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Abstract: Purpose : To present early and midterm results of the periscope endograft (PG) technique to maintain left subclavian artery (LSA) blood flow in thoracic endovascular aortic repairs (TEVAR) involving zone 3. Methods : From April 2010 to January 2013, 14 consecutive high-risk patients (11 men; mean age 70±8 years, range 56-87) underwent TEVAR with the PG technique for 10 thoracic aortic aneurysms (TAA), 2 traumatic aortic ruptures, and 2 aortic dissections without a suitable landing zone (>2 cm distal to the LSA). Five procedures were performed emergently for rupture (3 TAAs and the 2 trauma cases). Two patients had a periscope deployed in an aberrant right subclavian artery. The periscope endografts were sized 1 to 2 mm larger than the branch artery at the intended landing zone. The caudal end was extended distal to the intended distal landing site of the thoracic stent-graft, which was usually deployed after the PG. Both the PG and thoracic stent-grafts were generally molded using the kissing balloon technique. Outcomes analyzed were immediate technical success, perioperative mortality and morbidity, aneurysm diameter change, and periscope endograft patency. Results : Immediate technical success was 100%, with all procedures completed as planned. Perioperatively, one periscope occluded and one of the ruptured TAA patients died. One percutaneous access site hematoma required only conservative management. At a mean follow-up of 26±9 months (range 9-37), there was no additional PG occlusion. The Kaplan-Meier estimate of PG patency was 93% at 2 years. Conclusion : The periscope endograft is a simple technique to maintain perfusion to the LSA in cases where the aortic stent-graft crosses its ostium. The PG technique can be performed transfemorally and even percutaneously, and it can be applied to all supra-aortic branches. Early and midterm results are encouraging, but more experience and long-term results are mandatory before this technique can be widely recommended.

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◆CLINICAL INVESTIGATION ◆

Periscope Endograft Technique to Revascularize the Left Subclavian Artery During Thoracic Endovascular Aortic Repair

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Purpose: To present early and midterm results of the periscope endograft (PG) technique to maintain left subclavian artery (LSA) blood flow in thoracic endovascular aortic repairs (TEVAR) involving zone 3.

Methods: From April 2010 to January 2013, 14 consecutive high-risk patients (11 men; mean age 70±8 years, range 56–87) underwent TEVAR with the PG technique for 10 thoracic aortic aneurysms (TAA), 2 traumatic aortic ruptures, and 2 aortic dissections without a suitable landing zone (>2 cm distal to the LSA). Five procedures were performed emergently for rupture (3 TAAs and the 2 trauma cases). Two patients had a periscope deployed in an aberrant right subclavian artery. The periscope endografts were sized 1 to 2 mm larger than the branch artery at the intended landing zone. The caudal end was extended distal to the intended distal landing site of the thoracic stent-graft, which was usually deployed after the PG. Both the PG and thoracic stent-grafts were generally molded using the kissing balloon technique. Outcomes analyzed were immediate technical success, perioperative mortality and morbidity, aneurysm diameter change, and periscope endograft patency.

Results: Immediate technical success was 100%, with all procedures completed as planned. Perioperatively, one periscope occluded and one of the ruptured TAA patients died. One percutaneous access site hematoma required only conservative management. At a mean follow-up of 26±9 months (range 9–37), there was no additional PG occlusion. The Kaplan-Meier estimate of PG patency was 93% at 2 years.

Conclusion: The periscope endograft is a simple technique to maintain perfusion to the LSA in cases where the aortic stent-graft crosses its ostium. The PG technique can be performed transfemorally and even percutaneously, and it can be applied to all supra-aortic branches. Early and midterm results are encouraging, but more experience and long-term results are mandatory before this technique can be widely recommended.

