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Mid-term Results of Chimney and Periscope Grafts in Supra-aortic Branches in High Risk Patients

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WHAT THIS PAPER ADDS

The use of chimney and periscope grafts for the treatment of aneurysms involving the supra-aortic branches is reported with mid-term follow-up. This tool uses off the shelf devices and it can be employed in the emergency setting. This single centre experience reports the use of self expandable covered stents for parallel graft construction with particular attention to a standardised technique. The limited experience and follow-up available allow the use of this technique in high risk patients unfit for conventional surgery.

Purpose: Report mid-term outcomes of thoracic endovascular aneurysm repair (TEVAR) with chimney and periscope grafts (CPG) in supra-aortic branches (SAB).

Methods: Retrospective analysis, from October 2009 to May 2014, of patients with aneurysms requiring TEVAR with zone 0/1/2 proximal landing in association with at least one CPG in the SAB. All patients were considered at high risk for conventional surgery. Peri-operative mortality and morbidity, retrograde type A dissection, maximum aortic transverse diameter (TD) and its post-operative evolution, endoleak, survival, freedom from cardiovascular re-interventions, and CPG freedom from occlusion during the follow-up were analysed.

Results: Forty-one patients (28.05% EuroScore II) with thoraco-abdominal aortic aneurysm (17%), arch aneurysm (39%), descending aneurysm (34%), and aneurysm extending from the arch to the visceral aorta (10%) were included. Fifteen (37%) patients were treated non-electively. Fifty-nine SABs were treated with the CPG technique: one, two, three, and four CPG were employed in 71%, 19%, 5%, and 5% of patients, respectively. The proximal landing was in zone 0 in 49% of patients, zone 1 in 17%, and zone 2 in 34%. Technical success was 95%. Peri-operative complications and neurological events were registered in six (14.6%) patients and there were 5 deaths (12%). At a median follow-up of 21.2 (mean 22, SD 18; range 0–65) months, type I/III endoleaks were registered in three (7%) cases and re-intervention in six (15%) patients. A significant aneurysm sac shrinkage ($p<.001$) was reported at mean follow-up and no significant aneurysm sac increase (>5 mm). The estimated 2 year survival, freedom from re-intervention, freedom from endoleak, and freedom from branch occlusion were 75%, 77%, 86%, and 96%, respectively.

Conclusion: The chimney and periscope grafts technique was shown to be safe in aortic aneurysm disease involving the supra aortic branches, even in an emergency setting using off the shelf devices. Mid-term follow-up results in this high risk population are good, but longer follow-up is mandatory before this technique is used in intermediate-risk patients.

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INTRODUCTION

Thoracic endovascular aortic repair (TEVAR) is the first line approach for the treatment of aortic disease involving the descending thoracic aorta with reduced mortality and morbidity rates compared with conventional surgery.[1]

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Aneurysm extension over supra-aortic branches (SAB) still represents a limitation to standard TEVAR. Fenestrated and branched devices have been introduced with promising results in the elective setting to overcome such limitations.[2] Also chimney and periscope grafts (CPG) in the SAB have been reported, but experience and follow-up is generally very limited. Herein, mid-term experience with this technique is reported.

METHOD

From October 2009 to May 2014, data from patients treated with CPG in the SAB were collected in the clinical information system of the University Hospital of Zurich (KISIM 4.901; Dendrite, Dendrite Clinical System, Henley-on-Thames, UK).

Indications for treatment were aneurysmal aortic disease (ascending, arch or descending) requiring TEVAR proximal landing in zone 0, 1, or 2 in association with at least one CPG in the SAB. All patients were considered high risk for conventional surgery. The high risk profile for conventional surgery (graft replacement) with a Euroscore II >5% and/or presenting multifocal aneurysm locations was defined according to Andersen et al., including comorbidities (age >65 years, coronary artery disease, heart failure, chronic obstructive disease, and impaired renal function) and anatomical characteristics (thoraco-sternotomy incision and two stage open repair).[3] At the study institution there is a policy for high risk patients unfit for conventional surgery with a life expectancy more than 2 years. In younger/fitter patients, SAB rerouting in association with standard TEVAR is the preferred choice. In more frail patients a total endovascular solution is preferred with adequate anatomy. Surgical and endovascular solutions for SABs were combined in cases of anatomical challenge. Interventions were planned on CT angiography in all patients.

