

# Overcoming Anatomic Limitations to EVAR With Chimney and Periscope Grafts

Technical tips and tricks for using chimney and/or periscope grafts to successfully treat a wide range of complex aortic aneurysmal pathologies.

**BY FELICE PECORARO, MD; THOMAS PFAMMATTER, MD; MARIO LACHAT, MD; DIETER MAYER, MD; ZORAN RANCIC, MD, PhD; MICHAEL GLENCK, MD; GILBERT PUIPPE, MD; AND FRANK J. VEITH, MD**

Open surgical treatment was the unchallenged gold standard for all thoracic, abdominal, and thoracoabdominal aortic aneurysms until endovascular aneurysm repair (EVAR) was introduced some 20 years ago.<sup>1</sup> Since then, with the desire to reduce rates of procedure-related mortality and morbidity, EVAR has been progressively extended to more challenging aortic anatomies, especially to abdominal or thoracic aortic aneurysms involving the renovisceral or aortic arch branches.<sup>2</sup>

The branched or fenestrated stent grafts that have been used for most of these complex EVAR cases have highlighted the advantages of endovascular repairs. However, these branched and fenestrated EVARs have some limitations.<sup>3</sup> In order to extend endovascular repair to patients whose anatomy is unfit for branched or fenestrated stent grafts or open repair, parallel graft techniques using chimney grafts (CGs) or periscope grafts (PeGs) have been developed.<sup>4</sup> Following the report of good early results, several recent series have confirmed midterm durability similar to other endovascular repair techniques.<sup>5,6</sup> We report the most important tips and tricks we have used to perform EVAR with CGs and/or PeGs.

## PLANNING THE PROCEDURE

Accurate preoperative planning is essential for a successful EVAR procedure based on the use of parallel

TA CTA provides information on the potential access sites and the best routes from these sites to the target artery or arteries.

grafts, either with CGs or PeGs. In order to assess and understand the anatomy and extent of the aortic and branch pathology and to perform accurate endoluminal diameter and length measurements, high-definition thoracoabdominal CT angiography (TA CTA) with 3D reconstructions is a basic necessity and is required in all cases. Three-dimensional magnetic resonance imaging might be an alternative imaging source, but we have no experience with this technique. TA CTA provides information on the potential access sites and the best routes from these sites to the target artery or arteries. If the aortic arch shows severe atherosclerotic disease with possible floating plaques, a supra-aortic access might be contraindicated. In addition, if the aortic arch (type II or III arch) or thoracoabdominal aorta is elongated with a siphon-like configuration, access to the renovisceral vessels from above might be quite cumbersome, and

accurate navigation or trackability may be difficult or even impossible. In such cases, a transfemoral approach is best.

### PATIENT SELECTION

If a CG- or PeG-based EVAR procedure is considered, landing and sealing zones consisting of a normal vessel wall diameter and a morphology  $\geq 2$  cm in length is required in both the aorta and its branches. Shorter landing zone(s) might still be appropriate, especially in the aortic branches, but these should be the exception and involve greater risk and special deployment techniques. Even if technically feasible, the risk of a persistent endoleak, or so-called gutter endoleak, is increased.

### ENDOVASCULAR DEVICE OPTIONS

The tools necessary for CG and/or PeG procedures are universally available as off-the-shelf devices. Sizing of these grafts is based on the manufacturer's recommendations, generally approximately 1-mm oversizing in regard to the native artery. CG and/or PeG length have to be chosen so that at least 1 cm of the CG or PeG extends beyond the covered part of the aortic stent graft. More than one stent graft might be necessary to achieve the appropriate CG or PeG length. In this case, a minimum of 2.5-cm overlapping of the different compounds of the CG or PeG should be used. In our experience, most CGs and/or PeGs have been constructed using self-expanding stent grafts (Viabahn, Gore & Associates, Flagstaff, AZ). Rarely, only bare-metal stents were used to construct the CG and/or PeG (Wallstent, Boston Scientific Corporation, Natick, MA; and Palmaz Blue or Corinthian SES, Cordis Corporation, Bridgewater, NJ). If necessary, self-expandable stents should be deployed into the CG and/or PeG to treat a residual stenosis detected during or after the procedure. To increase periprocedural visibility, especially in a case of multiple CGs and/or PeGs, we have used primary relining with self-expandable stents (mostly Wallstents).

