Endovascular aortic repair. A review article.

S K Misser MB ChB (Natal), Dept. of Radiology, Nelson R Mandela School of Medicine (UKZN), Inkosi Albert Luthuli Central Hospital
J Maharajh MB ChB (Natal) FC Rad. Diag(SA) Mmed, Dept. of Radiology, Nelson R Mandela School of Medicine (UKZN), Inkosi Albert Luthuli Central Hospital
N Paruk MBChB (Natal) FCS (SA), Dept of Surgery, Nelson R Mandela School of Medicine (UKZN), Inkosi Albert Luthuli Central Hospital

Abstract
This paper discusses the management of abdominal aortic aneurysm, the use of diagnostic imaging modalities and patient selection criteria in endovascular aortic repair (EVAR). A review of the literature highlights benefits and limitations of available management techniques [1-15].

Keywords: Doppler ultrasound, stent-graft, digital subtraction angiography

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 athors [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 reformats 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.

Figure 1: CTA image after bolus administration demonstrates the lumen and surrounding thrombus. Note also peripheral calcification.

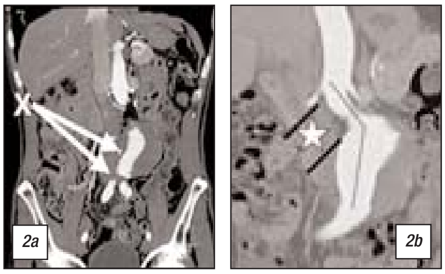

Figure 2a & Figure 2b
Coronal reconstructions on two different patients demonstrates the value of CTA in revealing extraluminal detail, vascular calcification (X), angulation of aneurysm neck to sac and length of the neck from renal arteries (*).

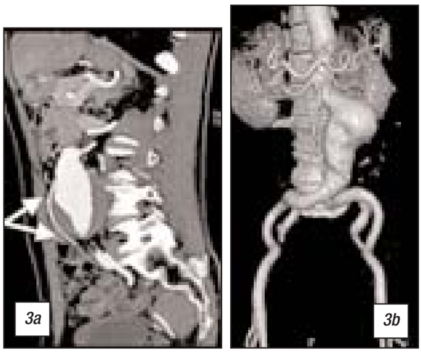

Figure 3a & Figure 3b
Sagittal CTA reconstruction (Figure 3a) demonstrating an infrarenal aneurysm with the inferior mesenteric artery (‡) draped over the aneurysm. This is a common finding at CTA. Volume rendered 3-d reformat (Figure 3b) of the AAA.

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.

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

MRA

The use of MRA in peri-procedural assessment for EVAR is limited to patients with renal failure, known allergy to iodinated contrast 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.

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

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. Tortuosity, 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].

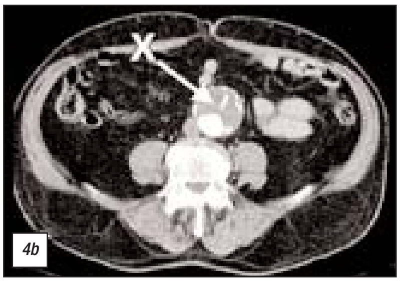

Figure 4a & Figure 4b
Sagittal reconstruction (Fig 4a) and axial image (Fig 4b) reveals branch vessel (X), probably inferior mesenteric artery, passing through the aneurysm sac. This may rarely reperfuse the sac and lead to a Type II endoleak.

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

ENDOLEAK TYPE	DESCRIPTION OF ENDOLEAK
I	Attachment site leak due to poor seal at attachment sites
II	Retrograde filling of the aneurysm sac by a patent branch
III	Due to device component fault or tears in graft material
IV	Leakage due to graft material porosity

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

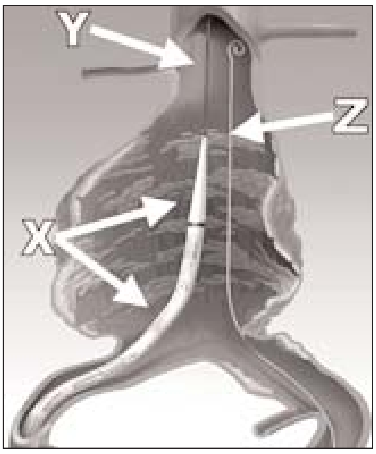

Figure 5[#]: Illustration to show introduction of the bifurcated stent graft (X) via the right femoral artery over a "stiff" guide wire (Y). Pigtail catheter (Z) via the contralateral femoral artery allows diagnostic angiography throughout the procedure [# Illustrations courtesy of Medtronic].