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Key words: thoracic aorta, thoracic aortic aneurysm, dissection, arch aneurysm, thoracic endovascular aortic repair, stent-graft, left subclavian artery, periscope graft, deployment technique, proximal landing zone

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Several open[1] and endovascular[2–7] methods have been described to maintain/restore blood flow to the left subclavian artery (LSA) during thoracic endovascular aortic repair (TEVAR) of aneurysms extending to or involving the LSA origin. Adding to this assortment of approaches, we present a 3-year experience with the transfemoral LSA periscope endograft (PG) technique in TEVAR procedures requiring stent-graft coverage of the LSA.

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METHODS

Patient Cohort

Between April 2010 and January 2013, 14 consecutive high-risk patients (11 men; mean age 70±8 years, range 56–87) considered unsuitable for conventional aortic arch surgery[7] and who required aortic stent-graft landing proximal to the origin of the LSA in zones 2, 1, or 0[8] underwent TEVAR with the PG technique. Multiplanar computed tomographic angiography (CTA) reconstructions were used to assess the exact extent of the lesions and to determine the best treatment options. In all cases, an adequate proximal stent-graft landing zone distal to the LSA (>2 cm) was absent. Ten patients presented a thoracic aortic aneurysm (TAA), 2 had an aortic dissection, and 2 had traumatic aortic rupture. Two patients (one trauma patient and one with a TAA) had an aberrant right subclavian artery treated with the PG technique. Five procedures were performed emergently (3 TAAs and the traumatic ruptures).

Periscope Endograft Technique

Remote access to the LSA was achieved percutaneously through the left common femoral artery using a preclose technique[9] with Proglide (Abbott Vascular, Redwood City, CA, USA) in 10 patients and through a surgical exposure and surgiclose technique[10] in the other 4. After introducing a 12-F sheath (Cook Medical, Inc., Bloomington, IN, USA), the LSA was catheterized typically using a Chuang reversed visceral (Cook Medical, Inc.) or JV1 (Cook Medical, Inc.) catheter and a soft J-wire guide (Cordis, Miami Lakes, FL, USA) or a Glidewire (Terumo Medical, Tokyo, Japan). A Hemobahn or Viabahn endograft (W.L. Gore & Associates, Flagstaff, AZ, USA) was then placed into the LSA over a stiffer Rosen (Cook Medical, Inc.) or Amplatz (Boston Scientific, Natick, MA, USA) wire. The PGs, sized 1 to 2 mm larger than the LSA at its intended landing zone, were positioned with a minimum of 2 cm into the branch, but without covering the left vertebral artery origin. The PG was generally deployed before the thoracic stent-graft, which was sized by adding half of the mean diameter of the PG to the mean aortic diameter.[11] If required, the Hemobahn/Viabahn was extended in order to land caudally to the distal aortic stent-graft landing zone. The aortic stent-graft and PGs were generally molded using the kissing balloon technique with a Reliant balloon (Medtronic Cardiovascular, Santa Rosa, CA, USA) and a standard angioplasty balloon (Foxcross; Abbott Vascular) in the PG. Molding was avoided in dissection cases.

In some patients, the periscope endograft was used in a sandwich configuration.[12] Here, the thoracic endograft was placed first with its proximal end landing distally from the LSA. The periscope endograft was then introduced and deployed. Following this, another aortic stent-graft was introduced and deployed landing in the arch or ascending aorta. In this way, the periscope endograft was positioned inside the aortic devices like the ham in a sandwich. To complete the procedure, balloon molding was performed.

On-table arterial pressure measurements were determined at the level of the radial arteries proximal and distal to the aortic stent-graft at the completion of the procedure. A pressure difference of 20% was considered significant and an indication to proceed with additional balloon molding of the periscope and/or thoracic stent-grafts and/or stenting (Wallstent; Boston Scientific Inc.). Most patients were treated with antiplatelet therapy (100 mg/d aspirin) and heparinization at thrombosis prophylaxis doses postoperatively. In trauma patients, heparinization was reduced or skipped. Before discharge, patients were switched to an oral anticoagulant

