

# Abdominal aortic aneurysm: diagnosis and management

**Evidence review U: Preventing abdominal  
compartment syndrome following repair of  
ruptured abdominal aortic aneurysm**

*NICE guideline NG156*

*Methods, evidence and recommendations*

*March 2020*

*Final*

*This evidence review was developed by  
the NICE Guideline Updates Team*



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# Preventing abdominal compartment syndrome following repair of ruptured abdominal aortic aneurysm

## Review question

What is the most effective approach in preventing abdominal compartment syndrome during surgical repair of a ruptured abdominal aortic aneurysm?

## Introduction

This review question aims to determine which approach(es) to preventing or managing abdominal compartment syndrome are most effective in people undergoing surgery for a ruptured abdominal aortic aneurysm (AAA).

## PICO table

**Table 1: Inclusion criteria**

Parameter	Inclusion criteria
Population	People undergoing surgery for a ruptured AAA <ul style="list-style-type: none"> <li>Subgroup: type of surgery</li> </ul>
Intervention	<ul style="list-style-type: none"> <li>Control/monitoring of abdominal perfusion pressure</li> <li>Type of sedation or analgesia</li> <li>Neuromuscular blockade</li> <li>Prokinetic motility agents</li> <li>Fluid resuscitation</li> <li>Diuretics and continuous venovenous hemofiltration/ultrafiltration</li> <li>Percutaneous catheter decompression</li> <li>Abdominal decompression</li> <li>Relaparotomy</li> <li>Laparostomy</li> </ul>
Comparator	<ul style="list-style-type: none"> <li>No intervention, placebo, or each other</li> </ul>
Outcome	<ul style="list-style-type: none"> <li>Mortality</li> <li>Adverse events of the approach to preventing or managing abdominal compartment syndrome</li> <li>Complications of surgery - abdominal compartment syndrome, kidney and bowel failure</li> <li>Need for additional intervention</li> <li>Quality of life</li> <li>Resource use, including length of hospital or intensive care stay and readmissions, and costs</li> </ul>

## Methods and process

This evidence review was developed using the methods and process described in [Developing NICE guidelines: the manual](#). Methods specific to this review question are described in the review protocol in Appendix A.

Declarations of interest were recorded according to NICE's 2014 conflicts of interest policy.

Two literature searches were performed to identify studies that assessed strategies for preventing or managing abdominal compartment syndrome during surgical repair of ruptured AAA. The first literature search used a randomised controlled trial (RCT) and systematic review (SR) filter while the second search used an observational study filter to identify potentially relevant studies.

The reviewer sifted the RCT database first to identify systematic reviews, RCTs or quasi-randomised controlled trials that met inclusion criteria for this review question. Since no evidence was identified from the RCT and systematic review literature search, the observational study database was sifted to identify non-randomised controlled trials, which were potentially relevant to the review question. Studies were excluded if they:

- were not in English
- were not full reports of the study (for example, published only as an abstract)
- were not peer-reviewed.

## **Clinical evidence**

### **Included studies**

From the RCT database of 1,975 abstracts, 1 study was identified as being potentially relevant to this review question. Following full-text review the study did not meet criteria for inclusion for this review question.

One study was identified as being potentially relevant in the observational study database of 1,710 abstracts. After reviewing the full manuscript of this study, it was not considered relevant to this review question.

Update searches were conducted in December 2017 to identify any relevant studies published during guideline development. The update RCT and the observational study databases contained 40 and 25 abstracts respectively. None of these were considered. As a result no additional studies were identified.

### **Excluded studies**

The list of papers excluded at full-text review, with reasons, is given in Appendix E.

### **Summary of clinical studies included in the evidence review**

No studies were included following full text review.

### **Quality assessment of clinical studies included in the evidence review**

No studies were included following full text review.

## **Economic evidence**

### **Included studies**

A literature search was conducted jointly for all review questions by applying standard health economic filters to a clinical search for AAA. This search returned a total of 5,173 citations. Following review of all titles and abstracts, no studies were

identified as being potentially relevant to the review question. No full texts were retrieved, and no studies were included as economic evidence.

