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The best option for complicated type B dissection with arch involved

Chang Shu[1,2,3], Tun Wang[1,2], Ming-Yao Luo[3], Kun Fang[3], Quan-Ming Li[1,2], Ming Li[1,2], Xin Li[1,2], Hao He[1,2]

[1]Department of Vascular Surgery, The 2nd Xiang-ya Hospital, Central South University, Changsha, Hunan 410011, China;
[2]Angiopathy Institute, Central South University, Changsha, Hunan 410011, China;
[3]Department of Cardiovascular Surgery, Chinese Academy of Medical Sciences and Peking Union Medical College Fuwai Hospital, Beijing 100013, China.

Thoracic endovascular aortic repair (TEVAR) is the first choice of type B aortic dissection (TBAD).[1-3] However, when the dissection involves an aortic arch with close proximity to the supra-aortic branches, the situation becomes complicated and challenging for classical TEVAR. In recent years, the Hybrid-ENDO vascular-Open arch repair (HENDO) theory that consists of some treatment strategies specifically for aortic arch lesions, becomes popular. Based on the HENDO theory, the modified endovascular technique, simultaneously aiming at the reconstruction of the involved supra-aortic branches and coverage of TBAD, is the first choice with promising future development. According to the specific anatomic situation and the pathology of the disease, hybrid or open surgery can be performed selectively.

Modified endovascular techniques

Endovascular repair of aortic arch dissection with chimney technique (ch-TEVAR) to preserve the flow of involved supra-aortic branches is technically feasible with acceptable effectiveness and safety.[3] In our previous report of 122 patients, all of the 143 target supra-aortic vessels were patent with the construction of chimney or double chimney technique, with no perioperative mortality recorded. Due to the use of off-shelf devices, some of these operations were performed emergently with the mean operation time of only 117 min.[3] Although there is no randomized study to compare ch-TEVAR with hybrid surgery or open surgery, according to some systemic evaluations, the established 30-day mortality rate (7.9%) for ch-TEVAR is lower than that for hybrid surgery (11.9%) or open surgery (9.5%).[4]

The main problem for ch-TEVAR is type Ia endoleak caused by incomplete adherence of aortic stent-graft to chimney stent-graft and aortic wall, namely gutter endoleak. Most of the type Ia endoleak either happened during operation or got detected by computed tomography angiography post-operatively. Yet, a few type Ia endoleak detected during later follow-up was reported. The incidence rate of type Ia endoleak is 1.2% to 20.0%[4] and is 10.7% in our study.[3] Though no type Ia endoleak associated mortality was reported, there is no clear consensus on the treatment. Most of the type Ia endoleaks were treated conservatively with close follow-up initially. The disappearance of type Ia endoleaks with conservative treatment may occur. The rest of the continuous type Ia endoleaks during follow-up were treated with different methods including coil embolization, proximal extension with cuff implantation, and continuous conservative treatment could be considered. Secondary open surgery is the most reliable method to seal type Ia endoleak with a sealing rate of >90%. However, it has a high risk of perioperative complications, such as acute renal failure and stroke. Besides, it is not fit for elderly patients.

Oversizing of aortic stent-graft and chimney stent-graft is correlated with the gutter endoleak. Some experts suggested 20% and 30% oversizing for aortic stent-graft and chimney stent-graft, respectively. However, excessive oversizing might lead to a retrograde type A aortic dissection. From our experience, the size of the stent-grafts should be selected according to the pathological and anatomical situation of the aortic arch. For TBAD with arch involved, excessive oversizing is unnecessary, and 15% and 5% for the aortic stent-graft and the chimney stent-graft, respectively, are appropriate to seal the aortic dissection and to prevent the gutter endoleak and retrograde type A aortic dissection.[3]

A novel gutter-free stent-graft for the branch artery, namely Longuette, was originally designed and used for ch-TEVAR. Compared with commercially covered stent-

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Correspondence to: Prof. Chang Shu, Department of Cardiovascular Surgery, Chinese Academy of Medical Sciences and Peking Union Medical College Fuwai Hospital, Beijing 100013, China
E-Mail: changshu_vascular@163.com

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grafts, the outer layer of the gutter-free stent-graft effectively decreases the incidence of type Ia endoleak.[5]

Stroke is a common surgical complication of the aortic arch, defined as a non-reversible neurologic deficit lasting for 1-week post-op. The etiology might differ among endovascular technique, hybrid operation, and open surgery, with the reported incidence in 1.2% to 5.6% for ch-TEVAR. The double chimney technique has more manipulations on supra-aortic branches, especially in innominate artery reconstruction, and is associated with a higher risk of neurological deficit.[3] For open surgery and hybrid repair, the incidence of stroke is 5% to 12% and about 7.6%, respectively,[4,6] higher than that for ch-TEVAR. Common etiology of cerebral ischemia includes stenosis/atherosclerosis in carotid/vertebral artery and aortic arch, manipulation on the carotid artery, and from compression of the chimney stent-graft. To decrease the risk of cerebral ischemia, some common strategies such as using a healthy aortic segment with fewer atherosclerosis as the proximal landing zone for aortic stent-graft, deployment of chimney stent-graft in innominate artery initially, and open control of carotid artery access site instead of percutaneous puncture should be considered.[3]

