Complete zone 0-10 aortic endovascular reconstruction

Mehdi Teymouri, MD, Manish Mehta, MD, MPH, Philip Paty, MD, Lalithapriya Jayakumar, MD, *and* Zachary W. Kostun, MD, *Latham, NY*

ABSTRACT

To the best of our knowledge, the present report is the first on the safety and efficacy of complete endovascular aortic reconstruction from zone 0 to 10 using a standardized approach and parallel stent graft configurations in high-risk patients considered unfit for surgery. During a 7-year period, five patients with complex thoracoabdominal aortic aneurysms and dissections involving zone 0-10 presented with rupture (n = 1; 20%), were symptomatic (n = 2; 40%), or had an aortic pseudoaneurysm (n = 2; 40%) and underwent complete endovascular zone 0-10 reconstruction using off-the-shelf stent grafts in parallel configurations that included chimneys, periscopes, and endovascular docking stations. The zone 0-5 complete arch chimney thoracic endovascular repair included chimneys that extended from the ascending thoracic aorta to the innominate, left common carotid, and left subclavian arteries and a thoracic stent graft extending from zone 0 to 5. The zone 5-10 aortic reconstructions were staged. Stage 1 included either thoracic stent graft and antegrade four visceral chimney placement or abdominal aortic stent graft and retrograde four visceral chimney placement. Stage II included completion of the remainder of the aortic reconstruction with cerebrospinal fluid drainage. A total of 15 aortic procedures included 34 chimneys (14 aortic arch and 20 visceral). Two patients (40%) underwent zone 0-5 aortic reconstruction first, and three patients (60%) underwent zone 5-10 aortic reconstruction first. The incidence of 30-day mortality, spinal cord ischemia, myocardial infarction, stroke, and visceral ischemia was 0%. At a mean follow-up of 4.5 ± 3.1 years, the aortic reconstruction-related mortality was 0%. All-cause mortality was 20%; one patient had died of pneumonia at 3 years postoperatively. Two endoleaks each occurred in zone 0-5 and zone 5-10 (40% for both groups). All endoleaks were treated with coil embolization. Complete endovascular zone 0-10 aortic reconstruction using parallel stent grafts with a docking station is a feasible and relatively safe technique that offers the ability to customize off-the-shelf devices for the treatment of high-risk patients with limited morbidity and mortality. (J Vasc Surg Cases Innov Tech 2023;9:1-8.)

Keywords: Docking; EVAR; Station; TEVAR; Zone 0-10

During the past three decades, much progress has been made in the endovascular treatment of complex thoracic and abdominal aortic aneurysms and dissections. The evolution of endovascular techniques and technology has allowed surgeons to manage aortic pathology affecting the ascending thoracic aorta to the iliac bifurcation using customized fenestrated-branched stent grafts and off-the-shelf devices in parallel stent graft—chimney configurations.[1-4] However, limited data exist for the treatment of aortic pathology that spans from the ascending thoracic aorta to the iliac artery bifurcation using parallel stent grafting (zones 0-10). We report our experience on the safety and efficacy of complete endovascular aortic reconstruction from zone 0 to 10 using a standardized approach and parallel stent graft configurations in select patients. The included patients provided written informed consent for the report of their case details and imaging studies.

METHODS

Five patients with complex thoracoabdominal aortic aneurysms and dissections involving zone 0-10 who underwent complete endovascular zone 0-10 reconstruction using off-the-shelf stent grafts in parallel configurations that included chimneys, periscopes, and endovascular docking stations were retrospectively analyzed.[3] All thoracic stent grafts were Gore TAG endoprostheses, the abdominal stent grafts were Excluder endoprostheses, the innominate chimney stent grafts were Excluder iliac limbs, and all other chimneys were Viabahn endoprostheses (all from W.L Gore & Associates, Flagstaff, AZ). All the patients were evaluated by multidisciplinary specialties, including cardiac and vascular surgery, and were considered unfit for open surgical repair because of either anatomic limitations or medical comorbidities. All the patients were managed with a single antiplatelet agent and underwent computed tomography angiography (CTA) of the chest, abdomen, and pelvis every 6 months.

From the Vascular Health Partners.

Author conflict of interest: M.M. is President and Chief Executive Officer of the Center for Vascular Awareness, Vascular Health Partners. M.T., P.P., L.J., and Z.W.K. have no conflicts of interest.

Additional material for this article may be found online at https://www.jvscit.org.

