The management of abdominal aortic aneurysms

Abdominal aortic aneurysms cause about 6000 deaths per year in England and Wales, predominantly from rupture. Significant progress has been made in recent years in developing minimally invasive, endovascular methods of treatment. This review evaluates the current management options for abdominal aortic aneurysm.

The first successful infrarenal aortic aneurysm repair was reported in 1951 by Dubost et al (1952). The management of aortic aneurysms has been revolutionized over the last 15 years with the advent of the aortic stent graft. Less heralded, but as important, have been the advances in anaesthetic, intensive care and cardiac risk management that have driven elective mortality down from around 10–15% in the 1950s to 1.5–5% today (Filipovic et al, 2005). Nonetheless rupture mortality remains at around 50% for those who undergo surgery, and it is hoped that the advent of a national screening programme will further improve mortality rates.

An aneurysm is a localized dilation of an artery equal to or greater than twice its original diameter. Aneurysms of the aorta can occur at any point along its length, but 95% of abdominal aortic aneurysms are found below the origin of the renal arteries (*Figure 1*). The vast majority of aortic aneurysms in the UK are the result of degenerative atherosclerotic disease with reduced arterial elasticity and subsequent dilation. About 5% of men (Scott et al, 1991; Lederle et al, 1997) and 1.5% of women (Scott et al, 1991) aged 65–80 years have an abdominal aortic aneurysm of ≥3 cm in diameter. These aneurysms are usually asymptomatic until rupture, at which point there is only a 10–20% survival rate (Ingoldby et al, 1986; UK Small Aneurysm Trial Participants et al, 1999). Of these deaths about a quarter occur before arriving in hospital, half are in patients refused surgery and the operative 30-day mortality is around 50% (UK Small Aneurysm Trial Participants et al, 1999). Increased rate of rupture is found in women, those with larger aneurysms, smokers and people with high blood pressure.

Medical management

Non-surgical management plays a significant role in the management of abdominal aortic aneurysms, particularly in reducing perioperative risk, and treating the associated modifiable risk factors associated with atherosclerosis.

Smoking is associated with a fivefold increase in aneurysm prevalence and has also been shown by Brady et al (2004) to increase the rate of aneurysm growth. Statins are associated with reduction in aneurysm growth rates in addition to their beneficial effects on the cardiovascular disease that often accompanies abdominal aortic aneurysms (Schouten et al, 2006). As well as their effects on blood pressure there is some evidence that angiotensin-converting enzyme inhibitors reduce the risk of aneurysm rupture (Hackam et al, 2006).

Perioperative optimization of medical problems is crucial to reduce complications. Of patients with peripheral arterial atherosclerotic disease 60% have angiographic evidence of a 70% stenosis in at least one coronary artery (Hertzer et al, 1984) and half of all perioperative deaths post-abdominal aortic aneurysm repair are cardiac in nature. Despite this the medical management of coronary risk factors is profoundly unimpressive. American data show that only 10% of vascular patients were prescribed aspirin and 11% a statin while admitted to a vascular unit (Kurzencwyg et al, 2006).

Figure 1. Computed tomography scan of an aorta showing an infrarenal abdominal aortic aneurysm (arrow).

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Beta blockers reduce cardiac morbidity and mortality tenfold in the 10% of patients at highest cardiac risk (Poldermans et al, 1999) and some studies suggest statins may reduce the risk of perioperative myocardial infarction and stroke (Kapoor et al, 2006). The authors' own unit adopts an aggressive approach to the possibility of occult coronary disease. All patients undergo a dobutamine stress echo before intervention, and any evidence of reversible myocardial ischaemia mandates coronary angiography and stenting or bypass of amenable lesions. Long-term survival after major vascular surgery is also significantly improved if patients with moderate–severe coronary ischaemia undergo coronary revascularization (Landesberg et al, 2003).

Elective repair

When should an infrarenal abdominal aortic aneurysm be repaired? The accepted criterion for intervention is predicated on the results of the UK Small Aneurysm Trial. This randomized controlled trial demonstrated that abdominal aortic aneurysms between 4 and 5.5 cm had a rupture risk of approximately 1% per annum – a risk outweighed by the perioperative mortality associated with surgical repair.