Sizing of the aortic stent graft diameter is based on the approximate mean aortic diameter at the intended landing zone plus half the diameter of the single parallel graft, or half the sum of the diameters of all parallel grafts if more than one parallel graft is used. For example, if the mean aortic diameter is 24 mm, and two renal chimney grafts that are 6 mm each have been used, the diameter of the aortic stent graft that will be used is  $24 \text{ mm} + (6 + 6)/2$ , which equals 30 mm. If the aorta is not a perfect cylinder, the mean aortic diameter is determined as follows:  $(\text{greatest aortic diameter} + \text{smallest aortic diameter})/2$ . This sizing formula is used for all different types of aortic or branch stent grafts (Excluder

and TAG, Gore & Associates; Evita, Jotec GmbH, Hechingen, Germany; Talent, Medtronic, Inc., Santa Rosa, CA; and Zenith, Cook Medical, Bloomington, IN). In young patients (younger than 70 years), some oversizing (up to 10%) should be considered in order to anticipate natural aortic growth during the next few decades. Therefore, in a young patient with the previously mentioned grafts in the example equation, the aortic stent graft diameter would be 32 mm.

### TECHNIQUE

After the peripheral remote accesses have been exposed (cut down) or punctured, an intravenous bolus of 5,000 intravenous units of heparin is administered. During the procedure, heparin will be readministered regularly, so that the activated clotting time value (tested every 30 minutes) is  $> 180$  seconds or  $> 250$  seconds if supra-aortic accesses are used. The procedure starts with CGs and/or PeGs being built up. The aortic branches are cannulated with standard wires and catheters. In our experience, the Chuang visceral reverse curve catheter (Cook Medical) combined with a soft Terumo guidewire (Terumo Interventional Systems, Somerset, NJ) is the most useful combination for branch cannulations. Once the catheter is introduced a few centimeters inside the target artery, the Terumo guidewire is exchanged with a 260-cm Rosen wire (Cook Medical), and a 45-cm armed sheath (Arrow-Flex sheath, Arrow International, a division of Teleflex, Durham, NC) is introduced near the origin of the aortic branch. The Rosen wire has an atraumatic tip and is relatively stiff.

The intended parallel graft, CG or PeG, is then introduced, deployed, and molded to achieve good anchorage. The molding balloon diameter should match the diameter of the CG and/or PeG; its length is usually 20 mm. When using Viabahn stent grafts longer than 5 cm, the Arrow-Flex sheath is left near the vessel ostium and slowly and stepwise pulled back while the Viabahn device is deployed. This prevents parallel graft displacement during CG and/or PeG deployment. The same procedure is repeated according to the number of aortic branches to be addressed. CG and/or PeG stent graft positioning into the target arteries should be approximately 2 cm. Deployment should be preceded by an angiographic control with the appropriate C-arm angulation to avoid inadvertent coverage of important side branches. After all CGs and/or PeGs have been deployed, the aortic stent graft will be positioned and deployed.

During deployment of the aortic stent graft, a percutaneous transluminal angioplasty balloon is inflated inside the aortic branches (inside the Viabahn), and gentle pullback traction is applied. This maneuver allows align-

ment of the CG and/or PeG parallel to the axis of the aorta and prevents the grafts crossing at the level of the aortic stent graft landing zone. The procedure is completed after angiography has proven correct positioning and functioning of all devices and after a kissing-balloon maneuver has optimized full molding of all components within the aortic neck. When the target artery landing zone is shorter than 1 cm, the CG and/or PeG could alternatively be deployed after the aortic stent graft has already been deployed. In the latter case, the undeployed CG and/or PeG is pressed against the aortic wall and maintained in this position. This stabilizes it during its deployment; as a result, its placement will be very accurate.

### CONFIGURATION AND REMOTE ACCESS

The configuration of CGs and/or PeGs, the relative number used, and the routes of implantation are based on patient anatomy, the number of aortic branches involved, and the type of aortic disease. The flexibility of this parallel graft technique allows a tailored approach in every case. CGs are generally introduced and deployed from a supra-aortic access site, the brachial artery, or the axillary artery. They originate cranially from the proximal landing zone of the aortic stent graft and get antegrade flow. Conversely, PeGs are introduced transfemorally, originate distally from the distal aortic landing zone, and get retrograde blood flow. The periscope configuration usually allows an extension of the distal landing zone.