Correspondence: Manish Mehta, MD, MPH, Center for Vascular Awareness, Vascular Health Partners, 713 Troy-Schenectady Rd, Ste 125, Latham, NY 12110 (e-mail: MMehta@communitycare.com).

The editors and reviewers of this article have no relevant financial relationships to disclose per the Journal policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

2468-4287

https://doi.org/10.1016/j.jvscit.2023.101111

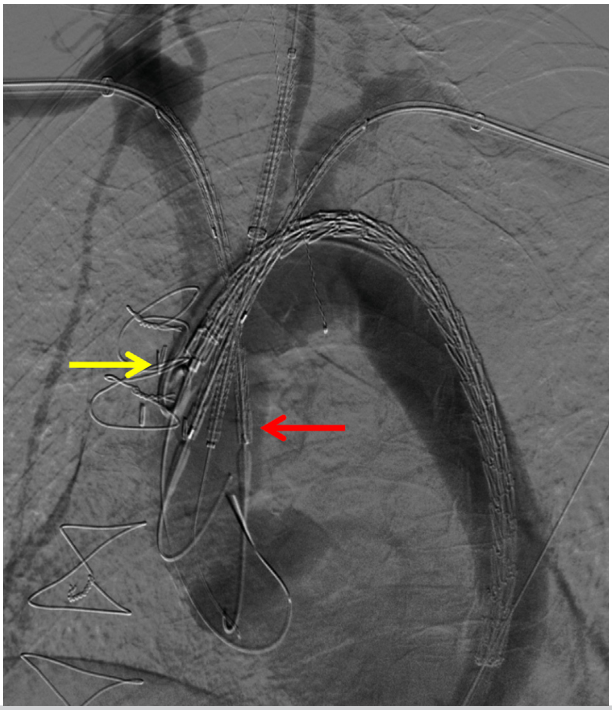

Fig 1. Viabahn chimney stent grafts extending from the ascending thoracic aorta into the innominate artery, left common carotid artery, and left subclavian artery. The cTAG thoracic stent graft proximal landing zone (*yellow arrow*) is ~1 cm distal to the proximal chimney stent graft landing zone (*red arrow*).

Fig 2. Completion arteriogram after zone 0-5 complete arch chimney thoracic endovascular repair.

The zone 0-5 complete arch chimney thoracic endovascular repair included femoral access for thoracic endovascular aneurysm repair (TEVAR) and bilateral axillary and left common carotid access for chimneys that extended from the ascending thoracic aorta just distal to the sinotubular junction to the innominate, left common carotid, and left subclavian arteries (Figs 1 and 2). All zone 5-10 visceral chimney thoracoabdominal endovascular repairs were staged to minimize spinal cord ischemic complications. When using parallel stent graft configurations, we generally oversize the main body aortic stent grafts by 25% to 30%.

Stage 1 included creation of an endovascular docking station. A thoracic stent graft was placed in the descending thoracic aorta with the distal landing zone several centimeters above the level of the celiac artery. The visceral chimneys were placed antegrade within the thoracic stent graft lumen. The chimney stent graft overlap length was customized to allow for adequate overlap within the thoracic stent graft, was two times the thoracic stent graft diameter, and ended ≥3 cm short of the top edge of the thoracic stent graft. In the present series, the shortest antegrade visceral chimney length was 15 cm. The proximal thoracic stent graft collar beyond the chimney stent grafts was used as the distal landing zone for zone 0-5 TEVAR. The visceral chimneys were reinforced with self-expanding stents and left unrestrained (Fig 3). The chimney stent graft orientation was confirmed via computed tomography before the stage 2 procedure.

Stage 2 included EVAR and a bridging stent graft that connected the thoracic and abdominal stent grafts. During this stage, we routinely oriented all visceral chimneys anteriorly or posteriorly to the bridging stent graft. We attempted to confirm the orientation of all chimneys was in either the anterior or posterior position, because, in our experience, chimney to chimney opposition minimizes the incidence of gutter endoleaks compared with chimney to main body stent graft opposition. This was accomplished using the technique of spinning and advancing a pigtail catheter from the infrarenal aorta into the thoracic aorta across the chimneys and then advancing a Lunderquist stiff wire (Cook Medical Inc, Bloomington, IN) through the pigtail catheter for bridging stent graft delivery. With the patient in the supine position, in the vast majority of cases, this technique will allow the pigtail catheter to assume an anterior position to all four chimney stent grafts. The subsequent bridging stent graft will then be allowed to maintain an anterior orientation, with the chimneys deflected to lie posteriorly during thoracic device deployment. Although it is also possible to maintain the orientation with these positions reversed (chimneys anterior and the bridging stent graft posterior), because the purpose of this technique is to align the chimneys within the same plane (Fig 4). A similar technique is used across the thoracic arch (Fig 5).

