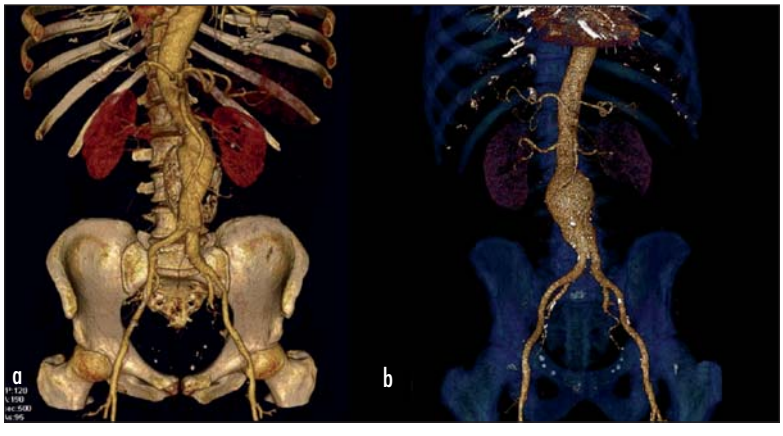
A review of endovascular management of abdominal aortic aneurysm

Abdominal aortic aneurysm is a common finding in older men and is often asymptomatic, either being found incidentally or presenting with acute rupture. This article will discuss the current indications for treatment and the clinical evidence behind the options currently available.

Abdominal aortic aneurysm is defined as focal enlargement of at least 50% greater than normal diameter (*Figures 1a* and *b*). In practice this equates to aortic diameter of 3 cm or greater. Although first described by Vesalius in the 16th century, the first successful attempts at treatment did not occur until the mid-20th century. Early surgical techniques included ligation of the aorta, or wrapping cellophane around the outside of the aneurysm as performed on Albert Einstein in 1949. The current surgical procedure of opening the aneurysm and suturing a prosthetic graft of either polytetrafluoroethylene (PTFE) or Dacron fabric inside the aortic lumen was described independently by Javid and Creech in the late 1950s. This provides a robust repair with significantly lower operative mortality rates than earlier techniques, currently ranging between 1.8 and 10%.

Figure 1. a. Volume-rendered three-dimensional computed tomography image. b. Same image with bones 'subtracted' to show the aneurysm morphology more clearly.



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The first endovascular repair, described by Parodi et al (1991), involved custom-made devices using metal stents sewn to the ends of fabric grafts. Currently there are several commercial stent-grafts available for endovascular treatment of aortic aneurysms. All the systems operate on a similar principle of building up a modular graft within the lumen of the aneurysm via access catheters in the common femoral artery in each groin. Endovascular repair offers significantly lower perioperative mortality and shorter hospital stays. However, not all aneurysms are suitable for endovascular repair, and as a relatively new technique the longer term durability of the repair is not known.

This article gives an overview of abdominal aortic aneurysm, including risk of rupture and indications for treatment, imaging assessment and patient selection, the relative benefits of endovascular *vs* open repair, and future developments. Further details of the endovascular procedure including an overview of potential complications can be found in the complementary article by Sadat et al (p. 151).

Abdominal aortic aneurysm

Abdominal aortic aneurysm is a degenerative process of the aortic wall associated with increasing age, history of smoking, hypertension and hypercholesterolaemia. Aneurysms are five to nine times more common in men with a prevalence of 6% in men over 80 years old. Familial clusters exist with a 15–25% risk of aneurysm for male first-degree relatives (Tilson and Seashore, 1984). Aneurysms are less common in people of African and Asian origin, and are very rare in those under the age of 50 years (Lederle et al, 2000).

Most aneurysms are asymptomatic and are detected either as a pulsatile upper abdominal mass on routine clinical examination or more commonly as an incidental finding on radiological investigations. Aneurysms can present with pain which is thought to indicate impending rupture. In general the risk of rupture is related to the size of the aneurysm. Small aneurysms (3–5 cm) tend to enlarge slowly and are unlikely to rupture. The risk of rupture increases over 5 cm, reaching 50% risk of rupture per year for aneurysms over 8 cm diameter. *Table 1* shows the estimated annual risk of rupture from pooled data published by the British Heart Foundation (2008). Other markers of increased risk of rupture include rapid

growth rate (greater than 0.5 cm per year), uncontrolled hypertension, and certain aneurysm morphologies.

