

Anaesthesia for endovascular aneurysm repair

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Abstract

A patient with an abdominal aortic aneurysm can have surgical management through either an open or endovascular approach. The use of an endovascular approach has benefits for the patient by being a less invasive approach with initially lower mortality and morbidity and lower lengths of hospital stay, although longer term outcomes match open techniques. The endovascular technique requires more specialist equipment, including stents and imaging equipment. In the UK they are usually performed in specialist hospitals with teams of interventional radiologists, vascular surgeons and anaesthetists working together. Patients presenting for endovascular repair of their abdominal aortic aneurysm can present the anaesthetist with range of complex comorbidities which require specific management and optimization pre-operatively. The intraoperative management of the patient can vary, depending on patient, surgical and anaesthetic factors, from local anaesthetic, regional techniques or general anaesthesia. The postoperative complications are generally minimal, but the patients require lifelong follow up, making the procedure more expensive than an open procedure.

Keywords Abdominal aortic aneurysm; anaesthesia; endovascular; preoperative assessment; technique

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Repair of abdominal aortic aneurysms (AAA) using endovascular stents is now the most common form of corrective intervention compared to open surgery. It is usually performed in specialist centres with the surgery being undertaken by multidisciplinary teams consisting of vascular surgeons, interventional radiologists and anaesthetists. This article addresses the anaesthetic implications of endovascular aneurysm repair (EVAR).

AAA prevalence and outcomes

The abdominal aorta is usually 2 cm in diameter and defined as aneurysmal at 3 cm or above. The most significant risks factors for developing an AAA are: male, increasing age, smoking, genetic factors (increased risk of a AAA with a first-degree relative

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Learning objectives

After reading this article, you should:

- be able to discuss the positives and negatives of endovascular repair of an abdominal aortic aneurysms compared to open techniques
- have an understanding of different preoperative assessment techniques for patients undergoing endovascular repair of an abdominal aortic aneurysm
- be able to explain and discuss the various anaesthetic options available for the patient

with a AAA), hypercholesterolaemia, hypertension, inflammatory vasculitis and trauma.

The prevalence of AAA in the UK is 5–10%,¹ with symptomatic AAA in men ranging from 25 per 100,000 at 50 years old, up to 78 per 100,000 people at 78 years old. Over the last 10 years surgical techniques for aneurysm repair have undergone immense changes with a move from conventional open repair to minimally invasive techniques. Mortality from elective EVAR surgery is 0.8% compared to 3.8% in open repairs.² EVAR has multiple advantages over open repairs including a lower physiological insult, less haemodynamic instability due to reduced blood loss, no cross clamping induced morbidity, a decreased metabolic stress response, lower risk of organ damage and earlier ambulation resulting in a shorter hospital stay. The adoption of this technique has allowed surgical repair of AAA to be undertaken in patients previously deemed to be at an unacceptably high risk for open repair. However, there is uncertainty regarding the long-term advantages of the procedure and its cost effectiveness.

If the AAA ruptures, only 50% of patients reach hospital alive and of those that do only 50% survive.³ Therefore, surgery is usually performed electively if there is a rapid rate of growth of the aneurysm or if the aneurysm is greater than 5.5 cm in diameter. The annual rupture risk is outlined in [Table 1](#).

Centralization of services and screening

There is robust evidence that large centres undertaking high numbers of AAA surgery have lower mortality than smaller units. This is likely to reduce the number of smaller vascular centres and increase workload at larger centres as centralization is implemented.

The NHS AAA screening programme was fully implemented in 2013 and aims to screen all men via ultrasound at the age of 65 years.⁴ Aneurysms between 3 cm and 5.4 cm are followed up with repeat ultrasound scans and those with aneurysms over 5.4 cm are referred for review by a vascular surgeon.

