Fenestrated and Branch Aortic Stent Grafts

There is a role for fenestrated and branch aortic stent grafts in the treatment of difficult aortic aneurysms.

BY JOHN L. ANDERSON, FACS, FRACS

Aortic stent grafts have now been used in the treatment of aortic aneurysm for a period in excess of a decade. Many patients, however, may remain unsuitable for such techniques on the basis of nonfavorable aortic anatomy. Most commonly, this decision relates to the presence of a nonsuitable infrarenal aortic neck. Evidence has shown a higher incidence of type I proximal endoleak when established guidelines are disregarded, often leading to explantation of the stent and surgical conversion.

The introduction of fenestrated and branched stent grafts into clinical practice in 1997 has overcome many of the problems associated with an unsuitable proximal neck.[1,2] Such grafts allow use of the juxtarenal and transrenal segments of the aorta for proximal fixation

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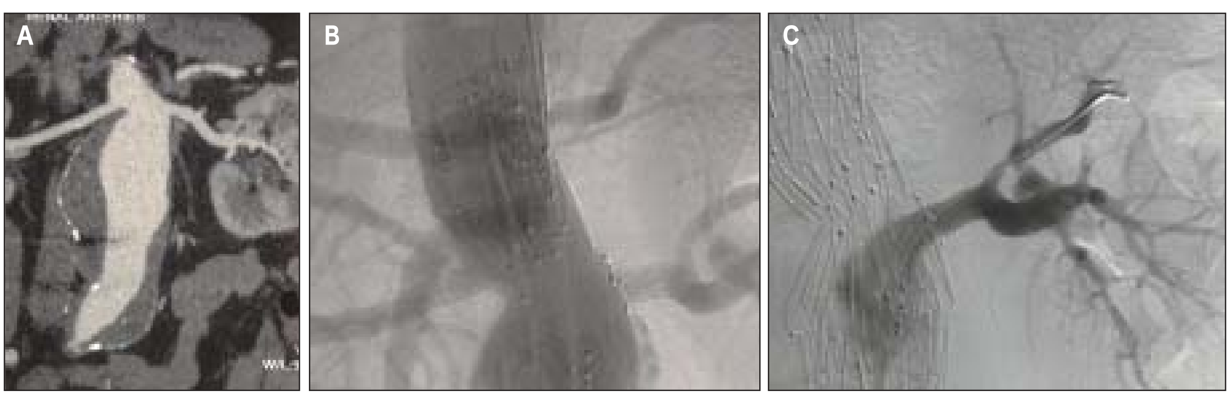

Figure 1. A 62-year-old man with ischemic heart disease, respiratory disease, and peripheral vascular disease presented with a large juxtarenal aortic aneurysm with an unfavorable neck due to length, shape, and angulation. Note that graft-to-wall contact is not possible in relation to the right renal artery (A). Treatment carried out with Zenith quadruple fenestrated graft. The vessels targeted for revascularization are the celiac, superior mesenteric artery, right renal, and left renal. Initial image after implantation shows an endoleak at the left renal (6 mm X 8 mm) fenestration (B). For the endoleak arising from the left renal artery, a Jomed (Beringen, Switzerland) stent graft was used (branched endograft) to achieve a satisfactory seal (C).

