# An autopsy case of retrograde in situ branched stent grafting for a complex aortic arch aneurysm

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## ABSTRACT

Although retrograde in situ branched stent grafting (RIBS) is one possible treatment option for thoracic aortic aneurysms, concerns exist regarding the durability of the stent graft (SG) at the junction between the main SG and the branched SG. We report on the autopsy results of a patient treated with RIBS for a complex aortic arch aneurysm. The patient had died of a nonaortic cause 14 months after the RIBS procedure. On computed tomography analysis and a leak test, the harvested SG was intact without any stent fracture, stenosis, or junctional leak at 1 atm water pressure (760 mm Hg). (J Vasc Surg Cases Innov Tech 2022;8:313-318.)

**Keywords:** Aortic arch aneurysm; In situ fenestration; Thoracic aortic aneurysm; Thoracic endovascular aortic repair

Thoracic endovascular aneurysm repair has become the first-line treatment of descending thoracic aortic aneurysms. Thoracic endovascular aneurysm repair for arch thoracic aortic aneurysm has remained challenging because it requires a sufficient proximal landing zone while maintaining the blood flow of the cervical vessels.

Retrograde in situ branched stent grafting (RIBS) is becoming more common in the clinical setting as one technique for cervical branch reconstruction,[1-6] in addition to the chimney technique[7,8] and branched or fenestrated stent graft (SG) placement.[9-12] However, significant concerns exist about the short- and long-term graft durability of the RIBS technique. Possible problems include the development a type III endoleak (EL) at the junction of the main SG and branched SG.

In the present report, we have described the autopsy of a patient who had undergone RIBS, in which we were able to harvest the SG. This allowed us to examine the junctions between the main SG and branched SGs. The institutional review board of the Jikei University School of Medicine approved the report of the present case (acceptance no.: 33-392 [11016]), and the patient's family provided written informed consent.

## CASE REPORT

A 73-year-old woman was referred by the cardiothoracic department of another institution for treatment of a complex aortic arch aneurysm after presenting with recurrent nerve palsy. In addition to her status of thrice weekly hemodialysis for chronic kidney disease, she had undergone multiple percutaneous coronary interventions for three-vessel disease and ascending aorta replacement for an aortic aneurysm. Computed tomography (CT) angiography revealed an aortic arch aneurysm measuring 68 mm in diameter and an abdominal aortic aneurysm measuring 45 mm in diameter. The aortic arch aneurysm had originated distally to the anastomosis of the prior replacement and involved three cervical branches with dilatation and severe tortuosity (Fig 1). Because of this challenging morphology, the patient was not a candidate for total arch repair or branched SG. Thus, the only remaining option was the RIBS procedure.

RIBS was performed with the patient under general anesthesia. We exposed the common femoral artery and both common carotid arteries (CCAs) and punctured the bilateral brachial arteries.[13] As reported previously, we performed the RIBS procedure as follows.[6] First, we deployed the conformable TAG (C-TAG; W. L. Gore & Associates, Flagstaff, AZ) for the main SG. Second, we used a bent percutaneous transhepatic gallbladder drainage (PTGBD) needle (18 guage × 200 mm; Hanaco Medical, Saitama, Japan) to penetrate the SG. Third, we reconstructed the left CCA (LCCA) with a Viabahn endoprosthesis (W. L. Gore & Associates). Fourth, we reconstructed the brachiocephalic artery (BCA) with the Excluder internal iliac branch endoprosthesis (W. L. Gore & Associates). Next, we deployed a balloon-expandable Express LD stent (Boston Scientific Corp, Natick, MA) at the junction between the main SG and branched SG to augment the fixation and prevent the occurrence of a type III EL. Finally, we used the gutter balloon technique to maintain

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Author conflict of interest: T.O. serves as a consultant to W. L. Gore & Associates. K.S., T.B., R.N., H.O., M.O., M.H., and H.T. have no conflicts of interest.