Demographic and clinical data were collected including the NSQIP[4] and the EuroSCORE II risk model.[5] The New York Heart Association (NYHA) heart function[6] and the Global Initiative for Chronic Obstructive Lung Disease (GOLD)[7] were employed to assess cardiac and respiratory function. The study was approved by the local ethics committee and all patients gave informed consent for the procedure itself and the anonymous data collection and analysis. Earlier data with shorter follow-up for 29 of these patients have been published previously inside a multicentre study.[8]

Technical success was defined according to TEVAR reporting standards.[9] Outcomes measured included peri-operative mortality and morbidity, retrograde type A dissection, maximum aortic TD and aneurysm volume with post-operative evolution, endoleak, survival, freedom from re-interventions, and freedom from CPG occlusion during the follow-up.

Follow-up consisted of clinical examination and CTA performed at 3, 6, and 12 months, and annually thereafter. CTA was performed with low dose contrast (40cc) and, to protect renal function, patients were generously hydrated intravenously pre and post CTA. Patients with renal function impairment were followed with non-contrast computed tomography and duplex ultrasound (DUS) imaging of the aorta and target vessels. For endoleak with a stable or reduced aneurysm sac, follow-up with clinical examination, CTA, and echocardiography was repeated every 6 months. For increasing sac size, imaging follow-up was performed within 3 months and if growth was detected a redo procedure was performed. Median follow-up was 21.2 (mean 22, SD 18; range 0—65) months.

Statistical analysis

Means and standard deviation (SD) or median and range were reported for parametric data; absolute values and percentages for non-parametric data. Differences in pre-operative and post-operative maximum aortic TD were assessed using the *t* test. Kaplan—Meier curves were used to estimate survival and freedom from cardiovascular re-intervention. Statistical significance was considered at $p < .05$. For Kaplan—Meier curves, confidence intervals (CI) and standard error exceeding 10% were reported. Statistical analysis was performed using SPSS 16.0 (SPSS Inc., Chicago, IL, USA).

Technique

Procedures were performed in a dedicated angio-suite (Artiszeego; Siemens AG, Forchheim, Germany) or in a hybrid room (Philips Medical Systems, Inc., Shelton, CT, USA) in 31% and 69%, respectively, of cases.

As reported, accesses were selected according to the anatomy and the intention to address SABs according to the proximal landing zone.[10] For chimney configuration access was performed with consideration of the target vessel. For the brachiocephalic trunk (BCT), access was generally performed percutaneously from the right axillary/brachial artery. Alternatively, surgical access via the right carotid artery (RCA) was employed. The left carotid artery (LCA) was accessed via surgical access and the left subclavian artery (LSA) via percutaneous axillary/brachial access.

For periscope configuration access was via the femoral artery (surgical or percutaneous).[11,12] All percutaneous accesses were performed with the preclosure technique (Proglide, Abbott Vascular, Redwood City, CA, USA),[13] under DUS imaging. Axillary percutaneous access was performed using the micropuncture technique to reduce the risk of nerve or plexus damage.[14]

For the chimney configuration, after gaining access to the target vessel, a standard wire (Boston Scientific, Natick, MA, USA) was inserted and placed in the ascending aorta. For the periscope configuration, the SABs were engaged from the femoral access with a long introducer sheath. Before sheath introduction, 5000 units of heparin were first administered. Heparin administration was then modulated to maintain an activated clotting time > 300 s to reduce the risk of thrombus generation and cerebral events while wire, catheters, and stent grafts were parked in the ascending aorta and/or aortic arch. In addition, patients were kept in the Trendelenburg position during aortic stent graft deployment to reduce the risk of brain air embolism. For both the chimney and periscope configurations a stent graft (Hemobahn or Viabahn; W.L. Gore & Associates, Flagstaff, AZ, USA) was positioned in the target SAB over a Rosen (Cook Medical, IN, USA) or Amplatz (Boston Scientific) wire with the support of a sheath.

The aortic stent graft was then introduced and positioned at the intended proximal landing zone (TAG; W.L. Gore & Associates). Generally, first the CPG stent grafts, then the aortic stent graft were deployed. During the procedure, systolic blood pressure was mostly maintained at about 100–120 mmHg. When landing an aortic stent graft in zone 0, a short period of slight hypotension with systolic pressure around 100 mmHg was induced with short acting vasodilators. For long descending aorta coverage, the systolic blood pressure was maintained > 120 mmHg.

After deployment of the CPGs, sheaths were reinserted for stabilisation and for eventual proximal and/or distal stent graft extension. The aortic stent graft was parked and deployed approximately 1 cm distal to the CPG position.

