Initial Experience of Modified Four-Branched Graft Technique and Antegrade TEVAR in Acute Type A Aortic Dissection

Hung-Tao Chou, MD, Jen-Ping Lo, NP, Chai-Hock Chua, MD, Ming-Jen Lu, MD, and Chia-Hsun Lin, MD

Background: We report the initial experience of modified four-branched graft technique for proximal aorta and arch repair, feasibly combined with antegrade thoracic endovascular aortic repair (TEVAR) to extend distal aortic reconstruction in acute type A aortic dissection.

Methods: From 2011 to 2013, 12 consecutive patients with acute type A aortic dissection were indicated for arch surgery and underwent surgical replacement of proximal aorta, arch replacement or debranching procedure, and concomitant TEVAR for distal aortic repair.

Results: A good surgical field was obtained in all patients. No major complications developed but two hospital deaths were attributed to end-organs damage preoperatively. Good and fast remodeling of thoracic descending aorta was demonstrated in 11 patients in postoperative CT imaging and no aneurysmal dilatation of visceral aorta had been observed in 10 patients during follow-up periods.

Conclusion: Modified four-branched graft technique facilitated proximal aorta and arch repair, and provided excellent neurological outcome and favorable short-term results. Single-stage operation combined with antegrade TEVAR is feasible and effective to extend the repair down to the descending aorta, and thus achieved good remodeling of thoracic descending aorta.

Keywords: type A, aortic dissection, four-branched graft, TEVAR, antegrade
been successfully applied for the treatment of aortic aneurysm and type B dissection with good results.3) Hence, open repair of proximal aorta and arch combined with TEVAR for distal aorta performed in the same setting, the surgical invasiveness was minimized and the results were improved.4) We reported the initial experience of modified four-branched graft technique for proximal aorta and arch repair and concomitantly antegrade TEVAR for descending aorta reconstruction in acute type A aortic dissection patients indicated for arch surgery.

Materials and Methods

From 2011 to 2013, 12 consecutive patients with acute type A aortic dissection were indicated for arch repair due to arch dissecting aneurysm formation exceeding 4 cm or carotid artery dissection. All patients underwent proximal aorta and arch repair using modified four-branched graft technique and simultaneously antegrade TEVAR for descending aorta repair. The extensive aortic lesions, proximal aortic root reconstructions, arch procedures, TEVAR profile, follow-up time and aorta morphological change were listed on the Table 1. This study was approved by the Institutional Review Board and written informed consent was obtained from all the patients.

