Pitfalls and Complications of Fenestrated and Branched Endografts

Insight provided by dynamic imaging.

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Endovascular aortic repair (EVAR) has progressed rapidly during the last 15 years. An overview of the expanding frontier of EVAR is shown in Table 1. The first experience with fenestrated stent grafts for preserving visceral arterial branches in the treatment of abdominal aortic aneurysms (AAAs) was described by Park et al in 1996.[5] EVAR with fenestrated and branched endografts represents the current frontier in endoluminal aortic therapy and offers new treatment options for patients with challenging anatomy and who are at high risk for conventional aortic surgery.

Approximately half of patients with an infrarenal AAA have anatomy that is insufficient for treatment using standard endovascular grafts. The problem of inadequate neck sizes can be solved by grafts with fenestrations or branches. Repair with fenestrated or branched grafts serves two purposes: exclusion of flow to the aneurysm and maintenance of flow to the vital aortic branches (Figure 1).

> "Approximately half of patients with an infrarenal AAA have anatomy that is insufficient for treatment using standard endovascular grafts."

Fenestrated and branched devices have been used in all sections of the aorta, including the infrarenal aorta and aortic arch. Important requirements for successful fenestrated or branched EVAR and thoracic EVAR (TEVAR) are careful planning, including high-resolution imaging and precise measurements, appropriate device design, and an experienced endovascular team.

TABLE 1. HISTORY OF EVAR

Investigator	Year	First Description
Dotter et al[1]	1969	Concepts for endovascular stent grafting for aortic lesions
Parodi et al[2]	1991	Performance of elective endovascular repair of infrarenal AAA
Yusuf et al[3]	1994	Endovascular repair of ruptured AAA
Dake et al[4]	1994	Elective endovascular repair of TAA
Park et al[5]	1996	Elective endovascular repair of AAA with fenestrated graft
Inoue et al[6]	1997	Elective endovascular repair of TAAA with branched graft
Inoue et al[7]	1999	Elective endovascular repair of aortic arch aneurysm with branched graft
Stanley et al[8]	2001	Elective endovascular repair of TAAA with fenestrated graft
Chuter et al[9]	2001	Elective endovascular repair of TAAA, involving four visceral vessels, with multibranched graft

TAA, thoracic aortic aneurysm; TAAA, thoracoabdominal aortic aneurysm.

Fenestrated and branched grafts are devices that expand the application of endovascular grafts to a wider range of patients. However, new devices present new complications. The recent advent of dynamic imaging provides a tool to understand why these complications may occur, to elucidate clues on how to minimize such complications, and ultimately, to suggest how the next generation of fenestrated and branched endografts might be better designed to improve outcomes.

RECENT COHORT STUDIES: WHAT ARE THE PROBLEMS?

Reported results of several cohort studies of patients undergoing fenestrated and branched endograft repair of AAAs with a short proximal neck or juxtarenal AAAs are shown in Table 2. The technique appears to be feasible, and low mortality rates are reported. Good results are reported for patients undergoing fenestrated EVAR after previous aortic surgery, as well.[16,17] Saito et al reported good results of TEVAR with a branched endograft.[18] However, the fenestrated and branched technique is not without problems, several of which have been suggested by recent cohort studies and case reports.

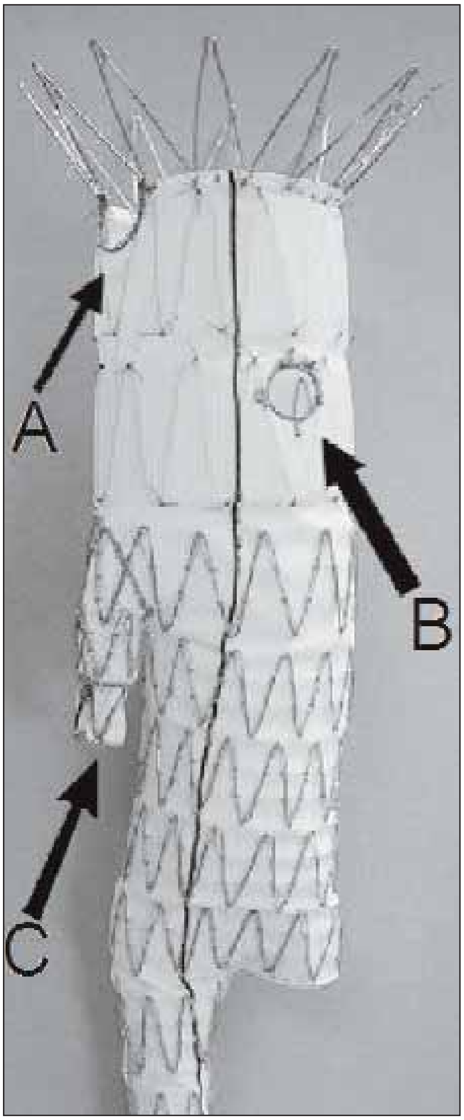

Figure 1. A branched endograft: scallop (A), small fenestration (B), and premade branch (C).

Several articles have shown that fenestrated and branched endografts are associated with relatively high risks of visceral branch loss and renal complications. During fenestrated EVAR involving the renal arteries, the renal perfusion is often temporarily interrupted, and catheters are manipulated within and close to the renal artery. Nearly 10% of renal arteries have occluded in short and midterm follow-up.

