

# Recent Advances in Aortic Aneurysm Surgery

## Understanding Endovascular Aortic Aneurysm Repair (EVAR)

**A**ortic aneurysm surgery has previously been associated with significant morbidity and mortality because traditional methods of repair have involved open surgical techniques. Over the last decade, the use of minimally invasive fluoroscopy guided surgical methods, otherwise known as endovascular surgery, has positively improved the outcomes of aortic aneurysm repair. Juan Parodi was widely credited with the use of the first stent graft for the repair of aortic aneurysms<sup>1</sup>. Ever since then, stent grafts have undergone rapid technological and material improvements such that their use has become standard device in what is now known as Endovascular Aortic Aneurysm Repair (EVAR). EVAR is associated with significantly lower morbidity and mortality when compared to conventional open surgical techniques<sup>2,3</sup>. Moreover, patients deemed as high risk for general anaesthesia and open repair may now be eligible for EVAR, as most EVAR cases are performed under regional and local anaesthesia. The access for EVAR is usually via femoral artery cutdowns. This is much less morbid than open techniques where one or more body cavities may have to be exposed to gain direct access to the aorta. In addition, recent advances in arterial vessel closure devices have facilitated the development of completely percutaneous EVAR techniques, in which the whole surgery is conducted via femoral artery puncture techniques.

For EVAR to be performed successfully, certain conventional anatomical criteria have to be fulfilled (Table 1). However, with advances in stent graft design and with increasing operator experience with EVAR, complex aneurysms that by criteria were previously unsuitable for endovascular repair are now being treated with EVAR. Some of these include thoracic aortic aneurysms and

dissection, thoracoabdominal aneurysms that involve one or all of the celiac, superior mesenteric and renal arteries, short-necked juxta/para renal aneurysms and common iliac, external or internal iliac artery aneurysms. Much of this "new frontier" in endovascular repair of aortic and iliac aneurysms can be attributed to improved stent graft design and better fluoroscopic imaging modalities.



Table 1: Conventional Anatomical Criteria for successful EVAR  
 (a) Neck length of at least 1.5 cm from lowest renal artery  
 (b) Angle between long axis of neck and aneurysm body less than 60 degrees  
 (c) Iliac arteries not tortuous and excessively calcified  
 (d) Femoral artery diameter >6mm (at least 18Fr)

## Short-necked/ Juxtarenal Aneurysms – Fenestrated Stent Grafts (FSGs) and Chimney Grafts (CGs)

These aneurysms are so named because the aneurysmal dilatation begins less than 1.5 cm from the lowest renal artery. These aneurysms account for about 15% of all AAAs. Indications for treatment include transverse diameter of more than 5.5 cm, development of symptoms (regardless of diameter) or development of complications related to the aneurysm, for example, distal lower limb or visceral vessel emboli. Conventional EVAR stent grafts require at least a 1.5 cm neck length (distance from the renal arteries to aneurysm sac) to allow for adequate sealing of the proximal portion of the stent graft device. Deploying such a stent graft with <1.5 cm neck length may result in either morbid coverage of the renal arteries or a leak around the seal zone into the aneurysmal sac (otherwise known as an endoleak). The availability of stent grafts with openings for the renal vessels (fenestrations) has negated the issue of short necks (Fig 1). These fenestrated stent grafts are custom-made to the individual patient anatomy based on high-definition fine-sliced CT scans of the aneurysm. Once deployed, the fenestrations would be in line with the renal artery orifices and additional short covered stents (Atrium V12, Atrium Corp) will be introduced from the main stent graft body through the fenestrations, into the renal arteries to provide a tight seal (Fig 1). Due to its bespoke nature (a 6-week manufacturing period is needed), FSGs are unsuitable for use in emergency circumstances, such as ruptured/ leaking aneurysms. Moreover, the use of such stent grafts requires specialised training and good fluoroscopic imaging techniques. Fenestrated stent grafts are also not widely available in some countries (e.g. USA, China). As a result, surgeons in these countries have developed the Chimney Graft (CG) technique for juxtarenal AAs. The CG technique utilises off the shelf conventional stent grafts and covered stents and as such, can be used in emergency situations. Essentially, covered stents are first deployed in the renal arteries and out into the aorta in an upward direction (like a chimney) into the descending aorta, following which a conventional stent graft, introduced from the femoral arteries in a retrograde fashion, is deployed in line with the covered stents. While FSGs have reported good outcomes with high patency rates and low mortality rates at up to 5 years<sup>4</sup>, results from the use of CGs are limited due to it being a relatively new technique<sup>5</sup>. Certainly, the use of these FSGs and CGs have extended the scope of effective treatment for juxtarenal AAAs.



Fig 1: Juxtarenal AAA: Photo of Fenestrated Stent Graft with opening for renal artery (thin arrow) and angiogram above showing deployed FSG with left renal artery covered stent in-situ (thick arrow). Photos Courtesy of Cook Medical Australia Inc.