An update search was conducted in December 2017, to identify any relevant health economic analyses published during guideline development. The search found 814 abstracts; none of which were considered relevant to this review question. As a result no additional studies were identified.

### **Excluded studies**

No studies were retrieved for full-text review.

### **Evidence statements**

No evidence was identified for this review question.

### **The committee's discussion of the evidence**

#### **Interpreting the evidence**

##### ***The outcomes that matter most***

The committee agreed that the outcomes that matter most are survival and absence of cardiac, pulmonary, renal and wound complications.

##### ***The quality of the evidence***

No evidence was identified for this review question.

##### ***Benefits and harms***

The committee wanted to highlight that abdominal compartment syndrome is a complication that is associated with both EVAR and open surgical repair for ruptured as there is a general misconception that the condition only occurs after open surgical repair. The committee agreed that a clear benefit of the recommendations is that clinicians would be mindful of abdominal compartment syndrome during postoperative monitoring. This would ensure that abdominal compartment syndrome is identified and treated earlier, before a person's condition deteriorates. The committee discussed the potential for harm due to overdiagnosis and unnecessary surgical treatment of mild abdominal compartment syndrome that does not need invasive surgical intervention. The committee agreed unnecessary surgery was unlikely to happen as their recommendations were confined to raising awareness of the possibility, rather than encouraging intervention in every case.

##### **Cost effectiveness and resource use**

As the recommendations were informative in nature (as opposed to directive), the committee believed that the recommendations would have no material impact on costs and use of NHS resources.

##### **Other factors the committee took into account**

The committee discussed whether recommendations were needed about how to diagnose and treat abdominal compartment syndrome. As no studies were identified comparing diagnostic and treatment strategies, the committee agreed that there was no information available to guide their considerations. Furthermore, the committee

agreed that such recommendations would be too prescriptive as the treatment approach would be dependent on the skillset, clinical judgment and preference of the treating vascular surgeon and/or interventional radiologist.



# Appendices

## Appendix A – Review protocol

### Review protocol for preventing abdominal compartment syndrome during surgical repair of a ruptured abdominal aortic aneurysm

<b>Review question 25</b>	<b>What is the most effective approach in preventing abdominal compartment syndrome during surgical repair of ruptured abdominal aortic aneurysm?</b>
Objectives	To determine which approach(es) to preventing or managing abdominal compartment syndrome are most effective in people undergoing surgery for a ruptured abdominal aortic aneurysm
Type of review	Intervention
Language	English only
Study design	Systematic reviews of study designs listed below Randomised controlled trials Quasi-randomised controlled trials Non-randomised controlled trials If insufficient evidence identified, prospective cohort studies presenting comparative evidence will be considered (n >500; >12 month follow-up; multicentre)
Status	Published papers only (full text) No date restrictions
Population	People undergoing surgery for a ruptured abdominal aortic aneurysm Subgroup: type of surgery
Intervention	Control/monitoring of abdominal perfusion pressure Type of sedation or analgesia Neuromuscular blockade Prokinetic motility agents Fluid resuscitation Diuretics and continuous venovenous hemofiltration/ultrafiltration Percutaneous catheter decompression Abdominal decompression Relaparotomy Laparostomy
Comparator	No intervention, placebo or each other
Outcomes	Mortality Adverse events of the approach to preventing or managing abdominal compartment syndrome Complications of surgery - abdominal compartment syndrome, kidney and bowel failure Need for additional intervention Quality of life Resource use, including length of hospital or intensive care stay and readmissions, and costs
Other criteria for inclusion / exclusion of studies	Exclusion: Non-English language Abstract/non-published (i only)
Baseline characteristics to be extracted in evidence tables	Age Sex Size of aneurysm