Although most patients did not require dialysis, this complication is clearly a deviation from that seen with standard infrarenal endografts and deserves scrutiny. In one series by Muhs et al, one patient died in the hospital as a result of acute intestinal ischemia, and a second patient presented with a branch vessel stent fracture with resultant nonfatal intestinal ischemia.[13] Inability to deploy stent grafts, stent fracture, all types of endoleaks, graft migration, and branch vessel occlusion are some of the more commonly reported complications of fenestrated and branched endografts.

CAN NEW TOOLS EXPLAIN FAILURES?

Motion of the Aorta

The size of the aorta changes considerably during the cardiac cycle—up to 15%—both before and after EVAR.[19] The longitudinal motion of the aorta is considerable, as well.[20] The largest change in AAA diameter is located at the level of the suprarenal part of the aneurysm neck. The maximal change in diameter of the thoracic aorta is 10% during the cardiac cycle.[21] The movement of the diameter in the aortic arch is even higher.[22] The different forces that cause this motion and which are also exerted on the endovascular grafts may play a role in the development of complications.[23] These forces are notable for fenestrated and branched grafts because these grafts often consist of multiple modules and acute branch points into side vessels.

The natural pulsatility of the aortic environment must be taken in consideration when sizing and deploying aortic stent grafts because failure may lead to graft migration and intermittent type I endoleaks. Slight migration of a standard infrarenal stent graft (ie, 3 mm) may have little clinical consequence, but a similar migration of a fenestrated or branched endograft would result in side branch occlusion. Any migration of a fenestrated or branched graft can result in catastrophic adverse events.

Side Branch Artery Motion

Side branch artery motion (2.5 to 4 mm) during the respiratory and cardiac cycle is significant.[24,25] Endograft configurations (fenestrated, suprarenal, or infrarenal) may affect motion of the involved visceral branches,

TABLE 2. FENESTRATED/BRANCHED ENDOGRAFTING: AAAs WITH A SHORT PROXIMAL NECK OR JUXTARENAL AAAs									
Investigator	No. of Patients	No. of Target Vessels	Mean Follow-Up (y)	30-Day Mortality Rate	Late Mortality, End of Follow-Up	Visceral Branch Loss, End of Follow-Up		Reduced Renal Function	Dialysis-Dependent Renal Failure
						Per Branch	Per Patient		
Anderson et al[10]	13	33	NR*	0%	0%	3%	8%	15%	0%
O'Neill et al[11]	119	302	1.6	0.8%	13.4%	7.6%	NR	25%	3.4%
Semmens et al[12]	58	116	1.4	3.4%	10.3%	9.5%	17.2%	6.9%	0%
Muhs et al[13]	38	87	2.2	2.6%	13% (1 y)	8%	NR	5.3%	0%
Ziegler et al[14]	63	118	1.9	1.6%	22.2%	7.8%	NR	22%	1.6%
Scurr et al[15]	45	117	2	2.2%	13%	3.4%	NR	NR	NR

*Range 0.25 to 2. NR, not reported.

Figure 2. The stents that were deployed through the fenestrations in the renal arteries measured at least 2.4 cm in length from the renal ostia.

possibly resulting in adverse events and visceral branch loss. More insight into the differences of renal artery motion between endograft configurations has been provided by Muhs et al using dynamic cine-CTA with a 64-slice scanner.[26] Studied fenestrated devices with renal stents all had stents that were extended in the renal artery at least 2.4 cm (Figure 2). Suprarenal and infrarenal fixated standard endografts did not significantly alter renal artery movement compared with the movement before endografting. The fenestrated grafts with renal stents reduced renal artery motion significantly (0.3 vs 1.2 mm; P=.01). Fenestration without stents did not significantly alter renal artery movement.

> "This stabilization of the branch orifice has the unintended consequence of translating the motion normally distributed over the artery's length and focusing it at the distal end of the side branch stent."

Unstented fenestrations may move in and out of alignment with the fenestration, allowing for intermittent side branch occlusion and eventual vessel occlusion. More likely, the side branch stents hold the branch vessel in alignment, stabilizing the main body of the fenestrated stent graft in relation to the orifice of the side branch. Dynamic CT imaging suggests this is in fact the case. However, this stabilization of the branch orifice has the unintended consequence of translating the motion normally distributed over the length of the artery and focusing it at the distal end of the side branch stent. Dynamic imaging clearly demonstrates a compliance mismatch at the end of the side branch stent in a branched endograft and the beginning of the native artery. This mismatch has the potential to result in stent fracture and accelerated intimal hyperplasia. The longer-term consequences remain unknown.

Renal Complications

Several articles have reported associations between unstented fenestrations and renal artery occlusions. Muhs et al showed in their study with midterm follow-up that all postoperative occlusions occurred in unstented fenestrations or unstented scallops.[13] No occlusions occurred in stented vessels. Semmens et al reported factors that were predictive of loss of the target vessel: a proximal neck angulation of >60°, multiple renal vessels, a vessel diameter <4 mm, and no stent placement in the fenestration.[12]

SUMMARY

EVAR with stented fenestrated or unibody branch grafts is feasible and good short- and midterm results are reported. Loss of visceral branch patency is one of the most important complications. Dynamic imaging shows considerable movement of the aorta and the side branch arteries. This new imaging modality has the potential to explain many of the pitfalls and complications of fenestrated and branched stent grafts. Use of dynamic imaging may aid in the development of the next generation of devices, taking into account the vibrant aortic environment into which they are placed. ■

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