**Preservation of Aortic Arch Branches Using Chimney and Sandwich Stent Grafts**

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**Purpose:** To share our hybrid endovascular experiences using chimney or sandwich stent grafts for acute aortic arch pathologies.

**Methods:** Hybrid procedures for a distal aortic arch aneurysm and an ascending anastomotic aortic aneurysm rupture were reported. Right to left common carotid and left axillary artery bypasses were located. Covered stents were inserted into the innominate artery, with the flow-proximal end located in the ascending (standard chimney) or the descending aortic stent graft (retrograde sandwich).

**Results:** Both cases had no signs of brain ischemia. Aneurysms are decreasing in size.

**Conclusion:** Chimney and sandwich techniques were technically feasible in the complex and acute situations.

**Keywords:** carotid artery bypass; retrograde sandwich; covered stent

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**INTRODUCTION**

Endovascular stent graft was introduced as a less invasive treatment for the cases intolerant with conventional surgical treatment. However, the cases with unfavorable anatomical factors are empirically more unfit to surgical procedures. The surgical procedures increase the technical difficulty and invasiveness, related to the preservation of blood circulation of aortic branches. With the advent of endovascular techniques, management of aortic branches has thus come into sharp focus. Fenestrated or branched stent-graft techniques may cast a light on the future treatment of such complicated cases. Unfortunately, such devices cannot be used in acute situations, since they have to be customized and fabricated to fit the case-specific anatomy. The purpose of this report is to share our endovascular experiences of chimney or sandwich technique for the treatment of acute and complex aortic arch pathologies.

**CASE REPORTS**

**Rapidly expanding distal aortic arch aneurysm**

The patient was a 76 year-old male, who had acute myocardial infarction (MI) in the left main coronary arterial area. The saccular aneurysm with the maximum diameter supersizing 6 cm was detected during the hospital stay, which expanded to 8 cm in a month. Mainly because of the recent MI and an increased level of serum creatinine (210 µmol/L), conventional arch repair (logistic Euroscore = 13.19, Japan score = 21.1) was considered unsuitable, and the patient was referred to us for an endovascular solution. A right common carotid (CCA) -left CCA -left axillary artery (LAXA) bypass was created using a 6 mm of Dacron graft (Gelsoft ERS, Terumo, Tokyo, Japan), lead through the retropharyngeal space and costoclavicular passage. A thoracic stent graft (40 mm × 15 cm, Gore TAG Thoracic Endoprothesis, W.L. Gore & Associates, Flagstaff, AZ) was introduced from the right common femoral artery
(RCFA) with the proximal end located in the ascending aorta. As a “chimney” stent graft, an ancillary component of an abdominal aortic endograft (14.5 mm × 7 cm, iliac leg extension of Gore Excluder AAA Endoprothesis, W.L. Gore & Associates, Flagstaff, Az) was used to preserve the circulation of INA. Aortic and branch stent grafts were inflated carefully. A keen attention was utilized to avoid the aortic injury, which may be caused by an over expansion due to the balloons located in the parallel position. Left subclavian artery (LSA) was coiled-embolized with platinum-tungsten coils (Interlock fibered IDC occlusion system, Boston Scientific Corporation, Boston, MA). A final angiogram found no signs of endoleak. The patient tolerated the whole procedure, and showed no signs of ischemic stroke postoperatively. Three-dimensional CT at the 12th postoperative month found no signs of endoleak and a marked reduction of aneurismal diameter (Fig. 1).

**Ascending aortic anastomotic rupture**

The patient was a 79 year-old female, who had a previous surgical history of ascending aortic grafting for acute aortic dissection five years ago, and omentum patch thereafter for the postoperative dehiscence of median sternotomy. Computed tomography, performed for acute chest discomfort, revealed chronic and contained rupture of the ascending anastomotic aortic aneurysm rupture (Fig. 2). A right CCA-left CCA-LAxA bypass was created as aforementioned. Because of the flexion in the ascending aortic graft, the proximal insertion of chimney stent graft was considered hazardous to get a proximal endoseal. The first (distal) thoracic stent graft (34 mm × 15 cm, Gore TAG Thoracic Endoprothesis, W.L. Gore & Associates, Flagstaff, AZ) was delivered through the RCFA, and located with the proximal end located about five millimeters distally to the opening of the inominate artery (INA). A covered stent (14.5 mm, iliac leg extension of Gore Excluder AAA Endoprothesis, W. L. Gore & Associates, Flagstaff, Az) was delivered from the INA into the endolumen of distal thoracic stent graft in the descending aorta. The proximal thoracic stent graft (34 mm ×15 cm) was deployed with the proximal end located inside the previous ascending graft. The distal end of the second (proximal) stent graft was located, so that 6 cm of the covered stent for the INA was held (i.e.,