CPGs were oversized 1–2 mm with respect to the target SAB. The aortic stent graft was sized according to the formula: mean aortic diameter at landing zone + half the diameter of each CPG used. A minimum of 2 cm overlapping between the aortic and the CPG stent graft was required at the proximal/distal landing zones. Proximal landing zone and adequate (>2 cm) overlapping were identified pre-operatively from the CTA. These data were confirmed during the positioning of the CPG and aortic stent graft before deployment (Fig. 1). When more thoracic stent grafts were required to cover long aortic segments (i.e. Crawford II or III thoraco-abdominal aortic aneurysm [TAAA]), connection was performed with a sequential distal to proximal deployment. The overlap between stent grafts was about 5 cm; in very angulated aortas or when aortic stent grafts were of similar diameter, longer overlapping was preferred. The CPGs and the aortic stent graft were moulded using the kissing balloon technique.

Moulding of the stent grafts was performed using corresponding PTA balloons for the CPGs and the Reliant balloon (Medtronic, Santa Rosa, USA). To avoid aortic wall stress and minimise the risk of aortic dissection, the aortic stent graft and CPG were moulded sequentially in zone 0 and great care was taken to ensure that the Reliant balloon did not extend into the native aorta.

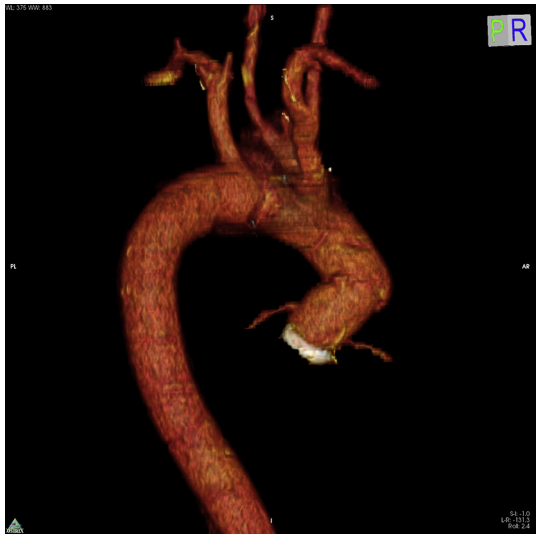

Figure 1. Three dimensional CT angiography volume rendering showing an arch aneurysm involving the supra-aortic branches.

Intra-operative arterial pressure measurements were made in all vessels treated with a CPG and in the aorta (at the junction between the stent graft and the native vessel). A mean pressure drop > 20% was considered to be a cutoff for additional CPG and/or thoracic stent graft ballooning. A final angiogram was performed to complete the procedure (Fig. 2). Since 2015 all parallel grafts have been primarily reinforced by a corresponding Wallstent (Boston Scientific) relining the entire length over which the CPG could be compressed when running parallel to the aorta.

For TAAA, to reduce the risk of spinal hypoperfusion, the systolic blood pressure was maintained between 120 and 150 mmHg throughout the procedure and for 6 weeks after intervention. For spinal cord symptoms, a 50 mL bolus of mannitol 20% was given and repeated every 2–4 hours. In addition, a bolus of hydrocortisone was given intravenously. Patients with spinal cord ischaemia symptoms were transferred to the ICU for blood pressure (systolic pressure >140 mmHg; mean arterial pressure 70–90 mmHg) and haematocrit optimisation (>30%).[10] Post-operative medication consisted of 100 mg aspirin daily and therapeutic heparinisation during hospitalisation. At discharge, patients were switched to dual antiplatelet therapy (100 mg aspirin and 75 mg clopidogrel per day).

All patients underwent CTA before discharge (Fig. 3). Follow-up was performed according to the reported protocol.

RESULTS

Forty-one patients were included, with a mean age of 68.03 (SD 13; range 27–87) years, with a mean pre-operative NSQIP and EuroScore II of 14.23% (SD 8; range 11–18) and 28.05% (SD 14; 22–34), respectively. During the same period, a surgical SAB debranching procedure was performed in 38 patients. Comorbidities and risk factors are reported in Table 1.

The indication for CPG treatment was a TAAA in seven (17%) cases, an arch aneurysm in 16 (39%); a descending aneurysm in 14 (34%); and an aneurysm extending from arch to the visceral aorta in the remaining four (10%) patients. Of the seven TAAA, two were Crawford type I, three Crawford type II, one Crawford III, and one Crawford IV. In 14 (34%) cases there was associated type B dissection.