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

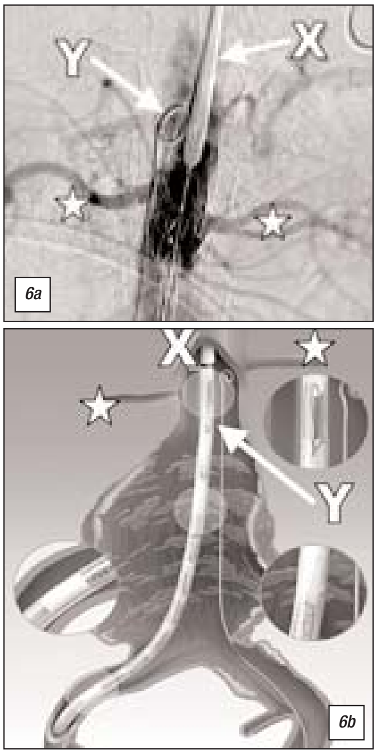

Figure 6a & Figure 6b[#]
DSA image (Fig 6a) and illustration (Fig 6b) with stent graft positioned at the proximal attachment site. Deployment process has been initiated. Check angiography is done at this stage, via pigtail catheter (Y), to confirm renal artery (*) patency. (X = nose cone of the device) [# Illustrations courtesy of Medtronic].

and Figures 7a & 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

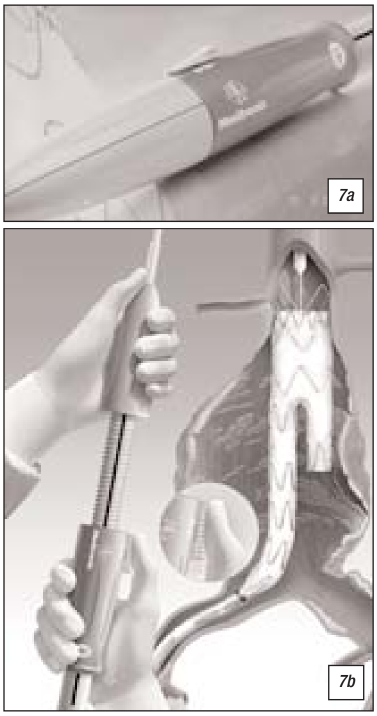

Figure 7a[#] & Figure 7b[#]
Figure 7a is a close-up view of the Medtronic TALENT™ showing the stent graft handle and delivery system. Figure 7b demonstrates the mechanism of deployment of the graft, with the contralateral limb orientated correctly for the placement of the attachment limb, via the contralateral femoral artery.
[# Illustrations courtesy of Medtronic.]

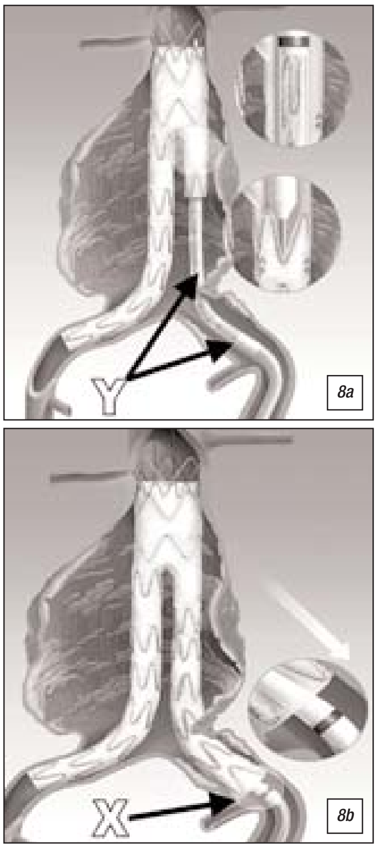

Figure 8a [#] & Figure 8b [#]
The attachment limb (Y) is advanced via the contralateral femoral artery (Fig 8a) and aligned to the bifurcated device. Balloon (X) dilatation is performed to ensure tight seal at attachment sites.
[# Illustrations courtesy of Medtronic].

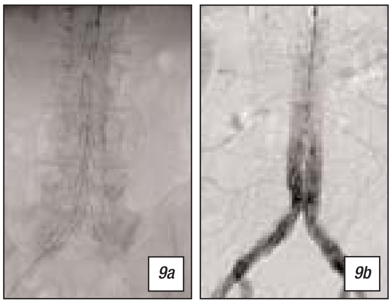

Figure 9a & Figure 9b
Unsubtracted image (Fig 9a) demonstrates the position of the stent graft after complete deployment. Final DSA image (Fig 9b) reveals exclusion of aneurysm sac and good distal iliac flow.

occasion not even a radiologist, run the risk of disastrous consequences, should the need for surgical conversion arise. Although a rare occurrence, the probability for open conversion exists in every patient, and as such should be respected and anticipated.

