Treatment of acute visceral aortic pathology with fenestrated/branched endovascular repair in high-surgical-risk patients

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**Objective:** The safety and feasibility of fenestrated/branched endovascular repair of acute visceral aortic disease in high-risk patients is unknown. The purpose of this report is to describe our experience with surgeon-modified endovascular aneurysm repair (sm-EVAR) for the urgent or emergent treatment of pathology involving the branched segment of the aorta in patients deemed to have prohibitively high medical and/or anatomic risk for open repair.

**Methods:** A retrospective review was performed on all patients treated with sm-EVAR for acute indications. Planning was based on three-dimensional computed tomographic angiogram reconstructions and graft configurations including various combinations of branch, fenestration, or scallop modifications.

**Results:** Sixteen patients (mean age [± standard deviation], 68 ±10 years; 88% male) deemed high risk for open repair underwent urgent or emergent repair using sm-EVAR. Indications included degenerative suprarenal or thoracoabdominal aneurysm (six), presumed or known mycotic aneurysm (four), anastomotic pseudoaneurysm (three), false lumen rupture of type B dissection (two), and penetrating aortic ulceration (one). Nine (56%) had previous aortic surgery and all patients were either American Society of Anesthesiologists class IV (n = 9) or IV-E (n = 7). A total of 40 visceral vessels (celiac, 10; superior mesenteric artery, 10; right renal artery, 10; left renal artery, 10) were revascularized with a combination of fenestrations (33), directional graft branches (six), and graft scallops (one). Technical success was 94% (n = 15/16), with one open conversion. Median contrast use was 126 mL (range, 41-245) and fluoroscopy time was 70 minutes (range, 18-200). Endoleaks were identified intraoperatively in four patients (type II, n = 3; type IV, n = 1), but none have required remediation. Mean length of stay was 12 ± 15 days (median, 5.5; range, 3-59). Single complications occurred in five (31%) patients as follows: brachial sheath hematoma (one), stroke (one), ileus (one), respiratory failure (one), and renal failure (one). An additional patient experienced multiple complications including spinal cord ischemia (one) and multiorgan failure resulting in death (n = 1; in-hospital mortality, 6.3%). The majority of patients were discharged to home (63%; n = 10) or short-term rehabilitation units (25%; n = 4), while one patient required admission to a long-term acute care setting. There were no reinterventions at a median follow-up of 6.2 (range, 1-16.1) months. Postoperative computed tomographic angiogram was available for all patients and demonstrated 100% branch vessel patency, with one type III endoleak pending intervention. There were two late deaths at 1.4 and 13.4 months due to nonaortic-related pathology.

**Conclusions:** Urgent or emergent treatment of acute pathology involving the visceral aortic segment with fenestrated/branched endograft repair is feasible and safe in selected high-risk patients; however, the durability of these repairs is yet to be determined. (J Vasc Surg 2013;58:56-65.)

Despite the evolution of aortic stent graft design, 30%-45% of all patients who present with abdominal aortic aneurysms will have unfavorable anatomy to undergo elective endovascular repair with commercially available devices.1,2 From the Division of Vascular Surgery and Endovascular Therapy and Division of Thoracic and Cardiovascular Surgery. University of Florida College of Medicine. Author conflict of interest: none.

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often because of proximity or involvement of the visceral aorta. Good-risk patients may tolerate elective, open repair of complex aneurysmal disease extending into the visceral aorta; however, patients with poor cardiac, pulmonary, and/or renal function have >40%-70% morbidity and 40%-60% perioperative mortality in the emergent setting.3-8 Although significant advancements in anesthetic care, operative technique, and postoperative management have occurred, these results have not substantially changed over the past 3 decades.8,9 Outcomes for thoracoabdominal aortic aneurysm (TAAA) repair are largely determined by the clinical presentation, with procedures performed emergently being highly correlated with perioperative mortality.3,10-12 The use of “chimney,” “snorkel,” and “periscope” techniques, as well as fenestrated and branched endografts has greatly broadened the management options for patients with aortic disease extending to the visceral segment.2,13-16 As evidenced by the growing body of literature, the use of these techniques is becoming increasingly common, with promising outcomes being reported for patients with highly lethal conditions.17,20
Clinical trials are currently underway for prefabricated, customized devices for the visceral aorta, but these require weeks to months to manufacture and, thus, cannot be used in the emergent setting. Moreover, devices designed for “off-the-shelf” use are also being developed and currently entering clinical trials but are likely many years from widespread availability.\(^2\1,2\2\) Because of these limitations, surgeons have used device modification to facilitate treatment of patients who are deemed to be prohibitively high risk for open repair.\(^2\3\) The application of these techniques in the urgent or emergent setting remains unproven and poorly represented in the current literature.