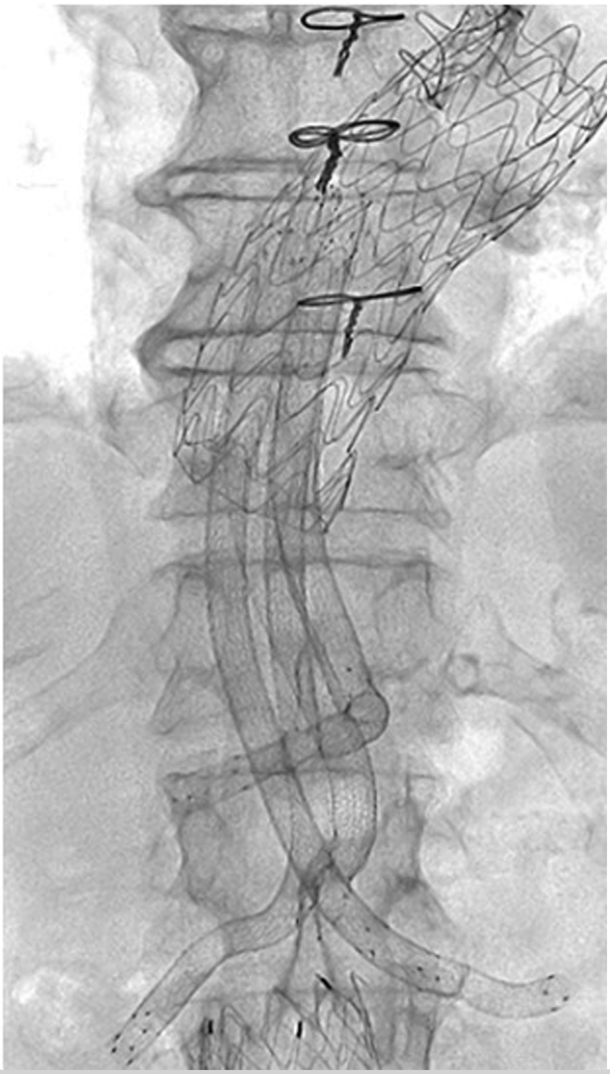

Fig 3. Main body docking station deployed in the descending thoracic aorta several centimeters above the celiac artery. The antegrade visceral chimneys are deployed inside the thoracic stent graft, leaving a ≥3 cm proximal thoracic stent graft collar to be used as the distal landing zone of the zone 0-5 thoracic endovascular aneurysm repair device.

For patients who required zone 0-5 chimney TEVAR first, antegrade visceral chimney placement via a brachial approach was not technically feasible. In these cases, all visceral chimneys were placed in a retrograde "periscope" orientation. The zone 5-10 visceral chimney thoracoabdominal endovascular repair was staged to minimize spinal cord ischemic complications. Stage 1 included EVAR and retrograde visceral chimneys with the proximal landing zone in the visceral arteries and distal landing zones in the infrarenal aortic stent graft. In the periscope orientation, the shortest chimney length in this series was 10 cm. The chimneys were reinforced with self-expanding stents and left unrestrained. Stage

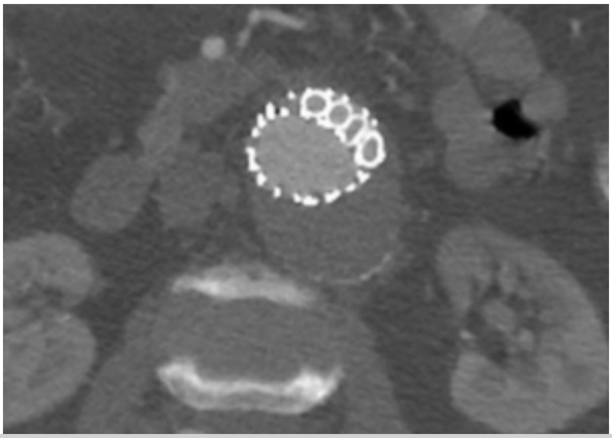

Fig 4. Postoperative computed tomography angiogram indicating zone 5-10 chimney stent graft orientation.

2 included placement of the bridging stent graft connecting the thoracic and abdominal stent graft (Figs 6 and 7). All stage 2 procedures were performed with cerebrospinal fluid (CSF) drainage.