Twenty-six (63%) patients were treated electively and 15 (37%) non-electively. Aneurysm symptoms were reported in six patients (15%), and rupture in nine patients (22%). In 11 (27%) cases, an open debranching of 26 SABs was required before the CPG treatment. In six patients, left carotid to left subclavian artery debranching was also performed. In addition six (15%) patients required open visceral debranching and six (15%) CPG to visceral arteries before the main procedure. Open debranching of SABs was indicated in patients presenting endovascular challenges including shaggy aorta and/or significant atherosclerotic deposits in aortic branches or dissected stem and/or severe kinking of aortic branches, to reduce potential procedural complication of EVAR. The mean pre-operative maximum

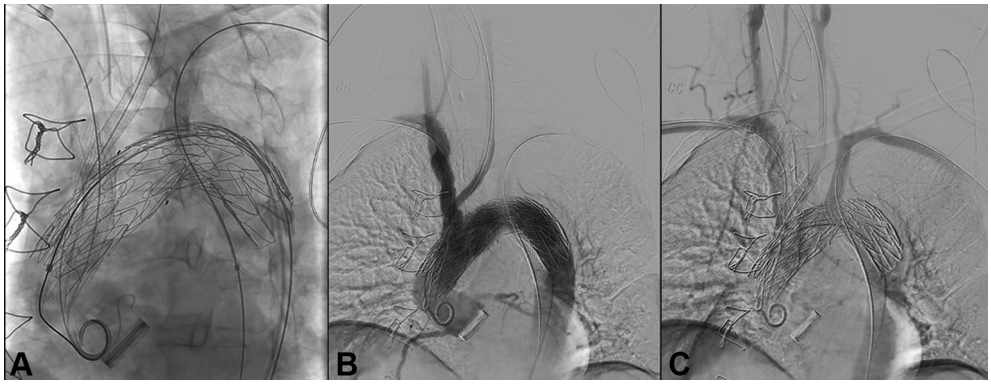

Figure 2. (A) Intra-operative view of a triple supra-aortic chimney and periscope graft. The chimney configuration was used for the brachiocephalic trunk and the left carotid artery. The periscope configuration was used for the left subclavian artery. Note the overlapping between the aortic stent graft and the chimney and periscope grafts. (B) Intra-operative arteriogram. Early phase after contrast injection showing patency of the chimney grafts to the brachiocephalic trunk and the left carotid artery. (C) Intra-operative arteriogram. Later phase (about 1 s) after contrast injection showing patency of the periscope graft to the left subclavian artery and the chimney grafts.

transverse aortic diameter and aneurysm volume were 61.38 (SD 17, 26—100) mm and 416 (SD 531, 43—2670) mL, respectively.

A total of 59 SABs were treated by the CPG technique (mean of 1.4 vessels per patient). No significant differences were observed for the number of SABs treated in elective and non-elective cases (40/26 vs. 59/15; p=.24). In 29 cases a single CPG was used, in eight a double, in two a triple, and in four a quadruple. The chimney configuration was employed in 30 (51%) vessels and the periscope configuration in 29 (49%). Eight (14%) brachiocephalic trunks (BCT), six (10%) right carotid arteries (RCA), 15 (25%) left carotid arteries (LCA), and 30 (51%) left subclavian arteries (LSA) were treated using the CPG technique. Self expandable stent grafts were used in all vessels. These were relined with self expandable uncovered stents in 26/59 (44%) SABs.

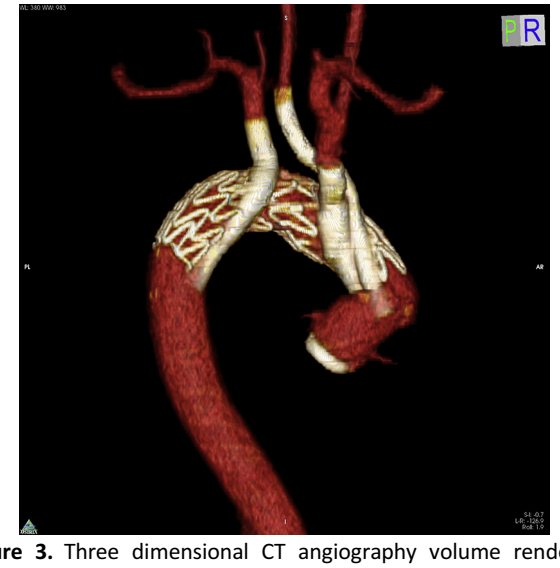

Figure 3. Three dimensional CT angiography volume rendering showing patency of the chimney grafts to the brachiocephalic trunk and the left carotid artery and the periscope graft to the left subclavian artery.

According to the Ishimaru classification,[15] the thoracic stent graft proximal landing zone was in zone 0 in 20 (49%) patients, zone 1 in seven (17%) patients, and zone 2 in 14 (34%) patients. In all cases the TAG (W.L. Gore & Associates) thoracic stent graft was employed for TEVAR.

Technical success was achieved in all but two cases (95%). Peri-operatively, five (12%) deaths occurred. Two

Table 1. Demographic and pre-operative clinical data.