This study was performed to determine our outcomes with surgeon-modified, fenestrated, and branched surgeon-modified endovascular aneurysm repair (sm-EVAR) devices in high-risk patients with acute visceral aortic disease.

METHODS

Subjects and database. A retrospective review of our endovascular aortic registry was queried for patients treated with acute pathology approximating or involving the visceral segment of the aorta. Patients treated with sm-EVAR were identified and those treated with “chimney” stents or debranching procedures were excluded. Between January 2010 and July 2012, 16 patients were identified. Indications included symptomatic or ruptured presentations of the following pathologies: TAAA, anastomotic pseudoaneurysm, dissection-related and mycotic aneurysm, as well as penetrating aortic ulceration. Urgent patients were categorized by presence of symptoms defined by a presentation of abdominal, flank, and/or back pain that was not attributable to a nonaortic pathology. Emergent presentations were defined by evidence of radiographic rupture and/or hemodynamic lability. This study was approved by the University of Florida Institutional Review Board (#161-2012).

All subjects were initially considered for open repair but subsequently judged to be prohibitively high risk due to the predicted likelihood of experiencing profound morbidity or death with open repair based on a combination of medical comorbidities\(^2\4,2\6\) and/or anatomic complexity. Although individualized to each scenario, high-risk anatomic criteria generally included acute complicated dissections, visceral patch pseudoaneurysms, and mycotic aneurysms. Medical high risk was defined as patients anticipated being unable to tolerate aortic cross-clamping or open thoracotomy (because of a combination of multiple advanced medical comorbidities). Significant medical comorbidities were defined based on the Society for Vascular Surgery (SVS) reporting guidelines.\(^2\6\)

Because of the unique constellation of medical and anatomic factors that defined high risk for each patient, there was consensus opinion obtained regarding risk for open repair in each case among the members of the group (Vascular Surgery and/or Cardiovascular Surgery) that open repair was prohibitively high risk. Patients were anticipated to have a reasonable probability of successful endovascular repair, and the patients and/or their families were thoroughly informed of the “off-label” nature of this type of repair.

Patient records were reviewed to obtain demographic and medical history, as well as details of case conduct and technical outcome. Preoperative computed tomographic angiograms (CTAs) were reviewed to evaluate aortic anatomy. Although a variety of aortic pathologies were treated, lesion extent was categorized into the Crawford classification according to the reporting standards for thoracic endovascular aortic repair (TEVAR).\(^2\7\) In an effort to further highlight the magnitude of the type of open surgical reconstruction that would be required if not completed with endovascular repair, as well as to risk-stratify patients for spinal cord ischemia events related to the boundaries of the aortic treatment zones. Patient records were reviewed to capture perioperative morbidity. Preoperative SVS comorbidity risk scores were calculated in a manner previously reported (\(\geq8\) considered high medical risk).\(^2\6,2\8\) The Social Security Death Master File was queried to determine survival.

Preoperative planning and operative technique. All patients were able to be hemodynamically stabilized at presentation and admitted to the intensive care unit for resuscitation and patient/family counseling prior to operative intervention. Those with contained rupture were managed with permissive hypotension with a goal mean pressure above 50 mm Hg, similar to reported descriptions of ruptured aneurysm management.\(^2\9\) When time allowed, prophylactic spinal drainage was utilized. Descriptions of the endovascular technique, with the addition of custom grafts, have been previously reported.\(^3\0,3\1\) Details of spinal prophylaxis and spinal drain placement as well as the description of the individualized endografts are beyond the scope of this manuscript.