The risk of rupture rises as aortic diameter increases, with a risk of approximately 10% per annum at 6 cm and 25% at 8 cm or greater at 6 months (Lederle et al, 2002). Therefore, abdominal aortic aneurysms of between 4 and 5.5 cm are followed up with ultrasound screening until they reach threshold. Thereafter decision making must be individualized; fit patients should be offered intervention at this point, while those with major comorbidities (renal failure, cardiac failure, severe airways disease) should only be treated when the risk of death from the size of the aneurysm outweighs the risk of perioperative mortality. A rate of expansion of greater than 1 cm per year or the presence of symptoms associated with an aneurysm are the other accepted indications for elective repair.

Open repair

Open repair of uncomplicated infrarenal abdominal aortic aneurysm has long been the accepted method of treatment for fit patients at risk of rupture. Aneurysm size and morphology is evaluated using ultrasound and computed tomography scanning and mandatory preoperative investigations include evaluation of cardiac, renal and respiratory function (Harris, 2006).

Following laparotomy minimal dissection is used to make space for clamps on both common iliac arteries and the abdominal aorta below the renal vessels and above the neck of the aneurysm. Clamps are applied and the aneurysm sac is opened. Back bleeding from lumbar and inferior mesenteric arteries is controlled by over-sewing their origins. An inlay technique is used to sew a synthetic graft into the normal calibre aorta at the neck of the aneurysm. Distally the graft is sutured onto the aorta just above its bifurcation as a tube graft or onto the iliacs as a bifurcated graft in the presence of iliac disease. The aneurysm sac is plicated over the graft and the retroperitoneum and abdomen are closed (Harris, 2006).

The major complications specific to open abdominal aortic aneurysm repair are bleeding, embolization of clot or thrombus leading to lower limb ischaemia and early or late graft infection (Harris, 2006). Myocardial infarction or stroke can follow declamping of the graft with subsequent hypotension as the legs are revascularized. One of the key arguments for proponents of open as opposed to endovascular repair is the reduced complication and reintervention rate once the patient has been treated. This may be optimistic; late aneurysmal dilation of the aorta above and below the graft can occur, but is not specifically looked for in many units (Kalman et al, 1999). The authors adopt a policy of computed tomography follow up at 5 years to ensure continued native artery dilation has not resulted in a further aneurysm in those undergoing open repair.

What is the current 30-day mortality of open elective repair? In randomized prospective trials comparing open to endovascular repair (UK Small Aneurysm Trial Participants, 1998; Greenhalgh et al, 2004; Prinssen et al, 2004) open repair carried an approximate 5% mortality. While this constitutes level 1 evidence, it only pertains to participating units, which tend to be large vascular units, that can perform endovascular as well as open repair and have a high degree of expertise. This may not reflect 'true' mortality in small hospitals with a low volume of aneurysm caseload. National discharge data suggest open mortality is 7.5% in the UK, and this figure may be nearer to the truth as it reflects all comers (Filipovic et al, 2005).

It has become increasingly apparent that provider characteristics can predict mortality after elective abdominal aortic aneurysm repair; high volume hospitals, high volume surgeons, monospecialty vascular units and even monospecialty training all have an inverse relationship to mortality (Dimick et al, 2003). The message is that patients with aortic aneurysms should be referred to large vascular units rather than small general surgical units for a better outcome.

Endovascular repair

Further dramatic falls in mortality for elective abdominal aortic aneurysm repair have resulted from the endovascular revolution. In 1990 the endovascular stent graft was introduced by Parodi et al (1991). It aimed to reduce the morbidity associated with open repair of abdominal aortic aneurysms and offer a minimally invasive method of treatment to patients unfit for an open operation. Endovascular repair can be performed under general or local anaesthetic and involves insertion of an expandable, covered metal stent into the aorta via the femoral arteries (*Figure 2*).