<b>Review question 25</b>	<b>What is the most effective approach in preventing abdominal compartment syndrome during surgical repair of ruptured abdominal aortic aneurysm?</b>
	Size of haematoma Operative time Comorbidities BMI
Search strategies	See Appendix B
Review strategies	Appropriate NICE Methodology Checklists, depending on study designs, will be used as a guide to appraise the quality of individual studies. Data on all included studies will be extracted into evidence tables. Where statistically possible, a meta-analytic approach will be used to give an overall summary effect. All key findings from evidence will be presented in GRADE profiles and further summarised in evidence statements.
Key papers	None identified

## Appendix B – Literature search strategies

### Clinical search literature search strategy

#### Main searches

Bibliographic databases searched for the guideline

- Cumulative Index to Nursing and Allied Health Literature - CINAHL (EBSCO)
- Cochrane Database of Systematic Reviews – CDSR (Wiley)
- Cochrane Central Register of Controlled Trials – CENTRAL (Wiley)
- Database of Abstracts of Reviews of Effects – DARE (Wiley)
- Health Technology Assessment Database – HTA (Wiley)
- EMBASE (Ovid)
- MEDLINE (Ovid)
- MEDLINE Epub Ahead of Print (Ovid)
- MEDLINE In-Process (Ovid)

#### Identification of evidence for review questions

The searches were conducted between November 2015 and October 2017 for 31 review questions (RQ). In collaboration with Cochrane, the evidence for several review questions was identified by an update of an existing Cochrane review. Review questions in this category are indicated below. Where review questions had a broader scope, supplement searches were undertaken by NICE.

Searches were re-run in December 2017.

Where appropriate, study design filters (either designed in-house or by McMaster) were used to limit the retrieval to, for example, randomised controlled trials. Details of the study design filters used can be found in section 4.

#### Search strategy review question 25

**Medline Strategy, searched 11th September 2017**

**Database: Ovid MEDLINE(R) 1946 to August Week 5 2017**

**Search Strategy:**

- 1 Aortic Aneurysm, Abdominal/
- 2 Aortic Rupture/
- 3 (aneurysm\* adj4 (abdom\* or thoracoabdom\* or thoraco-abdom\* or aort\* or spontan\* or juxtarenal\* or juxta-renal\* or juxta renal\* or paraarenal\* or para-renal\* or para renal\* or suprarenal\* or supra renal\* or supra-renal\* or short neck\* or short-neck\* or shortneck\* or visceral aortic segment\*).tw.
- 4 (AAA\* or RAAA\*).tw.
- 5 Endovascular Procedures/ or Vascular Surgical Procedures/
- 6 (endovascular\* adj4 aneurysm\* adj4 repair\*).tw.
- 7 (endovascular adj4 aort\* adj4 repair\*).tw.
- 8 (upper adj4 abdominal adj4 (repair\* or surger\* or surgic\* or operat\* or procedur\*).tw.
- 9 (EVAR or EVRAR or FEVAR or F-EAVAR or BEVAR or B-EVAR).tw.

**Medline Strategy, searched 11th September 2017****Database: Ovid MEDLINE(R) 1946 to August Week 5 2017****Search Strategy:**

