Endovascular Repair of Infra-renal Aortic Aneurysms: Principles and procedure

Mithun J Varghese MD, DM* Riya Jose MD§

Affiliation: Department of *Cardiology and § Anesthesiology, Christian Medical College, Vellore, India.

Abstract

Endovascular repair is a minimally invasive alternative to open surgical repair of infra-renal abdominal aortic aneurysms (AAA). Although this is a fairly recent development, the majority of elective aneurysm repairs worldwide are performed percutaneously owing to the low morbidity and mortality associated with it. This review details how an endovascular repair of an infra-renal AAA is performed from an interventional cardiologist’s perspective, with special emphasis on pre-operative planning, endograft selection, vascular access techniques, device deployment and post-procedure follow-up.

Key words

Endovascular aneurysm repair; EVAR; Infrarenal aortic aneurysm; Endograft; procedure; How to do EVAR

Introduction

Abdominal aortic aneurysm (AAA) is a fairly common, yet under-recognized manifestation of atherosclerosis, which could result in grave complications such as aneurysm rupture and consequent death. For decades open repair was the sole therapy available for this condition, but with the introduction of endovascular repair by Volodos in 1987 and Parodi in 1991, an equally effective alternative treatment has emerged. The lower morbidity and mortality associated with endovascular repair and the progress in endograft technology has resulted in a paradigm shift in the way abdominal aneurysms are being managed. This modality is gradually replacing open surgery as the treatment of choice in patients with aneurysms of suitable anatomy, despite the higher cost of the endografts and unresolved issues concerning long term outcomes. This concise review is directed towards interventional cardiologists, who are interested in the procedural minutiae of endovascular aneurysm repair (EVAR) for treatment of infra-renal AAAs.

Indications and Case Selection

An aneurysm of the aorta is said to exist when the diameter of the aorta exceeds 1.5 times the normal or the absolute diameter exceeds 30mm. Aneurysms may be fusiform or saccular in shape and usually contain thrombus. Hence, luminograms obtained by conventional angiography and three dimensional reconstructions of computerized tomography angiography (CTA) frequently underestimate the true diameter of the aneurysms. The optimal size of aneurysm for which repair is needed is uncertain. Although recent ESC guidelines recommend AAA repair at diameters exceeding 55mm in men and 50mm in women for fusiform aneurysms, this cut-off is not applicable to saccular aneurysms, rapidly enlarging ones, as well as those associated with familial syndromes such as Marfan syndrome and Loeys-Dietz syndrome. ‘Small’ aneurysms (30-55mm) need to be monitored closely for rapid expansion or development of symptoms, in which case, repair is indicated.

Pre-procedural Evaluation

The EVAR procedure, in essence, involves re-lining the aorta with an endograft inserted via the femoral artery, so that the aneurysm is excluded from the systemic circulation. Successful execution of this entails careful pre-procedural planning, preferably using CTA with three dimensional reconstruction. Imaging aids assessment of the following: (a) the extent of the aneurysm (b) upper and lower landing zones for the endograft (c) any
major branches of the aorta arising from the aneurysm or endograft landing zones and (d) the status (diameter, tortuosity, calcification) of the vascular access and approach vessels including the common femoral, external and common iliac arteries and the aortic bifurcation.

In view of the frequent co-existence of coronary artery disease in patients with aortic aneurysms, we routinely perform a coronary angiogram prior to EVAR. Concurrently, digital subtraction angiography of the aneurysm using a marker pigtail catheter complements the information provided by CTA.

**Structure of the Abdominal Aortic Endograft**

A precise understanding of the anatomy of available endografts and their strengths and weaknesses is essential for selection of the appropriate device. The US Food and Drug Administration (FDA) approved bifurcated endografts for treatment of infra-renal AAA that are currently available in the Indian market are the Medtronic Endurant and the Cook Zenith Flex endografts. In addition, the Lifetech Ankura AAA endograft was introduced in India recently, although it is not approved by the US-FDA. The features of these devices are enumerated in Table 1.

