Introduction

Although insidious in its progression, an abdominal aortic aneurysm (AAA), is by far one of the most feared vascular lesions managed in cardiovascular practice. The ominous threat of unexpected rupture of larger (>5.5cm) aneurysms has been, for several decades, the impetus behind the need for earlier surgical intervention, by open abdominal aortic repair. The associated potential complications of renovascular compromise, distal thrombo-embolism, mesenteric ischaemia and aneurysm leak are all avoidable by earlier intervention. Parodi’s [1] landmark introduction of the endovascular approach to the management of AAA, by transfemoral stent-graft interposition, heralded a new era in management of these patients. This interventional radiological procedure, presently widely performed internationally, has revolutionized the management of AAA. Herein we describe the early experience we have had at our center in the peri-procedural investigation and follow-up management protocols of patients with AAA treated by endovascular aortic repair (EVAR).

Pre-EVAR imaging

Good quality pre-procedural imaging is of paramount importance in the planning of an EVAR. Most centers employ color-duplex ultrasound, computed tomographic angiography (CTA), magnetic resonance angiography (MRA) and catheter digital subtraction angiography (DSA) in the pre-procedural assessment. The choice of modality is determined by a number of factors, for example, patient factors, availability of equipment and cost constraints.

Duplex colour-Doppler ultrasonography

Ultrasound generally is the initial confirmatory test performed, based on clinical suspicion of an AAA.
Location and size of the aneurysm, particularly renal and iliac arterial involvement, are documented. Intraluminal clot and true luminal dimensions are also noted. Flow dynamics within the aneurysm is readily demonstrated by duplex colour-Doppler imaging. Intravascular ultrasound has also gained popularity in patients where the use of iodinated contrast infusion is to be minimized [2].

**CTA**

The second pre-procedural imaging modality is CTA, which has been deemed to be the best available technique by many authors [3]. Our protocol commences with an un-enhanced spiral computer tomographic (CT) acquisition to assess vascular calcification and obtain a rough idea as to the extent of the aneurysm. This is followed by a thin section, 2mm, helical craniocaudal series from the level of the diaphragm to the common femoral artery bifurcation. A bolus of 120-140milliliters of iodinated contrast is utilized at a high flow rate of >4milliliters/second. A trigger voxel region of interest (ROI) is set over the descending thoracic aorta with mean threshold value of 100 Houndsfield units. Manual triggering may also be performed by the operator. Complete acquisition of the volume data in a single (18 seconds) breath-hold is obtained using a Somatom Sensation 16-slice-multirow-detector CT scanner (see Figure 1). Reformations are performed in coronal (Figures 2a & b) and sagittal as well as three-dimensional volume-rendered reconstructions (Figures 3a & b). The major advantage of CT scanning over DSA is the multiplanar capability with oblique reformatts that are in the vessel plane, allowing accurate measurements [4]. CTA allows for clear depiction of extraluminal considerations including mass effect, visceral involvement (e.g. renal) and other incidental intra-abdominal pathology, which may impact on choice of therapy.

**DSA**

DSA remains the gold standard of pre-procedural imaging for EVAR. Vascular outline, especially at the outer limits of the aneurysm to which the stent-graft will be anchored, is assessed for thrombus, eccentric plaque or heavy calcification. Some authors recommend the routine use of graduated pigtail catheters with centimeter markers along the length of the catheter [5] but these are not essential as measurements may be accurately obtained at post-processing using available software. DSA views performed include antero-posterior (AP) and lateral abdominal aorta, oblique views of the aneurysm neck and AP and oblique views of the pelvis. The more important measurements taken are outlined in Table1.
MRA
The use of MRA in peri-procedural assessment for EVAR is limited to patients with renal failure, known allergy to ionized radiation or where the use of ionizing radiation is contra-indicated. Advantages include the excellent contrast resolution of magnetic resonance imaging and the ability to delineate the internal aneurysm dynamics, where flow-related phenomena and mural thrombi are easily appreciated. Motion artifacts from peristalsis or breathing can reduce resolution. Yusuf et al; [6] also noted that MRA occasionally yields over-estimation of iliac artery stenoses due to high velocity signal loss from downstream turbulence. This has an impact on access artery assessment.