- 10 (Anaconda or Zenith Dynalink or Hemobahn or Luminexx\* or Memoth-erm or Wallstent).tw.
- 11 (Viabahn or Nitinol or Hemobahn or Intracoil or Tantalum).tw.
- 12 or/1-11
- 13 Intra-Abdominal Hypertension/
- 14 (abdominal adj4 compartment adj4 syndrome\*).tw.
- 15 ((intra-abdominal or intra abdominal or intraabdominal) adj4 hypertens\*).tw.
- 16 or/13-15
- 17 12 and 16
- 18 (prevent\* or avert\* or avoid\* or stop\*).tw.
- 19 17 and 18
- 20 monitoring, physiologic/
- 21 ((continuous\* or continual\* or physiologic\*) adj4 monitor\*).tw.
- 22 ((monitor\* or control\* or observ\* or check\*) adj4 (intra-abdominal\* adj4 pressure\*)).tw.
- 23 ((monitor\* or control\* or observ\* or check\*) adj4 (intraabdominal\* adj4 pressure\*)).tw.
- 24 ((monitor\* or control\* or observ\* or check\*) adj4 (intra abdominal\* adj4 pressure\*)).tw.
- 25 ((monitor or control or observ\* or check\*) adj4 (abdom\* adj4 pressure\*)).tw.
- 26 ((monitor or control or observ\* or check\*) adj4 (abdom\* adj4 tension)).tw.
- 27 IAP.tw.
- 28 Pressure/
- 29 Partial Pressure/
- 30 (perfus\* adj4 pressure).tw.
- 31 exp Analgesia/
- 32 Analgesi\*.tw.
- 33 Pain management/
- 34 (Pain\* adj4 (manag\* or relie\*)).tw.
- 35 conscious sedation/ or deep sedation/
- 36 sedat\*.tw.
- 37 Neuromuscular Blockade/
- 38 ((neuromuscular or myoneural) adj4 block\*).tw.
- 39 (nerve\* adj4 muscl\* adj4 block\*).tw.
- 40 (neuromuscular adj4 inhibition).tw.
- 41 (prokinetic\* or gastroprokinetic\* or gastrokinetic\*).tw.
- 42 (motility adj4 agent\*).tw.
- 43 Gastric Emptying/de [Drug Effects]
- 44 (stomach adj4 empty\* adj4 accelerat\*).tw.
- 45 (gastric\* adj4 empty\* adj4 accelerat\*).tw.
- 46 Fluid Therapy/
- 47 (fluid\* adj4 resuscitat\*).tw.
- 48 exp Diuretics/
- 49 diuretic\*.tw.
- 50 (saluretic\* adj4 agent\*).tw.
- 51 Hemofiltration/
- 52 (haemofiltrat\* or hemofiltrat\*).tw.
- 53 (CAVH or CVVH).tw.
- 54 Ultrafiltration/

**Medline Strategy, searched 11th September 2017**  
**Database: Ovid MEDLINE(R) 1946 to August Week 5 2017**  
**Search Strategy:**

55 (ultrafiltrat\* or ultra-filtrat\* or ultra filtrat\* or hyperfiltrat\* or hyper-filtrat\* or hyper filtrat\*).tw.  
 56 Decompression, Surgical/  
 57 ((catheter\* or abdominal\*) adj4 decompress\*).tw.  
 58 Laparotomy/  
 59 (laparotom\* or laparostom\* or minilaparotom\* or relaparotom\*).tw.  
 60 or/19-59  
 61 12 and 60  
 62 animals/ not humans/  
 63 61 not 62

## Health Economics literature search strategy

### Sources searched to identify economic evaluations

- NHS Economic Evaluation Database – NHS EED (Wiley) last updated Dec 2014
- Health Technology Assessment Database – HTA (Wiley) last updated Oct 2016
- Embase (Ovid)
- MEDLINE (Ovid)
- MEDLINE In-Process (Ovid)

Search filters to retrieve economic evaluations and quality of life papers were appended to the population and intervention terms to identify relevant evidence. Searches were not undertaken for qualitative RQs. For social care topic questions additional terms were added. Searches were re-run in September 2017 where the filters were added to the population terms.

### Health economics search strategy

**Medline Strategy**

Economic evaluations  
 1 Economics/  
 2 exp "Costs and Cost Analysis"/  
 3 Economics, Dental/  
 4 exp Economics, Hospital/  
 5 exp Economics, Medical/  
 6 Economics, Nursing/  
 7 Economics, Pharmaceutical/  
 8 Budgets/  
 9 exp Models, Economic/  
 10 Markov Chains/  
 11 Monte Carlo Method/  
 12 Decision Trees/  
 13 econom\*.tw.  
 14 cba.tw.  
 15 cea.tw.  
 16 cua.tw.  
 17 markov\*.tw.