Although there are minor differences between endografts made by different manufacturers, the fundamental structure of a bifurcated endograft remains the same. The AAA endograft has two main components: the main body, which extends from the aorta into one iliac artery, and a contralateral limb (contra-limb) component which overlaps a short contra-gate in the main body. Endografts are made of Dacron or PTFE supported by a self-expanding metallic skeleton sewn on to their inner aspect. Endografts have radio-opaque markers sewn on to their upper and lower ends and also at the level of the contra-gate for fluoroscopic visualization during the procedure. Details of endograft structure are shown in Figure 1.

**Table 1:** Table shows the comparison between three endografts currently available in India, namely Medtronic Endurant, Cook Zenith Flex and Lifetech Ankura endografts. (* Aneurysm neck angulation in relation to long axis of aorta # Distal diameter of the contralateral limb graft)

<table>
<thead>
<tr>
<th>Endograft Device</th>
<th>CT Sizing method</th>
<th>Treatable aneurysm neck diameter</th>
<th>Treatable iliac diameter</th>
<th>Minimum aortic neck length</th>
<th>Maximum aneurysm neck angulation*</th>
<th>Minimum iliac seal length</th>
<th>Minimum access diameter of main body</th>
<th>Minimum access diameter of contralateral limb</th>
<th>Graft aortic main body length to bifurcation (excluding bare stent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medtronic Endurant</td>
<td>Inner to inner diameter</td>
<td>19-32 mm</td>
<td>8-25mm</td>
<td>10mm</td>
<td>60 degrees</td>
<td>15mm</td>
<td>Graft size 23-25mm = 5.7mm</td>
<td>Graft size 28-36mm = 6.4mm</td>
<td>Graft size# 10-16mm = 4.5mm; Graft size 20-28mm = 5.1mm</td>
</tr>
<tr>
<td>Cook Zenith Flex</td>
<td>Outer to outer diameter</td>
<td>18-32 mm</td>
<td>7.5-20mm</td>
<td>15mm</td>
<td>60 degrees</td>
<td>10mm</td>
<td>Graft size 22-26mm = 7.1mm; Graft size 28-32mm = 7.7mm; Graft size 36mm = 8.5mm</td>
<td>Graft size# 8-10mm = 5.3mm; Graft size 12-24mm = 6mm</td>
<td>Graft size 22-32mm = 82mm; Graft size 36mm = 95mm</td>
</tr>
<tr>
<td>Lifetech Ankura</td>
<td>Inner to inner diameter</td>
<td>18-32mm</td>
<td>8-22mm</td>
<td>15mm</td>
<td>60 degrees</td>
<td>15mm</td>
<td>Graft size 20-26mm = 7mm</td>
<td>Graft size 28-36mm = 7.6mm</td>
<td>Graft size# 10-22mm = 6mm</td>
</tr>
</tbody>
</table>

Figure 1: The figure 1A shows unsheathed bifurcated endograft and its contralateral iliac limb graft (Medtronic Endurant). The corresponding fluoroscopic image is shown in figure 1B for comparison.
Principles of Device Selection

Certain broad principles should be borne in mind while selecting appropriate devices for the EVAR procedure. Currently available devices require a proximal and distal landing zone with a relatively normal diameter and of length at least 1 to 1.5 cm for complete exclusion of the aneurysm. Any compromise on this sealing zone could result in an endoleak which would result in raised pressure within the sac and enlargement of the aneurysm. Extreme angulation of the infra-renal aorta could also cause problems with aneurysm sealing. Usually the aneurysm neck to body angle should be less than 60 degrees for most of the commonly available devices. The device chosen should be 10-15% larger than the diameter of the aneurysm neck. The sizes of devices available are limited and hence, the treatable aortic neck diameter ranges from 18 to 32 mm. The diameter of the delivery system of the main body of the endograft ranges from 6 to 8 mm depending on the type of device and endograft diameter. The minimum diameter of the common femoral and external iliac artery should be greater than this for delivering the device into the aorta. In case of unilateral luminal narrowing of these arteries, the main body of the device may be introduced through the contralateral femoral artery. The endograft selected should be such that the length from the top of the endograft to the tip of the contra-gate should be shorter than the infra-renal aortic length. This ensures that the caudal end of the contragate will open in the aorta itself above its bifurcation. The distal end of the device should end as close as possible to the iliac artery bifurcation to maximize distal sealing and stability of the limb. In patients with common iliac artery aneurysm the device can be extended to the external iliac artery on that side covering the internal iliac artery. However, occluding the iliac arteries on both sides must be avoided, as this might result in pelvic and gluteal ischaemia.