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All patients remained hemodynamically stable during induction, and anesthetic preparation was performed concomitantly with graft modification. A two-team approach was used to achieve vascular access while the graft was prepared. Patients were repaired with a variety of endograft configurations including fenestrated/branched “composite” grafts (nonmodified Endologix Powerlink at the bifurcation with a surgeon-modified Cook TX2 proximally, \(n = 1\)), modified bifurcated grafts (\(n = 1\)), and fenestrated/branched tube grafts (\(n = 14\)) with or without a distal bifurcated Cook Zenith device (Fig 1).

This report is not intended to be a technical description of how to perform graft modification, and each graft was highly customized to the patient’s anatomy, so a detailed narrative of each case is beyond the scope and purpose of this analysis. However, various methods of modification were employed to accommodate individual anatomy, including combinations of scallops, fenestrations, and directional graft branches (Fig 1). As a general rule, fenestrations and scallops were placed in segments of the device that would approximate the aortic wall diameter with full main body deployment, and branches were used when the target vessel was in an aneurysmal segment of the aorta.
The following principles were applied to all modified grafts. The single scallop in this series was made at the distal aspect of a TX2 graft, and was 12 mm in depth and 15 mm wide. Fenestrations were reinforced with a thin (~1 mm) polytetrafluoroethylene cuff created from a 6- or 7-mm Atrium SST bypass graft (Atrium USA, Hudson, NH) and sewn in place with a Gore suture (W. L. Gore & Associates, Newark, Del) along with a radiographic marker created from the end of a 0.014-inch Boston Scientific Thruway wire (Boston Scientific, Natick, Mass). Directional graft branches were made with their orientation in-line with the direction of the target branch vessel (straight or downward orientations). They were created using a portion of a 6-8 mm Gore Viabahn stent graft (W. L. Gore & Associates) (based on the target vessel diameter). Downward branches were secured with a CV6 Gore suture (W. L. Gore & Associates) with a radiographic marker at the base and were oriented such that they would approximate the orientation of the target vessel. Straight branches were typically ~3 mm length and placed directly over the site of the target vessel.

Temporary diameter-reducing sutures were placed to allow perfusion through and around the graft into the branch vessels during catheterization. This was achieved using a combined method of a posterior diameter-reducing wire (similar to that described by Oderich31) proximally and circumferential diameter reduction distally using 5-0 chromic sutures. The proximal sutures were deployed by wire removal, and the distal sutures were opened using a compliant balloon (Cook CODA [Cook Medical] or Medtronic Reliant [Medtronic, Inc, Minneapolis, Minn]), prior to deployment of the stent grafts used for branch vessel revascularization (Fig. 2). Using both the wire-released diameter reduction proximally and the
balloon-released reduction distally allowed staged deployment of the endografts to ensure successful branch-vessel revascularization. Cook Zenith infrarenal endografts were also modified in some patients, with posterior diameter reduction achieved using the top cap wire passed through and through the graft in a similar manner as described above.

The procedures were performed in a hybrid operating room, and the technique for deployment depended on the strategy for branch vessel revascularization that was employed. For grafts with downward branches, the vessels were revascularized from brachial or axillary access and generally revascularized one at a time. For fenestrations and straight branches, revascularization was performed via femoral access, and typically access to all of the branch vessels was achieved prior to full graft deployment.

In this series of patients \( (n = 15/16) \), the majority of femoral access was obtained percutaneously using a “Preclose” technique as described previously. In selected cases, iliac angioplasty and stent graft placement were used to create an endovascular conduit to facilitate device entry based on a previously published report. Branch vessel location was noted with intravascular ultrasound and/or aortography. After unsheathing the device, access to the inner portion of the graft was usually obtained from the contralateral femoral artery. In some cases, ipsilateral access was obtained after deployment of the proximal portion of the endograft and removal of the delivery system. In either case, in the event that branches were revascularized from the femoral access, a Gore TAG sheath (W. L. Gore & Associates) \( (20 \text{ or } 22F) \) was placed within the body of the endograft and used to allow branch vessel access with multiple smaller sheaths (Fig 2).