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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.2022.04.007

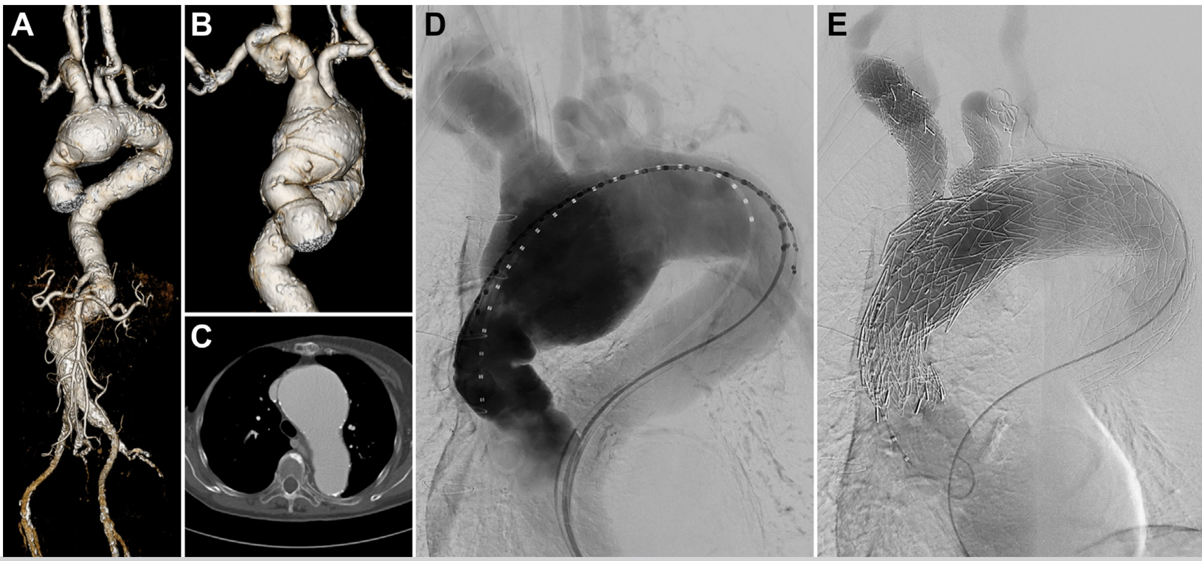


**Fig 1.** Preoperative computed tomography angiography. **A,** Left oblique view of reconstructed three-dimensional image. **B,** Front view of reconstructed three-dimensional image. **C,** Axial image. These images show the thoracic aortic aneurysm involving three cervical branches with dilatation and severe tortuosity, and the abdominal aortic aneurysm. **D,** Initial angiography. **E,** Completion angiography.

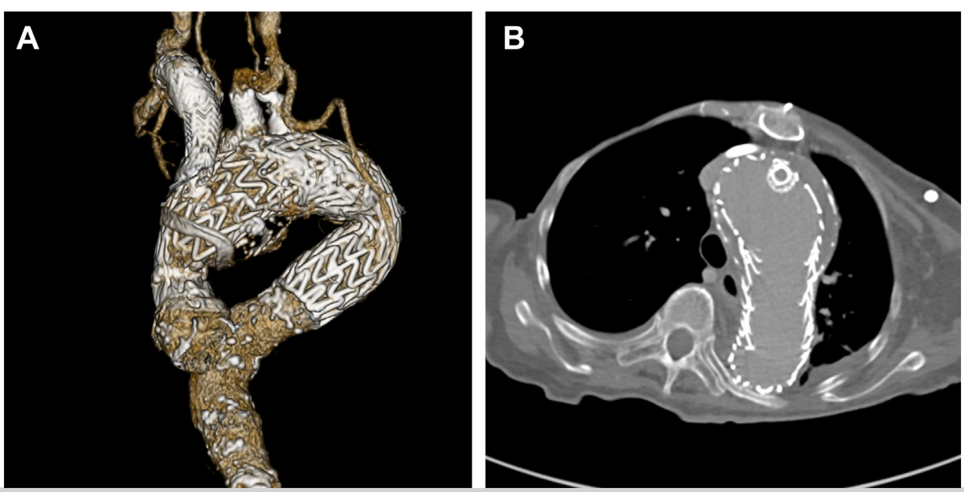


**Fig 2.** Computed tomography angiography at 12 months postoperatively. **A,** Left oblique view of reconstructed three-dimensional image. **B,** Axial image showing the thrombosed thoracic aortic aneurysm. The branched stent graft (SG) and bare metal stent in the SG was for the brachiocephalic artery (BCA).