Rupture usually results in rapidly fatal haemorrhage. At least two thirds of patients with ruptured abdominal aortic aneurysm die before reaching hospital. The cases that reach hospital and are considered suitable for open surgical repair have a 50% perioperative mortality (within 30 days of surgery). This results in a total early mortality for ruptured abdominal aortic aneurysm in excess of 80%.

Open surgical repair

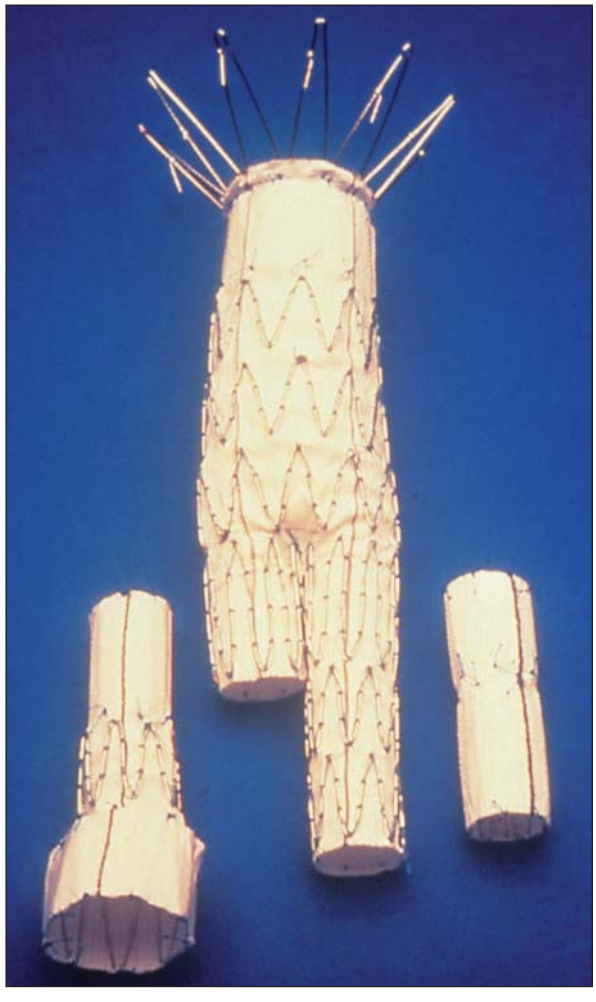
Elective open repair is still the default option in many centres, with long-term follow up showing a low risk of subsequent rupture or other significant complication. It is, however, a major operation with significant associated mortality (2–10%) and morbidity which often requires long hospital stay. The risk of rupture must be balanced against the operative risk. If the patient is considered fit for surgery, the option of open repair is usually offered when the aneurysm reaches 5.5 cm (Brewster et al, 2003). As comorbidity tends to increase with age, earlier pre-emptive repair of smaller aneurysms has been suggested. However, the UK Small Aneurysm Trial Participants (1998) showed no survival benefit to this strategy.

Table 1. Risk of rupture related to aneurysm size

Aneurysm diameter (cm)	Annual risk of rupture (%)
4.0–5.4	0.5–1.5
5.5–6.0	5–15
6.0–6.9	10–20
7.0–7.9	20–40
>8.0	30–50

From British Heart Foundation (2008)

Figure 2. Cook Zenith modular stent-graft.



Endovascular aneurysm repair

Elective endovascular repair of abdominal aortic aneurysm involves placement of a modular stent-graft within the aortic lumen to exclude blood flow from the aneurysm sac. It usually consists of a series of stainless steel or nitinol (a titanium alloy) stents covered with Dacron fabric (*Figure 2*).

