Surveillance of patients post-endovascular aneurysm repair

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Postgrad Med J 2007;83:750–753. doi: 10.1136/pgmj.2007.062851

Endovascular aneurysm repair (EVAR) is increasingly being employed as an alternative to open surgical repair for patients with abdominal aortic aneurysms. The surveillance of patients post-EVAR has traditionally been carried out with regular computed tomographic scans which have in part been responsible for the high costs associated with this procedure. Duplex has been proposed as an alternative, but researchers have so far been unable to devise a standardised protocol for this surveillance. This review aims to provide a clear understanding of currently employed imaging modalities and discuss future surveillance possibilities for this patient group.

Abdominal aortic aneurysms continue to be a leading cause of morbidity and mortality in the developed world. Currently, patients with an aneurysm size >5.5 cm or with a rate of aneurysm expansion >1 cm/year are considered for elective repair, either open or endovascular. Endovascular aneurysm repair (EVAR) was first introduced by Parodi *et al*¹ in 1989 and has gained popularity over the years. This procedure is commonly performed through bilateral groin incisions to access the common femoral arteries, through which a stent graft is deployed within the aorta and the aneurysm is excluded from the circulation. EVAR is associated with its own potential complications, including graft migration, kinking and fracture, endoleaks and limb outflow impairment. These complications have necessitated life long follow up of patients post-EVAR.

Endoleaks, defined as persistent blood flow outside the graft, but within the aneurysm sac,² can affect up to 20% of patients undergoing EVAR.³ These are thought to be responsible for most treatment failures beyond the first year. Endoleaks have been classified into five types depending upon the origin of the leak (table 1). High flow and persistent low flow endoleaks causing an increase in aneurysm size have been associated with an increased risk of aneurysm rupture.

Post-EVAR, patients routinely undergo imaging at regular intervals to detect these complications. Computed tomography (CT) scanning has been widely regarded as the best current method for surveillance of this group of patients.² Duplex scanning has been proposed as an alternative to CT, but its use has not become commonplace because of the reported variation in its sensitivity and specificity in detecting these complications compared to CT.^{4–7}

IMAGING MODALITIES FOR EVAR SURVEILLANCE

The imaging modalities commonly employed for surveillance of patients post-EVAR include CT

angiography, magnetic resonance angiography (MRA) and duplex ultrasound (DUS). Plain abdominal radiography is routinely used to evaluate graft kinking and fracture. This review discusses these modalities in detail and assesses their benefits and limitations.

Computed tomography (CT)

CT angiography is widely regarded as the current modality of choice for surveillance of patients post-EVAR (fig 1). It has been demonstrated to be superior to conventional catheter angiography in detecting endoleaks.⁸ CT angiography delivers comprehensive vascular and non-vascular imaging and is convenient for patients due to its relatively quick scan acquisition time and widespread availability.

Commonly employed CT surveillance protocols recommend regular scans at 1, 6 and 12 months post-implantation and at yearly intervals thereafter. CT surveillance scans have evolved from a single arterial phase protocol to biphasic (arterial and a delayed scan) and triphasic protocols (an initial non-contrast scan followed by an arterial first pass scan and a delayed scan). Traditionally, a triphasic protocol has been preferred for post-EVAR surveillance. The non-contrast scan helps to identify high density materials. This enables differentiation between true endoleaks and areas of calcification or high attenuation that mimic endoleaks (pseudo-endoleaks).⁹ The arterial first pass scan is followed by a delayed scan that aids in the detection of slow flow endoleaks which might have been missed on the first pass scan.^{9–11}

Contrast agents traditionally used for CT angiography comprise iodinated compounds that have been associated with an increased risk of anaphylaxis and nephropathy. Currently employed agents for post-EVAR CT angiography are organic (non-ionic), low osmolar compounds such as iohexol and ioversol. These agents are more hydrophilic and less chemotoxic when compared to older contrast agents.^{12–17}

Magnetic resonance angiography (MRA)

MRA is an alternative imaging modality for EVAR surveillance and can provide imaging comparable, if not superior, to conventional CT scanning. A recent study, comparing the sensitivities of MRA and CT angiography for endoleak detection after EVAR, found MRA to be very sensitive in detecting slow flow endoleaks.¹⁸ MR offers an advantage over CT scanning as it is free from radiation and does not employ iodinated contrast media.