For multiple ch-TEVAR, the space allocation should be reasonable, especially in the reconstruction of all supra-aortic branches. Forward deployment of all branched stent-grafts in the triple chimney technique leads to overcrowding in the proximal landing zone, and the risk of type Ia endoleak increases correspondently. An ideal solution is the snorkel technique for the left subclavian artery (LSA).[3]

Fenestration technique (f-TEVAR), including *in vitro* (namely, physician-made, physician-modified, or on-the-table) and *in situ*,[7,8] is another feasible endovascular technique. Compared with ch-TEVAR, there is no risk of gutter endoleak. However, structure modification of the original aortic stent-graft that causes mechanical factor changes within the aortic stent-graft is the main long-term uncertainty for f-TEVAR. For *in vitro* f-TEVAR, high quality of pre-operative anatomic assessment, especially the three-dimension structure of the aortic arch, and accurate intra-operative planning from an experienced surgeon are crucial. Many anatomic factors, such as aortic arch tortuosity and/or rotation, might cause aortic stent-graft spinning and consequent mismatch of the fenestration and the supra-aortic truck. Thus, a relatively large fenestration is suggested, especially for the crucial carotid and innominate artery. Besides, deployment of a covered stent-graft in the small fenestration was recommended by some experts for enhanced reliability. The position of fenestration is more accurate for *in situ* f-TEVAR compared with *in vitro* f-TEVAR. However, *in situ* f-TEVAR requires the use of needles and even lasers at the orifices of supra-aortic branches, which is associated with the potential risk of aortic injury. In addition, procedure complexity, time, the volume of contrast used, and intra-op blood loss are significantly higher for *in situ* f-TEVAR than that for ch-TEVAR or *in vitro* f-TEVAR. Besides, tortuosity and/or stenosis of supra-aortic branches might lead to many difficulties. However, there is no evidence of a higher rate of mortality or complication caused by increased complexity.[7] Single-vessel laser fenestration is reported to suffer from endoleak in 2.5%, stroke in 2.5%, and retrograde dissection in 1.7%. More complications occur in multi-vessel *in situ* fenestration.[8]

There are several kinds of "off-shelf" branched endograft currently in clinical trials designed to reconstruct the LSA during endovascular treatment for aortic arch diseases, such as the Valiant Mona stent graft (Medtronic Inc., Santa Rosa, CA, USA), the Gore Thoracic Branch Endoprosthesis (TBE, WL Gore, Flagstaff, AZ, USA), the Inoue Stent Graft (PTMC Institute, Kyoto, Japan), and the Castor Branched endograft (Microport Medical, Shanghai, China). The Castor device is the only one that addresses aortic dissection, and the only commercially available one in China. Theoretically, "off-shelf" branched stent technology that avoids gutter endoleak and fits the anatomic feature of the aortic arch, is the best option. However, the current devices can only reconstruct the LSA and still have many insufficiencies. More research and clinical trial are needed in the future.

Hybrid aortic arch repair

Currently, most methods of endovascular arch vessel revascularization need commercial endograft off-label use, and the long-term result is under research. So, according to "Chinese Expert Consensus on Hybrid Technique on Treating Thoracic Aortic Pathologies Involving the Aortic Arch" published in 2020 by the National Society of Vascular Surgery, hybrid operations, especially extra-anatomic bypass (eg, carotid-subclavian bypass, carotid-carotid bypass, subclavian-carotid transposition, ascending-innominate/carotid bifurcated bypass) should be delineated in the treatment of complicated TBAD with arch involved.[2] The technical success rate is almost 90%, and the mortality risk ranges from 0% to 14.3%. Complete debranching and TEVAR are associated with unsatisfactory outcome, which the mortality rates is reported from 27% to 70%, three times higher than hybrid repair in zone 1.

Stroke, nerve injury, and endoleak are the main complications in hybrid operation. Clamping or embolism formation during the debranching and revascularization manipulation is the reason for stroke. The most common nerve injury is left recurrent laryngeal nerve injury, which is caused by the surgical exposure and transposition of the proximal LSA. Insufficient length of the proximal landing zone for TEVAR, though the hybrid process extends a wider proximal landing zone, remains the main reason for endoleak.

Open surgical repair

Currently, with the rapid development of endovascular surgery and hybrid operation, open surgery for TBAD with the arch involved is rarely performed. The procedure involves the replacement of the dissected aortic segment, excision of the septum, organ protection techniques (eg, hypothermic circulatory arrest and systemic temperature management, distal aortic perfusion, visceral organ perfusion techniques), and management of major aortic

branch vessels (eg, supra-aortic branches, visceral arteries, iliac arteries, intercostal arteries, and lumbar arteries).[2] However, according to contemporary experience, for selected patients, such as the chronic TBAD with an extremely huge false lumen and the patients with connective tissue disease that are unfit for any other surgery, open surgery is still elective and can be performed safely with low stroke and paraplegia rates.[2]

Conflicts of interest

None.

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