A visual representation of a complete zone 0-10 aortic endovascular reconstruction is provided in the Supplementary Video (online only).

CASE SERIES

Patient 1. A 58-year-old man with Marfan syndrome and prior ascending aortic repair for type A aortic dissection (TAAD) presented with aortic arch rupture in 2007. He underwent emergent zone 0-5 TEVAR with an innominate and a left common carotid artery chimney, left carotid artery to subclavian artery bypass, and proximal left subclavian artery embolization. No major postoperative complications occurred. Follow-up CTA at 1 and 2 years revealed exclusion of the thoracic arch aneurysm. In 2019, 12 years later, he presented with an expanding 7.4-cm paravisceral thoracoabdominal aortic aneurysm and underwent four-vessel retrograde chimney thoracoabdominal aortic aneurysm repair with CSF drainage. His postoperative course was unremarkable. The 1-year follow-up CTA revealed a visceral chimney gutter endoleak, and he underwent catheter-directed coil embolization. In 2022, the patient died of septic complications of pneumonia.

Patient 2. A 72-year-old man with home oxygen-dependent chronic obstructive pulmonary disease, coronary artery disease (CAD), and hypertension presented with a 7.0-cm paravisceral aortic aneurysm and a 6.8-cm thoracic arch aneurysm. He presented with unexplained abdominal pain, and the abdominal aortic aneurysm was tender to palpation. He underwent zone 5-10 four-visceral chimney endovascular thoracoabdominal aortic aneurysm repair with CSF drainage. During the next few months, he underwent staged zone 0-5 TEVAR, with arch

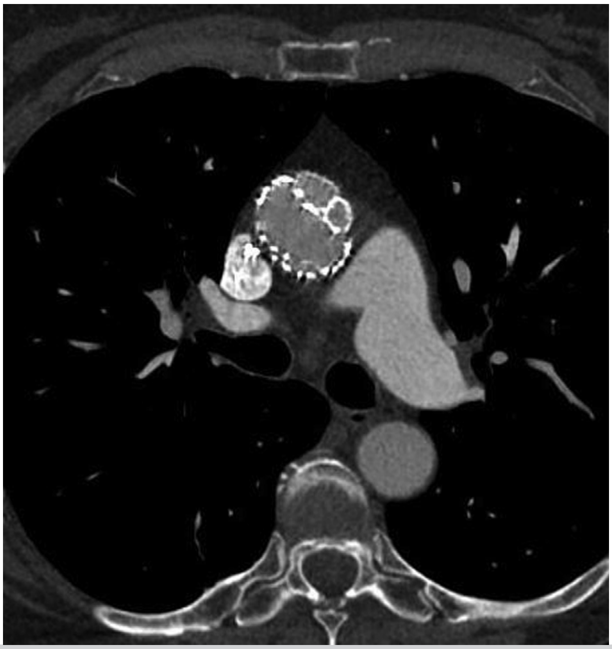

Fig 5. Postoperative computed tomography angiogram indicating zone 0-5 chimney stent graft orientation.

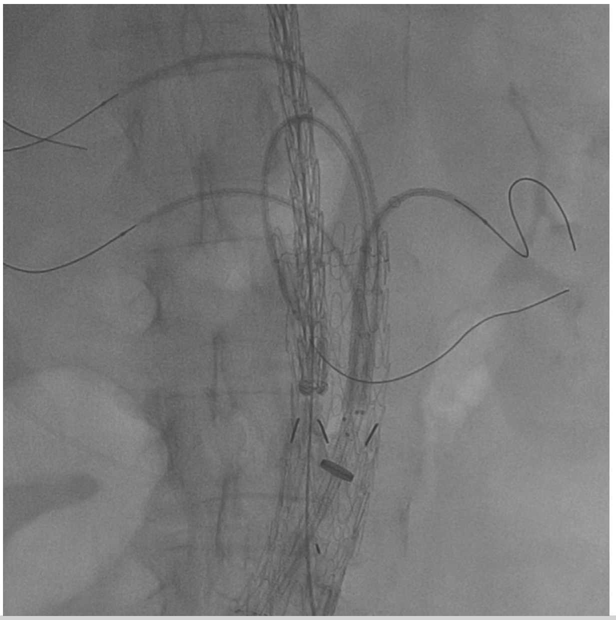

Fig 6. The bifurcated main body aortic stent graft is deployed several centimeters below the renal arteries and becomes the docking station for the retrograde chimney stent grafts. The chimneys are positioned, extending from the visceral arteries to the bifurcated aortic stent graft. Additional thoracic endoprosthesis is positioned as a bridging stent graft, which connects the distal zone 0-5 device to the proximal zone 5-10 device.

chimneys to the innominate, left common carotid, and left subclavian arteries. The procedure was performed with CSF drainage. At the 2-year follow-up, he was noted to have a visceral chimney gutter endoleak and underwent translumbar catheter-directed embolization. At year 9, the patient developed a recurrent gutter endoleak and underwent successful catheter-directed embolization.

