National Institute for Health and Care Excellence

Draft for consultation

Abdominal aortic aneurysm: diagnosis and management

Evidence review D: Monitoring for abdominal aortic aneurysm expansion and risk of rupture

NICE guideline <number>

Evidence reviews

May 2018

Draft for Consultation

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ISBN:

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Monitoring for abdominal aortic aneurysm expansion and the risk of rupture

Review questions

What is the most effective frequency for monitoring people with a) a small and b) a medium unruptured abdominal aortic aneurysm for signs of aneurysm expansion and risk of rupture?

Which imaging techniques are most useful when monitoring people with an unruptured abdominal aortic aneurysm to predict risk of rupture?

Introduction

Several imaging techniques can be used to monitor abdominal aortic aneurysms (AAAs), and it is not clear which one is most effective. It is important to establish how often aneurysms should be monitored to keep the risk of rupture as low as possible while making the best use of NHS resources. The aim of these review questions was to determine the most appropriate imaging techniques and frequency of surveillance for people with AAAs; that is, the review sought to examine how frequently and how people should be monitored for signs of aneurysm expansion and risk of rupture.

PICO tables

Table 1: Inclusion criteria for most effective frequency of monitoring

Parameter	Inclusion criteria
Population	People with a confirmed unruptured AAA
Interventions	Scans at intervals other than: a) Scan every year (AAA >3cm to <4.5cm in diameter) b) Scan every 3 months (AAA ≥4.5cm to <5.5cm in diameter)
Comparators	Current practice (NAAASP) a) Scan every year (AAA >3cm to <4.5cm in diameter) b) Scan every 3 months (AAA ≥4.5cm to <5.5cm in diameter)
Outcomes	i) AAA rupture Unplanned (non-elective/emergency) repair of an AAA surgery in relation to (referral for) elective surgery Mortality; survival Acceptability to patients Resource use and cost ii) AAA expansion AAA rupture Unplanned (emergency or non-elective) repair

Table 2: Inclusion criteria for most effective imaging technique for monitoring (diagnostic component)

Parameter	Inclusion criteria
Population	People with a confirmed AAA ≥3cm in diameter
Reference standard	Surgical confirmation alone, including post-mortem, of rupture during follow-up (preferred evidence) CT and/or surgical confirmation, including post-mortem, of rupture during follow-up
Index tests	Ultrasound CT MRI Wall stress analysis, including finite element analysis (FEA)

Table 3: Inclusion criteria for most effective imaging technique for monitoring (intervention component)

Parameter	Inclusion criteria
Population	People with a confirmed AAA ≥3cm in diameter
Interventions	Ultrasound CT MRI Wall stress analysis, including finite element analysis (FEA)
Comparators	Each other
Outcomes	Adverse events Downstream effects, mortality (all-cause, aneurysm-related), rupture, surgical repair for asymptomatic, symptomatic and ruptured aneurysms Acceptability of approach to patients and clinicians Resource use and cost

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.

A broad search strategy was used to pull in all studies that examine the diagnosis, surveillance or monitoring of AAAs. This was a 'bulk' search that covered multiple review questions. The reviewer sifted the database to identify all studies that met either of the sets of criteria above, with the full protocols for both questions given in Appendix A.

Frequency of monitoring

The reviewer sifted the database to identify all studies that examined which imaging techniques are most useful when monitoring people with an unruptured AAA to predict risk of rupture. The review was developed with 2 parts: first, a diagnostic review of cross-sectional studies to ascertain the sensitivity and specificity of different approaches (see Table 2), followed by an intervention review of randomised, quasi-randomised and non-randomised controlled trials to which imaging techniques are most acceptable to patients and clinicians, taking into account the safety profiles of the approaches (Table 3).

Imaging techniques for monitoring

The reviewer sifted the database to identify all studies that examined which imaging techniques are most useful when monitoring people with an unruptured AAA to predict risk of rupture. The review was a mixed methods review with 2 parts: first, a diagnostic review of cross-sectional studies to ascertain the sensitivity and specificity of different approaches (see Table 2), followed by an intervention review of randomised, quasi-randomised and non-randomised controlled trials to which imaging techniques are most acceptable to patients and clinicians, taking into account the safety profiles of the approaches (Table 3)

Reasons for exclusion

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 an initial database of 12,786 abstracts, 33 were identified as being potentially relevant. Following full-text review of these articles, none were identified as meeting the criteria for inclusion in this review.