Anaesthesia

Conventionally EVAR is performed under general anaesthesia owing to the need for bilateral large sized arteriotomies for device delivery. However, many of these patients have significant cardiovascular and pulmonary comorbidities, which increase the risk of a general anaesthesia. Recent advances in device technology have resulted in smaller sized delivery systems and the evolution of reliable percutaneous vascular closure devices, which obviate the need for general anaesthesia. In experienced hands and in selected patients with a relatively ‘simpler’ anatomy, the procedure may be performed solely under local anaesthesia.

Vascular Access

The EVAR procedure requires bilateral femoral arterial accesses - one for the main bifurcated device and one for the contra-limb. These were conventionally obtained using femoral arterial cut-down; however, in recent times this has been replaced by percutaneous sheath-based vascular closure systems such as Perclose ProGlide or Prostar XL (Abbott Vascular). Both these require percutaneous anterior-wall puncture of the common femoral artery under fluoroscopic or ultrasound guidance. After obtaining the access, the site of entry is confirmed by sheath angiogram and the skin and subcutaneous track are adequately dilated using a hemostat to allow the passage of the large endograft delivery system. Two Perclose-ProGlide devices deployed at an angle of about 90 degrees to each other are needed for closure of the large hole in the arterial wall made by the endograft delivery system. After the first Perclose device is introduced, it is turned 45 degrees clockwise and advanced further till bleeding is seen from the marker port. Sutures are then deployed and left untied and the ends secured with mosquito clamps. This is then repeated with the second device which is turned 45 degrees in the counterclockwise direction. The Prostar XL device, which has two sutures, is advanced till bleeding is seen from the marker port; subsequently, both the sutures are deployed simultaneously, needles retrieved and sutures left untied till the end of the procedure. The drawbacks of percutaneous closure include additional costs incurred and the need for training and constant practice to maintain proficiency; these limitations are offset by its relative swiftness and avoidance of surgical exposure of the artery and the related morbidity and discomfort.

In patients with small, tortuous, stenotic or occluded femoral and iliac arteries, it may not be possible to advance the endograft delivery system into the aorta. In some of these patients, prior balloon dilatation of stenotic lesions in the access arteries may allow delivery system advancement into the aorta. Alternatively, the narrow segment may be ‘paved’ with covered stents and then ‘cracked’ open by high-pressure dilatation using non-compliant balloons. It may be more expedient, however, to surgically create a temporary conduit to the distal common iliac artery to introduce the device.

Deployment of the Graft

Aortic aneurysms are frequently lined with thrombus, which may be a potential source of embolization during the procedure. Hence, it is always preferable to cross the aneurysmal segment only once and avoid excessive manipulation of the wire and catheter in the diseased segment. In our practice, we cross the aneurysm with an angled Glidewire (Terumo, Japan), which is then exchanged to an extra-stiff wire such as a Lunderquist wire (Cook Medical, Bloomington, IN), the tip of which is placed in the descending aorta just distal to left subclavian artery. As far as possible, the upper end of the endograft should start at the level of the lower of the two renal arteries in order to maximize the upper sealing zone. It is useful to mark this renal artery with a catheter, to facilitate exact endograft positioning. We use the contralateral femoral or left brachial arterial access to position a catheter in the lowest renal artery. The catheter is stabilized with an indwelling 0.018-inch guidewire; contrast injection through the catheter enables precise positioning of the upper end of the covered segment of the endograft at the lower edge of the lowest renal artery. The left brachial approach offers an additional advantage that, in case the endograft accidently occludes the lowest renal artery after deployment ‘chimney stenting’ of the occluded vessel can be performed to restore blood flow; the downside of the brachial approach is the need to manipulate a catheter in the distal aortic arch which carries cerebral embolic risk.