Technique

The CPB was employed with right atrium drainage, right axillary and one femoral arterial perfusion. Moderate hypothermia at 32°C was maintained, proximal aorta was first repaired with graft replacement using a commercialized four-branched knitted polyester graft (Vascutec, Glasgow, Scotland) (Fig. 1A). The length between proximal anastomosis to the first branch is about 2–3 cm to leave the room for cross-clamping on the next redo open heart surgery. After the proximal reconstruction was achieved, the right innominate artery was anastomosed to the first 10 mm branch of aortic graft. The right innominate artery clamp was then released and the coronary arteries were reperfused through the return from the right axillary artery (Fig. 1B). The body temperature was re-warmed and the heartbeat was resumed soon. In sequence, the left common carotid artery was anastomosed to the second 8 mm branch of graft, and was reperfused immediately (Fig. 1C). The distal aortic anastomosis site depended on the integrity of aortic tissue and the length of distal four-branched graft. For the purpose of concomitant TEVAR procedure, there should be 3 cm length of distal aortic graft between the origin of last branch and distal aortic anastomosis, which would be the proximal landing zone for the thoracic stentgraft implantation across the anastomosis. Open anastomosis without aortic clamping was carried out to facilitate distal aortic anastomosis under lower body circulatory arrest by stopping femoral arterial return. The aortic cross clamp in front of innominate artery was released and the arch intima was examined. If there was no severe tear of arch intima, the anastomosis was done close to innominate artery after excision of the clamping site and the debranched arch was preserved for exclusion (Fig. 1D, Fig. 2). Once there was no 3 cm landing length for thoracic stentgraft, the proximal arch was partially excised for anastomosis. In addition, if there was severe tear of arch intima, total arch replacement was performed (Fig. 3) and the anastomosis was done at proximal descending aorta. After the distal aortic anastomosis was accomplished, the left subclavian artery was anastomosed to the third 8 mm branch of graft. The CPB was weaned off at 37°C and the TEVAR proceeded. The Gore TAG (WL Gore & Assoc, Flagstaff, AZ) thoracic stent-graft was delivered antegradely and deployed via the fourth branch of aortic graft, after shooting angiogram to demonstrate the aortic lesion, to identify the true lumen and proximal entries, and to determine the distal landing site and the length of device. Our strategy to avoid paraplegia is not to extend the stent-graft beyond T8 and to revascularize left subclavian artery whenever possible intra-operatively. In addition, the most important is to maintain stable hemodynamic condition perioperatively. An aortic balloon catheter was expanded over the proximal landing zone and graft overlaps. The stentgraft in the proximal landing zone of distal four-branched graft was fixed from the outside by palpation of the inside stentgraft using 2-0 Ticron (Covidien, Mansfield, MA) full-layer sutures with Teflon (Impra Inc, subsidiary of C.R. Bard, Tempe, AZ) felts at each quadrant to prevent migration and endoleak. The complete angiogram was shot to confirm the final result and finally the fourth branch of aortic graft was ligated with sutures (Fig. 1E).