Research summary

There have been two major randomized control trials (RCT) in the UK that have reviewed the use of EVAR surgery in 1999 and 2003–EVAR 1⁵ and EVAR 2.⁶ Both of these studies concluded that there was no long-term survival benefit for patients undergoing EVAR

Rupture risk

Diameter of AAA (cm)	Rupture risk (%/year)
<4	0
4–5	0.5–5
5–6	3–15
6–7	10–20
7–8	20–40
>8	30–50

From Brewster et al., Guidelines for the treatment of abdominal aortic aneurysms, Report of a subcommittee of the Joint Council of the American Association for Vascular Surgery and Society for Vascular Surgery. *Journal of Vascular Surgery*, 2003 May; 37 (5):1106–17.

Table 1

surgery. However, the EVAR 1 trial, which studied EVAR versus open repair in patients considered fit for open surgery, demonstrated a significant reduction in 30-day mortality in the EVAR group but long-term mortality was similar in both groups. There were also graft-related re-interventions (4%) and higher costs of treatment in the EVAR group. The majority of reinterventions were for endoleaks, thrombosis, graft kinking and device migration.

EVAR 2 studied EVAR versus surveillance in patients deemed unfit for open surgery. It concluded significant 30-day operative mortality (9%) in the EVAR group. There was also no long-term benefit of EVAR over surveillance. EVAR 2 concluded that the patient cohort would be best managed with medical optimization and improving their fitness.

Older frail patients are most likely to be offered EVAR while younger fitter patients with longer life expectancy are usually offered open surgery. This avoids the long-term surveillance of grafts with the risks of repeated radiation and contrast exposure and also the longer-term complications of EVAR.

Due to the refinement of surgical techniques and experience in conjunction with improvements in graft technology there may be an improvement in long-term complications from EVAR surgery. However, patients suffering with vascular disease often have significant associated multiple comorbidities which adversely affect their life expectancy regardless of successful surgery on their aneurysm.

Surgical techniques – EVAR versus fenestrated EVAR

EVAR entails the use of a synthetic or fabric tube graft which self-expands in the aorta. The grafts vary from their simplest form such as a standard infra renal tube graft to complex stent grafts such as fenestrated, branched or chimney grafts. The surgical and anaesthetic considerations vary immensely depending on graft type with the simple grafts taking about 2 hours with minimal physiological disturbance and blood loss to highly complex grafts requiring a longer surgical time with a greater physiological insult for patient. The complex grafts require greater expertise and experience on the part of team and are hence performed in very few centres.

The repair of a simple infrarenal AAA is carried out by cannulation of both femoral or iliac arteries and insertion of an expandable aortic graft into the aorta under radiological guidance and then deployed when the operators have identified the correct position. The stent occludes the aneurysmal sac allowing blood

to flow across the aneurysm and the aneurysmal sac to thrombose. Another two grafts are then inserted into the iliac vessels acting as sleeves to the main graft.

Complex EVAR surgery is undertaken for juxtarenal or suprarenal AAA, and require more complex grafts, known as fenestrated EVARs. Specialist grafts are tailor made to match each individual patient's anatomy from a 3D CT reconstruction model of the patient's aorta, allowing for cannulation and stenting of the renal, superior mesenteric and the coeliac arteries. These complex grafts take longer to insert, involve increased radiation and contrast doses resulting in higher postoperative morbidity (Figures 1 and 2).

Anaesthetic issues for EVAR surgery

Anaesthetists play a vital role in the perioperative management of vascular patients. They are involved in:

- Preoperative assessment, risk stratification and optimization.
- MDT discussions regarding risk versus benefit of surgery especially for complex patients or complex procedures
- Intraoperative management to maintain haemodynamic stability and preserve organ function
- Preparation for significant blood loss
- Identification of the optimal level of postoperative care

Preoperative assessment

A multidisciplinary team approach is best for assessment and evaluation of EVAR patients. The team should include surgeons, interventional radiologists, vascular anaesthetists and cardiologists if indicated. The focus from an anaesthetic perspective should be optimization of comorbidities, assessment of functional reserve, surgical and non-surgical options and consideration of the patient views.