Follow-up

Post procedure imaging includes a CTA at or after discharge to confirm stent patency, aneurysm sac exclusion and absence of endoleaks. Patients in our institution are routinely followed-up at one, six, and 12 months following discharge. The follow-up entails ultrasound and CTA imaging (see Figure 10) to assess the graft. Renal artery patency and inadvertent renal ischaemia are documented with correlative blood electrolyte studies where necessary.

Figure 10: Post-procedural follow up CTA demonstrates well opacified stent graft in situ with surrounding thrombosed aneurysm. Note the kidneys perfusing normally.

Conclusion

In light of the multitude of risks associated with open surgical repair of aortic aneurysms, minimally invasive treatment options are gaining favor. The significant peri-operative risk reduction and quicker return to normal functioning has made EVAR particularly attractive to the medical profession and patients alike. Although the cost of current devices remains prohibitive at most 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.

Acknowledgements

- Mr Dirk Gey van Pittius, representative of Medtronic for the illustrations used in this review.
- Mr Anton Gopal, senior radiographer IALCH, for kind assistance with CT protocols and image capture.
- Dr Usha Chhagan for assistance with preparation of this manuscript.

References

1. Parodi J, Palmaz J, Barone H. Transfemoral Intraluminal graft implantation for abdominal aortic aneurysms. *Ann Vasc Surg* 1991; 5: 491-499.
2. Zarins C, White R, Schwarten D, Kinney E, Dietrich EB, Hodgson KJ, Fogarty TJ. AneuRx stent graft versus open surgical repair of abdominal aortic aneurysms: Multicenter prospective clinical trial. *J Vasc Surg* 1999; 29: 292-305.
3. Balm R, Eikelboom BC, van Leeuwen MS, Noordzij J. Spiral CT-angiography of the aorta. *Eur J Vasc Surg* 1994; 8: 544-551.
4. Armon M, Yusuf S, Latief K, Whitaker SC, Gregson RHS, Wenham PW, Hopkinson BR. Anatomical suitability of abdominal aortic aneurysms for endovascular repair. *Br J Surg* 1997; 84: 178-180.
5. Kaufman JA, Geller SC, Brewster DC, Fan CM, Cambria RP, LaMuraglia GM, Gertler JP, Abbott WM, Waltman AC. Endovascular repair of abdominal aortic aneurysms: Current status and future directions. *AJR* 2000; 175: 289-302.
6. Yusuf SW, Hopkinson BR. Magnetic resonance imaging of the aorto-iliac segment. In: Greenhalgh RM, ed. *Vascular Imaging for Surgeons*. London: WB Saunders, 1995: 237-245.
7. Finlayson SRG, Birkmeyer JD, Fillinger MF, Cronenwett JL. Should endovascular surgery lower the threshold for repair of abdominal aortic aneurysms? *J Vasc Surg* 1999; 29: 973-985.
8. Guirguis EM, Barber GG. The natural history of abdominal aortic aneurysms. *Am J Surg* 1991; 126: 481-483.
9. Stonebridge PA, Draper T, Kelman J, *et al*. Growth rate of infrarenal aortic aneurysms. *Eur J Vasc Endovasc Surg* 1996; 11: 70-73.
10. Nevitt MP, Ballard DJ, Hallet JW. Prognosis of abdominal aortic aneurysms: a population-based study. *N Engl J Med* 1989; 321: 1009-1014.
11. Sonesson B, Malina M, Ivancev K, Lindh M, Lindblad B, Brunkwall J. Dilatation of the infrarenal aneurysm neck after endovascular exclusion of the abdominal aortic aneurysm. *J Endovasc Surg* 1998; 5: 195-200.
12. Schumacher H, Eckstein H, Kallinowski F, Allenberg J. Morphometry and classification in abdominal aortic aneurysms: patient selection for endovascular and open surgery. *J Endovasc Surg* 1997; 4: 39-44.
13. Brown MJ, Fishwick G, Sayers RD. The post-operative complications of endovascular aneurysm repair. *J Cardiovasc Surg* 2004; 45: 335-347.
14. White GH, Yu W, May J, Chaufour X, Stephen MS. Endoleak as a complication of endoluminal grafting of abdominal aortic aneurysms: classification, incidence, diagnosis and management. *J Endovasc Surg* 1997; 4: 152-168.
15. May J, White GH, Yu W, Ly CN, Waugh R, Stephen MS, Arulchelvam M, Harris JP. Concurrent comparison of endoluminal versus open repair in the treatment of abdominal aortic aneurysms: Analysis of 303 patients by life table method. *J Vasc Surg* 1998; 27: 213-221.