Distal False Lumen Occlusion in Aortic Dissection With a Homemade Extra-Large Vascular Plug: The Candy-Plug Technique

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Purpose: To report a technique to create an extra-large vascular plug for occlusion of a large distal false lumen in chronic aortic dissection.

Technique: The “candy-plug” technique is demonstrated in a 58-year-old multimorbid man with a history of complicated acute type B aortic dissection and a 9-cm chronic thoracic false lumen aneurysm. The patient underwent a staged repair with a cervical debranching procedure as a first step and a thoracic endovascular aortic repair from the innominate artery to the celiac artery as a second step. To occlude the large false lumen from a distal route, a stent-graft was modified on-table with a diameter-restricting suture, giving it a wrapped candy–like shape. This plug was deployed into the false lumen, and the remaining opening was occluded with a standard vascular plug. On 3-month follow-up imaging, the thoracic false lumen aneurysm remained completely thrombosed.

Conclusion: The candy-plug technique can facilitate complete occlusion of chronic thoracic false lumen aneurysm by prohibiting distal false lumen backflow.

Key words: thoracic aortic aneurysm, aortic dissection, endovascular repair, stent-graft, thoracic aorta, vascular plug, physician-customized device

Aortic dissection is a severe disease affecting all segments of the aorta, and it is associated with high mortality if left untreated. Thyroid endovascular aortic repair (TEVAR) was introduced for the treatment of acute and chronic type B aortic dissection in 1999. Since then, TEVAR has become the mainstay of operative treatment for complicated acute type B aortic dissection, offering a clear benefit with lower mortality and morbidity compared to open surgical repair. Common practice for TEVAR in aortic dissection is the implantation of a tubular stent-graft to cover the proximal entry tear and redirect flow into the true lumen. This successful strategy results in false lumen thrombosis and aortic remodeling in a majority of patients with acute type B aortic dissection. Response to this endovascular treatment strategy is limited in patients with chronic dissections owing to the fibrotic tissue that reduces the capacity for aortic remodeling.

One unresolved issue with endovascular treatment of patients with chronic dissections is the inability to seal off the false lumen...
distally because most aortic dissections extend distally across the visceral aortic segment and often into the iliac arteries. This scenario is especially problematic in patients who develop false lumen aneurysm in the proximal descending aorta. In cases of ruptured false lumen aneurysms, it may not be possible to seal off the distal false lumen backflow into the aneurysm, leading to continued bleeding despite stent-graft coverage down to the celiac artery. One technique to occlude the distal false lumen is the use of fenestrated stent-grafts that allow covering an even longer segment of the aorta, thus occluding more entry points and reducing pressure and flow transmission into the false lumen. However, the fenestrated stent-graft technique requires advanced endovascular skills, long operating times, and customized fenestrated stent-grafts. A more simple way to obstruct the distal false lumen in patients with descending aortic false lumen aneurysms is to implant large diameter plugs after catheterizing the false lumen. However, the largest diameter vascular plug that is commercially available is 22 mm, which allows sealing of vessels up to 18 mm in diameter. We developed a novel technique to modify a Zenith thoracic stent-graft into an extra-large (XL) vascular plug to occlude a large distal false lumen in chronic aortic dissection.

**TECHNIQUE**

The technique is demonstrated in a 58-year-old man with a medical history of hypertension, obesity (body mass index 37 kg/m²), chronic renal insufficiency (glomerular filtration rate 33 mL/min), and type B aortic dissection who was admitted for open replacement of a stenosed (0.9 cm²) aortic valve. The patient had been treated in 2004 for a complicated acute type B aortic dissection and visceral ischemia with endovascular fenestration of the dissection membrane; in 2010, he received a femorofemoral crossover bypass for chronic leg ischemia due to true lumen collapse of the right common iliac artery. During preoperative workup for the planned aortic valve replacement, computed tomographic angiography (CTA) revealed a 9-cm false lumen thoracic aortic aneurysm (Fig. 1A), and the patient was scheduled for a hybrid endovascular repair.

Due to a short proximal landing zone (Fig. 1B), the patient first underwent a cervical debranching procedure that included a carotid-crossover bypass and a left carotid–subclavian bypass prior to TEVAR. Three weeks later, the endovascular procedure was performed in an operating room with a fixed imaging system under general anesthesia and systemic heparinization (100 U/kg). Following bilateral percutaneous femoral access, the true lumen was catheterized from the right femoral artery, and an extra stiff Lunderquist wire (Cook Medical, Bjaeverskov, Denmark) was positioned in the ascending aorta. Two custom-made Zenith thoracic low-profile stent-grafts (Cook Medical) with a proximal diameter of 46 mm tapering down to 28 mm
Side Table Customization