brain perfusion during the procedure. In the present patient, an additional Excluder aortic extender (W. L. Gore & Associates) for the BCA and main SG and an Excluder iliac extender (W. L. Gore & Associates) for the LCCA were required owing to dilatation of the BCA and LCCA. The left subclavian artery was embolized after confirming the intracranial communication of the bilateral vertebral arteries. Final angiography confirmed that the arch aneurysm was completely excluded without the occurrence of an EL (Fig 1). The patient had experienced recurrent nerve palsy requiring tracheostomy on postoperative day 3. After rehabilitation of oral intake, the patient was discharged to rehabilitation hospital recovery.

The patient was referred for a persistent high-grade fever and consciousness disturbance after receiving a severe acute respiratory syndrome coronavirus 2 vaccine at 12 months postoperatively. On admission, CT angiography had revealed a completely thrombosed aortic arch aneurysm with no evidence of an EL or SG-related complications (Fig 2). Despite the strenuous efforts of the physicians, the patient had died of suspected encephalomyelitis at 14 months after the RIBS procedure. To determine the definitive cause of death, a pathological autopsy was performed 10 hours after the patient's death with the family's consent.

The autopsy revealed no findings suspicious for aortic rupture or myocardial infarction. Thus, we concluded that the death had not

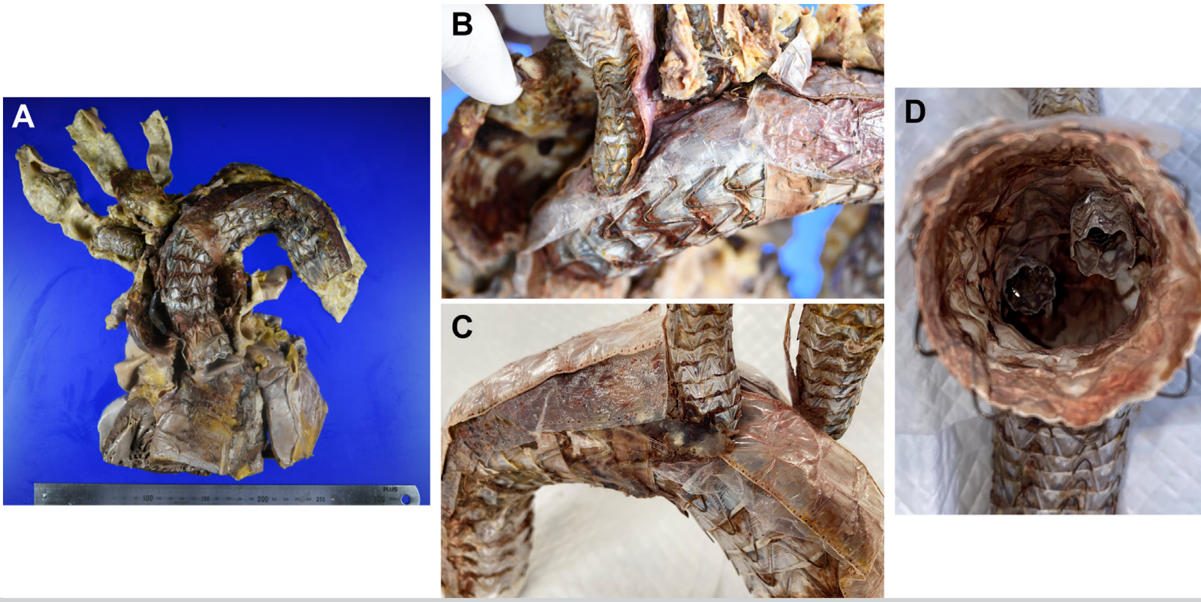


**Fig 3.** Harvested stent graft (SG). **A,** Specimen with the SG. **B,** External view at the junction between the main SG and the branch for the brachiocephalic artery (BCA). **C,** External posterior view at the junction between the main SG and the branch for the left common carotid artery (LCCA). **D,** Internal and frontal view of the SG. Note the intact SG, including the junctions between the main SG and branch SGs.