Number of patients	41
Mean age, years	68
Over 70 years (%)	21 (51)
Female (%)	14 (34)
Hypertension (%)	37 (90)
Chronic obstructive pulmonary disease (%)	29 (71)
GFR <60	14 (34)
Dialysis	2 (5)
GOLD 1 (%)	4 (10)
GOLD 2 (%)	8 (20)
GOLD 3 (%)	26 (63)
GOLD 4 (%)	3 (7)
Cardiac disease, (%)	28 (68)
Myocardial infarction <6 months (%)	6 (15)
Coronary artery disease (%)	22 (54)
NYHA I (%)	7 (17)
NYHA II (%)	13 (32)
NYHA III (%)	16 (39)
NYHA IV (%)	5 (12)
Lipid disorder (%)	17 (42)
Peripheral arterial disease (%)	10 (24)
Cancer (%)	6 (23)
Cerebral vascular disease (%)	18 (44)
Hostile chest (%)	21 (51)
Previous heart/aortic intervention	
Open surgery (%)	23 (34)
Endovascular surgery (%)	10 (15)
Elective repair	26 (63)
Non-elective repair	15 (37)
Pre-operative NSQIP	
Pre-operative EUROSCORE II	28.05

GOLD = Global Initiative for Chronic Obstructive Lung Disease; NYHA = New York Heart Association.

patients died intra-operatively because of massive cardiac tamponade during zone 0 TEVAR. The other deaths occurred on the second post-operative day (POD), the result of retrograde type A dissection; on POD 5 from multiorgan failure; and POD 21 from a stroke. Two deaths occurred in patients treated non-electively (3/26 [11.5%] deaths in elective cases and 2/15 [13.3%] deaths in non elective cases; $p=.87$).

Overall, peri-operative complications and neurological events were registered in six (14.7%) patients. Peri-operative complications were registered in three (7%) patients (2 elective and 1 non-elective case) and consisted of retrograde type A dissection in one case, respiratory insufficiency in one case, and myocardial infarction in one case. Another three (7%) patients (1 elective and 2 non-elective) had peri-operative neurological complications including stroke in one, spinal cord ischaemia in one, and stroke with spinal cord ischaemia in one; these neurological complications occurred in patients treated with single LSA CPG (1), double LSA and LCA CPG (1), and four CPGs (1), respectively.

In this series 28 patients were followed for at least 12 months and 18 patients for 24 months. No patients were lost during follow-up.

During follow-up a type I/III endoleak was registered in three (7%) cases (2 elective and 1 non-elective) consisting of one type Ia, one type Ib, and one type III. In addition, a type II endoleak was registered in three (7%) cases. A re-intervention was required in 6/41 (15%) patients: because of coil embolisation (2 patients for a type II and a type Ib endoleak); a redo TEVAR for a type III endoleak (1); LSA periscope graft stenting (1); aortic valve replacement for a retrograde type A dissection; and configuration change from chimney to periscope (1 patient because the chimney graft was too long) (Fig. 4). No significant differences in the number of re-interventions in elective and non-elective cases (15% vs. 13%; $p=.89$) were observed. The mean time to re-intervention was 2.22 (SD 3, 0—15) months. The aneurysm sac at mean follow-up was 55.34 (SD 17, 26—94) mm with significant aneurysm sac shrinkage ($p<.001$). Aneurysm volume at mean follow-up was 324 (SD 381, 26—2026) mL with a significant reduction ($p=.042$). No significant aneurysm sac increase was seen. In 17 patients significant aneurysm shrinkage was reported, and in the remaining 24 no significant difference was reported compared with baseline measurements.

The estimated survival at 12 and 24 months was 78% and 75%, respectively (SE 4.3, CI 41%—58%). The freedom from re-intervention at 12 and 24 months was 81% and 77%, respectively (SE 5.3, CI 37%—58%). The estimated freedom from endoleak at 12 and 24 months was 94% and 86%, respectively (SE 4.7, CI 44%—62%). The estimated freedom from occlusion at 12 and 24 months was 96% (SE 1.7, CI 60%—67%) (Fig. 5).

DISCUSSION

Open surgical treatment of aortic diseases involving SABs is still the gold standard,[1] and it can be carried out with circulatory arrest, cardioplegia, cardiopulmonary bypass, and moderate or deep hypothermia.[16] However, considerable mortality and neurological event rates of up to 29% and 18% respectively, have been reported for these procedures. Moreover, worse outcomes were reported in high risk patients.[17,18]

Hybrid treatment with supra-aortic debranching has been proposed in high risk patients, unfit for conventional surgery, to reduce the invasiveness of the conventional treatment. The peri-operative outcomes reported are encouraging, with reported mortality and neurological event rates of 11.9% and 7.6%, respectively.[19]

The hybrid approach was reported in combination with ascending wrapping in cases with no adequate zone 0 proximal landing, with promising results.[20,21] The advantage of hybrid repair is that it can be performed off-pump. However, both conventional and hybrid repairs do require at least a median sternotomy.