The preferred visceral branch stent grafts were Atrium iCAST (Atrium Medical Corporation, Hudson, NH). Stent graft length varied and depended on whether the endograft was directly opposed to the aortic wall or not. Stent grafts through fenestrations were deployed such that \( 3-4 \text{ mm} \) remained within the lumen of the endograft.

The portion of the stent graft within the target vessel was dilated to the vessel size, and the portion within the aortic lumen was flared using a 10- or 12-mm balloon.

Technical success was defined as successful graft deployment into the intended aortic segment(s), with revascularization of all visceral branch vessels, no evidence of extra-anatomic contrast extravasation, and absence of type I or III endoleak at case completion.

Surveillance protocol. All patients underwent an in-hospital CTA postoperatively with images obtained in 2-mm increments (including a noncontrast, arterial-phase and delayed venous phase) and then followed with a CTA performed using the same protocol at 1 month. If the patients had no renal dysfunction, follow-up CTAs were performed with the same imaging protocol at 6 months, 12 months, and annually thereafter. In the case of nondialysis-dependent renal dysfunction (estimated glomerular filtration rate \( <30 \text{ mL/min/1.73m}^2 \)), a noncontrast CT was performed and supplemented with visceral/renal duplex. CTA was only performed in these patients if aneurysm growth or findings on duplex warranted. Reintervention was defined as any secondary procedure that was performed to treat the initial intended aortic pathology or procedure-/device-related complications and required a return trip to the operating room.

Statistical analysis. All statistical analyses were performed using Stata software (v. 9.2; Stata Corp, College Station, Tex). Categorical factors were summarized using frequencies and percentages, whereas continuous variables were described using means, medians, and standard deviations. Categorical variables and continuous measures were compared between groups using Fischer exact test or two-sampled \( z \)-tests when indicated. Overall patient survival was estimated using Kaplan-Meier methodology. A significance level of 0.05 was assumed for all tests.

RESULTS

Subjects and preoperative characteristics. Between January 2010 and June 2012, 236 patients underwent TEVAR and 125 patients underwent EVAR at the
Table I. Patient demographics, comorbidities, and preoperative medical therapy history

<table>
<thead>
<tr>
<th>Demographics</th>
<th>N = 16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (± SD), years</td>
<td>68 ± 10</td>
</tr>
<tr>
<td>Sex (male)</td>
<td>14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Comorbidities</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypertension</td>
<td>15</td>
</tr>
<tr>
<td>Smoking/COPD</td>
<td>11</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>10</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>6</td>
</tr>
<tr>
<td>Chronic renal insufficiency</td>
<td>4</td>
</tr>
<tr>
<td>Diabetes</td>
<td>3</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>3</td>
</tr>
<tr>
<td>Congestive heart failure, EF &lt;40%</td>
<td>2</td>
</tr>
<tr>
<td>Mean SVS/ISCVS comorbidity score</td>
<td>12.8 ± 6.3</td>
</tr>
</tbody>
</table>

Medication history

| Antiplatelet therapy | 10 |
| β-blocker therapy    | 4  |
| Statin therapy       | 3  |

COPD, Chronic obstructive pulmonary disease; EF, ejection fraction; ISCVS, International Society for Cardiovascular Surgery; SVS, Society for Vascular Surgery; SD, standard deviation.