An update search was conducted in December 2017, to identify any studies published during guideline development. The search found 2,598 abstracts; of which, 1 full manuscript was ordered. Upon review of the full manuscript, it was not considered relevant to this review question.

Excluded studies

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

Summary of clinical studies included in the evidence review

No studies met the criteria for inclusion in this review.

Economic evidence

Included studies

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for AAA (see Appendix B). This search returned a total of 5,173 citations. Following review of titles and abstracts for these review questions, the full texts of 10 studies were retrieved for detailed consideration for review question 5 (imaging techniques), but none were retained. The full texts of 4 studies were retrieved for detailed consideration for review question 4 (monitoring frequency). One study met the inclusion criteria and was included. This study is detailed below. Original health economic modelling was not prioritised for either of these review questions.

An update search was conducted in December 2017, to identify any relevant health economic analyses published during guideline development. The search found 814 abstracts; all of which were not considered relevant. 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 F.

Summary of studies included in the economic evidence review

Thompson et al. (2013) compared the cost effectiveness of alternative surveillance strategies, using different surveillance frequencies following the detection of an AAA, with a ‘no screening’ strategy. Men identified as having an AAA of diameter 3.0 to 4.4 cm (‘small’) or 4.5 to 5.4 cm (“medium”) through a screening programme were monitored using surveillance frequencies ranging from 3-monthly to 3-yearly. The authors present a model-based cost–utility analysis. The Markov state-transition model was developed based on a previous model that was developed to analyse the cost effectiveness of population-level screening (Kim et al., 2007). A 30-year (lifetime) time horizon was adopted.

Clinical data were obtained from the previous model (Kim et al., 2007), NAAASP and the authors’ meta-analysis of patient-level data from 18 studies. Service-use data associated with elective and emergency repair of AAA were obtained from the EVAR-1 trial and the National Vascular Database. Costs included screening, surveillance scans, pre-surgical consultation, elective repair (EVAR and open surgery) and emergency repair (open surgery). Unit costs were obtained from NHS Reference Costs, the EVAR-1 trial and the previous screening model. General population age-specific utility values for the UK population were used to estimate QALYs.

Cost–utility results were presented for each surveillance strategy compared with a reference option of the current NAAASP surveillance strategy. Some results were in the south-west quadrant of the cost-effectiveness plane. For ease of interpretation, Table 4 presents deterministic model results rearranged in a conventional incremental format (that is, with each option compared with the next-cheapest non-dominated alternative).

Table 4: Base-case cost–utility results – Thompson et al. (2013)

Strategy AAA size: Recall interval	Incremental		
	Costs (£)	Effects (QALYs)	ICER (£/QALY)
Small AAA: 3 years Medium AAA: 3 months	–	–	–
Small: 2 years Medium: 6 months	£0.33	0.00004	£8,049
Small: 2 years Medium: 3 months	£0.88	0.00006	£14,426
Small: 1 year Medium: 6 months	£1.06	-0.00001	Dominated
Small: 1 year Medium: 3 months	£1.51	0.00007	£41,452

Strategy AAA size: Recall interval	Incremental		
	Costs (£)	**Effects (QALYs)**	**ICER (£/QALY)**
Small: 6 months Medium: 6 months	£1.70	-0.00007	Dominated
Small: 6 months Medium: 3 months	£1.62	0.00008	£276,667

The analysis identifies surveillance of small AAAs every 2 years and surveillance of medium AAAs every 3 months as being the strategy that provides the largest QALY gain while remaining cost-effective, at a value of £20,000 per QALY. This strategy is associated with an ICER of £14,426 per QALY gained compared with the next lowest-cost strategy. Compared with this optimal strategy, the approach that most closely represents current practice, of annual (small) and 3-monthly (medium) surveillance, is associated with an ICER of £41,452 per QALY gained. Annual (small) & 6-monthly (medium) surveillance, and 6-monthly (small and medium) surveillance strategies are both dominated, providing fewer QALYs at a higher overall cost. Deterministic sensitivity analysis showed that results were consistent under various modelling assumptions. Probabilistic sensitivity analysis was not presented.