In very-high risk patients,[3,22] as reported in this study (pre-operative NSQIP and EuroScore II of 14.23% and 28.05%), all patients were considered by the cardiovascular board to be unfit for conventional surgery and hybrid repair. In these circumstances a total endovascular solution to address the aortic arch and the SABs is a reasonable alternative.

Fenestrated and branched devices are currently under investigation with promising short-term results. In a recent series, 27 patients with arch aneurysm were treated with an inner branched endograft to maintain blood flow to the BCT and/or LCA. In that series, 100% technical success and no peri-operative mortality was reported. Cumulative neurological events were reported in 5/27 patients (18.5%; 2 major strokes, 1 minor stroke, and 2 transient spinal cord ischaemia). An early (<30 days) re-intervention was

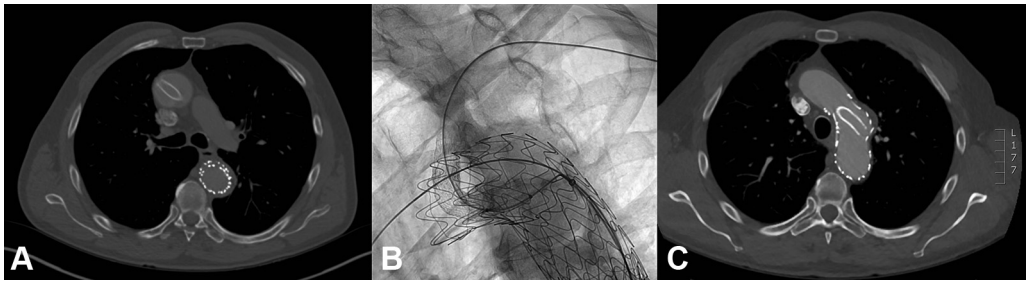

Figure 4. (A) Plain CT showing a chimney in the left subclavian artery in contact with the ascending aorta. (B) Intra-operative view of the configuration change from chimney to periscope. (C) Plain CT after configuration change.