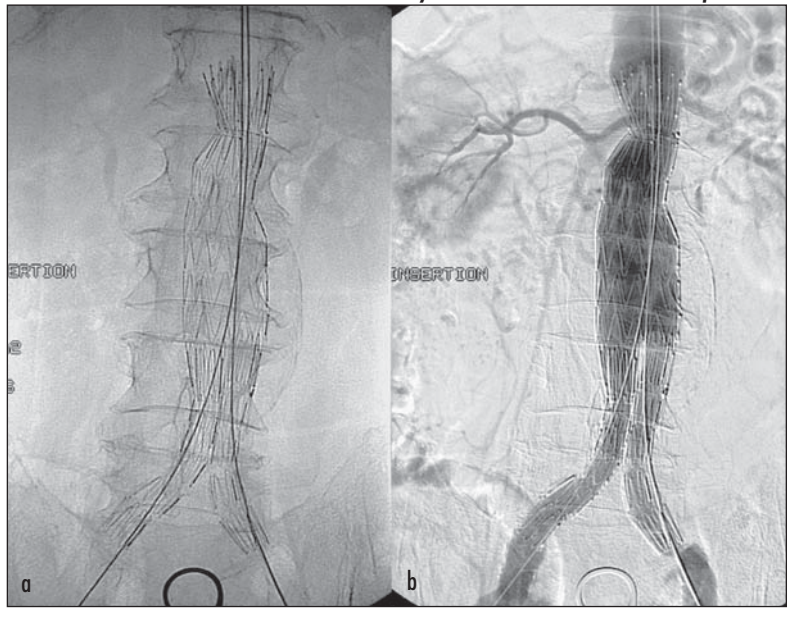
The main body and two limbs sleeve together and are sized to provide a tight seal against the infrarenal neck of the aneurysm and the walls of both common iliac arteries, effectively 're-lining' the aneurysmal segment of aorta. Although a minimally invasive procedure, the introduction systems are still relatively large calibre and usually require surgical exposure of the femoral arteries.

Figures 3a and *b* show a completion angiogram demonstrating the endovascular aneurysm repair (EVAR) stent-graft in situ.

Assessment and patient selection

People presenting with small aneurysms are offered annual (3–4 cm) or 6-monthly (4–5 cm) ultrasound follow up. Once the aneurysm has reached 5 cm on ultrasound scan a computed tomography (CT) angiogram of

Figure 3. Endovascular aneurysm repair. a. Pre-contrast image to show stent graft. b. Post-contrast to show successful exclusion of the aneurysm sac with no leak or other complication.



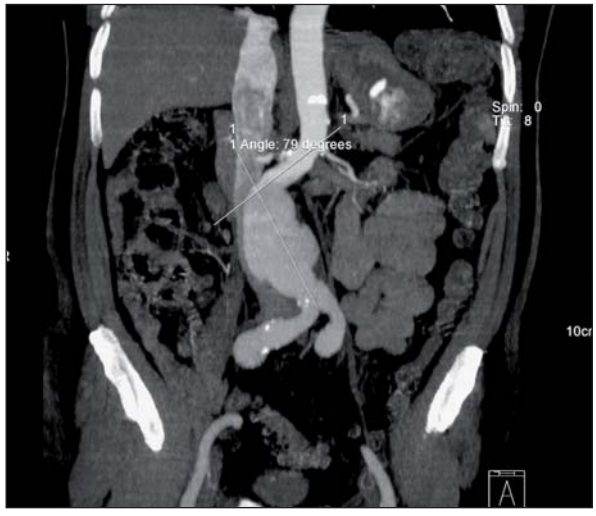
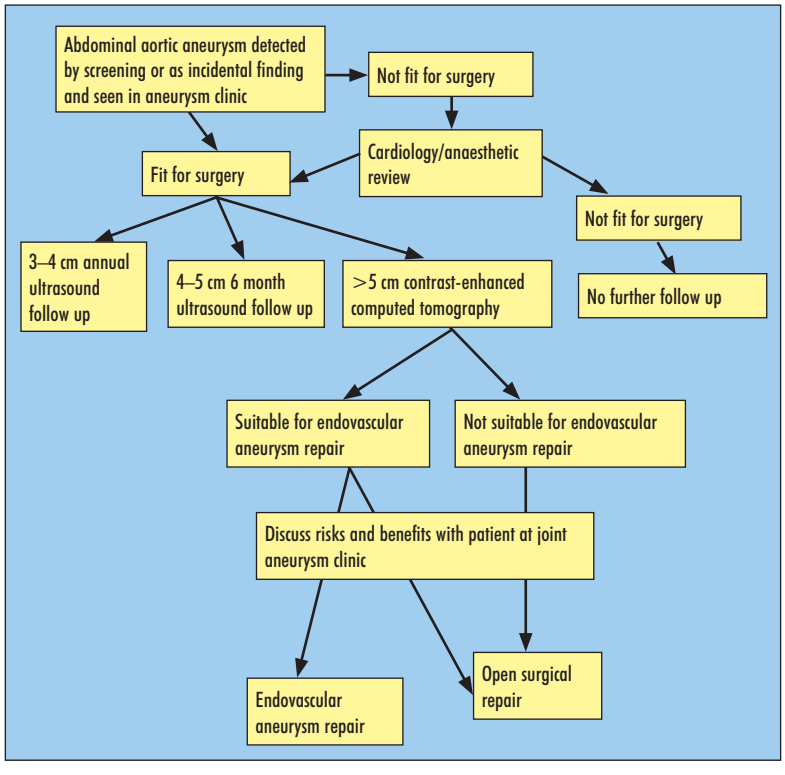