University of Florida. Of those, 16 patients (mean age [± standard deviation], 68 ± 10 years; 88% male [n = 14]) were treated with sm-EVAR for acute visceral aortic pathology. All patients remained stable perioperatively, and no procedures were abandoned due to hemodynamic lability. Patient demographics, comorbidities, and preoperative medication history are shown in Table I. The mean SVS comorbidity severity score was 12.8 ± 6.3 (≥8 considered high medical risk).22

Anatomic extent of disease is depicted in Table II. Mean aneurysm diameter was 7.5 ± 1.9 cm, and indications included a variety of suprarenal or thoracoabdominal aortic pathologies as follows: mycotic paravisceral aneurysm (four), symptomatic and/or ruptured juxta/suprarenal aneurysm (six), or symptomatic and/or ruptured degenerative thoracoabdominal aneurysm (six), and all patients were American Society of Anesthesiologists class IV (n = 9) or IV-E (n = 7). The majority of patients (56%; n = 9) had undergone previous open or endovascular aortic repair at a preoperative median time of 24.1 months (range, 1-71). Three patients had undergone prior TEVAR or EVAR and presented with type Ia/b endoleak.

Operative characteristics and branch vessel data.

Details of the branch vessels and specific types of device modifications are outlined in Table III. Technical success for endograft implantation and branch vessel revascularization was 94% (n = 15/16). There were a total of 44 intended target branch vessels with 40 successfully revascularized (91%) including 10 celiac arteries, 10 superior mesenteric arteries, 10 right renal arteries, and 10 left renal arteries. One patient accounted for all four failed revascularizations and required conversion to a hybrid debranching procedure, described in detail below.

All procedures were completed under general anesthesia, and preoperative spinal drainage was used in eight (50%) cases. Main body device TX-2 stent graft diameter components ranged from 28-42 mm (28-34 mm, n = 7; 36-42 mm, n = 9) and four patients required iliac angioplasty and stent graft placement to facilitate endograft delivery. One patient failed percutaneous access and required an iliofemoral endarterectomy and patch angioplasty.

Median contrast use was 126 mL (range, 41-245), and median fluoroscopy and procedure times were 70 (range, 18-200) and 240 minutes (range, 134-900), respectively. Comparison of urgent-symptomatic and emergent-ruptured procedures is demonstrated in Table IV, with significant differences noted in time from admission to the operating room, as well as fluoroscopy and contrast exposure. Endoleaks were identified intraoperatively in three patients (type II, n = 2; type IV, n = 1), with none of these requiring remediation to date.

Postoperative outcomes. Mean length of stay was 12 ± 15 days (median, 5.5; range, 3-59). The majority (68%; n = 10) of patients were discharged home or to
Table IV. Operative characteristics for urgent-symptomatic and emergent-ruptured indications of suprarenal and thoracoabdominal acute aortic pathology treated with surgeon-modified fenestrated endografts

<table>
<thead>
<tr>
<th>Variable</th>
<th>Urg-Syp (n=9)</th>
<th>Emer-Rupt (n=7)</th>
<th>P value&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time admission to OR, hours</td>
<td>28 ± 11</td>
<td>12 ± 9</td>
<td>.008</td>
</tr>
<tr>
<td>Cerebrospinal fluid drain</td>
<td>6</td>
<td>2</td>
<td>.3</td>
</tr>
<tr>
<td>OR time, minutes</td>
<td>373 ± 225</td>
<td>217 ± 86</td>
<td>.1</td>
</tr>
<tr>
<td>Fluoroscopy time, minutes</td>
<td>104 ± 50</td>
<td>50 ± 23</td>
<td>.02</td>
</tr>
<tr>
<td>Estimated blood loss, mL</td>
<td>617 ± 900</td>
<td>229 ± 57</td>
<td>.3</td>
</tr>
<tr>
<td>Crystalloid, liters</td>
<td>2.0 ± 1.2</td>
<td>1.6 ± 0.8</td>
<td>.5</td>
</tr>
<tr>
<td>Colloid, mL</td>
<td>388 ± 253</td>
<td>321 ± 345</td>
<td>.7</td>
</tr>
<tr>
<td>Packed red blood cells, units</td>
<td>1.3 ± 1.5</td>
<td>0.7 ± 1.2</td>
<td>.4</td>
</tr>
<tr>
<td>Contrast exposure, mL</td>
<td>148 ± 49</td>
<td>98 ± 39</td>
<td>.05</td>
</tr>
</tbody>
</table>

<sup>a</sup> P value determined using unpaired t-test and Fischer exact test when applicable.