The authors conclude that extending the interval for recall of men with 3.0 to 4.4 cm AAAs from 1 year to 2 years improves cost-effectiveness, but noted that some uncertainty remains, particularly due to the small absolute differences in expected QALYs and costs between the alternative strategies.

Evidence statements

No clinical evidence was identified for these review questions.

One partially applicable cost–utility analysis with potentially serious limitations suggests that, at a value of £20,000 per QALY gained, the optimal strategy is to monitor 65-year-old men with small (3.0–4.4cm) AAA once every 2 years and men with medium-sized (4.5–5.4cm) AAA once every 3 months. Monitoring men with medium-sized AAA less frequently than once every 3 months provides only small cost savings relative to the QALY losses incurred. Monitoring men with small AAA more frequently than once every 2 years provides only small QALY gains relative to the additional costs incurred. Compared with the optimal approach, the strategy currently adopted for screen-detected men – 1-yearly surveillance for small AAAs and 3-monthly surveillance for medium AAAs – is associated with an ICER of £41,452 per QALY gained. Probabilistic sensitivity analysis was not conducted.

Recommendations

D1. Offer surveillance with aortic ultrasound to people with an asymptomatic AAA:

- every 3 months if the AAA is 4.5–5.4 cm
- every 2 years if the AAA is 3.0–4.4 cm.

D2.See recommendation 1.1.4 on when to refer people to a regional vascular unit.

Research recommendations

RR1. What are the most effective and cost effective frequencies for monitoring people with unruptured AAA of different diameters, and what is the optimal threshold for repair?

Rationale and impact

Why the committee made the recommendations

The committee recommended ultrasound surveillance every 3 months for people with asymptomatic AAAs of 4.5–5.4 cm in diameter because:

- ultrasound is current practice and no evidence was found for other imaging techniques (CT, MRI or wall stress analysis)
- monitoring every 3 months is current practice for people with aneurysms of this size, and there was evidence that this frequency of monitoring offers the best balance between benefits and costs.

The committee recommended ultrasound surveillance every 2 years for people with asymptomatic AAAs of 3–4.4 cm in diameter because:

- ultrasound is current practice and no evidence was found for other imaging techniques (CT, MRI or wall stress analysis)
- the absolute risk of aneurysm rupture is low and so monitoring yearly (which is current practice) offers few benefits over monitoring every 2 years
- monitoring every 2 years offers the best balance between benefits and costs.

Impact of the recommendations on practice

People with small AAAs (3.0–4.4 cm) currently have an aortic ultrasound every year. Changing this to every 2 years should reduce costs to the NHS.

The committee's discussion of the evidence

Interpreting the evidence

The outcomes that matter most

The committee noted that preventing rupture, aneurysm-related mortality and all-cause mortality are important outcomes associated with the treatment of a person with an AAA. The committee noted that condition-specific outcomes (such as the number of ruptures missed by different monitoring intervals) would also provide useful information.

The quality of the evidence

No evidence was identified for the review question designed to explore which imaging techniques should be used to monitor confirmed AAAs. The committee noted that aortic ultrasound is the standard technique by which the size of an AAA will be monitored.

One study was identified for the review question regarding the frequency of monitoring. This was a cost-effectiveness analysis focused on the use of aortic ultrasound, including a meta-analysis of AAA growth and rupture rates.

The committee considered the AAA rupture rates in the cost-effectiveness analysis to be relatively low compared with the current perception of rupture rates in the clinical community. However, the committee discussed and agreed that the rupture rates presented in the study are more likely to reflect clinical reality. The current perception of rupture rates within the

AAA community is likely to have been influenced by early analyses of the MASS trial (Kim et al., 2007), which compares surgery with surveillance and reports rupture rates and mortality across both groups. The committee agreed that current clinical reality is likely to be different from the earlier MASS analyses, with risk factors for AAA and aneurysm rupture now being less prevalent in the general population (in particular due to reductions in the prevalence of smoking and cardiovascular disease and an increase in the use preventative treatments such as statins).