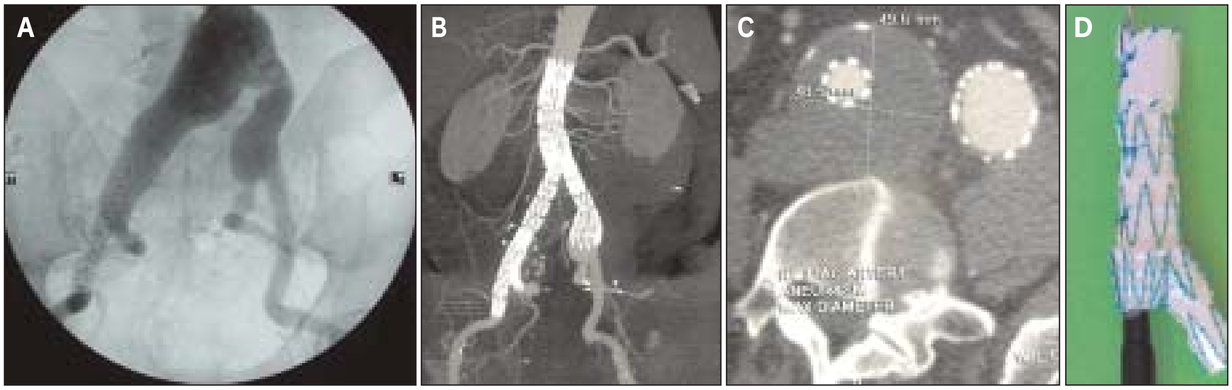

Figure 2. Angiography shows a large AAA along with a right common iliac artery aneurysm involving the hypogastric artery (A). A branched endograft was used to exclude the aneurysms while maintaining the hypogastric circulation (B). Follow-up CT scan shows complete exclusion of the right common iliac aneurysm with no endoleak (C). A branched endograft with a large flare for the contralateral limb was used in this case (D).

and sealing. Appropriate placement of suitable fenestrations within the graft neck allows continued perfusion of renal and, where necessary, visceral vessels. To date, all treatments have been carried out with the Zenith (Cook Incorporated, Bloomington, IN) graft. The use of such devices is now wide spread in Australia and has also been employed at several centers in Europe.

An increasing experience has led to relatively standard techniques of implantation with a significant degree of positive outcome. In particular, there has been a high incidence of success in relation to both target vessel revascularization and freedom from type I proximal endoleak.[1]

Improvements in graft design have expanded the clinical role of such devices, and many variations beyond simple fenestrations have now been employed to preserve targeted branch vessel perfusion. In some patients, this has included the use of branched aortic grafts (Figures 1A-C). To date, implanted vessels have included the renal, superior mesenteric, celiac, subclavian, and hypogastric arteries (Figures 2A-D).

GRAFT DESIGN AND DELIVERY

The key word in relation to design is customization—each graft being tailored for the individual patient. Such planning necessitates an adequate imaging work up to fashion a graft that is both specific and accurate for the patient in question. This aside, the majority of grafts are more similar than dissimilar.

Initial grafts were bifurcated and modular in nature, in keeping with the majority of grafts used at that time in standard endoluminal repair. All current grafts are termed composite—the proximal graft component is tubular in nature and contains all of the fenestrations or branches. The use of a noncovered Gianturco proximal stent restrained by a cap, as in the standard Zenith, permits a controlled release of the graft from the delivery system, with subsequent accurate placement in relation to the renal and other vessels (Figure 3).

In essence, implantation of the fenestrated tube creates the ideal neck, allowing completion by placement

Figure 3. Partial release of the upper graft. Note the proximal cap remains in place. Graft rotation and longitudinal movement remains possible. Note the right renal fenestration markers are in a "diamond" configuration in keeping with the anterolateral position of the renal ostium. Markers for the left renal are largely tangential, in keeping with the 3-o'clock position of the renal orifice. This image was generated with 7 mL of contrast using a pressure injector.

