fenestration techniques and troubleshooting intraoperatively. High-quality fluoroscopic imaging can be of paramount importance in these demanding cases. The durability of fenestrated and branched reconstructions has been evaluated with good short- and midterm results in the hands of experienced operators and specialized centers.

REFERENCES

Back-Table Tailored Stent Grafts
Surgeon Modified, Surgeon Approved

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Like the first reported abdominal aortic stent grafts, most commercially sold devices, such as the one modified by Pismisis et al,1 are tediously assembled by human hands. In reality, stent graft modification and implantation are analogous to the simpler tailoring and implantation of traditional synthetic surgical grafts. While years of clinical experience have demonstrated only rare mechanical failure of the surgical grafts themselves, concerns over stent graft durability still remain. When abdominal aortic stent grafts are pushed to their limits, they often do not perform well, especially in the long term.2 Device-dependent mechanical failures can result in expensive reinterventions, rupture, and death, ultimately erasing the short-term advantages of minimally invasive endovascular aneurysm repair.3 Food and Drug Administration-approved stent grafts are rigorously tested to perform within the constraints described in their indications for use and this is how they are best used—most of the time.

Emergent aortic aneurysm surgery is a significantly different beast than elective repair, and having to revascularize or clamp above the renal or visceral vessels typically magnifies the physiologic insult. A few series of surgeon-modified stent grafts built to preserve flow to the viscera have appeared, largely with good results, in an attempt to improve on the dismal results of open repair for these patients.4 These reports come from highly specialized centers with large endovascular experiences and even larger inventories of backup equipment for when things do not go as planned. These procedures are complex and technically demanding, and publication bias likely limits the surgeon-modified disasters that rarely, if ever, find their way into our journals.

The long waiting periods for customized, factory-made fenestrated stent grafts preclude their use in emergent situations and off-the-shelf solutions are under development.5 Until these become available, other methods such as surgeon stent graft modification and snorkeling provide additional lifesaving tools in our arsenal. If a surgeon has adequate training in advanced endovascular techniques and can replicate the usual methods of device construction and delivery system preparation, off-label use of surgeon-
modified stent grafts is likely a much less morbid approach to treating acutely symptomatic paravisceral aortic disease. Time will tell whether these procedures turn out to be durable, but at the end of the day it is better to have a live patient with a device good enough to stop the bleeding than to have an intact surgical graft in a grave.

REFERENCES