The committee discussed the assumption in the evidence that the quality of life of a person with an AAA is equal to that of the general population. It was noted that this assumption might not be appropriate, as people whose AAA has been repaired may be subject to morbidities and complications in excess of the general population; however, no evidence was presented to confirm this.

The committee agreed that the large sample size of individual patient-level data and its use of UK data were strengths of the analysis. Overall, the committee agreed that although the cost–utility results were subject to some uncertainty – particularly having not included a probabilistic analysis – they are suitable to inform decision-making. In particular, there was confidence that frequent monitoring of small AAA is unlikely to be cost effective, whereas there is greater uncertainty in how often medium-sized AAAs should be monitored.

Benefits and harms

The committee noted that the main risk to people with aneurysms between 3.0 cm and 5.4 cm in diameter who are being monitored for growth, is the risk of rupture. The risk of rupture posed by long intervals between monitoring scans can be avoided by performing more frequent monitoring.

The following risks to people currently being monitored with an AAA were also discussed:

- The impact on people whose small-sized aneurysm is currently monitored at yearly intervals, whose monitoring would be doubled to two years;
- The impact on people whose aneurysm grows from small to medium-sized, and therefore whose monitoring interval is reduced from two years to three months.

The committee recognised that communicating these changes to a person with an AAA would be important to limit their potential anxiety and safeguard their emotional wellbeing.

The committee discussed the risks associated with making a recommendation on monitoring based on aneurysm size alone, particularly when a person with a confirmed AAA may possess risk factors associated with increased aneurysm growth and/or rupture. The committee agreed that, in the absence of any evidence, it was unable to make a recommendation on monitoring intervals based on a patient’s risk profile but noted that clinicians should be aware of additional risk factors in individual patients.

Cost effectiveness and resource use

The only evidence identified for this topic was a modelled cost–utility analysis. This was applicable for the review question regarding the frequency of monitoring AAAs. The committee agreed that the model-based analysis was subject to some uncertainty, but agreed that this was always likely given the lack of randomised, comparative trials in this area. The committee agreed that the large sample size of individual patient-level data and its use of UK data were strengths of the analysis, offsetting its potential limitations somewhat, and making it suitable evidence to inform decision-making. The committee discussed the cost-effectiveness results, and noted that monitoring small-sized aneurysms once every 2 years, and medium-sized aneurysms once every 3 months, appears to be the most effective use of resources. The committee noted that this diverges from current practice for monitoring screen-detected AAA, and is estimated to produce a very small loss of quality-adjusted life-years compared to the status quo. However, the committee agreed that, even though the results were subject to some uncertainty, it is reasonably clear that monitoring small-sized aneurysms on a frequent basis is unlikely to be an effective use of resources – that is, the costs saved by monitoring less frequently would produce greater QALY gains if invested elsewhere in the NHS. The committee were mindful of the importance of cost-effective recommendations. Given the very small absolute risk of AAA rupture, it was agreed that the evidence presented was sufficient to recommend a longer surveillance interval than is currently used for people with small aneurysms.

Other factors the committee took into account

The committee focused part of their discussion around specific surveillance intervals for women, after noting that the data suggest there may be a higher risk of AAA rupture in women. The committee noted that the results of the economic model presented were not sensitive to AAA rupture rates, and therefore believed that the same recommendation was appropriate for men and women.