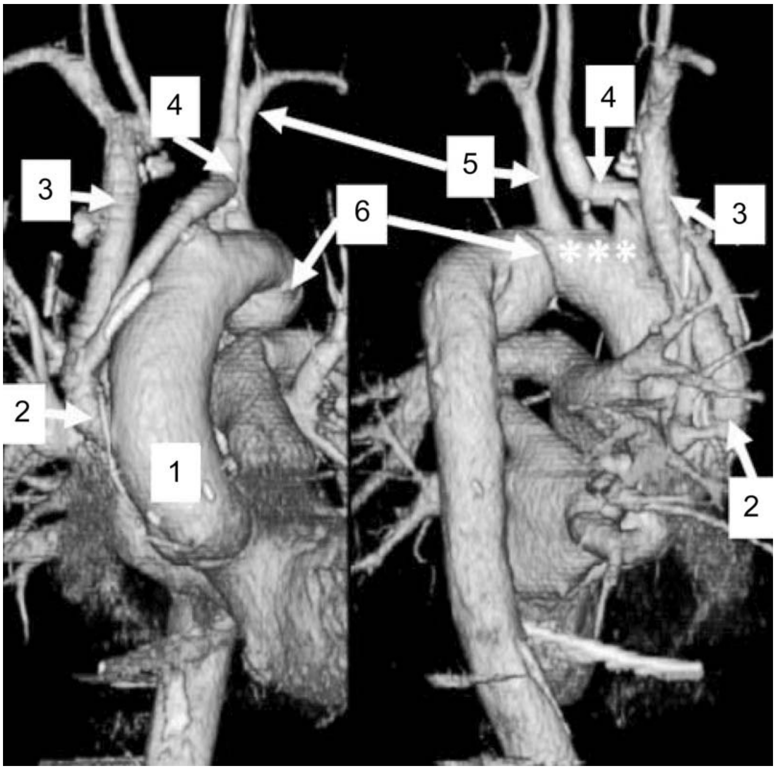

Figure 1 ◆ Hybrid repair of acute traumatic aortic rupture. In these 3-dimensional CT reconstructions, 1 is the ascending aorta after size reduction to 35 mm by external wrapping with Prolene mesh; 2 is the 14-mm polytetrafluoroethylene (PTFE) graft implanted end-to-side into the proximal ascending aorta; 3 is the end-to-side anastomosis to the brachiocephalic trunk; 4 is the 8-mm ePTFE graft and sutureless telescoping anastomosis using a 9-mm×5-cm Viabahn stent-graft to the left common carotid artery; 5 is the left subclavian artery; and 6 is the partially disrupted aortic wall, just at the level of the left subclavian artery. The asterisks indicate the supra-aortic trunks (note there is no landing zone in between these vessels).

and aspirin or to a dual antiplatelet regimen (aspirin and clopidogrel).

Outcome Measures and Statistical Analysis

Data were collected prospectively and recorded into the clinical information system of the University Hospital of Zurich (KISIM 4.901; Dendrite, Dendrite Clinical System, Henley-on-Thames, UK); the data were analyzed retrospectively in May 2013. Outcomes measured were immediate technical success, perioperative mortality and morbidity, aneurysm diameter change, and PG patency. Immediate technical success was defined as completion of the intended aortic and periscope stent-graft deployments.

Differences between preoperative and follow-up aortic aneurysm diameters were assessed using the *t* test; statistical significance was assigned at $p<0.05$. Primary patency was estimated using the Kaplan-Meier method. Statistical analysis was performed using SPSS (version 16.0; IBM Corporation, Somers, NY, USA).