Results

A good surgical field was obtained in all patients. There were two hospital deaths. Pre-operatively, one was complicated with acute myocardial infarction, severely impaired left ventricular function and SMA malperfusion, and the other developed bilateral carotid arterial dissection with occlusion resulting in large area of cerebral
<table>
<thead>
<tr>
<th>Patients age, gender</th>
<th>Arch dissection</th>
<th>Proximal reconstruction</th>
<th>Arch procedure</th>
<th>TEVAR</th>
<th>Follow-up (months); Aorta remodeling on CT</th>
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<tbody>
<tr>
<td>1. 46, male</td>
<td>Arch aneurysm, carotid dissection</td>
<td>Modified Bentall procedure</td>
<td>Replacement</td>
<td>Antegrade TAG 31–150 mm</td>
<td>42, false lumen thrombosis and regression down to diaphragm</td>
</tr>
<tr>
<td>2. 31, female</td>
<td>Arch aneurysm; Mild to moderate AR</td>
<td>Ascending aorta replacement, AV re-suspension</td>
<td>Replacement</td>
<td>Antegrade TAG 26–100 mm</td>
<td>40, false lumen thrombosis and regression limited within stent-graft; persistent distal false lumen but no dilatation</td>
</tr>
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<td>3. 35, male</td>
<td>Arch aneurysm, carotid dissection</td>
<td>Ascending aorta replacement,</td>
<td>Debranching</td>
<td>Antegrade TAG 31–150 mm</td>
<td>29, false lumen thrombosis and regression down to diaphragm</td>
</tr>
<tr>
<td>4. 49, male</td>
<td>Arch aneurysm, carotid dissection;</td>
<td>Ascending aorta replacement,</td>
<td>Debranching</td>
<td>Antegrade TAG 31–150 mm</td>
<td>26, false lumen thrombosis and regression down to diaphragm</td>
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<tr>
<td>5. 59, male</td>
<td>Arch aneurysm, carotid dissection with stroke</td>
<td>Ascending aorta replacement</td>
<td>Replacement</td>
<td>Antegrade TAG 31–150 mm</td>
<td>Mortality due to stroke with central failure; false lumen thrombosis and regression down to diaphragm</td>
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<tr>
<td>6. 53, male</td>
<td>Arch aneurysm, carotid dissection, AMI with LV failure, Severe AR, SMA malperfusion</td>
<td>Modified Bentall procedure</td>
<td>Replacement</td>
<td>Antegrade TAG 31–150 mm</td>
<td>Mortality due to LV failure</td>
</tr>
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<td>7. 55, female</td>
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<td>Ascending aorta replacement</td>
<td>Replacement</td>
<td>Antegrade TAG 31–150 mm</td>
<td>22, false lumen thrombosis and regression down to diaphragm</td>
</tr>
<tr>
<td>8. 47, male</td>
<td>Arch aneurysm</td>
<td>Ascending aorta replacement</td>
<td>Replacement</td>
<td>Antegrade TAG 31–150 mm</td>
<td>21 false lumen thrombosis and regression down to diaphragm</td>
</tr>
<tr>
<td>9. 61, female</td>
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<td>Replacement</td>
<td>Antegrade TAG 28–100 mm</td>
<td>19, false lumen thrombosis and regression down to diaphragm</td>
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<tr>
<td>10. 53, male</td>
<td>Arch aneurysm</td>
<td>Ascending aorta replacement</td>
<td>Replacement</td>
<td>Antegrade TAG 34–200 mm</td>
<td>13, false lumen thrombosis and regression down to diaphragm</td>
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<tr>
<td>11. 49, male</td>
<td>Arch aneurysm</td>
<td>Ascending aorta replacement</td>
<td>Replacement</td>
<td>Antegrade TAG 31–150 mm</td>
<td>12, false lumen thrombosis and regression down to diaphragm</td>
</tr>
<tr>
<td>12. 73, female</td>
<td>Arch aneurysm</td>
<td>Modified Bentall procedure</td>
<td>Debranching</td>
<td>Antegrade TAG 34–100 mm</td>
<td>12, false lumen thrombosis and regression down to diaphragm</td>
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TEVAR: thoracic endovascular aortic repair
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Despite of emergent operation, one patient died in heart failure on the 2nd post-operative day and the other died in stroke with central failure on the 15th post-operative day. Otherwise, no neurologic or major complications developed in 10 patients. The follow-up CT images showed good and fast remodeling of dissected descending aorta from the stent-graft down to the diaphragm. The true lumen re-expansion and false lumen thrombosis with regression had been well demonstrated in 11 patients. However, the false lumen thrombosis and regression were limited within the extent of stent-graft in Patient 2, due to the presence of distal stent-graft induced new entry (SINE) on the 1-week CT. During follow-up periods, no aneurysmal dilatation of visceral aorta was observed in all patients and no indication of re-intervention for Patient 2.

Discussion

Kato and coworkers demonstrated a four-branched graft technique and open thoracic stent-graft implantation for extensive aortic reconstruction in type A dissection patients in 2002. In their method, under CPB at 24°C with right axillary artery and femoral artery return and cardioplegic arrest, the proximal anastomosis of the ascending aorta has been completed first, and then supra-aortic bypass anastomoses from the four-branched graft to the left carotid artery and left subclavian artery are performed. The arterial return cannula is shifted form the femoral artery to the four-branched graft and the perfusion of cervical branches is restarted. Perfusion to the lower body is discontinued and open stent-graft implantation into the descending aorta is done. The distal portion of the four-branched graft is sutured directly to the stent-graft and the right innominate artery is bypassed last.

In our technique for proximal aorta and arch repair, we modified the sequences of supra-aortic bypass grafting and employed antegrade deployment of stent-graft after the distal anastomosis and circulatory restoration. By grafting the innominate artery first, the right axillary arterial return could re-perfuse the coronary arteries immediately and reduce the myocardial ischemic time, which is crucial to
the patients with left ventricular dysfunction. The left common carotid artery was grafted secondly and then was reperfused immediately after anastomosis. Although the left carotid anastomosis period represented only few minutes of unilateral cerebral perfusion, there was no additional ischemic time needed for further shifting the arterial return to the central graft as described by Kato and coworkers. Due to shortened myocardial ischemic time and no need of systemic circulatory arrest, the body temperature during CPB could be maintained at 32°C moderate hypothermia. Therefore, the complications related to profound hypothermia and prolonged CPB time could be avoided.