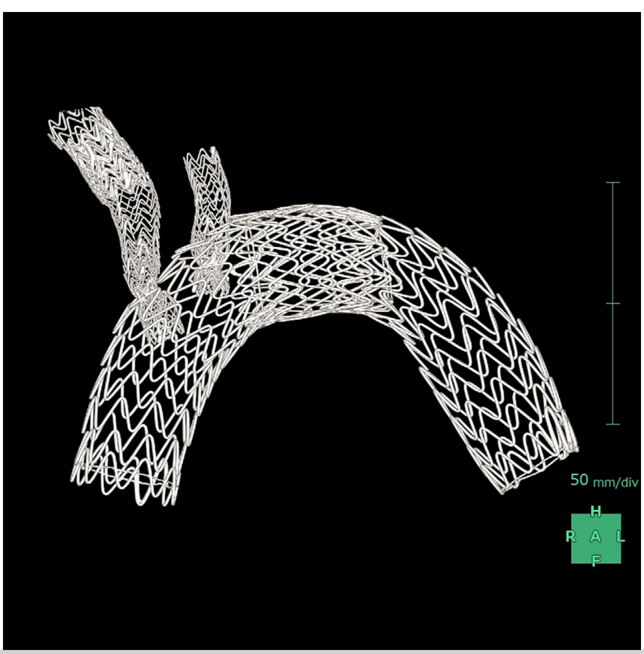


**Fig 4.** Reconstructed three-dimensional image of the stent graft (SG). This image was reconstructed using SYNAPSE VINCENT software (Fujifilm Medical).

been caused by any aortic or cardiac events. After formalin fixation, the SG was harvested from the specimen. Macroscopic examination revealed complete thrombosis of the aneurysm, adherence at each landing zone and the SG, including intact junctions between the main SG and branch SGs (Fig 3; Supplementary Fig 1). Additionally, no embolic cerebral infarction was found. CT was performed, and three-dimensional images were reconstructed using SYNAPSE VINCENT (Fujifilm Medical, Tokyo, Japan). These images showed no stent fracture and no stenotic lesion caused by compression with the stent strut of the C-TAG at the junctions (Figs 4 and 5). A leak test was performed after occluding all the outlets of the SGs with Coda balloons (Cook Medical Inc, Bloomington, IN) or Reliant balloons (Medtronic, Santa Rosa, CA; Supplementary Fig 2). Injection of saline solution at 1 atm (760 mm Hg) confirmed watertight seals at these junctions (Supplementary Video).

## DISCUSSION

We examined a branched SG reconstructed using the RIBS technique that was harvested at an autopsy 14 months postoperatively. We were able to perform a thorough macroscopic examination and obtained clear and detailed images using direct CT. Although the RIBS technique is widely recognized, graft durability at the junction of the main SG and branched SG has remained a significant concern. Several experimental studies have compared the fenestrated holes with various combinations of SG materials, fenestration methods (eg, needle puncture, radiofrequency method), and angioplasty balloons (eg, standard balloon, high-pressure balloon, cutting balloon).[14-18] In some of these studies, accelerated fatigue tests revealed increases in the size of the fenestration and fabric fraying.[17,18] Therefore, no consensus has been reached regarding the best combination in the clinical setting.

Based on our experimental data that the TAG had had the least fraying of the graft material, we have arrived at