Patient 3. A 56-year-old woman with home oxygen-dependent chronic obstructive pulmonary disease, Marfan syndrome, and a prior ascending aortic repair for TAAD presented with a thoracoabdominal aortic aneurysm and dissection starting at the level of the arch and extending up to the aortic bifurcation. The thoracic arch aneurysm was 7.4 cm, and the paravisceral aortic aneurysm was 6.6 cm. The arch dissection extended into the innominate artery. On physical examination, the patient's aortic aneurysm was tender to palpation. She underwent zone 0-5 TEVAR and chimney stent grafting to the innominate, left common carotid, and left subclavian arteries. The procedure was uneventful, and her abdominal aortic tenderness resolved. The following month, the patient underwent staged zone 5-10 four-visceral retrograde chimney thoracoabdominal aortic aneurysm repair with CSF drainage. The procedure was uneventful. On the 6-month follow-up CTA, a significant endoleak connecting the innominate artery dissection to numerous lumbar arteries was noted. The patient had a CSF drainage catheter placed and underwent translumbar catheter-directed endoleak embolization. The procedure was uneventful, and she was discharged home. The 3-year follow-up CTA showed that the thoracoabdominal aortic aneurysm remained excluded, with an incidental finding of celiac chimney stent graft occlusion. The patient was asymptomatic.

Patient 4. A 68-year-old man with severe CAD (30% ejection fraction), stage III chronic kidney disease, and prior ascending thoracic aortic repair for TAAD presented with a 6.5-cm arch pseudoaneurysm and dissection that extended into the innominate artery and abdominal aorta with a 7-cm abdominal aortic aneurysm. He underwent zone 5-10 four-visceral vessel chimney stent graft placement and endovascular thoracoabdominal aortic aneurysm repair with CSF drainage. The procedure was uneventful. The following month, he underwent zone 0-5 TEVAR and chimney stent grafting to the innominate, left common carotid, and left subclavian arteries, with CSF drainage. The procedure was uneventful. On the 6-month follow-up CTA, he was noted to have a retrograde endoleak from the innominate dissection and underwent transbrachial catheter-directed endoleak embolization. The 4-year follow-up CTA revealed a gutter endoleak, and he underwent catheter-directed embolization. The 7-year follow-up CTA revealed a small residual type II endoleak without a change in aneurysm size, and the patient received conservative follow-up.

Fig 7. Completion arteriogram after zone 5-10 complete periscope abdominal aortic endovascular repair.

Patient 5. A 65-year-old woman with severe CAD and a prior ascending thoracic aortic repair for TAAD presented with aortic dissection across the arch that extended to the aortic bifurcation into the right common iliac artery. She had a 6-cm pseudoaneurysm at the arch. The maximum thoracoabdominal aortic aneurysm size was 6.8 cm. The patient underwent zone 5-10 four-visceral vessel chimney stent grafting and endovascular thoracoabdominal aortic aneurysm repair with CSF drainage. The procedure was uneventful. Three months later, she underwent zone 0-5 TEVAR and chimney stent grafting to the innominate, left common carotid, and left subclavian arteries, with CSF drainage. The procedure was uneventful. On the 6-month follow-up CTA, the patient had a small type II lumbar endoleak without a change in aneurysm size and received conservative follow-up.