Appendices

Appendix A – Review protocols

Review protocol for review question 4: Most effective frequency of monitoring

Review question 4	**What are the most effective frequencies for monitoring people with an unruptured abdominal aortic aneurysm of different diameters for signs of aneurysm expansion and risk of rupture?**
Objectives	To determine appropriate intervals for surveillance of people with abdominal aortic aneurysms; that is, how frequently people should be monitored for signs of aneurysm expansion and risk of rupture to control – to acceptable levels – both the risk of rupture and the risk of growth to a size where surgery is indicated
Type of review	i) Intervention ii) Epidemiological
Language	English only
Study design	i) Systematic reviews of study designs listed below Randomised controlled trials Quasi-randomised controlled trials ii) UK registry data (National Abdominal Aortic Aneurysm Screening Programme)
Status	Published papers only (full text) No date restrictions
Population	People with a confirmed unruptured abdominal aortic aneurysm Subgroups: by aneurysm diameter, sex, ethnicity, comorbidities
Intervention (for i only)	Scans at intervals other than: a) Scan every year (abdominal aortic aneurysm >3cm to <4.5cm in diameter) b) Scan every 3 months (abdominal aortic aneurysm ≥4.5cm to <5.5cm in diameter)
Comparator (for i only)	Current practice (NAAASP) a) Scan every year (abdominal aortic aneurysm >3cm to <4.5cm in diameter) b) Scan every 3 months (abdominal aortic aneurysm ≥4.5cm to <5.5cm in diameter)
Outcomes	i) AAA rupture Unplanned (non-elective/emergency) repair of an abdominal aortic aneurysm surgery in relation to (referral for) elective surgery Mortality; survival Acceptability to patients Resource use and cost ii) Abdominal aortic aneurysm expansion Abdominal aortic aneurysm rupture Unplanned (emergency or non-elective) repair
Other criteria for inclusion / exclusion of studies	Exclusion: Non-English language Abstract/non-published (i only)

Review question 4	What are the most effective frequencies for monitoring people with an unruptured abdominal aortic aneurysm of different diameters for signs of aneurysm expansion and risk of rupture?
Baseline characteristics to be extracted in evidence tables	Age Sex Size of aneurysm Comorbidities
Search strategies	See Appendix B
Review strategies	i) 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. ii) Expert witnesses will attend a Committee meeting to answer questions from members of the Committee. They will be invited to present their evidence at a Committee meeting in the form of expert testimony based on a written paper. The Developer will write up the expert testimony and agree this with the witness after the meeting. i and ii) All key findings will be summarised in evidence statements.

Review protocol for review question 5: Imaging techniques for monitoring people with an unruptured abdominal aortic aneurysm to predict risk of rupture

Review question 5	Which imaging techniques are most useful when monitoring people with an unruptured abdominal aortic aneurysm to predict risk of rupture?
Objectives	To determine which imaging technique is most accurate in predicting risk of rupture in people with abdominal aortic aneurysm To determine which imaging techniques are most acceptable to patients and clinicians, taking into account the safety profiles of the approaches
Type of review	i) Diagnostic ii) Intervention
Language	English only
Study design	i) Systematic reviews of study designs listed below Cross-sectional studies ii) Systematic reviews of study designs listed below Randomised controlled trials Quasi-randomised controlled trials Non-randomised
Status	Published papers only (full text) No date restrictions
Population	People with a confirmed abdominal aortic aneurysm >3cm in diameter
i) Index tests ii) Interventions and comparators	Ultrasound (different approaches to measurement: from where to where?) CT MRI Wall stress analysis, including finite element analysis (FEA)

<table>
<tr><th>Review question 5</th><th>Which imaging techniques are most useful when monitoring people with an unruptured abdominal aortic aneurysm to predict risk of rupture?</th></tr>
<tr><td>Reference standard</td><td>Surgical confirmation alone, including post-mortem, of rupture during follow-up (preferred evidence)
CT and/or surgical confirmation, including post-mortem, of rupture during follow-up (it is likely that this will be considered lower quality – unless CT has 100% agreement with surgical confirmation, in which case it will be pooled in a single analysis with the data that uses surgical confirmation alone as the reference standard – and therefore given lower weight in the decision-making)</td></tr>
<tr><td>Outcomes</td><td>i) Diagnostic accuracy (sensitivity and specificity)
ii) Adverse events
Downstream effects, mortality (all-cause, aneurysm-related), rupture, surgical repair for asymptomatic, symptomatic and ruptured aneurysms
i and ii) Acceptability of approach to patients and clinicians
Resource use and cost</td></tr>
<tr><td>Other criteria for inclusion / exclusion of studies</td><td>Exclusion:
Non-English language
Abstract/non-published
Diagnostic accuracy measures for which both sensitivity and specificity are not available/ cannot be calculated
Publication before the year 2000</td></tr>
<tr><td>Baseline characteristics to be extracted in evidence tables</td><td>Age
Sex
Size of aneurysm
Position of aneurysm
Comorbidities
BMI/obesity/weight</td></tr>
<tr><td>Search strategies</td><td>See Appendix B</td></tr>
<tr><td>Review strategies</td><td>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.
<table>
<tr><th>Analysis</th><th>Reference standard</th><th>Index tests</th></tr>
<tr><td>1</td><td>Surgical confirmation alone</td><td>Ultrasound
X-ray
Aortography
CT
MRI
Angiography
Wall stress analysis
FEA</td></tr>
<tr><td>2</td><td>CT alone or in combination with surgical confirmation</td><td>Ultrasound
X-ray
Aortography
MRI
Angiography</td></tr>
</table>
</td></tr>
</table>