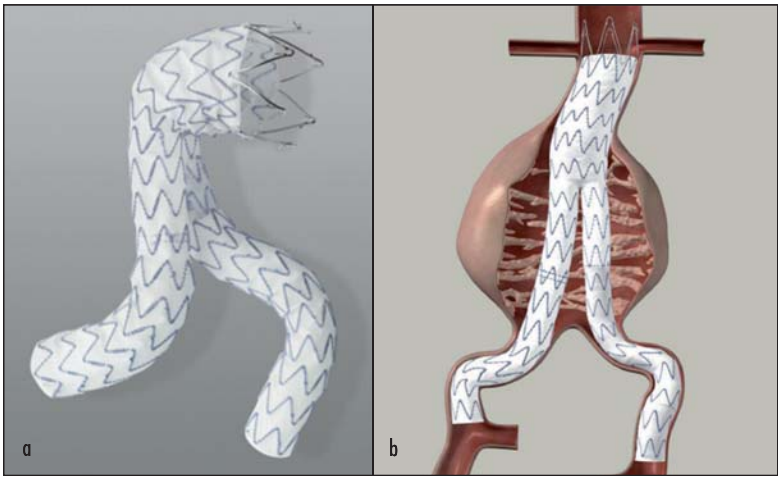

Figure 2. a. Bifurcated infrarenal aortic stent graft. b. Graft in place excluding the aneurysm sac.

Careful preoperative assessment of the morphology of each aneurysm is required to ensure that large enough 'landing zones' are present at each end of the aneurysm and that the patient's iliac arteries are able to accommodate passage of the collapsed stent into the aorta. Two-part bifurcated stents with a limb into each common iliac artery are most often used. Under fluoroscopic control the body of the stent graft and ipsilateral limb is placed and expanded. The body has a stub leg for the contralateral limb extension. This is cannulated via the contralateral femoral artery and the short limb inserted and expanded within the second iliac artery. Once a satisfactory position is achieved the graft is secured in place by 'ballooning' with an angioplasty balloon (Harris, 2006).

In two head-to-head trials of endovascular repair *vs* open repair the 30-day mortality rates were reduced from approximately 5% to 1.5% (Prinssen et al, 2004; EVAR Trial Participants, 2005). This advantage in aneurysm-related mortality was preserved to 4 years, although all-cause mortality (unsurprisingly in a cohort of patients with advanced atherosclerosis) remained equal in both arms. With figures demonstrating such a clear-cut advantage why would any patient suitable for endovascular repair receive an open procedure in preference?

The first and oft quoted reason is the complication rate demonstrated in these trials and registry data; there is a significantly higher rate of late complications (41% *vs* 9% in the first 4 years), as shown by the EVAR Trial Participants (2005). This is primarily a result of the presence of endoleaks – the presence of blood within the aneurysm sac potentially leading to pressurization and continued sac expansion with the risk of rupture. Endoleaks can occur at either end of the graft (type 1), or from back bleeding from lumbar or inferior mesenteric arteries (type 2). Type 3 endoleaks are found between pieces of a multi-part graft, and type 4 endoleaks are caused by blood leaking through the graft material itself. Any endoleak that causes increasing aneurysm sac size needs to be treated as there is still a risk of aneurysm rupture. This most usually applies to type 1 and type 3 endoleaks (Harris et al, 2000). The reintervention rate (usually an endoluminal approach with stent extension, relining or ballooning) has certainly fallen as it is now acknowledged that the most common type 2 endoleak is usually low pressure and does not need treatment if the sac size remains stable.

The other key issue limiting uptake is economic; while open repair is more expensive at the time of surgery (longer patient stay, intensive care unit use) the cost of stenting builds over time. In addition, to the cost of the stent graft itself (typically around £5000 for an off-the-shelf model) the annual follow up with computed tomography means an ever-burgeoning continued cost over time. In the UK the total cost of aneurysm-related treatment within 4 years of follow up was £13 258 for endovascular repair compared with £9945 for open repair. NHS primary care trusts are increasingly questioning the economics of endovascular repair, as are other European countries.

Emergency repair

Rupture of abdominal aortic aneurysm has about an 80–90% mortality, 25% of which occurs pre-hospital (UK Small Aneurysm Trial Participants et al, 1999) and this accounts for 1.4% of all deaths in men over the age of 65 years in England and Wales in 2005 (Office for National Statistics, 2006). Thirty-day mortality from open repair of ruptured abdominal aortic aneurysm has improved somewhat since the 1950s, but is still around 40% (Bown et al, 2002; Multicentre Aneurysm Screening Study Group, 2002a).

