FAILURE MODES AND REINTERVENTIONS

Predicting and Managing Failure in Fenestrated and Perivisceral Grafts

Understanding device durability and preventing long-term failure.

By Tara M. Mastracci, MD, FRCSC

The field of endovascular surgery is now 30 years old and with maturity has come both a better understanding of the strengths of the techniques and devices, as well as an ability to predict their modes of failure. However, despite learning many lessons over the years, devices continue to fail in some patients, so it is important to take stock of what we know to not repeat the errors of the past.

LONG-TERM COMPLICATIONS INHERENT IN ENDOVASCULAR THORACOABDOMINAL REPAIR

Very early in our experience with complex endovascular aneurysm repair, clinicians were apprehensive of the durability of branch stents; therefore, an early tenet of device design was to minimize coverage. Implicit in this motivation was a desire to ensure that spinal ischemia risk and radiation dose were minimized and that kidney function and superior mesenteric artery perfusion were not put at risk. It did not take long for evidence to emerge from a few high-volume centers about the perils of this approach—bare-metal stents compared with covered stents had a higher rate of renal stenosis,[1] and landing in nonparallel walled aorta made late endoleak more likely, even if the postprocedure angiogram was reassuring and endoleak-free.[2] Countless other authors began accumulating evidence that an aggressive approach to the landing zone provided long-term durability benefits that by far outweighed the early perioperative risk.

The aggressiveness of device design matured just as we became more confident in our technical skills, and hybrid imaging suites provided more tools to increase precision, like fusion imaging. Higher-volume centers began preaching a message that stands today: If the landing zone can extend into the parallel walled aorta above the visceral segment, the better the durability of the repair. This has been proven time and again, with centers routinely reporting a practice of placing four-vessel fenestrated devices into juxtarenal and perivisceral pathology, confident that a sealing zone as high as 6 cm above the celiac artery is unlikely to lead to spinal cord ischemia if perioperative complications can be kept to a minimum (publication forthcoming in 2022). Although difficult to prove, the "student" of follow-up scans will note anecdotally that the instability that comes with an expanding sealing zone is transferred to the branch stents when the sealing zone crosses visceral branches. Thus, branch stent loss, disconnection, or fracture is often an early warning sign that the proximal seal is failing, and intervention on the branch stent alone is rarely enough as adequate treatment.

Of course, proximal failure is not the only cause of branch vessel loss; often, placement of branch stents into highly tortuous branches or using longer branch stents may be the cause. This is most common in the renal arteries rather than the viscerals and has been well described.[3,4] Improvement in branch stent technology and improved accuracy of placement of main aortic bodies to limit the distance between the main body and the

branch may decrease this complication going forward. Additionally, the malrotation of fenestrated devices causing torsion forces on branch stents may also precipitate early failure.[5] Hopefully the introduction of fusion imaging will improve the accuracy of main body implantation, making this complication less common in the future.

Branch vessels are not the only indicator of long-term durability loss. Intercomponent movement, characterized by type III endoleaks, can commonly result when a stent is adjusting to life in a large aneurysm sac (moving to assume the greater curvature in a setting of insufficient overlap) or if a pressurized sac is causing greater expansion and elongation. This type of endoleak is easily bridged, and close measurement of overlap can predict this problem in consecutive follow-up. Conversely, if the overlap is long enough, the elongation can lead to kinking and occlusion without an endoleak, causing predictable downstream effects.

TYPES OF REINTERVENTIONS AND THE SKILLS/TOOLS NEEDED

Anecdotally, when devices fail, the best advice is to begin looking for a solution by surveying the entire aorta along the entire time course of its treatment. This commonly means reviewing imaging from the past, assessing vessels before the stent graft was placed, and assessing the behavior of the stent since placement. Connecting the appearance of the failing segment of aorta with its original appearance on the presurgical CT scan will give the operator a better understanding of the rate and pace of change in the aortic wall and the degree of disease that is likely to fail, hopefully sidestepping a similar mistake in the future. This gross overview of imaging will also help consolidate learning in the device designers' minds and possibly provide insight into how to design more durable repairs for other patients in the future. Of course, noting the presence of adjacent proximal or distal disease may encourage the operator to plan a more aggressive approach to treat the new diseased segment and improve durability going forward.

In addition, a broad overview of imaging will allow the operator to be sensitive to the other types of device failure, such as infection and/or undiagnosed connective tissue disorder. Frequent reinterventions or instrumentation for other organ systems (such as percutaneous coronary intervention) may put the patient at slightly higher risk of bloodstream infection and, by extension, aortic infection. The appearance of unremarkable aorta or highly tortuous smooth aorta in a young patient with a subsequent device failure may trigger a thought about connective tissue disease and may push the operator to consider conventional open solutions.

When branch failure is the only manifestation of long-term failure and the patient has a limited life expectancy, it may be appropriate to re-line branches as the sole reintervention for a failing device, with ample counseling to the patient that the problem is likely to recur. However, in the setting of a patient with a good life expectancy, a failing branched or fenestrated device should be considered for explant[6] or endovascular conversion.[7] Either option is a complex undertaking that should only be considered by teams with extensive open or endovascular experience. From an endovascular perspective, having a large armamentarium of ancillary equipment, several skilled operators, and the latest advanced imaging tools all assist in an endovascular conversion's success. Planning is imperative, and using preloaded catheters and staging the procedure makes for interventions that are manageable and more likely to be successful.

HOW BEST TO PREVENT THE NEED FOR REINTERVENTION

To avoid late failure, the best approach, by far, is to anticipate long-term failure and attempt to prevent it—in other words, designing a device that will fail well. Interrogating CT imaging and taking a thorough history before surgery, including assessing for connective tissue disease and family history, are incredibly important. Patients with first-degree relatives who also have aneurysmal disease are likely to present with a more aggressive aortopathy.[8] Paying close attention to the markers of "hostile neck"—including tortuosity, curvature, mural thrombus, and irregularity of walls—and avoiding areas such as landing zones is a good principle of stent graft design. If this means that coverage of the aorta for the intended device is longer than desired, consideration for open repair is appropriate at this stage. Although performing an aortic anastomosis in mildly diseased aortic tissue is not widely advised and does not prevent subsequent aortic degeneration, it does delay the need for subsequent reintervention. Anastomotic aneurysms often take centimeters of growth, or > 7 years, before reintervention is required,[9,10] whereas dilation of a landing zone will lead to type Ia endoleak after only a few millimeters of growth.

THE FUTURE OF FOLLOW-UP

After the device is implanted, the best insurance against failure is early recognition of problems. This is best done by constantly reviewing the entire spectrum of imaging—from preimplantation to current day—to have a true sense of aortic change. Frequently looking

at historical imaging allows the clinician to learn from decisions of the past and link past judgments to the current situation. Employing fusion imaging in the post-operative follow-up is an idea with potential and will hopefully play a larger role in standardizing and streamlining follow-up in the years to come.[11] ■

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Tara M. Mastracci, MD, FRCSC
St. Bartholomew's Hospital
Associate Professor
University College London
London, United Kingdom
tara.mastracci@nhs.net
Disclosures: Consultant to Cook Medical and Philips; chair of medical advisory board for Cydar Medical.