Review question 5	**Which imaging techniques are most useful when monitoring people with an unruptured abdominal aortic aneurysm to predict risk of rupture?**		
			Wall stress analysis FEA
	All key findings from evidence will be presented in GRADE profiles and further summarised in evidence statements		

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 questions 4 and 5

Medline Strategy, searched 13th April 2016 **Database: Ovid MEDLINE(R) 1946 to March Week 5 2016** **Search Strategy:**	
1	Aortic Aneurysm, Abdominal/
2	(aneurysm* adj4 (abdom* or thoracoabdom* or thoraco-abdom* or aort* or spontan* or juxtarenal* or juxta-renal* or juxta renal* or paraerenal* 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.
3	Aortic Rupture/
4	(AAA or RAAA).tw.
5	(endovascular* adj4 aneurysm* adj4 repair*).tw.
6	(endovascular* adj4 aort* adj4 repair*).tw.
7	(EVAR or EVRAR or FEVAR or F-EAVAR or BEVAR or B-EVAR).tw.
8	(Anaconda or Zenith Dynalink or Hemobahn or Luminex* or Memoth-erm or Wallstent).tw.

Medline Strategy, searched 13th April 2016 **Database: Ovid MEDLINE(R) 1946 to March Week 5 2016** **Search Strategy:**
9 (Viabahn or Nitinol or Hemobahn or Intracoil or Tantalum).tw. 10 or/1-9 11 X-Rays/ 12 (x-ray* or x ray* or xray* or x-radiation* or x radiation* or roentgen ray* or grenz ray* or radiograph*).tw. 13 Aortography/ 14 aortograph*.tw. 15 Tomography, X-Ray Computed/ (16 (cat scan* or ct scan* or cine ct or cine-ct or tomodensitomet*).tw. 17 ((computed or computer assisted or computeriz* or computeris* or electron beam* or axial*) adj4 tomograph*).tw. 18 Four-Dimensional Computed Tomography/ 19 (4d ct or 4dct or 4-dimensional CT or four dimensional CT).tw. 20 exp Tomography, Spiral Computed/ 21 ((helical or spiral) adj4 ct*).tw. 22 exp Magnetic Resonance Imaging/ 23 (nmr tomograph* or mr tomograph* or nmr imag* or mri scan* or functional mri* or fmri* or zeugmatograph* or cine-mri* or cinemri*).tw. 24 (proton spin adj4 tomograph*).tw. 25 ((chemical shift or magnetic resonance or magneti* transfer) adj4 imag*).tw. 26 exp Angiography/ 27 (angiograph* or arteriograph*).tw. 28 exp Ultrasonography/ 29 (ultrasound* or ultrason* or sonograph* or echograph* or echotomograph*).tw. 30 exp Echocardiography/ 31 echocardiograph*.tw. 32 Finite element analysis/ 33 (finite adj4 element* adj4 analys*).tw. 34 (finite adj4 element* adj4 comput*).tw. 35 FEA.tw. 36 ((wall adj4 stress adj4 analys*) or (wall adj4 stress adj4 comput*)).tw. 37 exp Computer simulation/ 38 Software/ 39 Image interpretation, computer-assisted/ or Radiographic image interpretation, computer-assisted/ 40 Imaging Three-Dimensional/ 41 exp Image enhancement/ 42 Stress, mechanical/ 43 (stress* adj4 mechanical*).tw. 44 (scan* or imag*).tw. 45 Watchful waiting/ 46 (watchful adj4 waiting*).tw. 47 Mass screening/ 48 screen*.tw.