Figure 4. Coronal computed tomography of aneurysm with unfavourable angled neck.

the aorta is required to assess the morphology and suitability for endovascular repair. Around 60% of abdominal aortic aneurysms are technically suitable for conventional endovascular repair. Technical contraindications to endovascular repair include extension of the aneurysm up to or above the renal arteries, excessive angulation of the aneurysm neck, and excessive tortuosity or stenotic or occlusive disease in the iliac arteries (*Figure 4*).

Some of these issues have been addressed by newer stent-grafts, but the complexity and cost of theses devices can increase exponentially. Younger age can be viewed as a relative contraindication to endovascular repair because of the current lack of data on the longer term durability of these stent grafts (Cronenwett, 2005) (*Figure 5*).

Figure 5. Management algorithm for asymptomatic abdominal aortic aneurysm.



Clinical evidence

Abdominal aortic aneurysm is a disease process associated with increasing age, and as such often occurs in individuals with significant comorbidities. It is a manifestation of systemic atherosclerosis and is closely associated with increased risk of coronary vascular disease, renal vascular impairment, hypertension and stroke. The less invasive procedure of endovascular repair is intuitively an attractive option in such a population. Early non-randomized trials reflected this with over-representation of comorbidity in the endovascular arms.

More recent Dutch, UK and USA-based randomized controlled trials have addressed this issue (DREAM, EVAR-1 and OVER). These trials randomized patients deemed fit for both procedures to open surgical and endovascular treatment groups. DREAM (351 patients) and EVAR-1 (1082 patients) have shown similar early and midterm results. Both showed favourable results for endovascular repair with 1.2% and 1.7% 30-day mortality compared to 4.6% and 4.7% 30-day mortality for open surgery (EVAR trial participants, 2004; Prinssen et al, 2004). The survival benefit is not sustained, with similar all-cause mortality for both treatment groups by 2 years (DREAM: Blankensteijn et al, 2005) and by 4 years (EVAR-1: EVAR trial participants, 2005a). Both studies showed a lower aneurysm-specific mortality in the endovascular treatment group, although this was only statistically significant for EVAR-1 (3.5% *vs* 6.3%). The complication rate is higher for endovascular than open surgical repair (17.6 per 100 person-years *vs* 3.3 per 100 person-years). However, many of these complications are relatively minor and the re-intervention rate of 6.9 per 100 person-years quoted in the EVAR-1 trial and the higher re-intervention rates in the 2000 EUROSTAR collaborative registry (Laheij et al, 2000) may reflect over-treatment. The OVER trial is ongoing and yet to publish data.

A second UK-based trial (EVAR-2: EVAR trial participants, 2005b) randomized 338 patients who were deemed unfit for open surgical repair to EVAR and best medical treatment or best medical treatment alone. During 4 years of follow-up, 142 patients died, with no significant difference in mortality between the two arms of the study. There was a 27% crossover rate to aneurysm repair from the no intervention group which reflects the difficulty of assessing 'fitness' and the fact that both assessment and patient expectations can change with time.

