

Applicability and midterm results of branch cuff closure with vascular plug in branched endovascular repair for thoracoabdominal aortic aneurysms

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ABSTRACT

Objective: This study assessed the applicability and outcomes of the closure of unused cuffs in branched endovascular aneurysm repair (b-EVAR) of thoracoabdominal aortic aneurysm.

Methods: We reviewed b-EVAR procedures at a tertiary referral center to identify patients who underwent incomplete branching and needed closure of the unused branch cuffs. An electronic database and intraoperative and follow-up imaging studies were reviewed to assess technical applicability and outcomes.

Results: Between January 2007 and December 2015, 17 patients underwent incomplete branching during b-EVAR. The unused branch cuff in one patient occluded spontaneously after b-EVAR and was excluded from this analysis. The remaining 16 patients underwent 11 elective and five emergency repairs. Amplatzer Vascular Plugs (St. Jude Medical, Plymouth, Minn) were used to successfully close 17 branches: 8 targeting preoperatively occluded target vessels, 3 optional branches where fenestrations were used instead, 5 after failures of catheterization or stent bridging to target vessels, and 1 renal branch of an atrophic kidney. Four branch cuffs were extended with a peripheral covered stent before plug deployment. Sixteen branch cuffs were closed intraoperatively, and the remaining cuff was closed percutaneously at a later occasion. Perioperative death occurred in two patients. Median follow-up duration was 19 months (interquartile range, 11-30 months). There was no endoleak or reintervention related to the plugged cuffs. Two late deaths occurred not related to the aneurysm. Two patients required reinterventions for type III endoleaks with interval sac expansions caused by aortic stent graft component separation in tortuous thoracic segments not related to the occluded cuffs.

Conclusions: Closure of the branch cuff of multibranched stent graft with Amplatzer Vascular Plug is feasible and effective. It was not associated with adverse aneurysm outcomes, and it is very useful especially when using an off-the-shelf device in the acute setting. (J Vasc Surg 2017;■:1-8.)

Endovascular aneurysm repair with branched stent graft (b-EVAR) is a valid option to treat thoracoabdominal aortic aneurysms (TAAAs), particularly in high-risk surgical patients. The goal of treatment is to exclude the aneurysm sac from the systemic circulation. However, there is also the need in TAAA repair to preserve perfusion to the aortic visceral and renal branches with fenestrations or branches.

Multibranched stent grafts are available in custom-made designs (CMD) and as standardized off-the-shelf (OTS) designs. CMD devices are used in the elective setting and tailored to specific patient anatomy. Under

these circumstances, branches of CMD devices are only left unconnected when catheterization of the target vessels (TVs) fails or intentional perfusion of the aneurysm is intended to prevent spinal cord ischemia.¹⁻³ The OTS devices are often used for urgent or emergency repairs where some of the branches may not have a patent TV for connection, such as in patients with a single kidney or celiac trunk occlusions.

Irrespective of the reason, a branch that is not bridged to a TV must be closed properly to prevent a persistent type III endoleak. In these cases, closure of the unused branch cuff with a vascular plug has been reported⁴ and widely adopted, but no data have been reported for aneurysm-related outcomes. This study reports the results of consecutive cases where vascular plugs were used for branch closure in b-EVAR of TAAA.

METHODS

Patients and design. All patients undergoing b-EVAR, of TAAA at a tertiary referral center from January 2007 to December 2015 were reviewed. The study included patients who underwent b-EVAR with incomplete branching and in whom at least one branch cuff was closed by a vascular plug. Medical records and imaging were retrospectively reviewed. All patients gave informed

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consent for b-EVAR, and approval by the Regional Ethical Committee was waived.

Devices. All of the aortic stent grafts implanted in these patients were thoracoabdominal side-branched stent grafts based on the Zenith platform (Cook Medical, Brisbane, QLD, Australia). The OTS device used in our institution was the Zenith t-Branch device (Cook Medical, Bjaereskov, Denmark) or the identical version before the commercial release, as suggested by Sweet et al⁵ and Chuter and Greenberg,⁶ or the CMD nitinol-based low-profile version.⁷ CMD branched stent grafts were individually made to match the anatomy of each patient. Branch cuffs had diameters of 6 to 8 mm and lengths of 18 to 21 mm, depending on the location and intended TVs. A single reinforced fenestration was incorporated in some of the CMD branched stent grafts (Fig 1), comprising one three-branched and three four-branched stent grafts.