**Fig. 1** A: Three dimensional CT angiography. The green area indicates excluded aneurysm. Arrows indicate the level of tilted plane above which the volume data was rendered as in B: Partial volume rendering image. Note deformation of the upper surface of the aortic stent graft. A w-shaped curve was formed so that it covered the aortic endoluminal surface of the covered stent.
sandwiched) between the second and first (distal) stent grafts. Completion angiography recognized no sign of endoleak. The INA stent graft was “sandwiched” by the distal and proximal aortic stent grafts (Fig. 3). Postoperative CT found a marked reduction of excluded volume of aneurysm or thrombus (Fig. 4).

**Fig. 2** Partial volume rendering (A) and axial images (B) of the preoperative computed tomography were shown. Arrows indicated the anastomotic aneurysm and widespread thrombus near the proximal anastomosis.

**Fig. 3** Postoperative CT angiography. Arrows in the left figure indicate the level of tilted plane above which the volume data was rendered as in the levels A and B. The covered stent was tightly sandwiched.

**Discussion**

Greenberg had reported that the proximal landing zone could be extended above the ostium of renal arteries by deploying a self-expanding stent into the renal artery with a segment of the stent running parallel to the aortic wall.
In the territory of arch vessels, Larzon introduced “top fenestrated technique,” wherein the circulation into LCA and left subclavian arteries were maintained similarly. Ohrlander proposed the term “chimney graft” when covered stents were employed in a similar fashion. Allaqaband has described another concept, the “sandwich technique,” which consists of one or more covered stents from inside of the previously deployed aortic stent graft into the target vessel(s). It obtains an endo-seal by deploying the next aortic stent graft inside, with the proximal opening of covered stent(s) uncovered.

“Chimney” and “sandwich” stent-graft techniques have some issues for consideration. One problem is a type I or III endoleak caused by branch stent grafts extending through the proximal and distal sealing zones. Theoretically, the more the branch stent grafts are used, the greater the potential for the leak. The longer the overlap zones are, the less likely the leak would be detected. In our literature search, maximally two stents per each proximal or distal aortic sealing zone were inserted, and the overlap zones seemed to be longer than 3 cm for the chimney stent graft and longer than 6 cm for the sandwich. The numbers of branch stent grafts could be reduced by the aforementioned surgical procedures. Blood supply into the stent grafts for the arch branches should be also considered. In the latter case, the stent graft into the INA was inserted so that the blood flow is delivered in the way opposite to the aortic main flow. We had concerned the adequacy of flow volume supplied in this fashion and had prepared the RCFA-RCA bypass. However, during this procedure, there was no significant decrease of brain oxygenation measured by photospectroscopy, and the case experienced no ischemic complications. No reports about the use of sandwich technique in combination to carotid arterial reconstruction, where the innominate arterial flow is reversely supplied, could be hitherto found in our literature search.

In the extra-anatomical bypass for these cases, the selection of proximal/distal anastomosis is an issue for considerations. In carotid arterial procedures, ischemic complications are mostly caused by the brain emboli. As we are aware of this issue, we selected cervical portion of common carotid arteries for the anastomosis of bypass grafts, where the deposition of atheromatous debris is less likely. If severe degree of brain ischemia is detected, usage of any form of arterial shunt could mitigate the degree of brain ischemia. Furthermore, durability and patency of chimney and sandwiched stent grafts should be monitored carefully, because these were under the influence of other stent grafts. It should be also reminded that long term patency of the extra-anatomical bypass could not be guaranteed. In addition, the case with atherosomatous diseases in carotid arteries or INA, indication of aforementioned techniques should be carefully decided.

In summary, so-called chimney or sandwich stent grafts seemed feasible for the treatment of acute and
complex aortic arch pathologies. These techniques inherently have the risk of damaging aortic sealing in their passages, and may have other case-specific problems. These problems would not be fully solved, but might be partially mitigated by current devices and techniques.

REFERENCES