RESULTS

The procedure was performed under local anaesthesia in 9 of 14 cases. In 3 patients, the PG was combined with a carotid artery chimney endograft, while 6 patients had the PG implanted to complete supra-aortic debranching needed for aortic stent-graft landing in zone 0 (Figs. 1–4). In 3 patients, the periscope endograft was used in the sandwich configuration described above. A mean of 2.0±0.7 (range 1–3) periscope stent-grafts

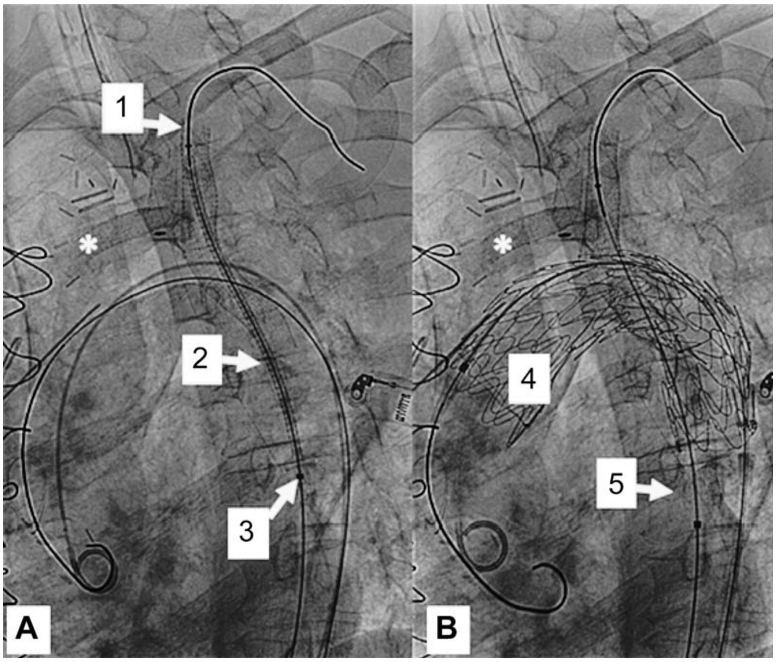

Figure 2 ◆ Periscope endograft technique. In these fluoroscopic views, (**A**) the periscope endograft with the first 11-mm×10-cm Viabahn (1 is the proximal and 2 is the distal end) already deployed. The second 11-mm×10-cm Viabahn (3) will be deployed after the thoracic stent-graft has been deployed. (**B**) The C-TAG (4) thoracic stent-graft and second Viabahn (5) are deployed. The asterisks indicate the 9-mm×5-cm Viabahn in the left common carotid artery used for VORTEC (see Figure 1).

and 1.4±0.4 (range 1–3) aortic stent-grafts were deployed per patient. Four patients required additional balloon molding and 2 had Wallstents deployed to resolve pressure gradients ≥20%.

All procedures were completed as intended (100% technical success). Mean procedure time was 119±19 minutes (range 90–145). At competition angiography, all PGs were patent, no significant endoleaks were detected, and there was no significant pressure gradient along the PG. A delay (~1–2 seconds) in the angiographic appearance of the systolic peak pressure in the left radial artery was observed. There was no neurological complication, either cerebral or peripheral.

One of the TAA rupture patients died 3 weeks postoperatively from an unrelated complication. An access site hematoma was managed conservatively. A significant stenosis in a periscope endograft unseen on the completion angiogram was suspected postoperatively in 1 patient who had a hemodialysis access on the left arm. An attempt to stent the stenosis at the level of the LSA ostium failed, and the periscope endograft occluded on the second day. In all other patients, the periscope endograft remained patent at a mean follow-up of 26±9 months (range 9–37). Estimated patency at 2 years was 93% (Fig. 5).

At the most recent CTA scan, one patient showed contrast enhancement within the aneurysm sac from an undetectable origin. The mean maximal aneurysm diameter significantly ($p<0.001$) decreased from 58.4±7.2 mm (range 45–67) to 54.0±6.6 mm (range 45–62) in the aneurysm cases.