There are established observational data (Lederle et al, 2000) that clearly demonstrate increasing risk of rupture with increasing aneurysm size. Guidelines issued by vascular surgical societies worldwide recommend pre-emptive repair of asymptomatic aneurysms at 5.5 cm. The UK Small Aneurysm Trial showed no benefit in earlier pre-emptive repair of smaller aneurysms (Powell et al, 2007). There has not been a formal randomized control-

led trial to assess the all-cause mortality following any form of aneurysm repair *vs* best medical management in an otherwise healthy population. Given the dismal survival following aneurysm rupture this study would be difficult to justify ethically. This does, however, mean that the whole principle of pre-emptive treatment of asymptomatic aneurysms is not based on level 1 evidence.

Cost

The stent-grafts for endovascular repair are undoubtedly more expensive than conventional surgical grafts, but this can be balanced against the lower perioperative morbidity and mortality and in particular, shorter hospital stays rarely requiring intensive care unit admission. Higher rates of secondary intervention and more intensive follow up increase the cost of endovascular repair.

Current follow-up protocols are based on the EVAR-1 trial and involve annual CT scan. Although useful to gather longer term follow-up data, there are issues with the monetary costs and radiation burden of this approach. With the current generation of stent-grafts the later complications of migration and device failure seem to be less common. The most significant predictor of adverse outcome is continued enlargement of the aneurysm sac whatever the cause. Accordingly some centres now rely on ultrasound for long-term follow up, using CT for initial post-procedure assessment and in cases of sac enlargement identified by ultrasound (*Figures 6a* and *b*).

The latest guidance from the National Institute for Health and Clinical Excellence (2009) concludes that elective endovascular repair of abdominal aortic aneurysms is a suitable treatment for use in the NHS, both in terms of clinical effectiveness and cost effectiveness.

New technology and the future

Stent-graft technology continues to progress with new devices allowing endovascular treatment of aneurysms with challenging anatomy. For example more flexible systems allow placement without kinking in more angulated necks and tortuous iliac arteries than is possible with conventional devices (*Figure 7*).

Where the aneurysm extends up to or above the renal arteries or beyond the common iliac bifurcation, fenestrated and branched devices can be used to maintain circulation to the abdominal visceral branches or internal iliac arteries (*Figures 8a* and *b*).

Although these new devices increase the cost and technical complexity of the procedure, the risk involved for the patient is little different to a standard stent-graft. As a result fewer and fewer cases are being turned down for EVAR on grounds of technical unsuitability.

Transposing the reduced procedural mortality of endovascular repair into the acute setting of a ruptured aortic aneurysm is an attractive prospect. Published 30-day mortality figures of 6–27% compare favourably with the average 50% mortality following open repair of ruptured aneurysm (Mehta et al, 2006; Wibmer et al, 2008).

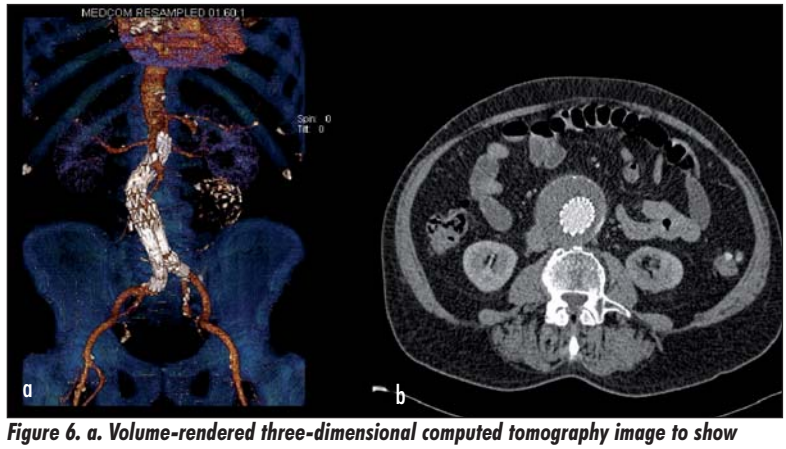


Figure 6. a. Volume-rendered three-dimensional computed tomography image to show stent graft position. b. Computed tomography axial cross-section showing exclusion of the aneurysm sac.

However, few centres in the UK currently have the resources to provide 24-hour cover by an endovascular team.