**Medline Strategy**

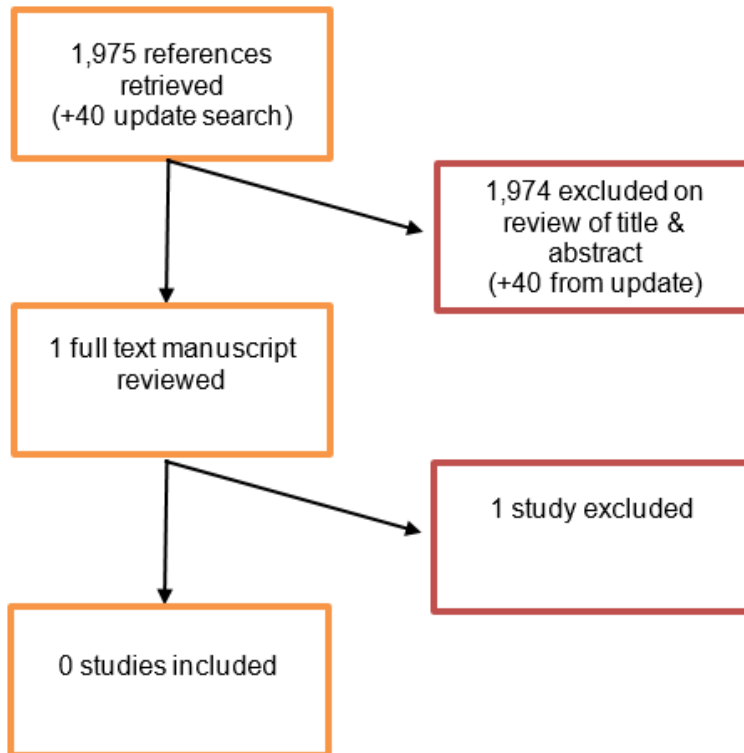
- 18 (monte adj carlo).tw.
- 19 (decision adj3 (tree\* or analys\*)).tw.
- 20 (cost or costs or costing\* or costly or costed).tw.
- 21 (price\* or pricing\*).tw.
- 22 budget\*.tw.
- 23 expenditure\*.tw.
- 24 (value adj3 (money or monetary)).tw.
- 25 (pharmacoeconomic\* or (pharmaco adj economic\*)).tw.
- 26 or/1-25