Recently, a transfemoral CG lift technique has also been described.<sup>7</sup> The lift technique is useful when conventional supra-aortic access and routes for CG deployment are considered high risk because of embolization from aortic arch disease or in an emergency setting to reduce the time of surgical access exposure. For the lift technique, standard access with a 7- or 8-F, 45-cm armed sheath and catheterization techniques as previously described are typically used to access the renal artery. Subsequently, a Viabahn stent graft is deployed as a PeG, with its proximal end below the renal artery. A corresponding angioplasty balloon is then positioned and inflated in the distal part of the Viabahn device within the renal artery to achieve optimal anchorage. The balloon is then deflated but remains in place, as it will be reinflated later. A stiff buddy wire (Lunderquist, Cook Medical; or Amplatz, Boston Scientific Corporation, Natick, MA) is then introduced coaxially into the transfemoral 45-cm armed sheath and upward into the aorta.

The aortic stent graft is introduced (generally, from the contralateral common femoral artery) and parked cranially to the aortic bifurcation. The percutaneous transluminal angioplasty balloon in the PeG in the renal artery is now fully reinflated. The Rosen wire is removed

---

The configuration of CGs and/or PeGs, the relative number used, and the routes of implantation are based on patient anatomy, the number of aortic branches involved, and the type of aortic disease.

---

about 10 cm to give unrestricted flexibility to the balloon catheter. The transfemoral armed sheath is then carefully advanced over the stiff wire, so that the PeG is "lifted up" or pushed up in the aorta by the sheath. In addition, the balloon catheter is pushed upward. At the end of this maneuver, the renal periscope has been transformed into a chimney. A second renal artery can be treated with the same procedure and lifted eventually at the same time as the first one. In this case, the "lift up" maneuver of both renal arteries should be performed once both stent grafts are deployed in PeG configuration. This double "lift up" maneuver can be performed simultaneously. The Rosen wire should then be reintroduced through the angioplasty balloon before deflating the latter. Finally, the aortic stent graft is advanced, positioned, and deployed immediately after the renal artery lift maneuver is completed. Kissing-balloon treatment of the CG(s) and aortic stent graft completes the procedure.

CGs and/or PeGs can also be used with the so-called sandwich technique in complex aortic disease to reduce periscope length. In this technique, the CG or PeG is placed between two aortic stent grafts (inside one and outside the other) to stabilize the chimney.<sup>8</sup>

### Intraoperative Patency Assessment

Completion angiography, selective angiography, and pressure pull-through manometry are necessary to assess the patency of all CGs and/or PeGs and detect eventual stenosis or endoleaks. It might be necessary to use more than one projection and selective catheter injections to obtain the correct imaging information. Pressure measurement must be performed at the level of the aorta, in the aortic stent graft, and inside any CG and/or PeG (at proximal and distal levels). A stenosis of > 50% and/or a systolic arterial pressure drop along a CG and/or PeG of > 20% require additional ballooning (eventually as a kissing-balloon technique) and/or stenting. In our experience, self-expandable uncovered stents, such as the Wallstent, are usually sufficient to treat CG or PeG residual stenosis. Completion angiography is also performed

CASE 1

An 80-year-old patient presented with a ruptured AAA. At the beginning of the procedure, an electromechanical dissociation required mechanical resuscitation. Despite that, EVAR was completed under local anesthesia. Preoperative TA CTA showed challenging infrarenal



Figure 1. Preoperative TA CTA.

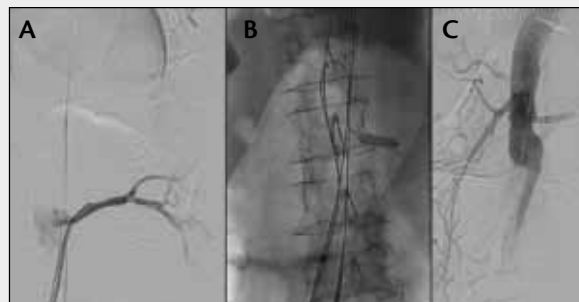


Figure 2. Arrow-Flex sheath and Rosen wire in the left renal artery (A). The Viabahn PeG lifted (B). Angiography after aortic stent graft deployment (C). Republished with permission of Intl Society of Endovascular Specialists ISES, from Chimney endografting for pararenal aortic pathologies using transfemoral access and the lift technique, Lachat M, Bisdas T, Rancic Z, et al, 20, 4, 2013; permission conveyed through Copyright Clearance Center, Inc.<sup>7</sup>