Patient selection
Based on preliminary imaging findings, the subject’s eligibility for EVAR is assessed. A triad of patient factors, aneurysm dynamics and graft properties is used to determine whether a patient may be a suitable candidate [5]. Several co-morbidities may preclude open surgical repair (see Table 2). Although EVAR was developed for the high-risk patient, recent evidence (EVAR 2 Lancet online 17 June 2005) revealed no overall survival benefit when compared with no intervention at four years following randomization. Patient selection remains important to gain maximum benefit with the procedure and greater time should be spent optimizing these high-risk patients.

The risk of aneurysm rupture is probably dependant on a number of factors but is most closely correlated with aneurysm diameter [7]. Annual rupture rates vary from <1% for aneurysms <4cm in diameter, up to 25% for those >5cm in diameter [8-10]. There is however no definite aneurysm size criterion by which one may suggest EVAR over open repair.

More relevant is the presence of a clear neck of abdominal aorta proximal to the top of the aneurysm. This is taken as 1.5cm for most stent-grafts, from the lower-most renal artery to the superior aspect of the aneurysm. The presence of accessory renal arteries may present a challenge to the team, especially if one such vessel is close (within 1-1.5cm) to the aneurysm. The team needs to weigh the benefit of EVAR in that patient, where an accessory renal artery may be sacrificed, resulting in a polar infarct.

A similar distal ‘clear space’ is required for tubular grafts. The diameter of these proximal and distal attachment sites is carefully measured to ensure that the available graft can fit the specifications of the patient’s anatomy. A tight seal at the attachment sites is ensured by upsizing the stent-graft by 10-20% compared to the measured vessel caliber at these sites [11]. Furthermore, to avoid kinking of the device, the angle between the aneurysm and the proximal aortic neck should be less than 60º to facilitate appropriate deployment.

AAA with complex aortic branching anatomy and particularly renal artery involvement is best managed by open surgical endo-aneurysmorrhaphy. Branch vessel re-implantation may be undertaken simultaneously. Experience with EVAR for acutely ruptured AAA is limited and most centers will only attempt surgical repair in such instances. The use of EVAR in infective/mycotic aneurysms is generally not recommended [5].

Currently available stent-grafts are much improved compared to their predecessors and some 60% of patients with AAA may now be treated by EVAR [12]. Graft dimensions however, remain significantly demanding, and proper ‘graft-patient matching’ is required. Stent-graft delivery systems are fairly bulky and require groin mini-dissections in most instances. Good caliber access vessels are mandatory. Tortuousity, atheromatous plaques and heavily calcified vessels are poor candidates for EVAR. External or common iliac angioplasty may sometimes be required to ensure subsequent passage of the device.

In many patients, pre-procedural imaging will reveal branch vessels arising from the aneurysm or iliac vessels (see Figures 4a & b). Type II endoleaks are caused by retrograde flow into the aneurysm sac by these collateral vessels such as the inferior mesenteric and lumbar arteries. The optimal management of these branches is uncertain as the significance of type II endoleaks is not well defined. An expectant management policy, with embolisation only if a persistent type II endoleak is demonstrated with increasing aneurysm sac size, is often practiced [13]. In selected patients, however, the use of pre-emptive branch vessel occlusion has reduced the incidence of such endoleaks (see Table 3) [14].