RESULTS

During a 7-year period, five patients with a variety of complex thoracoabdominal aortic pathologies presented with complex thoracoabdominal aortic dissections (n = 4; 80%) and aneurysms (n = 1; 20%) involving zone 0-10. These patients presented with rupture (n = 1; 20%), were symptomatic (n = 2; 40%), or had an aortic pseudoaneurysm (n = 2; 40%) and underwent complete endovascular zone 0-10 reconstruction (Table I). The mean postoperative follow-up period was 4.5 ± 3.1 years. Two patients had Marfan syndrome, and both had previously undergone ascending thoracic aortic reconstruction for acute TAAD. One of these patients was symptomatic, and the other had presented with rupture. In total, the five patients underwent 15 aortic procedures, including 34 chimneys (14 aortic arch and 20 visceral). The 34 chimneys included 5 innominate chimneys, 5 left carotid artery chimneys, 4 left subclavian artery chimneys, 1 left carotid–subclavian bypass, 5 celiac artery chimneys, 5 superior mesenteric artery chimneys, and 10 renal artery chimneys. The decision to perform zone 0-5 vs zone 5-10 aortic reconstruction was determined by patient presentation and aortic morphology. Two patients (40%) underwent zone 0-5 aortic reconstruction first, and three patients (60%) underwent zone 5-10 aortic reconstruction first. The technical success rate was 100%. The mean interval between staged zone 5-10 aortic reconstruction was 6 weeks, and all the unrestrained chimney stent grafts maintained their orientation without migration between procedures.

Table I. Patient demographics

Characteristic	No. (%) or mean ± SD
Gender	
Male	3 (60)
Female	2 (40)
Comorbidity	
Diabetes	1 (20)
Hypertension	5 (100)
Coronary artery disease	4 (80)
Smoker	3 (60)
COPD	2 (40)
Chronic renal insufficiency	1 (20)
Thoracic aortic aneurysm size, cm	7.1 ± 0.51
Abdominal aortic aneurysm size, cm	7.0 ± 0.27

COPD, Chronic obstructive pulmonary disease; *SD,* standard deviation.

On the first postoperative CTA, two endoleaks (40%) were identified in zone 0-5 (two patients with aortic arch dissection extending into the innominate arteries had a retrograde innominate endoleak into the false lumen) and two visceral chimney gutter endoleaks (40%) were identified in zone 5-10. All four patients underwent catheter-directed embolization (Fig 8). During patient follow-up, three additional gutter endoleaks were identified; all were treated with catheter-directed embolization (Table II). Two patients had persistent type II residual endoleaks with no change in aneurysm size, which were managed conservatively. In the present patient cohort, for asymptomatic patients, we treated gutter endoleaks that persisted for 6 months in non-shrinking aneurysms. For symptomatic patients, we treated gutter endoleaks when identified. None of the

Fig 8. Translumbar catheter-directed embolization of an endoleak after zone 0-10 reconstruction.

Table II. Patient procedures and outcomes

Variable	Zone 0-5	Zone 5-10
Aortic aneurysm	1 (20)	1 (20)
Aortic dissection and aneurysm	4 (80)	4 (80)
Chimneys/periscopes	14 (41)	20 (59)
Initial endoleaks	2 (40)	2 (40)
Chimney stent graft occlusion	0 (0)	1 (5)
Persistent endoleaks	1 (20)	2 (40)
Postoperative complications		
Cardiac	0 (0)	0 (0)
Cerebrovascular	0 (0)	0 (0)
Pulmonary	0 (0)	0 (0)
Renal	0 (0)	0 (0)
30-Day mortality	0 (0)	0 (0)

Data presented as number (%).

patients experienced major complications, including stroke, spinal cord ischemia, bowel ischemia, renal failure, limb ischemia, or death. At a mean follow-up of 4.5 ± 3.1 years, aortic reconstruction-related mortality was 0%. All-cause mortality was 20%; one patient had died of pneumonia at 3 years postoperatively. Chimney occlusion was noted incidentally in one chimney (2.9%); the patient was asymptomatic with celiac chimney occlusion.

DISCUSSION

Our experience with the endovascular docking station technique for staged complex aortic repairs originated nearly one decade ago. The fenestrated stent grafts currently available were not available then, and we did not have access to an investigational device exemption for physician-modified endografts with a fenestrated design. We recognize that other devices and approaches could also be used and that the present series was a small case series of a select patient population. Therefore, we remain guarded in drawing broad conclusions. Others have described isolated repairs of arch, thoracoabdominal, and aortoiliac aneurysms using a variety of different parallel stent graft in a "sandwich" configuration.[5-10] What is unique about our technique is that by creating an endovascular docking station, for the first time, we were able to stage zone 5-10 repair using parallel stent grafts and prevent spinal cord ischemic complications. Furthermore, our endovascular docking station technique allows for zone 5-10 to be treated before treating zone 0-5 and to preserve flow to the visceral vessels. In the present report, we describe our approach and experience with complete zone 0-10 endovascular aortic reconstruction using off-the-shelf stent grafts in parallel configuration using chimneys and an endovascular docking station for complex thoracoabdominal aortic aneurysms and dissections.