Although the technique of open antegrade thoracic stent-graft deployment under circulatory arrest had been reported with good results,\(^5\)\(^6\) antegrade deployment of thoracic stent-graft after the distal anastomosis and circulatory restoration is more advantageous. First, the stent-graft landed in the distal aortic graft across the anastomosis into the descending aorta and consequently would secure the distal anastomosis from bleeding. Thus the distal anastomosis can be performed simply in a short period without complicated reconstruction procedures requiring longer lower body circulatory arrest time. Secondly, after circulatory restoration, shooting angiogram can confirm the true lumen and identify the significant proximal entry tears for complete coverage to effectively eliminate the antegrade flow of false lumen. Moreover, the antegrade deployment technique through the fourth graft branch is feasible and quick, while retrograde deployment might encounter difficulties of small access arteries and device tracking through the false lumen, tortuous and angulated visceral and thoracic aorta, or possible inadequate length of device to reach the ascending aorta after arch debranching procedure, and no further femoral access needed.

Although the immediate surgical outcome for emergent proximal repair of acute type A aortic dissection has currently improved,\(^7\) the late complications requiring reoperation are reported as many as 40% of patients.\(^7\) The late reoperations are related to the fate of residual dissection of the arch or thoracoabdominal aorta and residual false lumen patency due to proximal unresected intimal tears and reentry in the distal aorta.\(^8\) The effectiveness of TEVAR procedure using stent-graft to cover-seal the proximal entry and induce favorable aortic remodeling in type B dissection is well demonstrated.\(^9\)\(^10\) The stent-graft enhanced the true lumen re-expansion and promoted the false lumen thrombosis and regression in proportion to the extent of stent-graft coverage over the descending aorta. As such, the complete false lumen thrombosis was observed around the surgical-stent in 94.5% of patients and in 71.9% of patients at the diaphragmatic level, reported by Sun and colleagues in their experience of treatment for acute type A dissection\(^11\) and the ability to halt or reverse aortic growth in the stented segment in 85% of patients is evident that TEVAR can protect the aortic wall from adverse morphologic changes in chronic distal dissection patients, reported by Kang and colleagues.\(^12\) Although TEVAR has contributed significantly to the remodeling of aortic dissection, there remains a concern with regard to the stiff stent-graft which may injure the fragile aortic septum. Stent-graft induced new entry (SINE) is defined as a new tear caused by the stent-graft at proximal or distal ends.
Factors of difference between arch diameter and true lumen diameter in the descending aorta (taper ratio) or the distal oversizing ratio calculated by the stent-graft area and true lumen area have been investigated to predict the development of SINE and thus the choice of taper-designed stent-graft or implantation sequence of distal small-sized stent-graft first is suggestive to prevent distal SINE. A high incidence of distal SINE was reported by Weng and colleagues, but low rates of complications and no distal SINE-related death happened. Complicated distal SINE can be successfully resolved by distal stentgraft repair.

In our initial experience of this single-stage hybrid surgery for acute type A dissection, despite of small number of patients, the surgical results and neurological outcome are good in acute type A emergent operations for patients with no organs damage. Modified four-branched graft technique facilitates proximal aorta and arch repair under moderate hypothermic lower body circulatory arrest, and consequently provided favorable surgical results and neurological outcome. Simultaneously, single-stage operation combined with antegrade TEVAR is feasible and effective to extend the repair down to the descending aorta, and as a result led to high incidence of good distal aortic remodeling.

**Disclosure Statement**

All authors have no conflict of interest.

**References**