Follow-up and reintervention. At a median clinical follow-up time of 6.2 (range, 1.2-16.1) months, one patient required reintervention for a type III endoleak at a superior mesenteric artery branch graft. This was successfully treated with repeat angioplasty and stent graft extension. Postoperative CTA was available for all patients and demonstrated 100% branch vessel patency. There were no migrations, component separations, fractures, or aneurysm ruptures. For cases of mycotic aneurysm presentations, blood culture positivity was confirmed in three of four cases (<i>Serratia, E coli, S aureus</i>), and all four patients were treated with 6 weeks of broad-spectrum intravenous antibiotics and then species-specific oral suppressive antibiotics for life.

Six patients have reached ≥6 months of follow-up and have imaging available for review. Of these six, aneurysm diameter reduction (≥5 mm) was noted in five of six (83%). Three patients had complete aortic remodeling around the stent graft (Fig 3) and one has a significant type III endoleak at the site of a superior mesenteric artery fenestration now pending endovascular reintervention (Table VI, online only, highlights individual patient outcomes for renal function and aneurysm diameter over the follow-up interval). Estimated 12-month survival after sm-EVAR for AAS is 88 ± 0.08% (Fig 4). There were two late deaths (separate from the previously described in-hospital death) at 1.4 and 13.4 months because of non-aortic related pathology (pneumonia resulting in respiratory failure and myocardial infarction).

**DISCUSSION**

Although this is a highly selected series of patients, this report demonstrates that branched and fenestrated endografts can be used in urgent or emergent settings with a high
degree of technical and clinical success in the treatment of complex visceral aortic pathology. Despite these patients being deemed prohibitively high medical/anatomic risk for open repair, a majority not only survived but were discharged without major morbidity.

Aneurysms involving the visceral segment of the aorta present a challenging clinical scenario, especially in the acute setting in high-risk patients. Historically, patients managed with intact TAAAs have been reported to have 10%-25% perioperative mortality.\(^9,34\) Despite some improvement in outcomes with elective operations attributable to advancements in anesthesia, operative techniques, and use of a variety of adjuncts to minimize postoperative morbidity,\(^35\) these results have not translated into the acute setting. Emergent
treatment of ruptured TAAAs has a reported mortality rate in excess of 50%. Because of these poor results, surgeons have sought other methods of repair in high-risk patients, such as hybrid debranching procedures. Despite the initial enthusiasm, these techniques have not consistently delivered better outcomes, and many continue to advocate conventional open repair. Indeed, because of these reports and our own sobering results, we have largely abandoned the use of hybrid visceral debranching as a method to treat high-risk patients.

Although our series is a highly selected patient population given their hemodynamic stability at presentation, they have multiple medical and anatomic factors that make them high risk. This is evidenced by the patients’ preoperative SVS comorbidity scores, the fact that many had undergone previous open repair, and that all were believed to be prohibitively high risk by a group of experienced surgeons at a tertiary care medical center with a practice that collectively treats approximately 600 aortic patients per year. Notably, seven of our patients in this series had ruptured thoracoabdominal aortic pathology, and six of these seven (85%) not only survived repair, but were discharged to home or a short-term rehabilitation facility. Despite these promising results, we emphasize that because of the questionable durability of modified stent grafts, we continue to offer open repair to those patients who are not believed to be prohibitively high risk.

It is anticipated that as fenestrated/branched endograft technology continues to develop, and “off-the-shelf” devices become available, surgeons will be able to treat even good-risk patients with symptomatic or ruptured suprarenal and thoracoabdominal aneurysms. Our results demonstrate that these technologies may provide an excellent alternative to emergent open repair in the future. This correlates well with the literature that has emerged regarding endovascular management of aortic emergencies involving the infrarenal and descending thoracic aorta. Unfortunately, widespread nontrial availability of these devices is years away, and even with adoption of this technology, there will continue to be patients whose anatomy precludes endovascular repair.