Initial treatment of patients presenting with ruptured abdominal aortic aneurysm is important and centres with an algorithm for assessment of these patients achieve better results than centres that do not have such an algorithm (Mastracci et al, 2008). A policy of permissive hypotension is widely used during resuscitation. This was first reported by Cannon et al (1918) during the First World War for the treatment of patients with major trauma. The theory behind permissive hypotension is to reduce primary haemorrhage by decreasing the pressure across an artery wall and to avoid disruption of a partially formed clot, leading to so-called secondary haemorrhage (Shaftan et al, 1965). Permissive hypotension may also maximize blood viscosity and minimize dilution of clotting factors until control of bleeding has been achieved (Bickell et al, 1991). Bickell et al (1994) found that permissive hypotension reduced mortality and complications of penetrating thoracic injuries, and this policy has been shown to be safe in ruptured abdominal aortic aneurysm (van der Vliet et al, 2007).

Endovascular repair of a ruptured aneurysm would appear to confer certain hypothetical benefits; the procedure can be performed under light anaesthesia or local anaesthetic, laparotomy and hypothermia are avoided as is cross clamping, and surrounding vulnerable structures (inferior vena cava, duodenum) are protected from inadvertent injury while dissecting through a retroperitoneal haematoma. Endovascular repair of ruptured abdominal aortic aneurysm was first performed in 1994 by Marin et al (1995). Two meta-analyses by Mastracci et al (2008) and Harkin et al (2007) have confirmed that short-term mortality is reduced from 40% to 21% and 18% respectively, although much of their data overlaps. In appropriate centres and subject to logistics and morphological suitability, patients with ruptured abdominal aortic aneurysm may be offered endovascular repair. Endovascular techniques are particularly suitable for those who would be refused open repair of ruptured abdominal aortic aneurysm on the grounds of age or co-morbidity. Hinchliffe and Braithwaite (2007) have shown no long-term benefit to endovascular repair over open repair of ruptured abdominal aortic aneurysm but extended follow-up data are not yet available. Prospective trials are planned.

Thoracoabdominal aortic aneurysm repair

Aneurysms that extend to the ostia of the renal arteries, or above into the visceral segment of the aorta, make repair significantly more difficult (*Figure 3*). Fortunately simple infrarenal abdominal aortic aneurysms make up 95% of all abdominal aortic aneurysms. Traditional open repair of thoracoabdominal aortic aneurysms involving thoracolaparotomy and proximal aortic cross clamping is associated with very significant operative mortality rates of up to 30%, but is still considered as a treatment option because of the 76% mortality at 2 years for people with this condition (Crawford and DiNatale, 1986).

Two main strategies have been developed to use endovascular repair technology and reduce the risk of open repair in the treatment of thoracoabdominal aortic aneurysms. The first of these is a hybrid technique, performed in one operation or as a staged procedure. As a progression from infrarenal stenting, isolated descending thoracic aortic aneurysms were treated with stent grafts rather than thoracotomy and open repair (Dake et al, 1994).

The problem of extending the new technology into the thoracoabdominal aneurysm was the ostia of the visceral arteries; a stent graft would necessarily cover them preventing blood flow to the abdominal organs. St Mary's Hospital, London developed a solution that involves taking grafts from either the distal aorta or common iliac arteries to perfuse the visceral arteries in a retrograde fashion (*Figure 4*) (Rimmer and Wolfe, 2003; Black et al, 2006). Once this is done an endovascular stent can be placed to exclude the aneurysm and cover the origin of some or all of the visceral arteries. The covered arteries are tied off to prevent a large type 2 endoleak. This technique avoids aortic cross-clamping, does not require a thoracotomy and has roughly halved

Figure 3. Thoracoabdominal aortic aneurysm (Crawford type 3).

Figure 4. Computed tomography scan of an aorta demonstrating stent graft insertion with hybrid visceral retrograde perfusion for thoracoabdominal aortic aneurysm.

mortality at 15%. Initially hybrid operations were reserved for patients who were unfit for conventional open surgery, but increasingly they are being offered to all suitable patients.

The fenestrated technique is probably an evolutionary step to total endovascular exclusion of these high-risk thoracoabdominal aortic aneurysms. Fenestrated grafts use custom-made stents with holes aligned to the origins of the arteries to be covered, known as fenestrations. Further covered stents are placed through these holes and into the visceral arteries, excluding the aneurysm. In the authors' experience, of 32 patients undergoing fenestrated stent grafts there is a 3% 30-day mortality. The largest series of these procedures by Roselli et al (2007) had 5.5% mortality at 30 days and 11% at 12 months.

