Concomitant carotid-carotid-axillary bypass with zone-0 branched endograft and transcatheter aortic valve-in-valve replacement via retroperitoneal access

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Carotid-carotid-axillary bypass with zone 0 branched TEVAR and ViV TAVR via retroperitoneal access

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**Glossary of abbreviations:**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AI</td>
<td>Aortic insufficiency</td>
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<tr>
<td>CTA</td>
<td>Computerized tomographic angiography</td>
</tr>
<tr>
<td>DHCA</td>
<td>Deep hypothermic circulatory arrest</td>
</tr>
<tr>
<td>PTFE</td>
<td>Polytetrafluoroethylene</td>
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<tr>
<td>SCM</td>
<td>Sternocleidomastoid</td>
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<tr>
<td>TAVR</td>
<td>Transcatheter aortic valve replace</td>
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<tr>
<td>TBE</td>
<td>Thoracic branched endoprostheses</td>
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<tr>
<td>TEVAR</td>
<td>Thoracic endovascular aortic repair</td>
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<tr>
<td>ViV</td>
<td>Valve-in-valve</td>
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Central message:

Endovascular solutions are expanding. Combining techniques and utilizing adjuncts can provide safe alternatives to very high-risk aortic procedures.

Central image legend:

3D reconstruction: branched zone 0 TEVAR with carotid-carotid-axillary bypasses and TAVR.
Introduction

Redo aortic surgery can be complex. Complexity is increased with aortic proximity to the posterior sternal table in combination with severe aortic insufficiency (AI). Re-entry in this situation requires deep hypothermic circulatory arrest (DHCA) before sternotomy. Ventricular fibrillation with cooling is inevitable, and severe myocardial distension from severe AI is known to be detrimental to myocardial protection.\(^1\,^2\) Ventricular distension can be mitigated by endoaortic balloon occlusion and venting the central port, or via a counter thoracotomy incision and directly venting the apex. These approaches have their limitations related to cardioplegia with the former and recirculation with the latter. In addition, DHCA on re-entry should allow for expeditious freeing and possible limited repair of underlying structures, followed by resumption of circulation until further dissection is completed, in preparation of definitive repair, cerebral vessel control and cardioplegia administration.

We present a case with dehiscence of a distal hemiarch anastomosis with multiple large pseudoaneurysms (PSA) immediately under the sternum, together with severe aortic insufficiency from a degenerated bioprosthetic valve. Re-entry with DHCA would have been prolonged due to the inability to expeditiously repair the distal anastomosis, nor to apply a clamp distal to it. As a result, resumption of circulation would have only been possible after definitive repair, which would entail an exceedingly long DHCA time that is associated with poor neurological outcomes.\(^3\,^4\) We present a non-traditional method to address this problem. Per institution, IRB approval was not required. Patient provided informed written consent for publication of study data.

Case

A 49-year-old female with a history of acute type A aortic dissection for which she underwent a supracoronary and hemiarch aortic replacement and a bioprosthetic aortic valve replacement. Her initial presentation was with paraparesis from static obstruction of her spinal arteries. Her first surgery was reportedly uneventful, however her paraparesis persisted and required a diverting colostomy. She presented to us with chest pain. Acute coronary syndrome was ruled out and computed tomographic angiography (CTA) showed an 8cm mass around her distal aortic anastomosis with multiple PSAs, the largest of which was an anterior 4cms PSA from a dehisced long segment, and another 3cm PSA from a defect along the aortopulmonary window (figure 1). Her native arch was calcified (figure 1B). Echocardiogram showed severe insufficiency of her aortic valve bioprosthesis.

Strategy
We considered peripheral cannulation for cardiopulmonary bypass, cooling with apical venting through a mini-thoracotomy and re-entry with DHCA. However, we had concerns regarding the duration of DHCA necessary before we could resume circulation (after cardiac dissection, head vessel control, myocardial protection, and definitive aortic repair). Moreover, the densely and circumferentially calcified arch may have caused significant difficulty with a surgically constructed anastomosis. Consequently, we pursued alternative strategies.

We considered thoracic endovascular aortic repair (TEVAR) of the dehisced anastomosis and a transcatheter aortic valve-in-valve replacement (ViV-TAVR). Challenges encountered included that coverage of the dehisced anastomosis necessitated coverage of her bovine trunk. Her available inflow for extra-anatomic revascularization of the head would have been her femoral vessels, which is known to have very poor patency rates. Moreover, CTA of her iliofemoral vessels showed her external iliac arteries to be 48mm in maximum diameter, prohibiting femoral access for TEVAR.

As a result, we decided to use a thoracic branched endoprosthesis (TBE) with zone 0 coverage, with the side branch into the innominate artery, preceded by carotid-to-carotid bypass and carotid-to-left axillary bypass, and followed by ViV-TAVR. For access, we decided to use a retroperitoneal common iliac artery conduit.