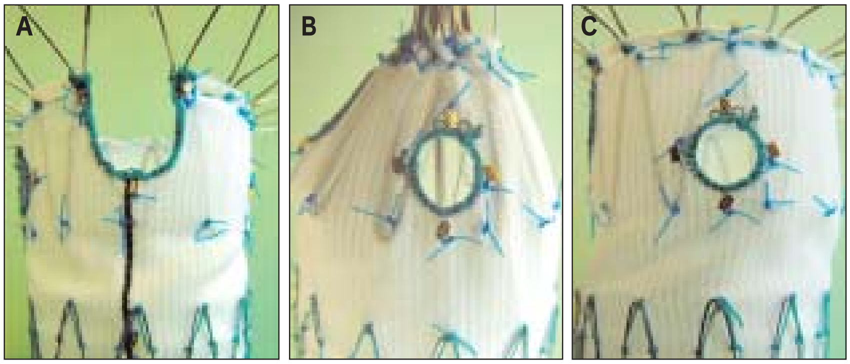

Figure 4. A scallop in the open position. Typically, this is used to provide continued perfusion of the celiac or superior mesenteric artery (A). A small fenestration in the proximal covered stent. At this stage, the proximal noncovered stent is contained within the proximal cap of the delivery system. This is the state in which the fenestration is catheterized during implantation (B). A small fenestration in the open position. Typically, this type of fenestration is used for renal artery perfusion (C).

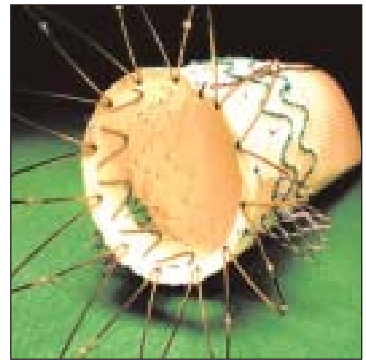

Figure 5. This image shows a bench model with the stents *in situ*. Note that the stents do not protrude into the lumen.

of a bifurcated modular graft distal to the upper component.

FENESTRATION AND BRANCH TYPE

Fenestration types are classified as scallop, small fenestration, and large fenestration (Figures 4A-C). More recently, fenestrations have been improved by the incorporation of a nitinol circumferential ring that strengthens the edge, allowing for a more stable fixation when balloon-expandable stents are employed for accurate alignment of fenestration and vessel ostia.

Typically, small fenestrations, usually measuring 6 mm X 8 mm tend to be used for renal implantation and are always placed at the primary site of seal.

Large fenestrations are typically used for the superior mesenteric artery and celiac vessels and generally are not associated with the site of seal. If these vessels are relatively close to the renal arteries it is easier to include

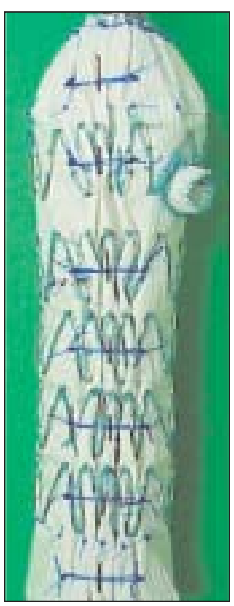

Figure 6. Use of a short branch is indicated in cases in which wall contact is not possible.