Figure 1 Simple infrarenal graft. (Courtesy of Lombard Medical).

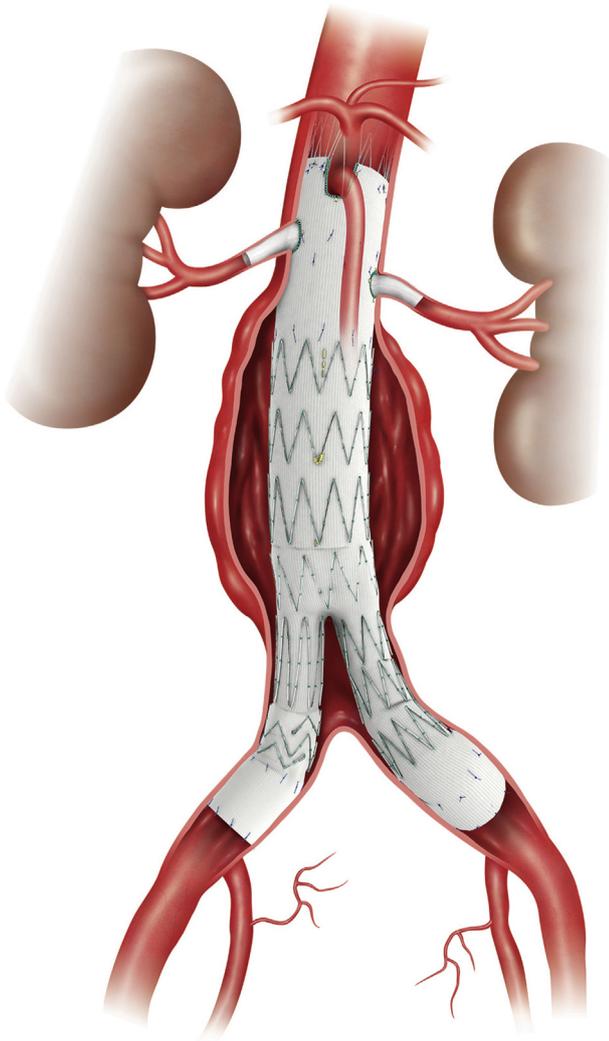


Figure 2 Complex fenestrated graft in situ. Permission for use granted by Cook Medical, Bloomington, Indiana.

EVAR patients are typically older and frailer than patients undergoing open repair. Comorbidities in this patient cohort include coronary artery disease, peripheral vascular disease, hypertension, hypercholesterolaemia, chronic obstructive airway disease and smoking. All patients should ideally receive an anaesthetic consultant led preoperative assessment providing an opportunity to comprehensively assess the patient's comorbidities, functional status, risk stratify, optimize comorbidities and rationalize medication. It also allows for patients to be counselled regarding the risks of different anaesthetic techniques, the risks of surgery and devise strategies for perioperative management and to manage the patient's expectations. The anaesthetist is also best placed to directly refer for specialist advice when indicated particularly cardiorespiratory assessment and optimization.

There is no universally accepted single risk-stratification model for vascular surgery. Commonly used risk scores are the Lee Revised Cardiac Risk Index and the POSSUM scoring system which can help to assess preoperative morbidity and mortality. However, their sensitivity as predictors of peri-operative mortality after elective aortic surgery is limited but may allow for the identification of low-risk cases.

Key risk factors to identify preoperatively include:

- history of ischaemic heart disease
- congestive cardiac failure
- previous cerebrovascular event (stroke or TIA)
- diabetes requiring insulin
- chronic kidney disease
- peripheral vascular disease.

All patients should have an ECG to exclude arrhythmias and ischaemia, a full blood count and renal profile. Baseline troponin is being tested more frequently as a raised level is indicative of an increased postoperative risk. Diabetic patients should aim for HbA1c <69 mmol/mol.⁷ Our centre has a pre-operative anaemia clinic to which patients can be referred directly. A trans-thoracic echocardiogram may be requested to look for valvular abnormalities, hypertrophy and systolic and diastolic dysfunction.