Fig 2: TAAs: Photo of pre-loaded branched stent graft above and angiogram showing graft in situ with covered stents in branches (thick arrows). Gold markers are stitched onto graft body to help in graft orientation during fluoroscopy (red ellipse and blue circle)

## Thoracoabdominal aneurysms – Branched Stent Graft, FSGs and CGs

Thoracoabdominal aneurysms (TAAs) involve both thoracic and abdominal aortic segments. As such, visceral branches from the aorta are frequently involved in the aneurysm sac. TAAs have been treated conventionally by open surgery, which involves exposure of the thoracic and abdominal cavities, or, extensive dissection in the retroperitoneal plane. As such, morbidity and mortality from such surgery is significantly higher<sup>6</sup> when compared to endovascular repair<sup>7</sup>. As with FSGs for juxtarenal aneurysms, additional fenestrations or scallops can be custom-made to accommodate the celiac, superior mesenteric arteries and renal arteries (Fig 2). As the number of fenestrations increases, a more advanced skill set is required for the operator to be

successful in deploying these grafts. Also, more fluoroscopy time and contrast may be needed. The chimney graft technique as described above, may also be used to treat TAAs. With more chimney branches, the likelihood of an endoleak around the proximal seal zone also increases. Some TAAs may be dilated to an extent that there is a significant gap distance between the main stent graft and visceral vessel orifice. For such cases, custom made stent grafts with side branch protrusions (instead of fenestrations) can be used (Fig 2). The concept is that the side branches will provide a bridge to reduce the distance from the main stent graft body to the visceral orifice, providing a better seal and minimising endoleaks. Through the branches are inserted covered stents into the visceral arteries. Moreover, these branched devices can be made with pre-loaded angiographic catheters and wires for easier cannulation of the viscera.

### Thoracic Aortic Dissections (Type B) and Aneurysms – Hybrid Debranching Surgery, Chimney Grafts

The management of Type B aortic dissections has been controversial due to the unpredictable nature of the dissections. The majority of Type B dissections remains stable and is managed medically. Indications for surgical treatment include development of acute symptoms such as extension of dissection to involve aortic branch vessels resulting in ischaemia, development of a significant secondary aneurysm (>6cm in width) or precipitation of an aortic rupture/leak. Conventional open surgery required sternotomy and placing patients on cardiac bypass with significant morbidity. By definition, Type B dissections begin just distal to the left subclavian artery branch of the aortic arch. In order for effective proximal seal of an endovascular stent graft, it has to be deployed such that it covers the subclavian or left common carotid or innominate arteries (1, 2 or all 3). In hybrid debranching surgery, these aortic arch branch vessels are revascularised using extra-anatomical bypass surgical techniques (e.g. right to left carotid artery bypass, carotid to subclavian artery bypass) before a stent graft is introduced from the femoral artery to land proximal to the aortic opening of the vessels to obtain a good seal. Alternatively, the chimney technique may be used with good reported results<sup>8</sup>. In this technique, covered stents are introduced in a retrograde direction from the carotid arteries or axillary arteries such that the stents openings are positioned in the ascending aorta, preserving forward flow into these vessels. A conventional stent graft is then introduced from the femoral artery to be deployed in line with the covered stents and covering the dissection or aneurysm. The main advantage of both hybrid and chimney techniques is the avoidance of a sternotomy and cardiac bypass.

### Iliac Aneurysms – Iliac Branched Device (IBD)

Up to 30% of aortic aneurysms are associated with concomitant iliac artery aneurysms, mostly in the common or internal iliac arteries<sup>9</sup>. And in this subset of patients, up to 50% have bilateral aneurysms. Indications for treatment include diameter more than 2.5 cm, development of symptoms or presence of a concomitant aortic aneurysm that requires treatment. Prior to the development of IBDs, endovascular treatment would include coil embolisation of the iliac aneurysm (internal iliac artery) and/or coverage of the aneurysm with a stent graft extension limb. Patients with bilateral iliac aneurysms treated using these methods frequently developed problems such as perineal and buttock ischaemia/ Claudication. Colonic

ischemia has also been documented, especially in patients where the sigmoid watershed blood supply is reliant on branches of the internal iliac artery<sup>10</sup>. IBDs (Fig 3) are designed with a main graft body and a side branch that is deployed with the main body in the common iliac artery extending into the external iliac artery with the side branch sitting in the internal iliac artery. A covered stent is then introduced into the side branch, into the internal iliac artery beyond the aneurysm thus covering it. If needed, IBDs can be deployed on both sides to treat bilateral disease or together with a main aortic stent graft to treat concomitant AAA and iliac aneurysms. More importantly, preservation of blood flow to one of both internal iliac arteries is maintained, thus avoiding the problems mentioned above.

