Endovascular advances in aortic intervention

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Introduction

The aorta is a large elastic artery and acts as the main conduit for distribution of oxygenated blood to the body. This organ can be subjected to various pathological processes including atherosclerosis, trauma, cystic medial degeneration and inflammation.

The specific disease processes that the aorta has gained the most notoriety for are abdominal aortic aneurysms (AAA) and thoracic aortic aneurysms (TAA), and it is here where the role of endovascular intervention comes to life. Although initially introduced as an alternative treatment to those not fit for open surgery, endovascular repair has transformed the management of these conditions. Using AAA and TAA as examples, the aortic endovascular treatment principles and advances will be discussed in this article. The principles and concepts that will be covered could be applied to other aortic disease processes such as aortic transection and dissections.

Principles of endovascular aortic treatment

The principles around endovascular treatment of the aorta involve the insertion of a stent graft across the diseased aorta, bridging two normal segments, the so-called proximal and distal landing zones. The stent graft is a metal meshwork tube covered by a material which relines the aorta. This facilitates the passage of blood through a conduit away from the diseased segment, thus reducing wall pressure, shear stress and subsequent disease progression. The success of this procedure hinges on the graft obtaining adequate wall apposition and seal at the two landing zones. The high radial force of the stent graft, with or without tiny metal hooks, prevents future migration of the stent graft and leaking of blood around the stent graft and into the sac surrounding it (endoleak).

Abdominal aortic aneurysms

AAAs are focal dilatations in the aorta, defined by a 50% increase over the vessel’s normal diameter or a diameter of greater than 3cm. The majority are caused by degenerative atherosclerotic disease, although this can also uncommonly be caused by inflammation, infection and trauma.

As the diameter of the aneurysm increases so does the risk of rupture which, if it occurs, has a mortality rate of greater than 50%. Treatment, surgical or endovascular, is therefore indicated when the risk of rupture is deemed greater than the risks associated with treatment.

Intervention is usually indicated when the aneurysm size is >5.4cm, diameter increases by >1cm per year and/or the patient becomes symptomatic with the aneurysm (develops pain and tenderness, distal embolisation or rupture).

Standard endovascular aneurysm repair (EVAR) involves the insertion of a stent graft across the AAA. This usually extends distally into two limbs where it lands in the common iliac arteries. This technique is usually appropriate for aneurysms that begin ≥1cm below the renal arteries and end ≥1cm proximal to the common iliac bifurcation. This allows the stent graft to seal above and below the aneurysm in healthy aorta, and have a stable position (figure 1).

Standard EVAR is not always possible in AAA. A significant number of patients have hostile anatomy, such as insufficient lengths of proximal or distal landing zones. Using the standard EVAR technique, the absence of satisfactory landing zones means that an adequate seal would not be possible, without extending the length of the stent graft and occluding vital branches of the aorta.

Advances in endovascular techniques and designs have provided innovative solutions to these challenges and have resulted in the manufacture of custom-made or off-the-shelf stent grafts which extend the length of the landing zones, while maintaining flow to the adjacent aortic branches. The so-called fenestrated endovascular aneurysm repair (F-EVAR) or iliac branch devices (IBD) are examples of such techniques.

F-EVAR

Pararenal AAAs originate <1cm below, at the level of (or juxtarenal) or above (suprarenal) the renal arteries. They therefore have an insufficient proximal landing zone length, due to the risk of compromising flow to the renal arteries or adjacent SMA or coeliac arteries.

F-EVARs are stent grafts that are designed with customised, carefully planned holes within the fabric, which allow perfusion of the visceral arteries (figure 2). The target vessels are catheterised and secured with stents to maintain blood flow, seal the aneurysm and prevent movement of the fenestrations without compromising visceral arteries. Published results of patients treated with F-EVAR have been encouraging, with excellent short and mid-term results. A systematic review on outcomes of F-EVAR supported this as a feasible safe and effective treatment. It demonstrated a technical success rate of 90.4%, a 30-day mortality rate of 2.1%, and an all-cause mortality rate of 16%. During a follow-up of 15-25 months, 93.2% of branch vessels were patent and 22.2% with 17.8% of patients needing secondary interventions.

