Editorial

The reverse frozen elephant trunk: the Thoracoflo® hybrid-graft

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Thoracoabdominal aortic aneurysm (TAAA) repair is counted among the most invasive treatments in cardiovascular medicine. Despite improved technological developments and new endovascular devices, the disease remains challenging, and repair techniques still carry a high procedural risk even if performed in highly specialized centers (1). Although open TAAA repair remains the gold standard for patients suitable for extensive surgery, there is a remarkable risk for perioperative morbidity in terms of spinal cord injury (SCI), stroke, dialysis, major bleeding, or re-thoracotomy/re-laparotomy, and perioperative mortality (2). Total endovascular thoracoabdominal treatment options with fenestrated or branched devices are less invasive but are still associated with a high rate of devastating complications and a considerable reintervention rate (1,3).

In order to reduce perioperative morbidity of TAAA repair, different multimodal strategies such as cerebrospinal fluid (CSF) drainage, staged repair, preprocedural coiling of intercostal arteries or sequential clamping have been implemented (4,5).

The technique of reverse frozen elephant trunk was developed to offer a less invasive staged repair technique for TAAA by avoiding thoracotomy, aortic cross-clamping, and extracorporeal circulation for selective visceral perfusion. The Thoracoflo® hybrid-graft (Terumo Aortic, Glasgow, UK) comprises of a proximal stent-graft section, which is deployed retrogradely into the descending thoracic aorta, attached via a sewing collar to a distal graft with seven branches for reno-mesenteric, lumbar, and iliac artery attachment. The higher radial force and the longitudinal stiffness of the stent-grafted section compared to the conventional Thoraflex® hybrid-graft can avoid collapse and migration during retrograde implantation against the blood-flow. By using preliminary end-to side anastomosis, retrograde visceral and antegrade ileo-hypogastric pulsatile blood-flow is preserved throughout the procedure after deployment of the stent-grafted section. Ischemic time is minimized to the time of anastomosis.

The graft is customized by stent-graft length and diameter as well as the orientation and diameter of the side branches according to patients' preoperative computed tomography scan. The device is landed in a previous thoracic endovascular aortic repair (TEVAR) or in a stable landing zone in native aorta. Exposure of the aorta can be performed by median laparotomy, or lumbotomy and visceral rotation with or without mobilising the left kidney, or thoraco-laparotomy.

The technique of Thoracoflo® implantation has been previously described in detail (6,7). Briefly, end-to-side anastomosis of one iliac branch of the graft to one common iliac artery or distal aorta is performed to ensure continuous retrograde pulsatile flow to the intestinal organs and spinal cord as well as antegrade perfusion to both legs. The proximal stent-graft is deployed retrogradely into the descending thoracic aorta via direct aortic puncture or through the celiac trunk ostium using Seldinger's technique, guided via transesophageal echocardiographic (TEE) guidance or X-ray.

After de-airing the side-branches, pulsatile blood-flow is established to the visceral and ileo-hypogastric vessels while

the native aorta is intact. Leaving the aneurysm unopened, celiac trunk, superior mesenteric artery and left renal artery are transected and anastomosed to the branches in end-to-end fashion. When blood flow is restored to these vessels, distal aortic cross-clamping is performed, and the aneurysm is opened. Back bleeding lumbar arteries are ligated, and the collar is sewed to the aortic wall. The right renal artery can be perfused via a catheter attached to the contralateral iliac branch of the Thoracoflo® hybrid-graft during collar anastomosis.

Finally, the right renal and both common iliac anastomoses are performed. The access branch of the graft can be used if additional TEVAR is required or for attachment of lumbar arteries.

This new concept of staged repair may reduce the risk for SCI. It is a viable alternative for endovascular and classic open TAAA repair, especially for patients with connective tissue disease and previous surgery as staged repair. Exact preoperative planning and following the instructions for implantation are mandatory to avoid pitfalls.

The surgical access route (thoraco-laparotomy *vs.* laparotomy) is up to the surgeon's or institutional preference and standards. In case TEVAR is required to create a suitable landing zone, it should be landed at least 4 cm above celiac trunk ostium to allow enough space for Thoracoflo® implantation. In the case of occluded access arteries, the TEVAR may be implanted through the access branch of the Thoracoflo® hybrid-graft during surgery.

Graft deployment can be performed under TEE guidance, however fluoroscopy is highly recommended in kinked aortic anatomies and narrow true lumens with difficult visualization of the guidewire in the ultrasound image.

To ensure safe retrograde visceral and antegrade ileo-hypogastric blood-flow, monitoring via an arterial line in the contralateral femoral artery can recognize kinking or compression of the prefusion branch during surgery.

For prevention of severe back-bleeding from patent intercostal arteries, preoperative endovascular occlusion by coil embolization of patent intercostal arteries or false lumen occlusion, or intraoperative snaring of the descending thoracic aorta or the intercostal arteries is highly recommended. Back-table cardiopulmonary bypass or rapid re-transfusion systems should be available in case of major bleeding during surgery.

It is important to conform to the deployment steps. The guidewire must be removed before retraction of the handle. Otherwise, the whole stent-graft section will be retracted, as the guidewire is located outside of the graft.

De-airing of the graft after deployment of the stent-graft section is of great importance to avoid air-embolism. Stop-cocks should be attached to all side branches to facilitate de-airing during the surgical process and to attach perfusion catheters e.g., for right kidney perfusion during collar anastomosis.

In case of fragile tissue of the iliac artery, the iliac side branch can be shortened instead of performing iliac end-to-end anastomosis. Customized design of the graft also enables distal aortic anastomosis with longer main body instead of bi-iliac attachment.

The success of TAAA repair clearly lies in a well-functioning interdisciplinary team of surgeons with experience in thoracoabdominal surgery (cardiac and vascular) endovascular specialists, and anesthesiologists. The Thoracoflo® hybrid graft offers staged repair without need for a hybrid room, avoiding thoracotomy, thoracic cross-clamping, and extracorporeal circulation for selective visceral perfusion. By adhering to the implantation protocol and respecting the safeguards and pitfalls, hybrid repair using the Thoracoflo® graft provides great potential as a new treatment option for TAAA repair.

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Footnote

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