The evolution of endovascular techniques and technology has encouraged their adoption in the management of complex aortic dissections and aneurysms.[6,11] However, even today, a subset of patients will be considered unfit for surgery and refused repair or will not meet the inclusion criteria for the currently available fenestrated and branched stent grafts. Furthermore, contemporary data on zone 0-5 TEVAR are evolving. A systematic review of contemporary outcomes of endovascular zone 5-10 thoracoabdominal aortic reconstructions using fenestrated and branched devices indicated rates of hospital mortality of 7.4%, spinal cord ischemia of 13.5%, and permanent paralysis of 5.2%.[7,12-15] We first reported our experience with zone 0 triple arch chimney TEVAR using a parallel stent graft configuration in 2014. A systematic review of current data with a similar technique indicated rates of procedure-related complications, chimney stent graft patency, gutter endoleaks, mortality, and conversion to open surgical repair of 6%, 99%, 11%, 4%, and 1%, respectively.[3,12] Similarly, our experience with zone 0-5 complete arch TEVAR using parallel stent graft configurations has been promising, with low procedure-related morbidity and mortality.

When treating select high-risk patients considered unfit for surgery with complex zone 0-10 aortic dissections and aneurysms, our approach has focused on patient safety and procedure feasibility. Case planning includes appropriate case selection and stent graft oversizing at the proximal or distal fixation sites, and we anticipate the occurrence of gutter endoleaks. To minimize gutter endoleaks, all arch chimneys and all visceral chimneys are oriented anteriorly or posteriorly to the thoracic and abdominal aortic stent graft. This technique allows for better stent graft opposition when in parallel configuration, and we believe it minimizes the incidence of gutter endoleaks and chimney stent graft strictures and kinks. Furthermore, it also allows for easier access to the gutter endoleaks when embolization procedures are planned. Additionally, this technique adopts the use of longer visceral chimneys to allow for longer parallel stent graft overlap zones and longer gutters. Pressure reduction across thrombosed endoleaks channels is directly proportional to the length of the endoleak channel and inversely proportional to the diameter of the endoleak channel.[15] Longer gutter endoleaks when thrombosed, with or without embolization procedures, likely result in significant pressure reduction and are less likely to allow aneurysm sac growth. Much has been reported on the natural history of gutter endoleaks, and the data have evolved with improved patient selection, stent graft sizing and overlap, and technical ability.[16] Ullery et al[16] reported their contemporary data, indicating that gutter endoleaks can occur in 30% of patients, can be relatively benign in many patients, and can spontaneous resolve in as many as 44% at 6 months, 65% at 12 months, and 88% at 18 months.

The endovascular docking station using a parallel stent graft configuration allows for the staging of endovascular zone 0-10 aortic reconstruction, which, in our experience, allows for planning of the procedures in accordance with patient aortic morphology and presentation. It provides the ability to bridge the zone 0-5 thoracic stent grafts to the zone 5-10 devices and to stage the endovascular zone 5-10 reconstruction into two parts to minimize the risk of spinal cord ischemia. In addition, the technical simplicity of the procedure combats physician fatigue, allows for a single visceral artery to be catheterized and manipulated at a time, and allows for case planning based on contrast usage for patients with chronic kidney disease. There is also flexibility with the option to stage visceral chimney placement, because it is not required to place all four visceral chimneys in one procedure.

Based on current data, it is difficult to decipher whether chimney orientation (antegrade chimneys vs retrograde periscopes) affects patency.[2,4] What we have learned is that chimney orientation requires careful consideration, particularly when the aorta is narrow (<30 mm) in zones 6 to 8, and chimney stent grafts likely have higher stenosis and occlusion rates if they have an acute angulation. Using longer chimneys allows them to bend gradually and avoids abrupt kinks. In patients with severe >60% visceral osteal stenosis, we routinely use balloon-expanding stents to treat the lesions before chimney stent graft placement. Also, all Viabahn chimney stent grafts are reinforced with self-expanding stents across the length of the chimney, which not only increases their radial force, but also allows for a gradual bend. With our adoption of these methods, we have had a low incidence of chimney occlusion during long-term patient follow-up.

Our technical approach to zone 0-10 aortic reconstruction included a standardized approach, as described in the Methods section, which is especially important in zone 5-10 reconstruction to build the endovascular docking station. The simplicity of this procedure only required appropriately sized stent graft deployment in the mid to distal thoracic aorta, transbrachial visceral artery cannulation, and appropriately sized tubular chimney stent graft deployment. Preoperative CTA-based visceral fenestration and branch orientation were not needed. The simplicity of the endovascular docking station included the ability to modify the chimney and periscope configurations and stop at any step of the procedure, if needed.