Historically, necessity has encouraged surgeons to develop innovative techniques for treatment of their patients, and many of these methods were initially developed without Food and Drug Administration (FDA) oversight. Examples of this span surgical history and include the treatment of emergent aortic disease by Drs Vorhees and Blakemore with an aortic graft crafted on a sewing machine to treat a ruptured aneurysm. More recently, Parodi and colleagues fashioned “homemade” endovascular devices for the treatment of infrarenal aneurysms. Further examples include the use of “chimney” and “snorkel” techniques to treat aneurysms involving the visceral aorta, as well as the modification of commercially available devices. These novel strategies offer promising solutions for high-risk patients with complex aortic pathology; however, the modular nature of the fenestrated strategies lends itself to intercomponent (eg, type III) endoleak, whereas the various snorkel or chimney techniques are at risk of perigraft “gutter” (eg, type I) leak. Given these limitations, we do not advocate the widespread use of these off-label techniques outside of an FDA-approved trial with an investigational device exemption. However, one can easily imagine various scenarios where patients may benefit from the use of off-label techniques, especially in emergent situations where patients are deemed “no option” or prohibitively high open surgical risk. Patients and/or their families in our series were all thoroughly informed of the off-label nature of the repair, and the surgeon took full responsibility for the success or failure of the operation.

There are several important limitations to this study including the fact that this effectively represents an extended case series of a small clinically and anatomically heterogeneous group of patients. Also, this is essentially a single-surgeon, single-center experience, and the results cannot universally be applied. The extensive endovascular experience, inventory, and postoperative ancillary support required to successfully treat these patients are unlikely to be reproducible in many centers. The significant risk of type II error, as well as potential overenthusiasm engendered for graft modification cannot be overstated. The focus of this report is to detail the outcomes of a complex group of patients managed urgently with complex endovascular techniques. The selection bias introduced by procedural planning, methods for intraoperative graft construction, and implantation techniques selects for hemodynamically stable patients, which undoubtedly facilitates the promising results in this study and further limits procedural applicability. This study was completed without an FDA-approved investigational device exemption for graft modification; however, the evolution in practice and different types of unique graft modifications (eg, using fenestration, temporary, and permanent...
diameter-reduction sutures and branch grafts within the same device) required to complete repair in a diverse group of aortic pathologies with variable presentations would not necessarily be possible within the constraints of this type of mandate. Despite these limitations, we believe that our results demonstrate that these techniques can be applied selectively with acceptable outcomes.

In conclusion, fenestrated/branched endograft repair can be safely performed for a variety of acute perivisceral aortic conditions. Longer follow-up and greater patient numbers are needed to determine durability and guide application of these techniques.

AUTHOR CONTRIBUTIONS

Conception and design: SS, AB
Analysis and interpretation: SS, AW, AB
Data collection: SS, AW
Writing the article: SS, TH, AB
Critical revision of the article: SS, AW, RF, TM, PH, TH, AB
Final approval of the article: SS, AW, RF, TM, PH, TH, AB
Statistical analysis: SS, AW
Obtained funding: Not applicable
Overall responsibility: AB

SS and AW share co-first authorship.

REFERENCES


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Additional material for this article may be found online at www.jvascsurg.org.
Table VI (online only). Change in renal function and aortic diameter after surgeon-modified fenestrated endovascular repair for acute visceral aortic pathology

<table>
<thead>
<tr>
<th>Patient</th>
<th>Clinical follow-up time, months</th>
<th>eGFR change</th>
<th>Change aneurysm diameter</th>
</tr>
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</table>

eGFR, Estimated glomerular filtration rate; NA, not available; SD, standard deviation.

Only 10 patients had contrasted imaging beyond 6 months postoperatively; Patients highlighted in bold are ones that died; if patients who survived to discharge are analyzed, the average decrease in eGFR after sm-FEVAR for acute visceral aortic pathology was 5.2 ± 9.8 mL/min/1.73 m². For all patients, the mean ± SD decrease in maximal aortic diameter change was 17 ± 21 mm.