Iliac branch device (IBD)

AAAs that extend to involve the common iliac arteries (CIA) are not uncommon, with unilateral common iliac aneurysm present in 43% and bilateral CIA aneurysms present in 11% of patients with intact AAAs. Distal aneurysmal extension therefore necessitates distal extension of the stent graft beyond the aneurysmal segment to ensure a healthy distal landing zone and therefore a good seal.

Traditionally, the endovascular approach involved extending the stent graft beyond the aneurysmal segment and origin of the internal iliac artery (IIA), landing in the external iliac artery (EIA). This approach allowed perfusion of the visceral arteries without compromising the inflow to the renal arteries, but this approach required the iliac bifurcation to be patent and distal iliac extension was technically not possible in patients with obstructive disease (stenosis or occlusion) of the iliac arteries. If the iliac arteries were patent, distal extension was possible. If the iliac arteries were not patent, the endoleak rate was very high (figure 3).

F-EVAR is a solution that is designed to overcome these problems, with the ability to treat AAA and simultaneously treat or manage the iliac artery disease. This is achieved with the use of a fenestrated stent graft, with or without iliac branch devices (IBD). With the use of F-EVAR, the iliac arteries are proximally secured with a stent, avoiding the need for transurethral balloon angioplasty (TBA) and the need for iliac orifice fenestration. The stent graft is then bridging two normal iliac segments, allowing distal perfusion of the visceral arteries. The success of this procedure hinges on the graft obtaining an adequate seal, and the iliac branches are maintained patent to allow the graft to seal proximally and distally (figure 4).

Conclusion

This article has reviewed the different endovascular technologies currently available for the treatment of AAA, the principles and concepts that will be applied to other aortic disease processes such as aortic transection and dissections, and advances in endovascular techniques and designs that have been developed to overcome existing problems.
iliac artery. The IIAs were embolised to prevent retrograde flow of blood into the aneurysmal sac (type 2 endoleak). This was associated with a wide range of complications, which varied greatly from being quite mild to very severe, including buttock ischaemia and impotence, particularly if both IIAs were embolised.

Internal iliac branch-graft devices (IBDs) (figure 3) offer an effective treatment for endovascular treatment of aortoiliac disease while preserving the IIA flow. This device is usually combined with a standard EVAR device. It consists of a bifurcated device with the main body placed in the CIA and the branches into the external and internal iliac arteries. This therefore provides satisfactory distal seal and preserves flow to the IIA, allowing treatment of patients with short or aneurysmal common iliac arteries.

IBDs have been shown to be a safe procedure associated with high technical success rates and encouraging mid-term patency. A review article looking at 196 patients demonstrated a success rate of 85-100% with no aneurysm-related mortality. Occlusion of IIA occurred in 12% of patients, with half of those patients developing claudication. Endoleak rates were low, with one type I endoleak and two type II endoleaks reported, all of which were managed endovascularly with success.9

Thoracic aortic aneurysms

TAAs are focal dilatations in the thoracic aorta and have a similar aetiology to AAAs as described above. They can involve the ascending aorta, aortic arch or descending aorta and require elective treatment when they expand rapidly (>1cm/year) or reach a diameter 5.5cm in the ascending aorta or 6cm in the descending aorta. Urgent treatment is indicated in acutely symptomatic patients (dissection, penetrating aortic ulcer or contained rupture).

TEVAR (B-TEVAR/ F-TEVAR/ S-TEVAR)

Thoracic endovascular repair (TEVAR) represents a valid treatment choice for thoracic disease, particularly those involving the descending aorta. A large retrospective study looking at the outcome of TEVAR in 110 patients demonstrated a technical success rate of 96.4% with good midterm results and a low mortality rate.6,10 Compared to open surgical repair, TEVAR was associated with reduced morbidity and mortality.11,12

In keeping with the principles of endovascular repair, TEVAR involves placing an endovascular stent across the diseased segment of the thoracic aorta, bridging two normal segments.