## Quality of life

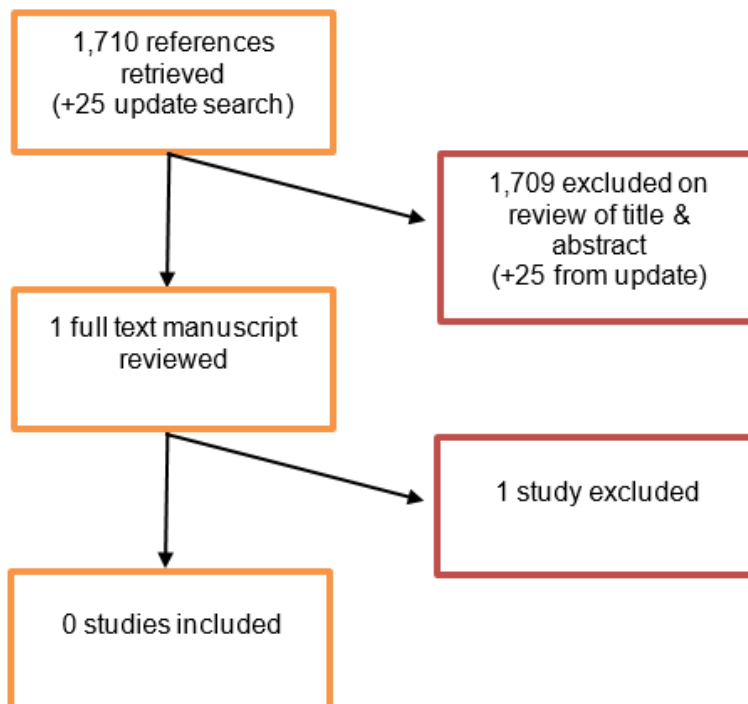
- 1 "Quality of Life"/
- 2 quality of life.tw.
- 3 "Value of Life"/
- 4 Quality-Adjusted Life Years/
- 5 quality adjusted life.tw.
- 6 (qaly\* or qald\* or qale\* or qtime\*).tw.
- 7 disability adjusted life.tw.
- 8 daly\*.tw.
- 9 Health Status Indicators/
- 10 (sf36 or sf 36 or short form 36 or shortform 36 or sf thirtysix or sf thirty six or shortform thirtysix or shortform thirty six or short form thirtysix or short form thirty six).tw.
- 11 (sf6 or sf 6 or short form 6 or shortform 6 or sf six or sfsix or shortform six or short form six).tw.
- 12 (sf12 or sf 12 or short form 12 or shortform 12 or sf twelve or sftwelve or shortform twelve or short form twelve).tw.
- 13 (sf16 or sf 16 or short form 16 or shortform 16 or sf sixteen or sfsixteen or shortform sixteen or short form sixteen).tw.
- 14 (sf20 or sf 20 or short form 20 or shortform 20 or sf twenty or sftwenty or shortform twenty or short form twenty).tw.
- 15 (euroqol or euro qol or eq5d or eq 5d).tw.
- 16 (qol or hql or hqol or hrqol).tw.
- 17 (hye or hyes).tw.
- 18 health\* year\* equivalent\*.tw.
- 19 utilit\*.tw.
- 20 (hui or hui1 or hui2 or hui3).tw.
- 21 disutili\*.tw.
- 22 rosser.tw.
- 23 quality of wellbeing.tw.
- 24 quality of well-being.tw.
- 25 qwb.tw.
- 26 willingness to pay.tw.
- 27 standard gamble\*.tw.
- 28 time trade off.tw.
- 29 time tradeoff.tw.
- 30 tto.tw.
- 31 or/1-30