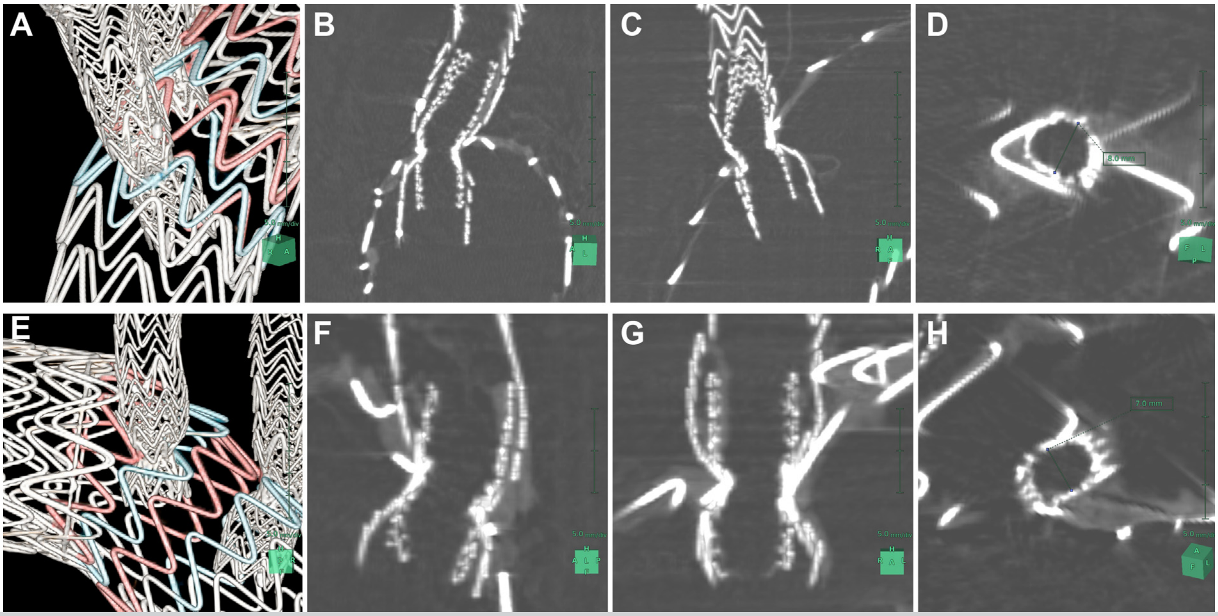


**Fig 5.** Computed tomography (CT) analysis of the junction between the main stent graft (SG) and the branched SG. **A-D,** Branched SG and bare metal stent. **E-H,** Branched SG and bare metal stent. Stent struts, which were located proximally and distally for the branched SG, are highlighted (proximally, *pink*; distally, *blue*). Vertical cross-section images adjusted for the branched SG were obtained (**B** and **F,** coronal section; **C** and **G,** sagittal section; **D** and **H,** axial section).

the following device combination and procedure: C-TAG for the main SG, Viabahn and the iliac branch endoprosthesis component for branch SGs, step-by-step dilatation with a 7F sheath dilator and a high-pressure balloon, and deployment of a balloon-expandable stent in the SG for reinforcement at the junctions. Using this technique, we have achieved acceptable initial clinical outcomes for high-risk patients with complex aortic arch aneurysms.[6] In the present case, we found no SG or stent fracture on macroscopic and CT analysis. Our ex vivo test was primitive, because it was performed under static pressure without flow. Nevertheless, we believe that the finding that no leakage had occurred at 760 mm Hg is valuable, because it has provided proof that no EL had developed, which will not always be apparent on enhanced CT scan testing or autopsy.

The disadvantage of the RIBS technique is the difficulty in reaching the ideal puncture site precisely using fluoroscopic two-dimensional imaging. If a strut of the main SG overlaps the fenestration, the fenestration cannot be tightly sealed or the branched SG could lead to stenosis. The ideal puncture site is the area without the stents, especially the valley of the stent. Aiming is made possible by fluoroscopic guidance and using a bent PTGBD needle. Compared with laser fenestration, the PTGBD has the advantage of haptic feedback and cost. In the present case, two branched SGs were fortuitously constructed to avoid the valley bottom of the strut. Although the C-TAG endoprosthesis has double lapping films at greater curvature, and puncture through these films is necessary, both branched SGs were patent without any stenosis at 14 months after insertion in our patient (7 mm in diameter for the LCCA and 8 mm in diameter for the BCA). Nevertheless, the development of a dedicated SG for the RIBS procedure, which has no strut interference, is desirable for the future.

## CONCLUSIONS

Although deliberate follow-up and larger scale clinical evidence are required, the findings from the present case suggest that RIBS could be a viable alternative treatment option for select high-risk patients.

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Submitted Jan 20, 2022; accepted Apr 4, 2022.

**Supplementary Fig 1.** Specimen with the stent graft (SG). *Bold black arrow* and *white arrowhead* point to ostium of the coronary artery and cusp of the aortic valve, respectively.

**Supplementary Fig 2.** Setup for the leak test. All outlets of the stent grafts (SGs) were blocked with Coda balloons (Cook Medical Inc) or Reliant balloons (Medtronic, Santa Rosa, CA).