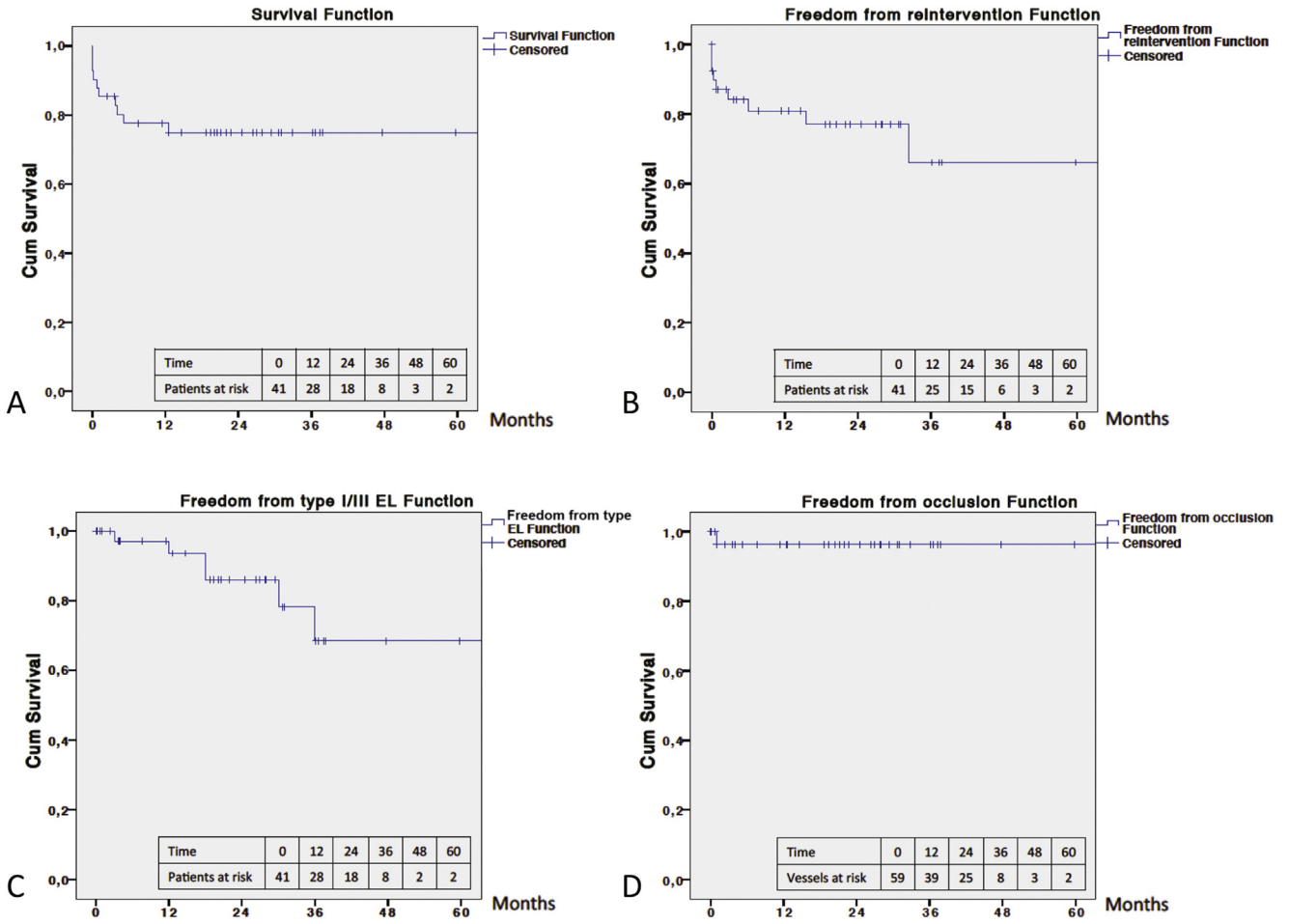

Figure 5. (A) Survival function. Standard error (SE) does not exceed 10% at 24 months (SE 4.3, CI 41—58). (B) Freedom from re-intervention function. SE does not exceed 10% at 24 months (SE 5.3, CI 37—58). (C) Freedom from type I/III endoleak function. SE does not exceed 10% at 24 months (SE 4.7, CI 44—62). (D) Freedom from occlusion function. SE does not exceed 10% at 24 months (SE 1.7, CI 60—67).

required in four patients (14.8%). Endoleak incidence was 11.1% (3 type II). During the mean follow-up of 12 months another two re-interventions were required.[2]

Clearly, the use of such customised devices does not fit in the emergency setting as reported for CPGs.[23] When the device is required to land in zone 2, a total endovascular solution with a single CPG graft in LSA in periscope configuration can be employed with no need for carotid to subclavian bypass.[11]

The reported experience with CPGs includes 37% of cases treated in an emergency setting with a global reported mortality rate of 12% and a zone 0 proximal landing in 20/41 (49%) cases. Although it can be argued that use of CPG in the carotid arteries or BCT increases the risk of cerebral neurological complications, these were reported in only two cases treated with a single and a fourfold CPG. By contrast, spinal cord complications appear to be dependent on the length of aortic coverage rather than the number of CPGs.

SAB debranching has been performed in some patients to facilitate the proximal landing zone, in cases of borderline ascending or arch diameter (35—38 mm). In such cases using two CPGs in the proximal landing zone was expected to generate gutter endoleak(s), despite use of the largest TAG (45 mm). In addition, SAB debranching has been performed in patients with atherosclerotic plaques in the arch and/or branch(es), branch vessel dissection, or severe kink of the SAB. It can be argued that SAB debranching combined with CPG procedure reduced the operative time of both procedures, wire manipulation during the CPG operation, and the risk of gutter endoleak. Endoleaks have been recognised as the major Achilles heel of the CPG technique because of channel gutters resulting from the apposition between the aortic stent graft and the CPGs. In this situation creating a sealing zone of more than 2 cm was identified as a means of decreasing the incidence of endoleak.[24,25] When the proximal landing is in zone 1 or 2, a sealing zone of more than 2 cm is mostly achieved using a periscope configuration. The advantages of landing proximally in zone 1 are that neither the BCT nor the ascending aorta is involved.

In this series a type I endoleak was reported in two (5%) cases; in one patient the endoleak was treated by coil embolisation, and in the other it resolved spontaneously during follow-up. There were no 'slow flow' or gutter endoleaks.[26] In this experience, the CPG were constructed exclusively with SECS and used with the TAG (W.L. Gore &

Associates) with the incidence of type I endoleak comparable with previous reports. A recent European experience of CPGs in SAB showed similar outcomes: the reported perioperative mortality, endoleak incidence, and neurological events were 9.5%, 10.5%, and 2%, respectively, in a cohort of 95 patients.[8] The retrospective analysis, the inclusion of different types of aortic disease, and the lack of a comparison group represent study limitations.

CONCLUSION

In selected patients unfit for conventional open aortic arch repair, a parallel graft technique using self expandable covered stent grafts as periscopes and/or chimneys to maintain branch perfusion is a safe treatment option. This holds true even in the emergency setting, where use of off the shelf devices allows fast track repair. Short- and mid-term follow-up show outcomes similar to other repair techniques.