## Appendix C – Clinical evidence study selection

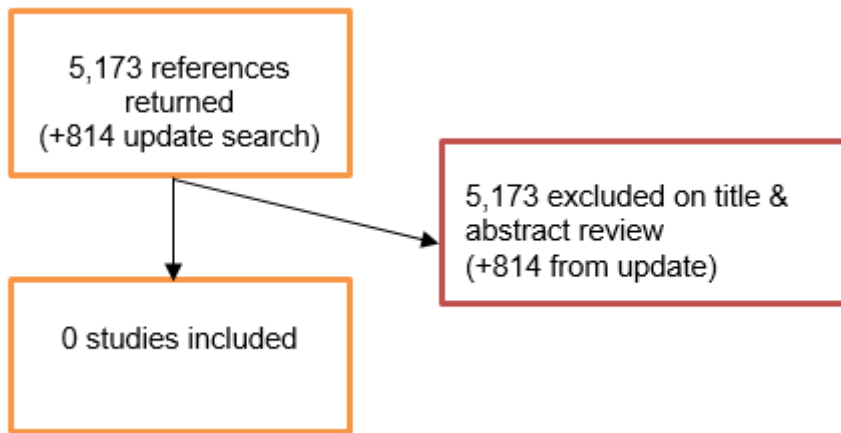
### RCT filter



### Observational study filter



## Appendix D – Economic evidence study selection



## Appendix E – Excluded studies

### Clinical studies

No.	Study	Reason for exclusion
1	Ersryd S, Djavani-Gidlund K, Wanhainen A, and Bjorck M (2016) Editor's Choice - Abdominal Compartment Syndrome After Surgery for Abdominal Aortic Aneurysm: A Nationwide Population Based Study. European journal of vascular and endovascular surgery : the official journal of the European Society for Vascular Surgery 52(2), 158-65	Retrospective cohort study. Furthermore, study does not assess approaches for preventing ACS. Instead authors report perioperative and post operative outcomes of patients who with ACS during surgical repair of ruptured AAAs.
2	Karkos Christos D, Menexes Georgios C, Patelis Nikolaos, Kalogirou Thomas E, Giatzidis Ioakeim T, and Harkin Denis W (2014) A systematic review and meta-analysis of abdominal compartment syndrome after endovascular repair of ruptured abdominal aortic aneurysms. Journal of vascular surgery 59(3), 829-42	Systematic review of prospective and retrospective studies. The systematic review mainly explored risk factors for acute coronary syndrome and clinical outcomes of patients with ACS. Upon review of individual studies, none of the prospective studies met criteria for inclusion in this review: less than 500 participants with ACS were included, no comparative evidence was reported, patients were followed up for less than 12 months or studies took place in single centres.

### Economic studies

No full text papers were retrieved. All studies were excluded at review of titles and abstracts.



## Appendix F – Glossary

### Abdominal Aortic Aneurysm (AAA)

A localised bulge in the abdominal aorta (the major blood vessel that supplies blood to the lower half of the body including the abdomen, pelvis and lower limbs) caused by weakening of the aortic wall. It is defined as an aortic diameter greater than 3 cm or a diameter more than 50% larger than the normal width of a healthy aorta. The clinical relevance of AAA is that the condition may lead to a life threatening rupture of the affected artery. Abdominal aortic aneurysms are generally characterised by their shape, size and cause:

- **Infrarenal AAA:** an aneurysm located in the lower segment of the abdominal aorta below the kidneys.
- **Juxtarenal AAA:** a type of infrarenal aneurysm that extends to, and sometimes, includes the lower margin of renal artery origins.
- **Suprarenal AAA:** an aneurysm involving the aorta below the diaphragm and above the renal arteries involving some or all of the visceral aortic segment and hence the origins of the renal, superior mesenteric, and celiac arteries, it may extend down to the aortic bifurcation.

### Abdominal compartment syndrome

Abdominal compartment syndrome occurs when the pressure within the abdominal cavity increases above 20 mm Hg (intra-abdominal hypertension). In the context of a ruptured AAA this is due to the mass effect of a volume of blood within or behind the abdominal cavity. The increased abdominal pressure reduces blood flow to abdominal organs and impairs pulmonary, cardiovascular, renal, and gastro-intestinal function. This can cause multiple organ dysfunction and eventually lead to death.

### Cardiopulmonary exercise testing

Cardiopulmonary Exercise Testing (CPET, sometimes also called CPX testing) is a non-invasive approach used to assess how the body performs before and during exercise. During CPET, the patient performs exercise on a stationary bicycle while breathing through a mouthpiece. Each breath is measured to assess the performance of the lungs and cardiovascular system. A heart tracing device (Electrocardiogram) will also record the hearts electrical activity before, during and after exercise.

### Device migration

Migration can occur after device implantation when there is any movement or displacement of a stent-graft from its original position relative to the aorta or renal arteries. The risk of migration increases with time and can result in the loss of device fixation. Device migration may not need further treatment but should be monitored as it can lead to complications such as aneurysm rupture or endoleak.

## Endoleak

An endoleak is the persistence of blood flow outside an endovascular stent - graft but within the aneurysm sac in which the graft is placed.