<table>
<thead>
<tr>
<th>ENDOLEAK TYPE</th>
<th>DESCRIPTION OF ENDOLEAK</th>
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<tr>
<td>I</td>
<td>Attachment site leak due to poor seal at attachment sites</td>
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<tr>
<td>II</td>
<td>Retrograde filling of the aneurysm sac by a patent branch</td>
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<tr>
<td>III</td>
<td>Due to device component fault or tears in graft material</td>
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<tr>
<td>IV</td>
<td>Leakage due to graft material porosity</td>
</tr>
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Table 1: Measurements taken at pre-procedural imaging

- Proximal aortic neck dimension
- Length from lowermost renal artery to the top of the AAA
- Angle between the long axis of proximal neck and axis of AAA
- Length of normal aorta from inferior aspect of AAA to the bifurcation
- If common iliac arteries (CIA) involved, measure the diameter of distal normal CIA
- Diameters of access arteries

Table 2: Co-morbidities in patients with vascular disease

- Severe coronary artery disease
- Renal impairment
- Chronic lung disease
- Obesity
- Congestive cardiac failure
- Chronic liver disease
- Previous laparotomy

Table 3: Endoleaks post-EVAR (based on [14])

- Leakage due to graft material porosity.

Figure 4a & Figure 4b
Sagittal reconstruction (Fig 4a) and axial image (Fig 4b) reveals branch vessel (X), probably inferior mesenteric artery, passing through the aneurysm sac. This may rarely repurface the sac and lead to a Type II endoleak.
EVAR procedure

A positive outcome for an EVAR procedure is dependant upon keen interaction between the vascular surgeon, radiologist, anaesthetist, radiographer and nursing staff. This team approach cannot be over-emphasized, with each member functioning as a link in a chain of individual but inter-dependant responsibilities. Informed consent is vital, with the patient fully aware that surgical conversion may need to be undertaken. Possible complications are discussed with the patient.

Depending on the patient’s medical condition, the appropriate anaesthesia is delivered. Epidural analgesia and conscious sedation are gaining in popularity. Some patients however may prefer, and do request, general anaesthesia. We begin by surgical dissection in both groins down to the level of the common femoral artery. By seldinger technique, 5Fr catheterization is performed and pre-stent angiography undertaken via a pigtail catheter.

The access vessel is again assessed and if necessary, angioplasty may be used to facilitate easier introduction of the delivery system. Careful constant screening and communication between the radiologist and radiographer is vital to allow precise positioning of the stent-graft prior to deployment (see Figure 5). Current designs of stent-grafts are predominantly self-expanding with the metal nitinol expanding to maximal caliber within the human body at a temperature above 37º.

Irrespective of the graft used, perhaps the most significant step, in the EVAR procedure, is to ensure that proper proximal and distal attachment sites have been secured and patency of the renal arteries has been maintained (see Figures 6a & b). An attachment limb is introduced via the contra lateral iliac artery and aligned to the aortic device (see Figures 8a & b). Once deployed, stent-graft positioning and aneurysm sac exclusion are confirmed by a check angiogram (see Figure 9a). At this point our protocol is to check the mean arterial pressure and routinely perform balloon dilatation (see Figure 9b) of the stent-graft, if the pressure is <80mmHg.

Up to 88% success rates for EVAR with aneurysm sac exclusion have been reported [15]. EVAR failure may occur due to a number of reasons, predominantly due to misplacement and device mal-deployment. In this worst-case scenario, the team should be prepared to undertake a conversion to open surgical repair. It is therefore advisable that EVAR be performed in a unit where such a conversion will be immediately possible.

Centers where EVAR is performed by a team not incorporating a vascular surgeon, and on
centers, the benefits are undeniable. The procedure is less stressful to the patient as compared to open surgery, intensive care stay is minimized with high care facility sufficing in the post-procedure period and reduced blood loss with rare need for transfusion are some of the added benefits of EVAR [2]. Advanced technology in graft design with addition of suprarenal fixation will allow more aneurysms with shorter necks to be treated [5]. The basis of EVAR success lies in the prevention of endoleaks, maintenance of renal vascularity, persistent graft patency and elimination of the threat of rupture. To this end, a finely tuned intervention team, with good quality imaging equipment, back-up service by vendors and friendly consultation liaison is essential.

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**References**