The American College of Cardiology and American Heart Association (ACC/AHA) or European guidance on perioperative cardiac risk assessment is useful in identifying patients that either need further investigation or best medical therapy to reduce their risk of a perioperative cardiac event. A non-invasive cardiac stress test is recommended for patients who have two risk factors and poor functional capacity. Although infrarenal EVAR is classed as an intermediate risk procedure the complex EVARs are definitely high risk. Most centres would perform some form of objective assessment of functional capacity.

An objective assessment of functional capacity should be performed before aortic surgery even for infrarenal grafts which carry an intermediate risk of conversion. Our centre performs cardiopulmonary exercise test (CPET) on all patients. Results which indicate increased risk in the peri operative period include:⁸

- peak oxygen consumption (PVO₂) of under 16 ml/kg/min
- anaerobic threshold of under 11 ml/kg/min
- any cardiac ischaemia induced during testing
- abnormal CPET may lead to referral to relevant teams for further assessment and optimization.

Medications should be assessed in the preoperative clinic. Cardiac medications such as beta blockers, aspirin, angiotensin converting enzyme (ACE) inhibitors and statins should be continued preoperatively. Statins and aspirin are recommended for high-risk vascular patients undergoing major vascular surgery. A significant proportion of EVAR patients will be on some form of anticoagulation. Warfarin should be stopped pre operatively and bridging therapy with low molecular weight heparins started if indicated. Aspirin may be continued preoperatively but other anti-coagulants such as other antiplatelets (clopidogrel and ticagrelor) and newer direct factor Xa inhibitors should be stopped preoperatively in a timely fashion.

The results of the preoperative assessment should be discussed in a multidisciplinary meeting and should guide further decision making.

Location

Most hospitals performing EVARs have hybrid theatre suites to facilitate the use of imaging and perform open surgery should the need for conversion arise. These specialist theatres may be in

remote sites in the hospital so issues related to isolated working environments should be taken into consideration when planning surgery. Point of care testing (blood gas machine and thromboelastography [TEG]) should be easily accessible.

Radiation is a hazard for theatre staff, especially the anaesthetist who needs to be in close proximity to patient. All theatre staff must wear radiation protecting lead gowns whilst imaging is taking place. Other protection equipment such as thyroid shields and protective screens should also be used.

Anaesthesia and intraoperative management

There are three main anaesthetic options for EVAR surgery: general, central neuro-axial (spinal, epidural or combined spinal epidural [CSE] technique) and local anaesthetic. There is limited evidence to show superiority of one technique over others and no difference in morbidity or mortality related to type of anaesthesia. It is often up to the discretion of the anaesthetist, patient preference and surgical factors determining the mode of anaesthetic. The factors to take into consideration are the pre-morbid state, significant respiratory disease, ability to lie flat for prolonged periods, ability to breath hold to provide improved picture quality, complexity and length of procedure, access required from axillary or brachial vessels and potential for major blood loss.

The overall aims for anaesthesia are the same for all three options:

- maintaining patient comfort for 3 to 4 hours whilst supine
- maintaining temperature and hydration throughout
- maintaining stringent blood pressure control especially at the time of stent deployment
- preparation for major blood loss
- monitoring anti coagulation.

There is evidence to support that specialization in vascular anaesthesia is associated with improved outcomes. It is prudent to have such high-risk cases managed by anaesthetists experienced in vascular anaesthesia.

Anaesthetic techniques – general anaesthesia

General anaesthetic helps to reduce patient anxiety and difficulties associated with lying flat for 3 to 4 hours. It also allows optimal patient positioning and suspension of ventilation for stent deployment along with the reduction of patient movement due to discomfort. GA also generally results in less bowel peristalsis and therefore can improve surgical views for the operation. The time limits associated with regional anaesthesia are removed and GA allows easy conversion to an open procedure if needed, which occurs in approximately 1% of cases.