CONCLUSIONS

Complete endovascular zone 0-10 aortic reconstruction using parallel stent grafts with a docking station is a feasible and safe technique that offers the ability to use off-the-shelf stent graft devices to customize treatment for high-risk patients in a staged manner with limited morbidity and mortality. Although our experience has been promising, for this approach to be useful in our armamentarium of techniques, we will need further studies across multiple centers and with larger patient populations.

REFERENCES

1. Harky A, Chan J, MacCarthy-Ofosu B. The future of stenting in patients with type A aortic dissection: a systematic review. J Int Med Res 2020;48:300060519871372.
2. Tanious A, Wooster M, Armstrong PA, Zwiebel B, Grundy S, Back MR, et al. Configuration affects parallel stent grafting results. J Vasc Surg 2018;67:1353-9.
3. Muetterties CE, Menon R, Wheatley GH 3rd. A systematic review of primary endovascular repair of the ascending aorta. J Vasc Surg 2018;67:332-42.
4. Mehta M, Paty PSK, Kostun Z, Teymouri M. Feasibility and safety of endovascular docking station with chimney stentgraft for staged Crawford types I to IV thoracoabdominal aortic aneurysm repair. J Vasc Surg 2019;69:e106.
5. Donas KP, Torsello GB, Piccoli G, Pitoulias GA, Torsello GF, Bisdas T, et al. The PROTAGORAS study to evaluate the performance of the Endurant stent graft for patients with pararenal pathologic processes treated by the chimney/snorkel endovascular technique. J Vasc Surg 2016;63:1-7.
6. Lobato AC, Camacho-Lobato L. Endovascular treatment of complex aortic aneurysms using the sandwich technique. J Endovasc Ther 2012;19:691-706.
7. Van Bakel TM, de Beaufort HW, Trimarchi S, Marrocco-Trischitta MM, Bismuth J, Moss FL, et al. Status of branched endovascular aortic arch repair. Ann Cardiothorac Surg 2018;7:406-13.
8. Rocha RV, Lindsay TF, Friedrich JO, Shan S, Sinha S, Yanagawa B, et al. Systematic review of contemporary outcomes of endovascular and open thoracoabdominal aortic aneurysm repair. J Vasc Surg 2020;71:1396-412.
9. Lindblad B, Bin Jabr A, Holst J, Malina M. Chimney grafts in aortic stent grafting: hazardous or useful technique? Systematic review of current data. Eur J Vasc Endovasc Surg 2015;50:722-31.

10. Hauck SR, Kern M, Dachs T, Haider L, Stelzmuller M, Ehrilch M, et al. Applicability of endovascular branched and fenestrated aortic arch repair devices to treat residual type A dissection after ascending replacement. J Vasc Surg 2022;76:1440-8.
11. De Beaufort HW, Trimarchi S, Korach A, Di Eusanio M, Gilon D, Montgomery DG, et al. Aortic dissection in patients with Marfan syndrome based on the IRAD data. Ann Cardiothorac Surg 2017;6:633-41.
12. Pape LA, Awais M, Woznicki EM, Suzuki T, Trimarchi S, Evangelista A, et al. Presentation, diagnosis, and outcomes of acute aortic dissection: 17-year trends from the International Registry of Acute Aortic Dissection. J Am Coll Cardiol 2015;66:350-8.
13. Ye C, Chang G, Li S, Hu Z, Yao C, Chen W, et al. Endovascular stent-graft treatment for Stanford type A aortic dissection. Eur J Vasc Endovasc Surg 2011;42:787-94.
14. Mehta M, Paty P, Bennett E, Britton L, Hnath J, Kreienberg PB, et al. Initial experience and lessons learned from complete endovascular zone 0 TEVAR and triple chimney technique for innominate, carotid and subclavian revascularization. J Vasc Surg 2014;60:821-2.
15. Mehta M, Ohki T, Veith FJ, Lipsitz E. All sealed endoleaks are not the same; a treatment strategy based on an ex-vivo analysis. Eur J Vasc Endovasc Surg 2001;21:541-4.
16. Ullery BW, Tran K, Itoga NK, Kalman RL, Lee JT. Natural history of gutter-related type Ia endoleaks after snorkel/chimney endovascular aneurysm repair. J Vasc Surg 2017;65:981-90.

Submitted Sep 9, 2022; accepted Jan 7, 2023.