Prior to deployment of the endograft, the operator should ensure that the contragate is oriented towards the
contralateral iliac artery and will fully open within the aorta above its bifurcation. If the tip of the contragate ends up in the ipsilateral common iliac artery, its cannulation from the contralateral iliac artery will prove difficult or impossible. As mentioned earlier, the lower end of the main device should, preferably, stop short of the internal iliac origin. After the device is positioned satisfactorily, it is unsheathed slowly, taking care to avoid graft displacement while it is deployed. After the device is fully unsheathed its tip capture mechanism is released. The exact method of unsheathing the device and releasing of tip capture mechanism differs between various manufacturers and the operator should be familiar with the ‘instructions for use’ provided for each device.

Complete deployment of the device is followed by re-sheathing of the delivery system, taking special attention to avoid snagging the endograft. The sheath and delivery system are, then, removed and replaced by an appropriately sized introducer sheath at the vascular access site.

**Contragate cannulation**

The contragate cannulation is generally performed from the contralateral femoral access using a Glidewire. This may prove challenging in patients with an unfavourably angulated aorta-iliac junction. In such cases, the wiring can be performed from an upperlimb access; the wire may then be snared out from the femoral access. After entry of the wire into the contragate is confirmed in orthogonal views, it is replaced by an extra-stiff wire such as an Amplatz Super Stiff wire (Boston Scientific, Marlborough, MA). An appropriately sized contralateral limb of the bifurcated device is then taken over this wire and deployed, starting from the flow-divider extending into the common iliac artery so as to obtain an adequate seal. Here again, the lower end should stop short of the internal iliac artery origin.

Following the deployment of the components of the bifurcated device, the sealing zones and connections of the device are moulded using a compliant balloon, such as the Coda balloon (Cook). A final digital subtraction angiogram is then performed using a pigtail catheter to verify the position of the endograft as well as to rule out the presence of any endoleak (Figure 2). After obtaining a satisfactory result, the vascular access sites are closed by tying the knots of the percutaneous vascular closure devices or surgically repairing the cut-down as the case may be.

**Preservation of Large Branches**

The chief limiting factor in selecting patients for EVAR is the need for an ample proximal sealing zone for the endograft. In patients with an inadequate aneurysm neck, conventional EVAR with infra-renal endograft deployment may result in type I proximal endoleak. In such patients, methods such as Chimney technique may allow aortic endograft deployment from above the renal arteries while preserving renal perfusion. This technique involves placement of balloon-expandable covered stents in the renal arteries parallel to the main endograft which is deployed at a higher level. Although conceptually appealing, it is associated with a high rate of endoleak due to the ‘gutter’ effect and, hence, the endograft needs to be oversized by >30% whenever this technique is planned.

In patients in whom multiple large visceral arteries arise from the proximal endograft landing zone or from the aneurysm itself, endovascular repair with or without chimney grafts may not be feasible and open surgery may be the only recourse. However, in those who are poor surgical candidates, EVAR may be done even with supra-renal aneurysmal involvement using custom-made fenestrated endografts. Due to the technical complexities these are best done in centers with extensive experience. The details of these are beyond the scope of this review.