The scanning protocol commonly employed for MR scanning of this patient group involves axial and/or coronal spin echo T1 weighted sequences and a contrast enhanced angiogram. Several

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Received 5 July 2007
Accepted 9 October 2007

Table 1 Classification of endoleaks²

Endoleak	Description (origin of flow)
Type 1	Attachment site leaks
A	Proximal
B	Distal
C	Iliac occluder
Type 2	Branch leaks
A	Simple (1 patent branch)
B	Complex (2 or more patent branches)
Type 3	Graft defect
A	Junctional leak or modular defect
B	Fabric disruption (midgraft hole)
Type 4	Fabric porosity (within 30 days of procedure)
Type 5	Endotension
A	With no endoleak
B	With sealed endoleak
C	With type 1 or 3 endoleak
D	With type 2 endoleak

synchronous phases are acquired beginning with the arterial phase and extending into the equilibrium and venous phases.^{18–20} This protocol maximises the chances of detecting complications.

MRA employs organic gadolinium compounds as contrast agents. These agents utilise the inherent paramagnetic properties of gadolinium to alter magnetic fields around tissues. This alteration of magnetic fields provides for improved visualisation of vascular structures that helps in the detection of complications post-EVAR.

Duplex ultrasound (DUS)

DUS has increasingly been used for surveillance of patients post-EVAR (fig 2). Widespread availability and relatively low cost association of DUS have made it popular with researchers. Yet its use has not become commonplace. This has been attributed to a lack of universal reproducibility of highly specific and sensitive results in detecting complications post-EVAR.^{4–7}

For a standard post-EVAR surveillance duplex, the aorta is scanned in both longitudinal and transverse planes using B mode imaging to determine the extent of the stent graft and to ascertain the maximum aortic sac diameter. Colour Doppler is then used to scan the aorta from the diaphragm or origin of renal arteries down to the common femoral arteries, evaluating the stent for integrity and kinking. Special attention is paid to the proximal and distal stent graft attachment sites and to the

origin of the inferior mesenteric and lumbar arteries to detect endoleaks.

Vastly improved endoleak detection rates have been reported by some recent studies employing contrast enhanced ultrasound.^{21–24} Second generation contrast agents, preferred nowadays, including Sonovue (sulphur hexachloride) and Levovist (galactose/palmitic acid), are gas-filled, stable microbubbles that have a high degree of echogenicity. These microbubbles cause an increase in backscatter, which is detected by ultrasound, and aids in the identification of endoleaks.

Surveillance costs

Patients post-endovascular aneurysm repair need lifelong surveillance to detect associated complications. Current surveillance protocols employing regular CT scans have implied a high cost association with EVAR. Typical post-EVAR CT and MR scans cost approximately £750–1000 (€1000–1400, US\$1500–2000) and £1000–1300 (€1400–1800, \$2000–2600), respectively. A typical post-EVAR surveillance duplex, in comparison, costs approximately £300–400 (€430–570, \$600–800).

DISCUSSION

CT scanning is currently the most widely used imaging modality for surveillance of patients post-EVAR. The prolonged nature of post-EVAR surveillance subjects patients to a substantial radiation dose and has significant cost implications. As discussed previously, the CT protocol considered most reliable in detecting complications consists of a triphasic protocol that exposes patients to a large radiation dose at every sitting. Some authors have suggested employing a biphasic protocol (unenhanced and arterial first pass scans), but others have argued about their reliability in detecting slow flow endoleaks.^{9–11} Some centres perform initial non-contrast scans only at the first scan opportunity. Subsequent scans are performed to a biphasic protocol, which are then compared with the initial non-contrast scan, thus minimising radiation exposure to patients.

A standard triphasic post-EVAR surveillance CT scan can expose patients to a radiation dose of approximately 20–30 milliseiverts (mSv), which is roughly equivalent to 300–400 plain x rays. Such a dose has been associated with a theoretical lifetime risk of radiation induced fatal cancer in about 1 in 2000 patients (0.05%).²⁵

The contrast media used for CT angiography have been associated with anaphylactic reactions and are potentially nephrotoxic, thereby precluding their use in elderly patients with impaired renal function. A significant proportion of the patient population with abdominal aortic aneurysms is elderly and often present with mild to moderate impairment of renal

Figure 1 Post-endovascular aneurysm repair surveillance contrast computed tomographic images with arrows pointing to flow inside the aneurysm sac.

Figure 2 Colour Doppler images of post-endovascular aneurysm repair patients with arrows depicting areas of high turbulence (endoleaks).

function. These potential drawbacks have prompted investigators to explore other imaging modalities for surveillance of patients post-EVAR.