- Type I – Perigraft (at the proximal or distal seal zones): This form of endoleak is caused by blood flowing into the aneurysm because of an incomplete or ineffective seal at either end of an endograft. The blood flow creates pressure within the sac and significantly increases the risk of sac enlargement and rupture. As a result, Type I endoleaks typically require urgent attention.
- Type II – Retrograde or collateral (mesenteric, lumbar, renal accessory): These endoleaks are the most common type of endoleak. They occur when blood bleeds into the sac from small side branches of the aorta. They are generally considered benign because they are usually at low pressure and tend to resolve spontaneously over time without any need for intervention. Treatment of the endoleak is indicated if the aneurysm sac continues to expand.
- Type III – Midgraft (fabric tear, graft dislocation, graft disintegration): These endoleaks occur when blood flows into the aneurysm sac through defects in the endograft (such as graft fractures, misaligned graft joints and holes in the graft fabric). Similarly to Type I endoleak, a Type III endoleak results in systemic blood pressure within the aneurysm sac that increases the risk of rupture. Therefore, Type III endoleaks typically require urgent attention.
- Type IV– Graft porosity: These endoleaks often occur soon after AAA repair and are associated with the porosity of certain graft materials. They are caused by blood flowing through the graft fabric into the aneurysm sac. They do not usually require treatment and tend to resolve within a few days of graft placement.
- Type V – Endotension: A Type V endoleak is a phenomenon in which there is continued sac expansion without radiographic evidence of a leak site. It is a poorly understood abnormality. One theory that it is caused by pulsation of the graft wall, with transmission of the pulse wave through the aneurysm sac to the native aneurysm wall. Alternatively it may be due to intermittent leaks which are not apparent at imaging. It can be difficult to identify and treat any cause.

## Endovascular aneurysm repair

Endovascular aneurysm repair (EVAR) is a technique that involves placing a stent –graft prosthesis within an aneurysm. The stent-graft is inserted through a small incision in the femoral artery in the groin, then delivered to the site of the aneurysm using catheters and guidewires and placed in position under X-ray guidance.

- Conventional EVAR refers to placement of an endovascular stent graft in an AAA where the anatomy of the aneurysm is such that the ‘instructions for use’ of that particular device are adhered to. Instructions for use define tolerances for AAA anatomy that the device manufacturer considers appropriate for that device. Common limitations on AAA anatomy are infrarenal neck length (usually >10mm), diameter (usually ≤30mm) and neck angle relative to the main body of the AAA
- Complex EVAR refers to a number of endovascular strategies that have been developed to address the challenges of aortic proximal neck fixation associated with complicated aneurysm anatomies like those seen in juxtarenal and suprarenal AAAs.

These strategies include using conventional infrarenal aortic stent grafts outside their 'instructions for use', using physician-modified endografts, utilisation of customised fenestrated endografts, and employing snorkel or chimney approaches with parallel covered stents.

### **Goal directed therapy**

Goal directed therapy refers to a method of fluid administration that relies on minimally invasive cardiac output monitoring to tailor fluid administration to a maximal cardiac output or other reliable markers of cardiac function such as stroke volume variation or pulse pressure variation.

### **Post processing technique**

For the purpose of this review, a post-processing technique refers to a software package that is used to augment imaging obtained from CT scans, (which are conventionally presented as axial images), to provide additional 2- or 3-dimensional imaging and data relating to an aneurysm's, size, position and anatomy.

### **Permissive hypotension**

Permissive hypotension (also known as hypotensive resuscitation and restrictive volume resuscitation) is a method of fluid administration commonly used in people with haemorrhage after trauma. The basic principle of the technique is to maintain haemostasis (the stopping of blood flow) by keeping a person's blood pressure within a lower than normal range. In theory, a lower blood pressure means that blood loss will be slower, and more easily controlled by the pressure of internal self-tamponade and clot formation.

### **Remote ischemic preconditioning**

Remote ischemic preconditioning is a procedure that aims to reduce damage (ischaemic injury) that may occur from a restriction in the blood supply to tissues during surgery. The technique aims to trigger the body's natural protective functions. It is sometimes performed before surgery and involves repeated, temporary cessation of blood flow to a limb to create ischemia (lack of oxygen and glucose) in the tissue. In theory, this "conditioning" activates physiological pathways that render the heart muscle resistant to subsequent prolonged periods of ischaemia.

### **Tranexamic acid**

Tranexamic acid is an antifibrinolytic agent (medication that promotes blood clotting) that can be used to prevent, stop or reduce unwanted bleeding. It is often used to reduce the need for blood transfusion in adults having surgery, in trauma and in massive obstetric haemorrhage.