![Figure 2: The 3-dimensional reconstruction of computerised tomographic angiogram (Figure 2A) and digital subtraction angiogram (Figure 2B) of an infra-renal aortic aneurysm is depicted. Figure 2C shows angiographic image after endovascular repair using a bifurcated endograft.](image)

![Figure 3: Computerised tomographic angiogram of an infra-renal aortic aneurysm extending upto the left renal artery (Figure3A). For a planned ‘chimney stenting’, two long sheaths taken from upper limb accesses were placed in both the renal arteries (Figure 3B). Simultaneous kissing ballooning of both the renal arteries and the endograft was performed for optimization to avoid endoleak (Figure 3C). Final angiogram is shown in figure 3D.](image)
EVAR in Patients with a Ruptured Aneurysm

Infra-renal AAAs often go undetected until their rupture. Such patients are usually hemodynamically unstable and in renal failure. EVAR has replaced open surgery as the treatment of choice in these patients owing to the higher morbidity and mortality associated with the latter. Arresting the bleeding takes precedence over aneurysm repair in the acute setting. Due to the need for detailed planning and a prolonged procedure, a bifurcated device may not be feasible in such patients. Aorto-uni-iliac (AUI) devices provide unique benefits in the treatment of these cases: these endografts have a long and tapering structure so that they fit the juxta-renal segment superiorly and one common iliac artery inferiorly. Their relatively simple structure permits rapid deployment in patients with bleeding aneurysms, and thus, immediately halts the bleeding. After stabilization, patient will need a surgical femoro-femoral bypass to restore blood supply to the contralateral lower limb.

Follow-up after the Procedure

The primary goals of follow-up are to detect endoleak (presence of blood flow outside the endograft and within the sac of the aneurysm), obstruction or occlusion of the limbs of the bifurcated endograft, component separation and device migration. Endoleak is fairly common following EVAR, with a reported incidence of one in four patients, during follow-up. First described by White in 1998, endoleak was later classified into five types depending on the etiology.  

Type I endoleak refers to perigraft flow into the sac through either the proximal (IA) or distal (IB) sealing zone, and is due to an inadequate seal. Type II endoleak is caused by retrograde flow into aneurysm from various branches of the infrarenal aorta (also referred to as a pararenal aneurysm) or iliac or lumbar arteries (IIA and IIIB). Endoleak caused by component disconnection or fabric holes is classified as type IIIA and IIIB respectively. Type IV endoleak refers to the filling up of the sac due to graft porosity in the first 30 days of device deployment. Lastly, Type V endoleak refers to continued expansion of aneurysm sac despite the absence of demonstrable endoleak (also called endotension). Type I and Type III endoleaks mandate aggressive treatment as they are associated with aneurysmal sac pressurization and late ruptures. Type II may also require treatment if it leads to enlargement of aneurysm on follow-up.

The most sensitive modality for detection of an endoleak is a contrast CT scan with a delayed arterial phase imaging after 300 seconds. Magnetic resonance imaging with blood pool contrast is another useful technique for endoleak detection. The European Society of Vascular Surgery recommends first follow-up imaging at 30 days post procedure with CT angiogram and plain X-rays in anteroposterior and lateral projections. If this imaging shows evidence of endoleak or less than one stent overlap between the components of the bifurcated device, a repeat imaging by contrast CT is performed at six months. If endoleak is persistent it needs to be treated depending on the etiology. If the 30 day imaging shows no evidence of endoleak, repeat imaging can be delayed till one year. After two consecutive CT imaging studies show absence of endoleak and a stable or shrinking AAA, further follow-up can be performed using duplex ultrasound and plain radiographs with special attention to the size of the aneurysm.

Conclusion

Successful outcome of an EVAR procedure hinges on appropriate patient selection and meticulous pre-operative planning. Detailed knowledge of the structure of the endografts available in the market, their strengths and limitations helps in selecting the best graft for an individual patient. The operator must also be familiar with the various techniques of branch preservation, contragate cannulation as well as access closure strategies for an optimal outcome. Care of these patients in the post-procedure period is equally crucial and involves recommended follow-up imaging to rule out endoleaks, device separation and aneurysm enlargement.

Acknowledgements

I express my sincere gratitude to Professor George Joseph for teaching me all that I know about endovascular aneurysm repair as well as for providing the clinical pictures used in this article.

References


Figure Legends

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