One of the most serious complications of thoracoabdominal aneurysm repair is paraplegia as a result of exclusion of the lumbar arteries. Both of these endovascular techniques have shown promise in reducing paraplegia rates, probably as a result of reduced blood loss, minimizing hypotension and by maximizing visceral perfusion. Despite the improved mortality figures for both these procedures the risk of severe complications and death persists.

Screening

Given the high mortality associated with ruptured infrarenal aneurysms, screening is undertaken to detect this common condition and treat it electively. Abdominal aortic aneurysm is a good candidate for a screening programme as it represents a significant cause of mortality and morbidity, is usually asymptomatic until rupture and has a well-defined and effective treatment available. Ultrasound screening for abdominal aortic aneurysms is relatively inexpensive, non-invasive and has good specificity (99.9%) and sensitivity (87.4%) (Lindholt et al, 1999).

There have been four randomized controlled trials to evaluate efficacy and the cost of a screening programme, two of which were based in the UK, one in Denmark and one in Australia. The data from these trials have been analysed in a Cochrane review by Cosford and Leng (2007). This meta-analysis showed a significant reduction in aneurysm-related mortality, but not all-cause mortality at 3–5 years follow up for men only.

The largest of these four trials was the Multicentre Aneurysm Screening Study, which was conducted in the south of England from 1997 to 1999. This study randomized 67 800 men from 65–74 years of age to either screening, using a single abdominal ultrasound scan, or control groups. Eighty per cent of the screening group took up the invitation to be screened and those with an aorta greater than 3 cm in diameter were followed up. The relative risk reduction of aneurysm-related death in the group who were invited for screening was 42% (95% confidence interval = 22–58) and in patients who attended screening it was 53% (95% confidence interval = 30–64).

The Multicentre Aneurysm Screening Study also estimated the cost associated with a screening programme. Over 4 years the cost of a screening programme per quality-adjusted life year was £36 000 and this was estimated to fall to around £8000 at 10 years (Multicentre Aneurysm Screening Study Group, 2002b).

The National Screening Committee recommended screening for abdominal aortic aneurysms in males at the age of 65 years in 2005, and a national screening programme has been agreed but not implemented. The prevalence of abdominal aortic aneurysms in men aged 65 is 4%, therefore 96% of men will have a normal aortic diameter and be discharged from the screening programme; if their aorta is dilated to 3 cm or more follow up will be arranged on either an annual basis (3–4.4 cm) or 3-monthly basis (4.5–5.4 cm) until threshold is reached.

KEY POINTS

- Abdominal aortic aneurysms are a common problem, particularly in men over the age of 65 years. They are usually asymptomatic until rupture, at which point mortality is 80–90%.
- Abdominal aortic aneurysms should usually be repaired when they are greater than 5.5 cm in diameter, growing at more than 1 cm per year or are symptomatic.
- In recent years use of endovascular stent grafts has reduced perioperative mortality from aneurysm repair from about 5% to 1.5%.
- Ultrasound screening for abdominal aortic aneurysms is efficacious and cost effective.
- Ruptured aneurysms can be repaired using endovascular techniques.
- Newer hybrid operations and fenestrated stent grafts can be used to treat complex thoracoabdominal aneurysms involving visceral arteries.

Conclusions

Abdominal aortic aneurysms are an important health problem with well-described and effective treatments. Screening programmes will help to identify patients at risk to ensure optimal management.

Endovascular aneurysm repair is increasingly used as the first choice operation for patients who require elective abdominal aortic aneurysm treatment. Its use has spread to emergency abdominal aortic aneurysm repair in centres with sufficient experience and logistical support. There is still an important role for open aneurysm repair in those patients who are technically unsuitable for endovascular repair and for haemodynamically unstable patients with ruptured abdominal aortic aneurysm. Thoracoabdominal aneurysm repair remains a formidable challenge, and the advent of new stent graft technology to treat these aneurysms heralds a bright future. **BJHM**

Figure 2 *is reproduced courtesy of Medtronic.*

Conflict of interest: Mr RGJ Gibbs has taught on Medtronic sponsored educational courses.

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