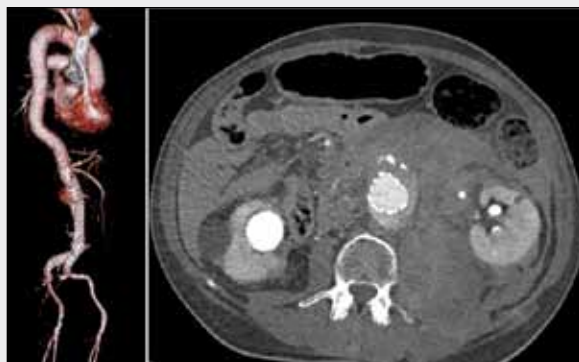


Figure 3. A type IA endoleak immediately post-EVAR.

anatomy with a short neck due to low onset of the left renal artery (Figure 1). Figure 2 shows angiographic images of the left renal artery chimney graft (by transfemoral lift technique) and bifurcated aortic stent graft (Endurant, Medtronic, Inc.) implantation. Postoperative TA CTA showed a low-flow type IA endoleak (Figure 3), and TA CTA showed spontaneous sealing of this endoleak at 1 week (Figure 4). Some months after EVAR, colon carcinoma was detected and treated with a laparoscopic-assisted colectomy. This procedure was complicated by anastomotic insufficiency and septic shock. Eleven months after the EVAR procedure, the patient is doing well and awaiting definitive colon reconstruction and closure of anus praeter. At this time, significant neck (Figure 5) and aneurysm (Figure 6) remodeling are evident.



Figure 4. Spontaneous endoleak sealing after 1 week.

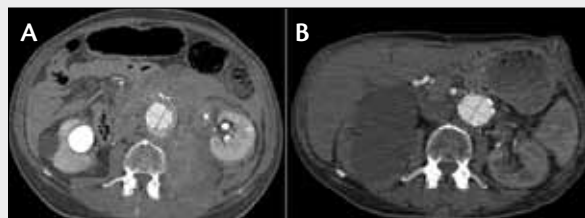


Figure 5. Preoperative imaging (A) and neck remodeling 11 months after EVAR (B).

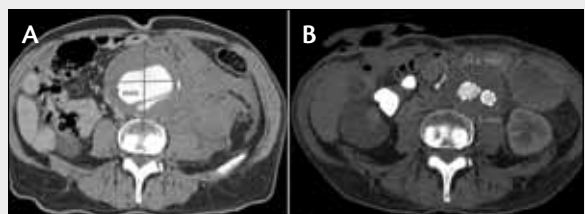
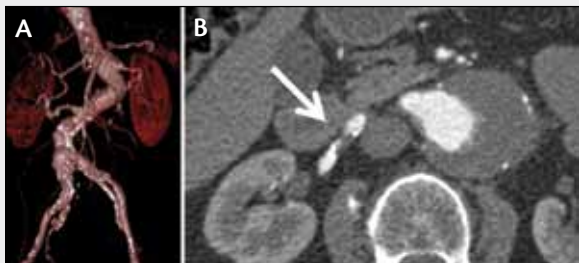


Figure 6. Preoperative imaging (A) and aneurysm remodeling 11 months after EVAR (from 80 mm to 60 mm) (B).

## CASE 2

An 84-year-old woman presented with a rapidly growing aortoiliac aneurysm. Figure 7 shows a three-dimensional reconstruction of preoperative CTA. The right kidney was fed by an atypically low-originating renal artery. An axial CT slice showed a AAA diameter

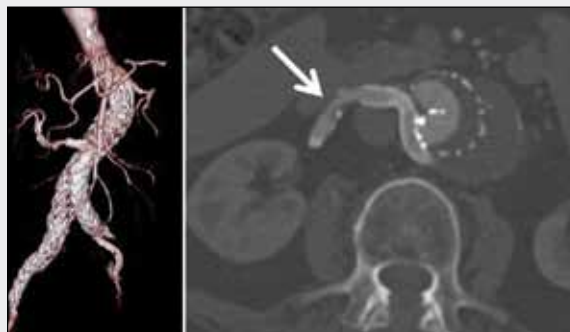


**Figure 7.** Three-dimensional reconstruction of the preoperative CTA. The right kidney was fed by an atypically low-originating renal artery (A). The axial CT slice shows a AAA diameter of 50 mm and the right renal originating out of the aortic aneurysm (B). The arrow demonstrates a low-grade right renal artery stenosis.