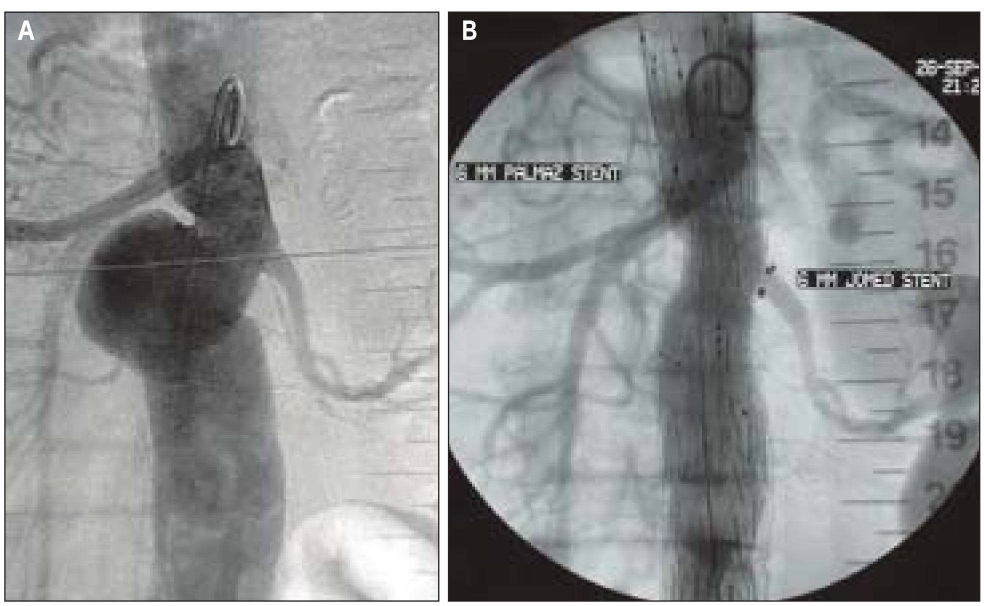

Figure 7. A false aneurysm noted 1 year after surgical repair for rupture. Wall contact with the renal artery on the left is not possible (A). Use of a body short branch with covered stent extension (Jomed) after angiography shows complete exclusion of the false aneurysm (B).

them in the graft neck rather than to attempt their avoidance. The nature of the Gianturco stent has a large role in determining where fenestrations can be placed and also sets the transverse measurement of the fenestration

To create a seal at the site of fenestration and vessel, it is paramount that there must be a secure contact between the fenestration and the vessel wall.

Balloon-expandable stents allowing extreme flaring of the luminal end are deployed to both align and fully open the area of fenestration-to-wall contact (Figure 5).

In cases in which fenestration-to-wall contact is not possible, use of a short branch may be indicated to span the gap. Any remaining gap between the branch and targeted vessel may be breached by a suitable covered stent (Figures 1B and 6).

INDICATIONS FOR FENESTRATED AND BRANCHED GRAFTS

1. Unsuitable proximal neck.
2. Late or early failure of previous surgically implanted aortic graft (Figures 7A and B).
3. Early or late failure of previous endoluminal aortic graft.
4. Preservation of hypogastric artery flow.

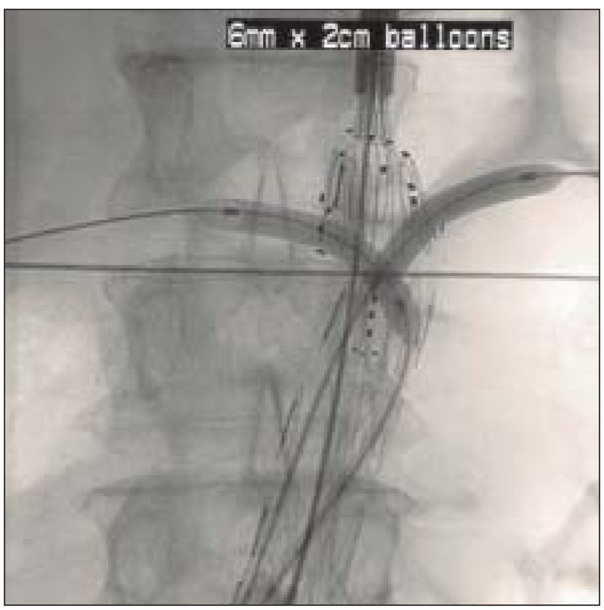

Figure 8. Balloons are placed in both renal vessels and inflated to a pressure of 2 to 4 atm prior to the release of the graft. With the balloons in place, the diameter-reducing tie and the proximal cap are released. With expansion of the graft the fenestrations can only travel along the balloon rail onto the targeted vessel ostia, thereby creating a good alignment between the targeted vessel ostia and the fenestration.

DEPLOYMENT TECHNIQUE

To achieve accurate alignment of targeted vessels, adequate positioning both in a longitudinal and rotational aspect is mandatory. For this reason, additional graft markers are placed on the graft to achieve precise rotational positioning. All fenestrations have radiopaque markers positioned at the 12-, 3-, 6-, and 9-o'clock sites around the circumference of the fenestration.

> "There have been no aneurysm-associated deaths and no conversion to open repair."