DISCUSSION

Maintenance of blood flow to the LSA is recommended by the Society for Vascular Surgery Practice Guidelines[13] because it has been shown to be an important measure to prevent paraplegia in TEVAR procedures. It may eliminate neurological complications from diminished left vertebral artery flow

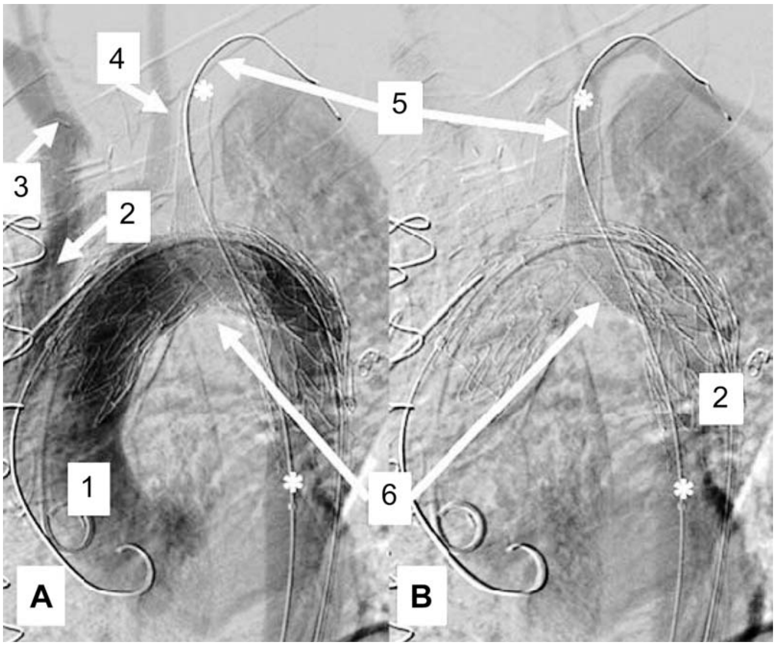

Figure 3 ◆ Completion angiograms [early (**A**) and late (**B**) images] after a periscope endograft technique. Note that the left subclavian artery (5) appears with some delay. 1 is the ascending aorta; 2 is the 14-mm ePTFE graft implanted end-to-side into the proximal ascending aorta; 3 is the end-to-side anastomosis to the brachiocephalic trunk; 4 is the 8-mm ePTFE graft and sutureless telescoping anastomosis using a 9-mm×5-cm Viabahn to the left common carotid artery; and 6 is the complete exclusion of the pseudoaneurysm, even in late phase pictures. The asterisks denote the proximal and distal ends of the periscope endograft.

and prevent arm claudication.[13] Extrathoracic carotid-to-subclavian artery bypass can be performed to maintain LSA flow, although its related morbidity, especially in trauma patients, is high.[1] Several groups in the early days of TEVAR development reported branch stenting to preserve blood flow to the supra-aortic trunks when their origins were covered by the main aortic endograft.[2–5,14,15]

More recently, the chimney endograft technique has been reported to be a feasible endovascular approach to maintain LSA flow.[16] This technique requires additional brachial, axillary, or subclavian artery remote access, with its related potential morbidity. Moreover, the chimney endograft might destabilize the proximal landing zone of the aortic stent-graft and has been suspected of increasing the risk of type Ia endoleak.[17]

Custom-made aortic arch and branched arch devices have been employed successfully to treat arch pathologies, maintaining blood flow in supra-aortic vessels.[18] Also, in situ laser fenestration has been reported as a valid option to restore blood flow after LSA coverage.[6] However, it requires dedicated materials not always available, especially in the emergency setting.

This report of a series of 14 consecutive patients shows that the PG technique is feasible and safe to maintain perfusion to the subclavian artery, with a 93% primary patency at 2 years. Major advantages of the PG technique accrue from the ability to use the standard transfemoral approach.[19] Moreover, the PG configuration does not interfere with the proximal landing zone of the aortic stent-graft, and the gutters in a periscope configuration are generally longer in comparison to a chimney. This longer sealing zone could reduce the risk of type I endoleak. Finally, different from the thoracic chimney graft, a PG configuration requires no wires to cross the aortic arch and only one in the aortic stent-graft. Thus, reducing the number of