**Figure 8.** Intraoperative findings of a transfemoral CG with lift technique. The transfemoral right renal artery is cannulated (A). Viabahn deployment in a PeG configuration (B). Viabahn chimney configuration after lift technique while a PTA balloon anchors the distal end inside the renal artery (C). Completion angiography (D).

of 50 mm and the right renal artery originating out of the aortic aneurysm, as well as a low-grade right renal artery stenosis. We decided to implant a transfemoral CG with the lift technique (Figure 8). The transfemoral right renal artery was cannulated, a 7-mm, 10-cm Viabahn device was deployed in a PeG configuration, and the Viabahn chimney configuration was achieved by lifting upward while a PTA balloon anchored its distal end inside the renal artery. We implanted an Endurant stent graft (28 X 16 mm, 14.5 cm), coiled the right hypogastric artery, and performed stent graft molding with a kissing balloon. Imaging showed unrestricted patency of the CG and complete sealing of the aortic aneurysm. At 2-year follow-up, CTA confirmed the absence of migration, complete aneurysm sealing, and a patent CG (Figure 9). The low-grade renal artery stenosis located distally from the Viabahn device was unchanged in comparison with the preoperative CTA. The right kidney size and renal function remained unchanged and normal. Finally, the aneurysm decreased in size by 15%.



**Figure 9.** CTA at 2-year follow-up.

to detect endoleaks and should include late-phase images. In our opinion, type I endoleaks that appear very early after contrast injection (especially if extending into and filling the aneurysm sac) and type III endoleaks require immediate correction with repeated kissing-balloon technique or additional stent grafting.

Low-flow endoleaks appearing late after contrast injection that do not fill the aneurysm sac, especially gutter endoleaks limited to the proximal and/or distal neck(s), can be treated conservatively. In our experience, if there is sufficient CG and/or PeG aortic graft overlap, these gutter endoleaks have a tendency to seal spontaneously in a short time.<sup>9</sup> However, endoleaks sometimes require treatment with coils and/or thrombin, Onyx liquid embolic system

(Covidien, Mansfield, MA), Amplatzer septal occluders (St. Jude Medical, Inc., St. Paul, MN), or stent graft extensions. Most endoleak sealing is performed via transfemoral access, but in some cases, translumbar access may be required. Generally, sealing can be achieved in one stage, but some cases require several reinterventions.

#### Perioperative Medication and Follow-Up Protocol

Therapeutic heparinization, used early postoperatively, is replaced by warfarin and aspirin therapy after a few days. Warfarin is stopped after a 3-month period and replaced by clopidogrel. Dual-antiplatelet therapy is used for approximately 12 months. Later, aspirin therapy alone is sufficient, in our opinion. As an alternative, the

The major advantage of the CG and/or PeG EVAR technique is that it can be applied in most anatomies using conventional EVAR devices that are universally available.

dual-antiplatelet regimen can be started early postoperatively. Imaging follow-up includes regular TA CTA with arterial and venous phases to detect low-flow endoleaks. Generally, TA CTA is performed at 6 weeks and 3, 6, and 12 months postoperatively and annually thereafter. In case of contraindication to TA CTA (eg, allergy or renal failure), a noncontrast CT and a contrast duplex ultrasound of the aneurysm sac and renal parenchyma can be used.

## DISCUSSION

Different endovascular approaches have been proposed and employed for the treatment of complex aortic pathologies. EVAR using fenestrated and/or branched devices is the most common alternative to open surgery,<sup>3</sup> but recently, CG and/or PeG EVAR have emerged as valuable alternatives.<sup>10</sup> The midterm results are promising and comparable to those of EVAR with fenestrated and/or branched devices, if certain technical precautions are used. However, the overall experience with CGs and/or PeGs is still relatively limited and short, with a mean follow-up period of < 3 years.<sup>5</sup> Thus far, there is no indication that the results will worsen with longer follow-up, but as with other endovascular repair methods, these CG and PeG techniques should be used with caution in young and low-surgical-risk patients.

The major advantage of the CG and/or PeG EVAR technique is that it can be applied in most anatomies using conventional EVAR devices that are universally available. As a consequence, these techniques can even be employed in emergent or urgent settings in most centers performing EVAR.<sup>10</sup> However, it must be emphasized that it is extremely important to proceed with the main steps of these techniques in a systematic manner to reduce the risk of complications or errors.<sup>11</sup> Any possible technical difficulties (eg, complicated aortic branch cannulation) should be recognized, and an appropriate strategy should be planned in advance.