Preoperative CTA data were analyzed using the Aquarius Intuition workstation (Tera-recon, San Mateo, CA, USA). A distal segment of the descending thoracic aorta with a maximum 36-mm diameter in the false lumen was chosen for placement of the plug. A 135-mm-long, 42-mm Zenith thoracic TX2 ProForm stent-graft (Cook Medical) was modified on a sterile side table by adding a diameter-restricting suture between two intermediate stents. First, the stent-graft was partially unloaded from the delivery system through the peel-away at the valve of the sheath (Fig. 2A). An Ethibond 2 thread (Ethicon, Norderstedt, Germany) was used to tie a diameter-reducing suture between the third and fourth Gianturco Z-stents so as to restrict the opening of the stent-graft at this point to a maximum diameter of ~10 mm (Fig. 2B). This customization would give the stent-graft a shape like a wrapped candy, with a waist just large enough to retrieve the dilator tip. After deployment of this XL vascular plug in the distal thoracic false lumen, the remaining minor opening could be fully closed with a vascular plug to seal off...
the distal false lumen. The diameter of this reducing suture was controlled by using a mosquito-clamp to make sure that the nosecone could be removed through the waist in the XL plug (Fig. 2C). Then the stent-graft was reloaded and prepared in a standard fashion (Fig. 2D).

Next, the false lumen was catheterized from the left femoral artery access, and another extra stiff Lunderquist wire was positioned carefully in the false lumen aneurysm. The customized 42-mm stent-graft was introduced and positioned in a segment of the false lumen of the descending thoracic aorta, which was identified on CTA to have a diameter <36 mm. The customized stent-graft was deployed in a standard fashion, and the dilator tip of the delivery system was carefully withdrawn through the waist in the candy-plug. A 20-mm Amplatzer Vascular Plug II (St. Jude Medical, St. Paul, MN, USA) was deployed in the waist of the candy-plug for complete occlusion (Fig. 3). Completion angiography demonstrated no residual flow into the false lumen aneurysm.
The patient had an uneventful recovery and was discharged on postoperative day 10. On follow-up CTA at 1 week and 3 months post treatment, the thoracic false lumen aneurysm remained completely thrombosed (Fig. 4).

**DISCUSSION**

The introduction of endovascular repair has fundamentally changed the management of type B aortic dissection during the last 15 years. In acute dissection, the strategy of covering the primary entry tear with a stent-graft has shown considerable promise to stimulate aortic remodeling, with true lumen expansion and false lumen thrombosis. Untreated, the true lumen may become very small or even occlude in chronic dissection, while the false lumen enlarges and becomes aneurysmal. In contrast to acute aortic dissection, re-opening of the true lumen is prohibited as the tissue is fibrotic, stiff, and has shrunken to a smaller diameter. The presence of a false lumen aneurysm together with the limited capacity for aortic remodeling in chronic dissection restricts the endovascular treatment strategy of covering the proximal entry tear alone with a stent-graft. As distal re-entries are well established and the distal false lumen backflow to intercostal arteries is not affected by this treatment strategy, the aneurysm remains perfused, with a continued risk for rupture.

During customization of the candy-plug, care needs to be taken to create a waist with an inner diameter that still allows retrieval of

**Figure 4** Postoperative CTA after implantation of a candy-plug. (A) Volume rendering and (B) multiplanar reconstructions demonstrating the position of the large diameter vascular plug in the distal false lumen (arrows). (C) Axial slice demonstrating no endoleak and thrombosis of the false lumen aneurysm. (D) Axial slice at the diaphragm demonstrating the position of the candy-plug with the Amplatzer vascular plug filling the central lumen (arrow).
the dilator tip of the delivery system. If retrieval of the dilator tip is difficult, we recommend advancing the tip of the sheath into the distal part of the candy-plug with contact to the waist of the extra-large plug to create a counterforce when pulling at the dilator tip. Especially in patients with ruptured false lumen aneurysms, this technique may be helpful to seal off the false lumen distally when backflow into the aneurysm needs to be interrupted.

Roselli et al.\textsuperscript{11} reported in 2011 an open surgical strategy to resect the dissection membrane in the intended distal landing zone of the descending aorta through a sternotomy during arch replacement in patients with chronic DeBakey type 1 dissection. This smart strategy sought to facilitate complete distal seal of the thoracic false lumen aneurysm by landing a thoracic stent-graft during a second procedure in this combined lumen. Konings et al.\textsuperscript{12} reported a similar approach via a subxiphoid incision and resection of the dissection membrane in the supraceliac aorta, extending Roselli’s technique even further distal without the need for thoracotomy or sternotomy in a patient with a chronic aortic dissection type B. Both strategies address the problem of false lumen backflow sufficiently, but require open surgery and aortic cross-clamping. Another significant difference to our reported technique is that blood flow is directed into both lumens distal to the stent-graft due to the fenestration, so there is a risk for distal formation of false lumen aneurysm and branch vessel ischemia.

The candy-plug customization technique we describe is strictly outside of the Instructions for Use of the products. Moreover, use of this technique has significant risks that need to be weighed against the advantages in every single patient. We hope to see large diameter vascular plugs developed for this upcoming treatment indication in the near future.

\textbf{Conclusion}

The candy-plug technique may be another means of facilitating complete occlusion of a chronic thoracic false lumen aneurysm by prohibiting distal false lumen backflow.
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