**Technique**

Under general anesthesia and cerebral monitoring, bilateral carotid cutdowns were done along the anterior borders of the sternocleidomastoids (SCM). Carotid arteries were controlled and nerves protected. The left axillary artery was exposed in the deltopectoral groove and the brachial plexus protected. A tunnel was created in the retropharyngeal space using blunt dissection just anterior to the cervical vertebral bodies, and an 8mm ringed-polytetrafluoroethylene (PTFE) graft was routed. Another retroclavicular tunnel was created using blunt dissection and a 6mm ringed-PTFE graft was routed (supplemental figure 1A). Heparin was given after tunneling. Carotids were sequentially clamped, and end to side anastomoses were constructed medial to the jugular veins. The left carotid anastomosis for the axillary bypass was more proximal and was constructed lateral to the jugular (jugular retracted medially). Axillary anastomosis was then constructed.

A temporary right ventricular pacer was placed through the right femoral vein for rapid pacing during TEVAR and TAVR deployments. Retroperitoneal exposure was achieved through an incision in the right iliac fossa with medial visceral rotation, identification of the aortic bifurcation, ureteral protection and control of the common iliac. A 10mm dacron graft was sewn end to side and externalized through the abdominal wall muscles and through the skin of the right groin (supplemental figure 1B). The graft was
then de-aired and clamped. The graft was accessed proximal to the clamp and serially dilated in the standard fashion, and a 24Fr sheath was inserted over a stiff wire (supplemental figure 1C).

Right upper limb arteries were too small for access so instead, we accessed the exposed right carotid, and a stiff glide wire was advanced into the descending aorta, snared, and externalized through the 24 Fr sheath. A thoracic branched endoprosthesis (TBE – WL Gore, Flagstaff, AZ) was loaded on both wires and advanced avoiding wire wrap. Stent graft was deployed in zone 0. We then cannulated the portal with a 15x60mm side branch stent graft over the glidewire and deployed it in the innominate artery. Then, this was ballooned with a compliant balloon. A proximal aortic extender was used to get more coverage proximal to the dehisced anastomosis. Angiograms showed no endoleaks and patent bypasses (supplemental figures 2A, 2B, and 2D).

Through the same sheath, the bioprosthetic valve was crossed, and a 26mm Evolut FX (Medtronic, Minneapolis, MN) valve was gently passed through the TEVAR endograft and deployed inside the degenerated bioprosthesis (supplemental figure 2C). Patient did not have heart block. Aortogram showed good coronary filling, and echocardiogram showed no paravalvular leak. The left carotid was ligated proximally. The iliac conduit was amputated with a short stump, and soft tissue layers were closed.

The patient’s recovery was uneventful and without neurological complications. The patient was discharged on postoperative day 8, and predischarge CTA showed and excellent result (figure 2).

Comment

The endovascular toolkit is expanding, and familiarity with its applications allows for modifying and combining approaches to provide safer strategies for highly complex situations. Transapical TAVR and TEVAR have been previously reported.\textsuperscript{5,6} The combination of zone 0 landing with a branched-TEVAR together with TAVR has, to our knowledge, not been previously reported. In this case, transapical approach was not considered because the ascending aorta was shorter than the shortest available TBE, prohibiting antegrade deployment. Retrograde advancement of the TAVR delivery system prior to the TEVAR would have been unsafe with the dehisced aorta. Advancement with the TEVAR in place involves cautious maneuvering to avoid migration of the newly deployed stent graft. The side-branch probably provides increased stability to the endograft during the TAVR delivery.

Endoconduits have been described, which entail controlled expansion and possibly rupture of the iliac vessels inside an oversized covered stent graft.\textsuperscript{7} In this case, we found the femoral arteries to be prohibitively small, requiring a near-doubling in size, so we elected to proceed with a retroperitoneal approach with direct common iliac artery access.
We believe our strategy is safer for the patient compared to a standard operation; however, the main limitation is that the patient received another bioprosthetic valve, which will eventually degenerate. Her long-term plans will include either a surgical mechanical valve or a ViV-TAVR, depending on the age at which this happens. If re-entry was necessary, it will not be problematic with the PSA excluded.

**Figure legends**

Figure 1. A, B and C: Preoperative CTA and reconstruction showing multiple pseudoaneurysms arising from the dehisced distal hemiarch anastomosis and calcified true lumen of the native arch

Figure 2. A, B and C: Postoperative CTA and reconstruction of the postoperative CT scan showing excluded pseudoaneurysms, no endoleaks and patent bypass grafts.

Supplemental Figure 1: A: Shows ring reinforced PTFE grafts routed in the retropharyngeal and retroclavicular routes prior to heparinization. B and C: show retroperitoneal conduit construction to the right common iliac artery and externalization into the right groin for large bore sheath access.

Supplemental Figure 2: A: Aortogram shows circumferential pseudoaneurysms around the distal ascending aorta and evidence of severe AI. B: Shows the deployed TBE and side branch with exclusion of the pseudoaneurysms and occlusion of the native left carotid and left subclavian orifices. C: Evolut FX TAVR valve deployed in a ViV fashion. D: Carotid-to-carotid bypasses and left carotid to axillary bypasses (prior to proximal ligation).

**References**