MR scanning, although reported to be very accurate in detecting slow flow endoleaks,¹⁸ is associated with its own set of potential problems. Apart from the high costs involved, patients with stainless steel stent grafts are not suitable for MR scanning due to excessive artefact susceptibility. Cardiac pacemakers, intracranial aneurysm clips or any other ferromagnetic implants are contraindications for MR scanning. The images obtained with MR scanning also have a lower spatial resolution than CT and may less reliably detect calcification. MR scan acquisition also takes longer than for CT. Claustrophobic patients often require sedation before MR scanning.

Newer open MR scanners provide weaker magnetic fields and have not been preferred for post-EVAR scanning. They provide for less detailed imaging compared to standard tunnel scanners and have an even longer scan acquisition time.

MR contrast agents (gadolinium), although considered to be safer than CT contrast agents in patients with mild renal impairment, have recently been found to be associated with nephrogenic systemic fibrosis in patients with severe renal impairment. Current Medicines and Healthcare Products Regulatory Agency guidance advises careful consideration before administering these contrast agents in patients with severe renal impairment (glomerular filtration rate <30 ml/min/1.73 m² or in patients who have had, or who are awaiting, liver transplantation).²⁶

DUS has gained popularity over recent years but it has been associated with its own potential drawbacks. Its operator dependent nature, difficulty in visualising abdominal viscera in patients of large body habitus, and bowel gas interference have all been responsible for its decreased uptake as a routine surveillance modality for post-EVAR patients.

Learning points

- Patients post-endovascular aneurysm repair (EVAR) need lifelong surveillance.
- There is, as yet, no ideal surveillance modality for patients post-EVAR.
- Duplex ultrasound is a safe and widely available modality that, with further optimisation and in combination with other currently available imaging modalities, may provide a clinically sound and cost effective surveillance programme for patients post-EVAR

Though some authors have reported vastly improved rates of endoleak detection following the use of ultrasound contrast media, this has not been uniform.^{21–24, 27} In 1999, a study conducted by McWilliams *et al*, comparing contrast enhanced duplex with arterial phase CT, found duplex to be very sensitive and specific and questioned whether endoleaks identified by duplex and missed by CT were not, in fact, true endoleaks.²⁷ A further study by the same group published in 2002, this time comparing contrast enhanced duplex with biphasic CT, could not reproduce the same results and found CT to be a better tool.²⁸ Henao *et al*, using a continuous infusion technique and comparing contrast enhanced duplex to biphasic CT, found duplex to be comparable to CT and suggested its use as a primary surveillance modality.²¹

Surveillance programmes need to be both clinically sound and cost effective. Post-EVAR surveillance has traditionally been carried out with regular CT scans that have, in part, been responsible for the high costs associated with it. A clinically proven surveillance programme incorporating DUS would offset some of these costs.

CONCLUSION

The ideal imaging modality for surveillance of patients post-EVAR would be inexpensive, widely available, provide

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universally reproducible results and subject patients to little or no radiation.

Every imaging modality used for this surveillance has been associated with its own set of advantages and disadvantages. DUS is inexpensive, does not use iodinated contrast media and is relatively easy to perform. These advantages would make duplex the ideal surveillance modality but for its reliability in producing highly sensitive and specific results, which still needs to be proven.

Further research is needed for identifying the absolute limitations of DUS for surveillance of patients post-EVAR. A post-EVAR surveillance protocol needs to be devised, which may well be a combination of currently available imaging modalities. Standardised duplex scanning may form part of such a protocol, with patients undergoing simultaneous CT and duplex scans for the first year. Surveillance for subsequent years may be carried out with duplex, CT being performed to investigate any complications detected by duplex.

MULTIPLE CHOICE QUESTIONS (TRUE (T)/FALSE (F); ANSWERS AFTER THE REFERENCES)

- (1) Post-EVAR patients require lifelong surveillance with conventional angiography
- (2) CT is currently the most widely used imaging modality for EVAR surveillance
- (3) The sensitivity and specificity of Duplex scanning post-EVAR has been proved to be comparable to CT scanning
- (4) Duplex contrast agents can be used in patients with renal impairment
- (5) MR angiography is suitable for surveillance of all patients post-EVAR

ACKNOWLEDGEMENTS

The authors would like to thank Ms Bridget Boyle, Ms Abigail Thrush (Vascular Technologists, Barts and The London NHS Trust) and Dr Matthew Matson (Consultant Radiologist, Barts and The London NHS Trust) for providing images for this review.

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Competing interests: None declared

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ANSWERS

(1) (F), 2 (T), 3 (F), 4 (T), 5 (F)