Medline Strategy, searched 13th April 2016
Database: Ovid MEDLINE(R) 1946 to March Week 5 2016
Search Strategy:

49 Population surveillance/
50 surveillan*.tw.
51 ((period* or test* or frequen* or regular* or routine* or rate or optimal* or optimis* or optimiz* or repeat* or interval*) adj4 (test* or monitor* or observ* or measur* or assess* or screen* or re-screen* or rescreen* or exam* or evaluat*)).tw.
52 ((aneursym* or sign* or diameter or risk*) adj4 (grow* or siz* or measur* or expan* or ruptur* or tear* or progress* or enlarg* or dilat* or bulg* or evaluat*)).tw.
53 Patient Selection/
54 ((patient or subject or criteria or treatment*) adj4 select*).tw.
55 ((follow-up or follow up) adj4 (visit* or repeat* or monitor* or assess* or care*)).tw.
56 Aftercare/
57 (aftercare or after-care).tw.
58 Disease progression/
59 ((disease or illness or condition) adj4 (progress* or worsen* or exacerbat* or deterior* or course or duration or trajector* or improv* or recur* or relaps* or remission)).tw.
60 or/11-59
61 10 and 60
62 animals/ not humans/
63 61 not 62
64 limit 63 to english language

Note: RCT, Systematic Review and Observational study filters appended to strategy.

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

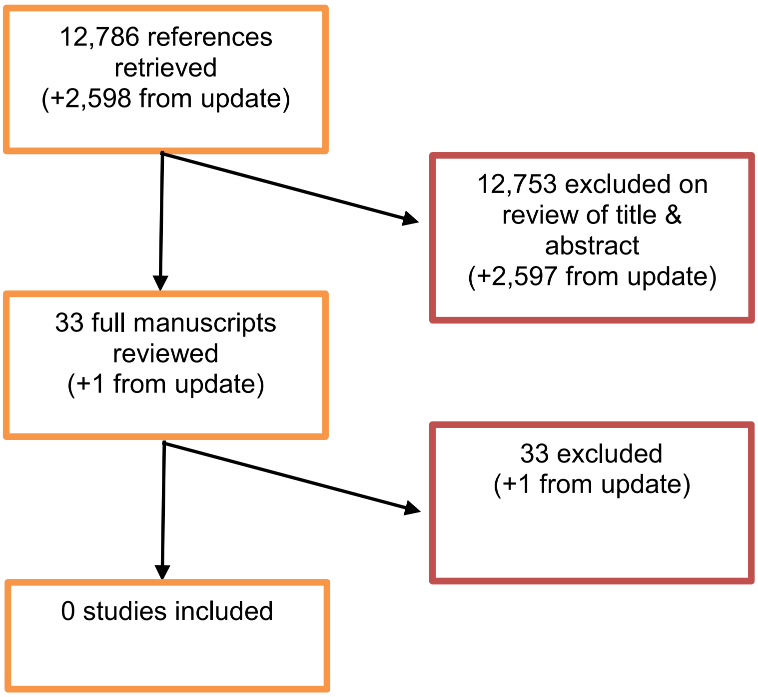
Economic evaluations
1 Economics/
2 exp "Costs and Cost Analysis"/

Medline Strategy
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. 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.