In conclusion, EVAR using CGs and/or PeGs is an effective technique to treat complex aortic aneurysmal pathologies. It can be used in both elective and emergent settings with off-the-shelf devices, with no need for

customized grafts. Performing the procedure according to standardized steps and meticulous preoperative planning using the tips and tricks we describe can allow good outcomes, even in difficult circumstances. ■

*Felice Pecoraro, MD, is with the Clinic for Cardiovascular Surgery, University Hospital in Zurich, Switzerland, and the Vascular Surgery Unit, University of Palermo in Palermo, Italy. He stated that he has no financial interests related to this article. Dr. Pecoraro may be reached at felicepecoraro@libero.it.*

*Thomas Pfammatter, MD, is with the Interventional Radiology Department, University Hospital in Zurich, Switzerland. He stated that he has no financial interests related to this article.*

*Mario Lachat, MD, is with the Clinic for Cardiovascular Surgery, University Hospital in Zurich, Switzerland. He stated that he has no financial interests related to this article.*

*Dieter Mayer, MD, is with the Clinic for Cardiovascular Surgery, University Hospital in Zurich, Switzerland. He stated that he has no financial interests related to this article.*

*Zoran Rancic, MD, PhD, is with the Clinic for Cardiovascular Surgery, University Hospital in Zurich, Switzerland. He stated that he has no financial interests related to this article.*

*Michael Glenck, MD, is with the Interventional Radiology Department, University Hospital in Zurich, Switzerland. He stated that he has no financial interests related to this article.*

*Gilbert Puijpe, MD, is with the Interventional Radiology Department, University Hospital in Zurich, Switzerland. He stated that he has no financial interests related to this article.*

*Frank J. Veith, MD, is with New York University Medical Center in New York, New York, and the Cleveland Clinic in Cleveland, Ohio. He stated that he has no financial interests related to this article.*

1. Coselli JS, Bozinovski J, LeMaire SA. Open surgical repair of 2286 thoracoabdominal aortic aneurysms. *Ann Thorac Surg.* 2007;83:S862-864; discussion S890-862.

2. Greenberg RK. Aortic aneurysm, thoracoabdominal aneurysm, juxtarenal aneurysm, fenestrated endografts, branched endografts, and endovascular aneurysm repair. *Ann N Y Acad Sci.* 2006;1085:187-196.

3. Amiot S, Haulon S, Becquemin JP, et al. Fenestrated endovascular grafting: the French multicenter experience. *Eur J Vasc Endovasc Surg.* 2010;39:537-544.

4. Lachat M, Frauenfelder T, Mayer D, et al. Complete endovascular renal and visceral artery revascularization and exclusion of a ruptured type IV thoracoabdominal aortic aneurysm. *J Endovasc Ther.* 2010;17:216-220.

5. Lachat M, Veith FJ, Pfammatter T, et al. Chimney and periscope grafts observed over 2 years after their use to revascularize 169 renovisceral branches in 77 patients with complex aortic aneurysms. *J Endovasc Ther.* 2013;20:597-605.

6. Donas KP, Pecoraro F, Bisdas T, et al. CT angiography at 24 months demonstrates durability of EVAR with the use of chimney grafts for pararenal aortic pathologies. *J Endovasc Ther.* 2013;20:1-6.

7. Lachat M, Bisdas T, Rancic Z, et al. Chimney endografting for pararenal aortic pathologies using transfemoral access and the lift technique. *J Endovasc Ther.* 2013;20:492-497.

8. Kolvenbach RR, Yoshida R, Pinter L, et al. Urgent endovascular treatment of thoraco-abdominal aneurysms using a sandwich technique and chimney grafts—a technical description. *Eur J Vasc Endovasc Surg.* 2011;41:54-60.

9. Donas KP, Pecoraro F, Torsello G, et al. Use of covered chimney stents for pararenal aortic pathologies is safe and feasible with excellent patency and low incidence of endoleaks. *J Vasc Surg.* 2012;55:659-665.

10. Pecoraro F, Pfammatter T, Mayer D, et al. Multiple periscope and chimney grafts to treat ruptured thoracoabdominal and pararenal aortic aneurysms. *J Endovasc Ther.* 2011;18:642-649.

11. Pecoraro F, Rancic Z, Pfammatter T, et al. Periscopes, chimneys, sandwich and VORTEC to facilitate abdominal and thoracoabdominal aortic aneurysm repair. *Gefäßchirurgie.* 2012;17:632-639.