Implantation techniques. All patients underwent b-EVAR under general anesthesia. A cerebrospinal fluid drainage catheter was placed in all but two patients. Spinal drainage was initiated in one of these two patients during postoperative period after signs of spinal cord ischemia developed.

The usual technique for b-EVAR has been described.⁸ In summary, a branched stent graft was oriented, positioned, and fully deployed keeping all of the branch cuffs above the designated TVs to facilitate subsequent cannulation and bridging with peripheral stent grafts. When the aortic stent grafts were also incorporating fenestrations, these were catheterized and bridged via femoral access before implantation of the bifurcated distal component and iliac limb. After complete implantation of all aortic and fenestration bridging stent grafts, femoral accesses were closed.

Bridging the branch cuff into the designated TV with a self-expanding peripheral stent graft was performed through cranial access, as previously described. Selective reinforcement with self-expanding or balloon-expandable bare stents was performed as needed.

Branch cuff closure technique. Unused branch cuffs were closed with a single-layered cylindrical or multilayered multilobular nitinol retrievable Amplatzer Vascular Plug (AVP) or Amplatzer Vascular Plug II (AVP-II), respectively (St. Jude Medical, Plymouth, Minn). In our first few experiences of branch cuff closures using vascular plug, we used the AVP and had deployed two AVPs inside a branch cuff to enhance thrombosis. After availability of the AVP-II, we discontinued using the AVP for this purpose, and the AVP-II became our preference when closing the branch cuffs.

A plug was deployed inside the branch cuff using a standard deployment technique as described by Ferreira et al⁴ (Fig 2, A). If accurate plug placement was difficult

ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective analysis of prospectively collected single-center registry data
- **Take Home Message:** Amplatzer plugs (St. Jude Medical, Plymouth, Minn) were used in 16 patients to close redundant cuffs of a multibranched thoracoabdominal stent graft. The technique was safe and effective at a median follow-up of 19 months.
- **Recommendation:** The authors suggest that a four-branch off-the-shelf stent graft can be used to repair thoracoabdominal aortic aneurysms in patients who have only 3 visceral branches if the redundant cuff is closed with an Amplatzer plug.

because of catheter instability, the branch cuffs were extended by placement of a peripheral stent graft, preferably a balloon-expandable stent graft, before the AVP-II was deployed (Fig 2, B). This technique will be discussed below. Plugging of the branch cuff was considered successful when a vascular plug was deployed in the intended position. Clinical success of the plugging of the branch was considered as the absence of migration of the plug, without plug-related endoleak and expansion of the TAAA.

Imaging and follow-up. Procedures were performed in a fully equipped hybrid room (Artis Zee; Siemens Healthcare, Erlangen, Germany). Iodine contrast (140–200 mg/mL) was used in all patients. Carbon dioxide angiography was used as an adjunct in 10 patients. Intraoperative cone-beam computed tomography (CT) was performed in 11 patients after all devices were implanted. Contrast-enhanced CT angiography (CTA), including a pre-enhancement, arterial phase, and delayed scans, was done 1 month and yearly postoperatively. Contrast-enhanced ultrasound imaging was used instead in one patient with renal insufficiency.

Endoleaks were assessed and classified according to reporting standards. Aortic diameters were measured in axial reconstructions as the perpendicular to the largest diameter to avoid overestimation caused by vessel tortuosity. Expansion or shrinkage was identified when the diameter changed by ≥ 5 mm.

Data presentation. Categorical variables are presented as absolute numbers and percentages, and continuous variables are presented as median and interquartile range. Statistical analysis was done with SPSS 23.0 software (IBM Corp, Armonk, NY).

RESULTS

Patients. We identified 17 consecutive patients who underwent incomplete branching during b-EVAR. The analysis excluded one of these patients because the open branch cuff occluded spontaneously. Of the

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