Endovascular Repair of the Aortic Arch and Ascending Thoracic Aorta

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Background

The aortic arch is wide, compliant, and mobile. Its flow rate is high and its branches supply an organ, the brain, with no tolerance for ischemia. In this location, an endovascular stent graft is difficult to deliver, difficult to secure, and prone to fatigue fracture, graft erosion, or migration. The only advantage is the opportunity for downstream access to vital arterial branches, and the presence of extensive collaterals to the subclavian artery. In the absence of a LIMA coronary bypass or a left-dominant vertebral artery, stent graft coverage of the subclavian artery appears to be well tolerated. Collateral flow usually suffices to prevent left hand ischemia at rest. Symptoms, when they occur, can be treated by carotid subclavian bypass. However, if more proximal segments of the aortic arch are to be excluded from the circulation, some provision has to be made for flow to the carotid arteries. The options include surgical bypass through a conventional graft from a remote artery, endovascular bypass through branches of the stent graft, various combinations of bypass and branching. Other options such as fenestration or double-barrel stent-graft insertion may also be used to lengthen the proximal implantation site without lengthening the seal zone.

Surgical Bypass

The presence of a LIMA coronary bypass or a left-dominant vertebral artery mandates carotid-subclavian bypass to the distal subclavian artery prior to stent graft insertion. Similarly, planned coverage of the left carotid artery should be preceded by carotid-carotid bypass. Things get more complicated when the implantation site involves the origin of the innominate (brachiocephalic) artery. Under these circumstances, possible sources of inflow include the ascending thoracic aorta and the femoral arteries. The choice depends on the patient's ability to tolerate median sternotomy, the embolic risk of aortic side-clamping, and the prospects for long-term patency of femoral to axillary bypass.

Endovascular Bypass

Only one group (Inoue and colleagues) has reported complete aortic arch exclusion using a multi-branched stent graft. Their ingenious technique involves simultaneous catheter mediated deployment of the entire stent graft and its branches. The stent graft is notable for discrete attachment rings and a high degree of flexibility, which make it well suited for use in the arch. Nevertheless, high rates of embolic stroke are probably the result of extensive catheter manipulation within the arch. We have performed in vitro evaluations of various modular multi-branched stent grafts, all of which proved to be too bulky or too difficult to catheterize to be used in such an unforgiving location.

Combined Endovascular/Surgical Bypass

A single branch from the stent graft to the innominate artery can serve as inflow for extra-anatomic reconstruction of the remaining arch branches. In this type of a procedure, the primary stent graft is essentially a large-diameter, upside down version of long-leg/short-leg bifurcated stent grafts used in abdominal aortic aneurysm repair. The endovascular portion of this procedure is very simple and very quick. Transcarotid access provides a short straight route to the ascending thoracic aorta, and ensures that the trailing limb of the primary stent graft ends in the innominate artery. Once introduced and oriented, the aortic part of the stent graft is easy to deploy during a single period of adenosine induced cardiac arrest, and its short wide stump is easy to catheterize from a femoral access site.

Fenestration

Downstream access to the left subclavian artery provides an opportunity for in situ fenestration of an otherwise intact unbranched aortic stent graft. The hole is made using the back end of a coronary guidewire, enlarged using cutting balloons, and secured using an uncovered stent. Pre-made fenestrations achieve the same effect, but exact placement can be difficult, since the curves of the aortic arch inhibit delivery system rotation. Another approach is to rely upon self orientation of a precurved stent graft, with a pre-made fenestration, inside a precurved delivery system. One problem common to all forms of fenestration is disruption of the seal and leakage into the aneurysm. Unless the aneurysm is confined to the inner curve of the arch, fenestrations often lengthen the attachment site, but not the seal zone.

Double-Barrel Stent Graft

An alternative to fenestration involves the insertion of a flexible covered stent (secondary stent graft) through the branch artery (subclavian and/or left carotid) and alongside the aortic (primary) stent graft. The secondary stent graft essentially moves the branch artery orifice to a more proximal location. In doing so it may disrupt the seal between the aortic stent and the outer curvature of the arch. The situation is analogous to fenestrated repair in that the additional stent grafts lengthen the attachment site and improve stent-graft orientation, but do little to enhance sealing between the primary stent-graft and the outer curve of the arch. The tendency toward leakage depends on the conformability of the primary stent graft. A conformable primary stent graft, like the Gore Excluder, folds around the secondary stent graft and fills in potential routes of leakage. Nevertheless, it is still advisable to blow up a balloon alongside the primary stent graft to test its leak-inducing potential before inserting the secondary stent graft.

Proximal Surgical Repair and Distal Endovascular Repair

Aneurysm or dissection involving the ascending thoracic aorta, aortic arch, and descending thoracic aorta can be dealt with in a staged fashion. Open repair of the ascending aorta and arch is followed by endovascular repair of the descending aorta, using an elephant trunk as the proximal implantation site, thereby avoiding lateral thoracotomy.

Conclusions

Endovascular repair of an aneurysm involving the distal arch is commonplace, and with a few additional maneuvers, an endovascular aneurysm repair can be carried all the way to the ascending thoracic aorta. However, atherosclerotic aneurysms of this area are rare by comparison with type A aortic dissection. Most cases of proximal aortic dissection remain beyond the reach of endovascular technique because they present emergently and often involve the aortic root. Endovascular treatment of this area would probably involve endovascular coronary bypass and endovascular valve repair. Therefore, an endovascular treatment for type A dissection remains a remote prospect.

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