When adequate alignment is achieved, controlled release of the graft is carried out. During release from the sheath, full expansion of the graft diameter is prevented by use of diameter-reducing ties held in place by an appropriate trigger wire.

In this way, some adjustment or rotation is still possible after the graft is delivered from the sheath. The upper graft remains closed due to the presence of the distal cap, which restrains the upper noncovered stent.

Using a contralateral groin approach, the lumen of the composite component is catheterized from below. Catheterization of the targeted vessels is then carried out from within the lumen of the graft. Appropriate angioplasty balloons are placed in the renal vessels to act as a balloon rail during release of both the diameter-reducing ties and the upper cap (Figure 8).

In this way, with complete graft expansion the fenestrations travel along the balloons to the vessel ostia. These balloons are then withdrawn leaving the guidewires in place. Graft-to-vessel stenting using noncovered stents is then carried out in relation to the targeted vessels. The stents are typically 18 to 20 mm in length and are placed two-thirds within the vessel and one-third within the aortic lumen (Figure 9). The stent diameter is sized to the target artery.

Flaring of the luminal component of the stent is then carried out to flatten it against the graft-aortic wall, allowing for subsequent recatheterization of the renal vessels at a later date should it become necessary. The procedure is completed with placement of the inferior bifurcated modular component.

RESULTS

To date, 50 patients have been treated by this technique. There have been no aneurysm-associated deaths and no conversion to open repair. One graft developed

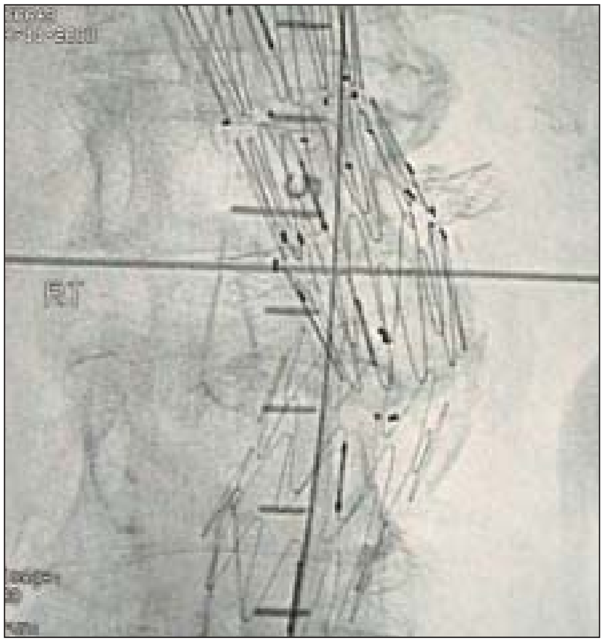

Figure 9. Graft-to-renal stenting using noncovered stents has been performed to maintain patency of the renal arteries.

an endoleak at the fenestration site 1 year after implantation and was readily corrected by use of a balloon-expandable stent graft placed through the fenestration. Subsequent follow-up imaging has shown continued shrinkage of the aneurysm sac.

CONCLUSION

Fenestrated stent grafting of the abdominal aorta is an alternate to open surgical repair in the presence of an unsuitable proximal infrarenal aortic neck. It can be performed with safety and efficiency and may also be used to salvage later failure of previous open or endoluminal treatments of the aorta. The introduction of branched grafts has allowed treatment of aneurysms in which fenestration-to-wall contact has not been possible. Variations of these techniques have allowed preservation of hypogastric artery flow in suitable cases. ■

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1. Anderson JL, Berce M, Hartley DE. Endoluminal aortic grafting with renal and superior mesenteric artery incorporation by graft fenestration. *J Endovasc Ther.* 2001;8:3-15.
2. Stanley BM, Semmens JB, Lawrence-Brown MM, et al. Fenestration in endovascular grafts for aortic aneurysm repair: new horizons for preserving blood flow in branch vessels. *J Endovasc Ther.* 2001;8:16-24.