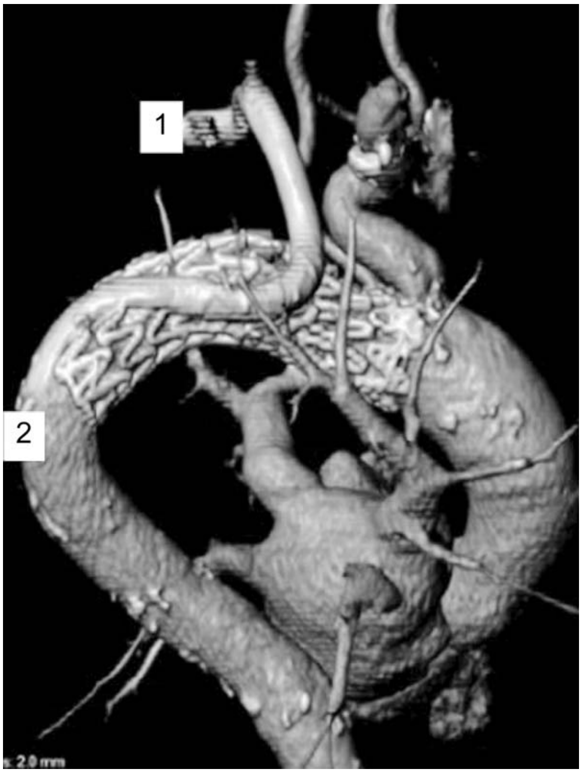

Figure 4 ◆ Follow-up CT (dorsal view of the aortic arch) performed 14 months postoperatively shows the distal (1) and proximal (2) ends of the patent periscope endograft.

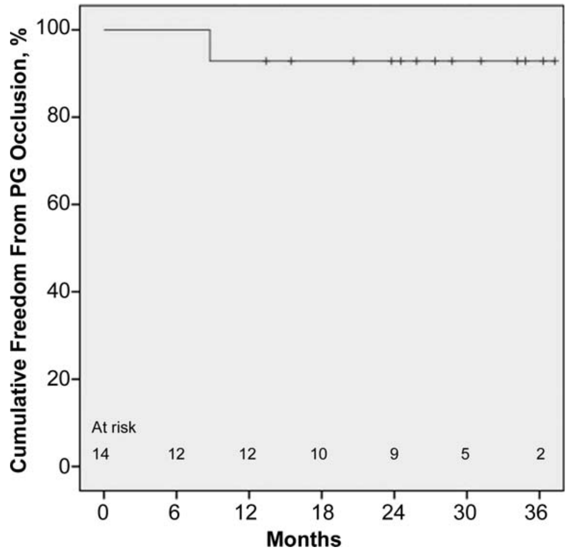

Figure 5 ◆ Freedom from occlusion for the periscope grafts (PG); standard error exceeds 10% at 25 months.

wires, catheters, or manipulations in the aortic arch might lower the risk of cerebral events.

The systolic delay into the left radial artery observed in all patients is possibly explained by the longer retrograde blood flow route to the LSA through the periscope endografts. This finding was not related to clinical symptoms in our cases. Both pulsation and pressure were absolutely synchronous and equivalent on both sides as confirmed by postoperative ultrasound examination.

To date, our overall experience with the periscope endograft technique applied to the visceral vessels has been excellent, with high midterm patency rates and stable aortic reconstructions.[11,20–23] These encouraging results appear to hold true for the subclavian artery. The use of high-end imaging machines is highly recommended in these endovascular procedures.[21] Moreover, relining the Viabahn with additional stents might increase the visibility of the periscope. Finally, the LSA periscope technique frees up the transbrachial or transaxillary access to the renovisceral or hypogastric vessels often used in complex reconstructions.

Conclusion

Our limited experience shows that the use of the periscope endograft technique to maintain perfusion to the LSA is a feasible and safe method with demonstrated patency for up to 2 years. The technique is an attractive alternative to open bypass surgery and standard chimney endografts. It could be used in patients with distal aortic arch and/or proximal descending aortic pathology, such as aneurysms, dissections, and traumatic aortic rupture. However, more experience and longer follow-up are required before this technique can be recommended for widespread use.

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