CONFLICT OF INTEREST

None.

FUNDING

None.

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Eur J Vasc Endovasc Surg (2017) 54, 302

COUP D'OEIL

Vertebral Penetration of an Inferior Vena Cava Filter

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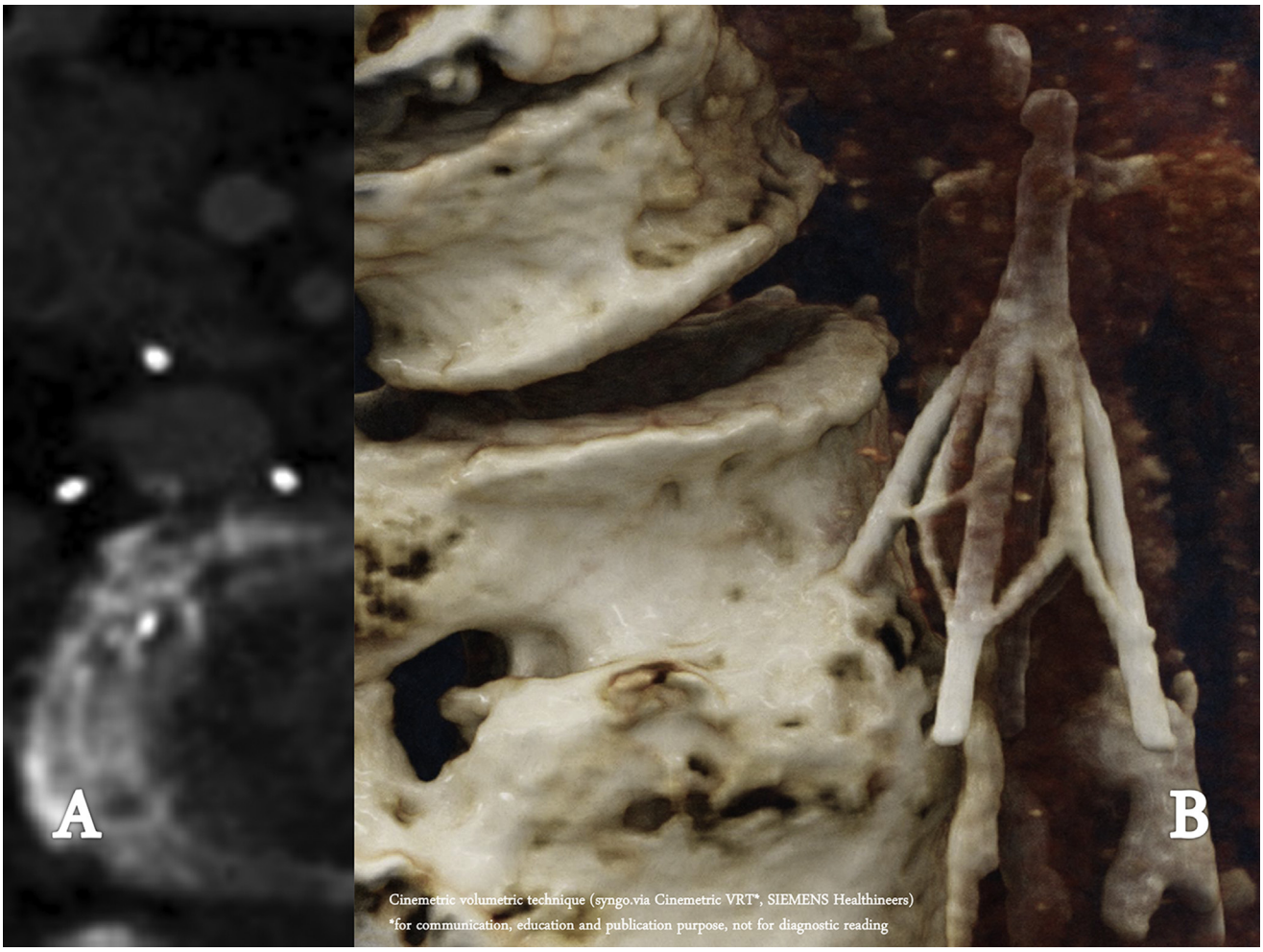

A 72 year old female underwent retrievable inferior vena cava filter (IVCF) implantation following a deep vein thrombosis complicated by pulmonary artery embolism. However, ten years later, a computed tomography scan for a suspected diagnosis of pneumonia showed the IVCF was penetrating the caval wall (A) and even the vertebral body (A, B). Interventional removal of the IVCF was not considered feasible given the extracaval IVCF protrusion with bony implantation; furthermore, given the high risk of major complications open repair was not possible either and the IVCF was left in place.

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