Achieving a satisfactory proximal landing zone poses TEVARs with their greatest challenge. This is mainly due to the angulated geometry of the aortic arch, uneven diameter, as well as proximity to the great vessels arising from the arch. Distally, achieving a satisfactory landing zone can also be challenging if the diseased distal thoracic aortic segment is adjacent to or involves the visceral arteries such as in thoracoabdominal aortic aneurysms (TAAA). The evolution and development of more conformable and repositionable thoracic stent grafts have helped tackle many of these issues.

A proximal landing zone of >2cm distal to the origin of the left subclavian artery (LSCA) is required to achieve satisfactory seal.

Similar to the techniques described in AAA with insufficient landing zones, advances in endovascular technology have addressed the challenges of the thoracic aorta by designing custom-made TEVARs that extend the length of the proximal landing zone, while maintaining flow to the great arch vessels aortic branches. These techniques include scalloped TEVAR (S-TEVAR), fenestrated TEVAR (F-TEVAR) and branched TEVAR (B-TEVAR).

S-TEVARs are custom-made stent grafts with a scallop designed to accommodate the origin of a supra-aortic vessel which would otherwise be covered (figure 4).

F-TEVARs work on the same principle as F-EVARs and are stents grafts that are designed with customised carefully planned holes within the fabric, that allow perfusion of the great arch vessels. These are then catheterised and secured with stents to prevent movement of the fenestrations.

B-TEVARs are an extension to the concept of F-TEVARs, but unlike F-TEVARs they are custom-built with stent graft branches that can be used to facilitate cannulation of the great vessels. These techniques are also applied to insufficient distal landing zones in the thoracic aorta, such as those encountered with thoraco-abdominal aortic aneurysms or aneurysmal chronic dissections (figure 5). Further details on these conditions and their management are beyond the scope of this discussion.

Although sparse, the published data on modified thoracic stent grafts is encouraging. S-TEVARs are becoming accepted for the treatment of thoracic aortic aneurysms with a short proximal landing zone13,14 with encouraging short and mid-term results. F-TEVARs and B-TEVARs also look encouraging with short and mid-term reports of high technical success rate and lower morbidity and mortality, especially when compared to redo open aortic surgery. Long-term outcome data are required to establish wider use of modified thoracic endografts.15,16

Other surgical and hybrid endovascular methods have been described for treating challenging aortas, such as endovascular sealing, chimney and periscope techniques, but further discussion about such procedures is beyond the scope of this article.

Conclusion

EVAR has come a long way since 1990 when the first endovascular AAA patient was treated with a Dacron graft anchored to a stainless steel stent. More recent advances in the endovascular field have transformed the management of aortic disease, facilitating treatment of pathologies previously thought to be unamenable to endovascular treatment and has enabled better outcome with fewer complications and risks to the patients.

The development of custom-made stent grafts with scallops, fenestrations, branches, or sometimes a combination of the three, have allowed an adequate seal to be formed between the device and aortic wall while maintaining flow and patency to crucial branches of the aorta.

References

Figure 1
Pre and post infrarenal AAA treatment with standard EVAR.

Figure 2
Pre and post treatment of juxtarenal AAA with four-vessel F-EVAR with fenestrations to the coeliac, SMA and renal arteries.

Figure 3
Pre and post treatment of AAA with bilateral CIA involvement using an IBD to preserve IIA flow bilaterally.

Figure 4
Pre and post treatment of TAA with a short 13mm proximal landing zone using an S-TEVAR.

Figure 5
Pre and post treatment images of a TAA with an insufficient distal landing zone, using a four-vessel B-TEVAR with branches to the coeliac, SMA and renal arteries.