The main aim for general anaesthetic is to limit changes in blood pressure by using cautious doses of anaesthetic induction agents augmented with opiates. A remifentanyl infusion is useful to allow for good analgesia and quick offset, although one must be cautious with frail patients. Overall, the primary goal is to maintain cardiovascular stability during laryngoscopy, intubation, surgical stimulation and extubation.

In the postoperative period, pain is not a significant factor as there are only two small groin incisions where local anaesthetic

infiltration will suffice for analgesia in the majority of cases. A few patients may need opioids postoperatively.

Regional or local anaesthetic techniques

This technique attenuates the need for cardiovascular depressant anaesthetic agents. There is less alteration in lung dynamics and a reduction in stimulation associated with laryngoscopy, intubation and extubation. There is possibly earlier detection of aneurysmal rupture as the patient will complain of retroperitoneal pain.

Regional techniques would incorporate either spinal, epidural or combined spinal epidural. The removal of epidural catheters needs to be timed appropriately with postoperative anti coagulants. Local anaesthetic techniques can be used for a percutaneous approach. This is also ideal for unstable and frail patients in emergency scenarios.

The patient can be administered sedation for anxiolysis but it is important to bear in mind a risk of progressing from a light plane of anaesthesia to deep anaesthesia, leading to hypoxia and aspiration. Airway manipulation can be more difficult due to patient position under the C arm and the risks of radiation to the anaesthetist.

Monitoring

All patients should have standard AAGBI monitoring as well as invasive arterial blood pressure monitoring as a minimum (to allow blood sampling and should be placed on the opposite side if upper limb access is required). Hourly urine output and temperature should be monitored.

There should be suitable IV access to deal with massive blood loss. The use of a central line is case dependent; prolonged operations, complex cases or frail patients with ischaemic heart disease may gain more benefit from a central line. Regular blood gas monitoring and the use of TEG should be used to guide treatment.

Other optional monitoring modalities would include cardiac output monitoring and electroencephalography (EEG) monitoring.

Transoesophageal Echocardiography (TOE) for EVAR

The use of TOE is increasing in popularity due to its ability to show real time images and help guide anaesthetic and surgical management. From a surgical perspective it allows evaluation of the aortic anatomy (mainly in the thoracic aorta) demonstrating atherosclerotic lesions, thrombus and dissections. It can also guide placement of the graft and help detect endoleaks intra-operatively. For the anaesthetist it can determine systolic and diastolic dysfunction, adequacy of filling (preload), vascular resistance and regional wall motion abnormality (i.e. myocardial ischaemia/infarction). Interpretation of these values can help guide inotrope, vasopressor or vasodilator usage and volume status. However, it is user dependent and not a skill currently available to most anaesthetists.

Blood loss

The main risks of bleeding are blood loss from access vessels, damage to large vessels during surgery and aneurysm rupture at the time of stent deployment. Cell salvage should be used for complex fenestrated EVAR surgery and rapid infusion devices should be readily available.

Anticoagulation

All patients are given heparin 5000 IU prior to the cannulation of vessels. A baseline activated clotting time (ACT) should be taken and then repeated a few minutes after the heparin is given. The ACT level would usually be around two to three times baseline levels for therapeutic anticoagulation. For prolonged procedures repeated heparin doses can be given whilst monitoring the ACT. There is usually no need to reverse the heparin with protamine unless there is excessive bleeding when reversal could be considered.

Renal protection

Postoperative renal dysfunction is common in EVAR patients. The main causes are:

- emboli being dislodged during stent deployment
- damage to renal arteries from catheter wires (stenosis or aneurysm)
- stent grafts either blocking renal arteries or causing an inflammatory reaction
- reperfusion injury from prolonged lower limb ischaemia
- intra-operative hypotension or hypovolaemia
- use of intravenous contrast agents.

To avoid postoperative renal dysfunction you should maintain adequate hydration, limit the use of contrast as much as possible and avoid nephrotoxic drugs in the perioperative period.