A community-based ultrasound screening programme for men over 65 years will increase the early detection of aneurysms and decrease mortality as fewer aneurysms will progress untreated to rupture (Ashton et al, 2002; Cosford and Leng, 2007). A similar programme has been approved in the UK and is currently awaiting implementation. This will undoubtedly increase the number of people presenting to medical attention and is likely to

Figure 7. The same aneurysm as* Figure 4 *treated successfully using a new more flexible stent-graft (Lombard Aorfix).

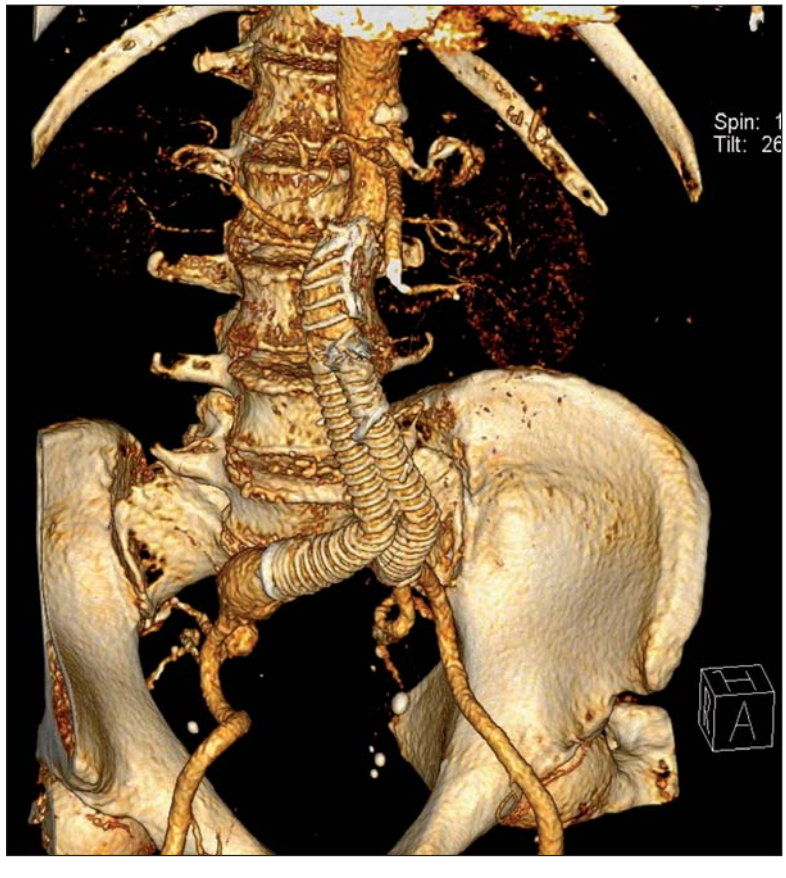


Figure 8. a. Computed tomography of a fenestrated stent-graft used to treat an aneurysm extending up to the renal arteries. b. Insertion of the covered renal stents through fenestrations in the wall of the main stent-graft.

increase public awareness of and demand for the more widespread availability of endovascular repair.

Conclusions

Endovascular repair of abdominal aortic aneurysm is a viable treatment option. Current recommendations are to offer repair to people with aneurysms of 5.5 cm or larger. Younger, fitter people should be considered for open surgical repair on the basis of more robust long-term follow-up data. Older, less fit patients should be offered endovascular repair. Those not fit for surgical repair do not gain survival benefit from EVAR. There is not a definitive answer at present and the decision whether to treat and by which modality should be made jointly with the patient following a full discussion of the risks and benefits. It should be remembered that the young fit person without significant comorbidity is rarely seen in an aneurysm clinic, and they may be the least willing to accept the higher early mortality associated with open surgical repair. **BJHM**

Conflict of interest: none.

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KEY POINTS

- At least 60% of abdominal aortic aneurysms are suitable for endovascular repair.
- Perioperative mortality is significantly lower than for open surgical repair.
- The initial cost is currently higher for endovascular aneurysm repair.
- Longer term level 1 evidence is awaited.
- Endovascular aneurysm repair has been approved by the National Institute for Health and Clinical Excellence for NHS use.

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