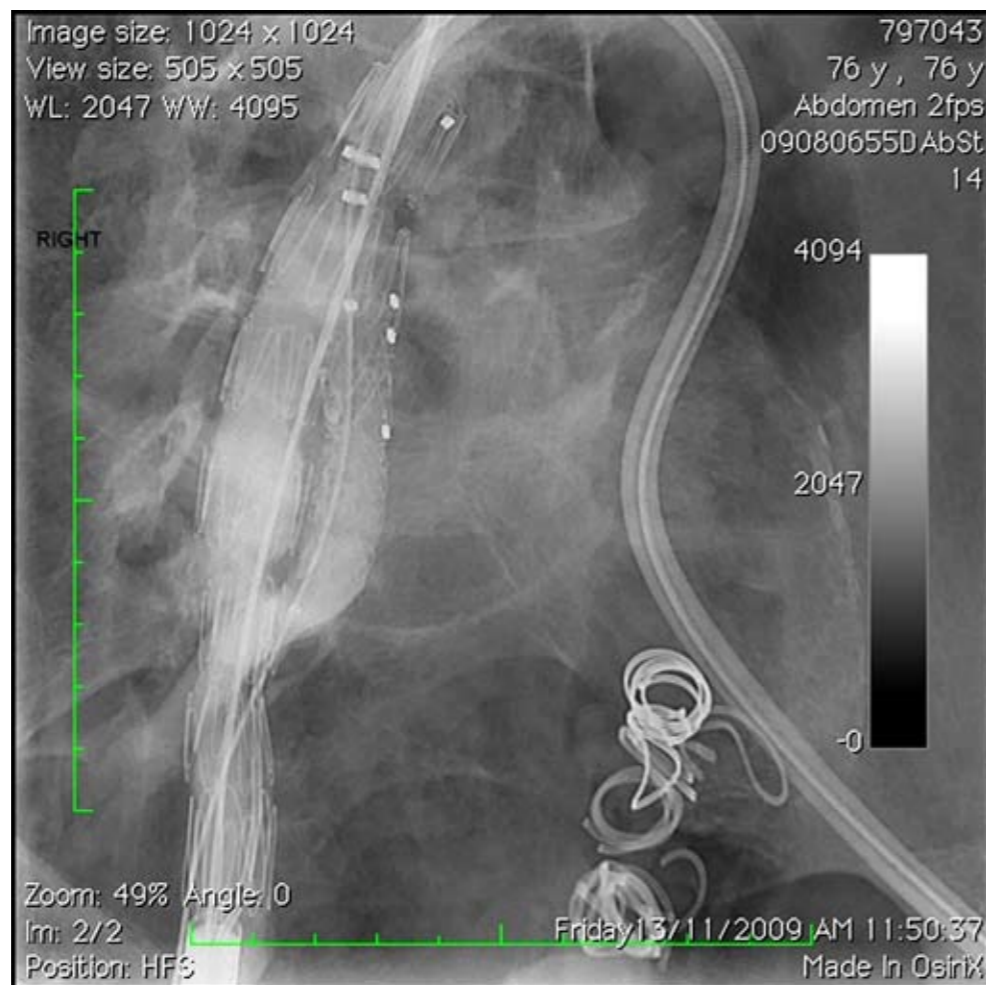


Fig 3: Iliac artery aneurysm: An Iliac Branched Device in-situ with covered stent in internal iliac artery (thin arrow)

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### Concerns with EVAR Repairs


There are a few concerns with the use of EVAR for aneurysmal disease. Nephrotoxicity may result from increased contrast load. Increased radiation exposure for patient and operator (of which the effects are unknown) is also a concern in complex cases, especially multi-branched or fenestrated stent grafts. The need to monitor for endoleaks also means that patients may undergo annual CT scan for life. However, with better imaging techniques (high resolution fluoroscopy) and improved stent design, coupled with better operator skills, the operative radiation exposure time and contrast load are expected to decrease. Moreover, monitoring of endoleaks can now be done using advanced ultrasound techniques, instead of CT scans, thus reducing patient radiation dose and costs.

### The Future

Several innovations in stent graft design

are in the pipeline. Amongst these are the developments of branched and fenestrated devices to accommodate the aortic arch vessels, pre-fabricated stent grafts with mobile branch limbs that can be used off the shelf, and stent grafts with better proximal seal zone mechanisms. These developments will certainly contribute to better treatment outcomes for complex aneurysms.

### Conclusion

With the advent of new stent graft designs and the improvement of endovascular techniques, the scope of treatment for complex aortic aneurysms has widened. With continued advances in these areas, patients who were previously deemed unsuitable or unfit for repair of their complex aneurysms may now be candidates for endovascular treatment. All patients with aneurysms should thus, be referred for evaluation and workup by a vascular specialist. 



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