Spinal cord monitoring and cerebrospinal fluid (CSF) drainage

There is a risk of spinal cord ischaemia if the aorta is covered by a graft over 20 cm long. However, it is very rare for simple EVAR surgery and more likely with fenestrated EVAR surgery. It can be caused by occlusion of the spinal cord feeder vessels by the graft (the largest being the artery of Adamkiewicz arising from T9-T12), a thromboembolic event or perioperative hypotension. Although rarely used, spinal cord monitoring involves observing somatosensory or motor evoked potentials using electrodes on the feet and scalp to record impulses. The main treatment is to avoid spinal cord ischaemia and relate to maintaining a normal blood pressure intra operatively. CSF drains would usually only be used in complex thoraco-abdominal aneurysms and fenestrated EVARs. The use of CSF drainage is achieved by inserting a catheter into the CSF pre-operatively below the level of L1-2 and draining fluid to a set pressure. Monitoring of the drain usually takes place in the critical care unit due to the complexity of equipment and the risks involved.

Postoperative care

Patients are admitted to the post-anaesthetic care unit for a 24-hour period to allow closer monitoring, checking for wound haemostasis and cardiovascular stability. Repeated blood gases should be taken to look for any signs of occult bleeding or ischaemia. Complex fenestrated EVARs, prolonged procedures, procedures with significant blood loss, patients with significant pre-existing cardiorespiratory disease or cases with the need for ongoing close monitoring such as spinal cord drains should be admitted to a critical care ward.

Types of endoleaks

Type	Percentage	Explanation of defect
I	15%	Incompetent seal at proximal (Ia) or distal (Ib) stent, can be immediate or delayed
II	75%	Retrograde flow into aneurysm sac from mesenteric or lumbar arteries
III	5%	Due to a functional leak in the graft or sutures
IV	5%	Due to increased graft wall porosity leading to plasma crossing the graft wall into the aneurysm sac

An endoleak is due to persistent arterial perfusion of the aneurysm after stenting. It leads to a risk of aneurysm rupture or expansion. It is defined by the source of the leak.

Table 2

Complications

Immediate surgical complications of EVARs are failed or mal-deployment of the stent, arterial rupture and dissection, embolization, ischaemia of the spinal cord, kidneys or bowel. In the long term, complications include endoleaks (Table 2), thrombosis and infections.

Medical complications are acute coronary events, arrhythmias, cardiac failure, acute renal failure, strokes, venous thromboembolism and post implantation syndrome.

Post-implantation syndrome

Endovascular stent grafting has been shown to produce a systemic inflammatory response syndrome with raised inflammatory markers, coagulopathy and pyrexia. It occurs in a mild form in approximately 30% of patients but only becomes clinically apparent in a much smaller number. These patients should have any infection treated appropriately with antibiotics and can be treated with steroids or non-steroidal anti-inflammatory drugs to reduce the inflammation.

Emergency EVAR surgery

Due to the increasing popularity of EVAR surgery for elective AAA, there has been an increasing use of EVAR surgery for ruptured AAA. The IMPROVE⁹ trial showed no evidence of improved 30-day mortality for EVAR over open repair for ruptured aneurysms, showing either is an option for a patient with a ruptured AAA.

Similar issues need to be considered such as massive blood loss and conversion to open surgery. Resuscitation equipment should include large-bore IV access, arterial line, cross-matched blood and cell salvage being readily available. An arterial line should be inserted prior to induction of anaesthesia. Good team work is vital to safely and efficiently transfer the patient from either the emergency department or the referring hospital to the hybrid theatre. Anaesthetic options include local anaesthetic or general anaesthetic. Central neuraxial technique presents more of a challenge due to patient positioning, haemodynamic instability and possible coagulopathy. Hence neuroaxial block is not advised for ruptured AAA.

Emergency management of AAA is covered on pages 287–292 of this issue. ◆

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