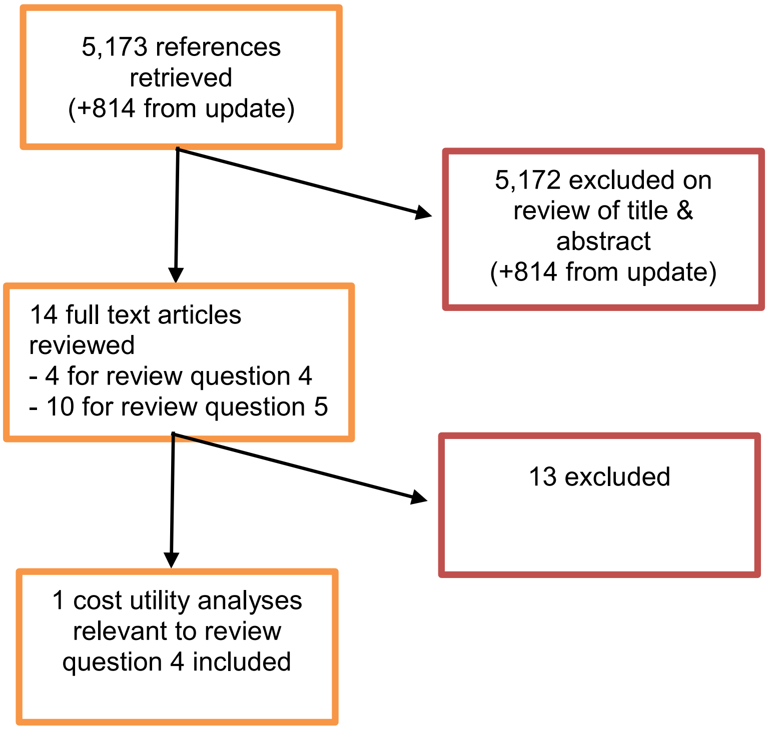
Medline Strategy	
16	(qol or hql or hqol or hrqol).tw.
17	(hye or hyes).tw.
18	health* year* equivalent*.tw.
19	utilit*.tw.
20	(hui or hui1 or hui2 or hui3).tw.
21	disutili*.tw.
22	rosser.tw.
23	quality of wellbeing.tw.
24	quality of well-being.tw.
25	qwb.tw.
26	willingness to pay.tw.
27	standard gamble*.tw.
28	time trade off.tw.
29	time tradeoff.tw.
30	tto.tw.
31	or/1-30

Appendix C – Clinical evidence study selection

Review questions 4 & 5 study selection



Appendix D – Economic evidence study selection



Appendix E – Economic evidence tables

Study, population, country and quality	Data sources	Other comments	Strategy	Incremental			Conclusions	Uncertainty
				Cost	Effect	ICER		
Thompson et al., 2013 [a] Men screened as having an AAA of diameter 3.0—4.4 cm (small) to 4.5–5.4 cm (medium). **Partially applicable** [a] **Potentially serious limitations** [b, c, d, e]	Effects: AAA clinical parameters from Multicentre Aneurysm Screening Study (2007), NAAASP and analysis of IPD from 18 studies (N=15,475). All-cause mortality from ONS. Costs: Resource use for operation length and hospital stay from National Vascular Database (2012). Unit costs from NHS Reference Costs. Residual costs from EVAR1 and MASS trials inflated using PSSRU. Repair by OSR only. £2010-11. Utilities: Population norm utilities only.	Model is based on a screening model (MASS), adapted to compare different surveillance strategies. All strategies are compared with screening; differences are then compared with each other. 30-year time horizon, with 3-month transition probabilities estimated from the IPD (mean follow-up: 0.92 to 8.59 years).	Reference strategy (lowest cost): Small AAA (3.0–4.4cm): 3-year interval. Medium AAA (4.5–5.4cm): 3-month interval.				'Lengthening the surveillance interval for aneurysms of 4.5–5.4 cm reduces net monetary benefit.' 'Increasing the interval for recall of men with aneurysms between 3.0 and 4.4 cm from 1 year to 2 years improves cost-effectiveness. Increasing it further to 3 years worsens cost-effectiveness.'	One-way sensitivity analyses were conducted: • AAA growth and rupture rates from UK population data; • AAA growth rates ±10%; • AAA rupture rates ±30%; • Alternative dropout and mortality rates; • Alternative cost inputs. 'Strategy C' (2 years, 3 months) was always cost-effective. No probabilistic sensitivity analysis. Unable to estimate correlated uncertainty around the 480 AAA growth and rupture rates derived from IPD meta-analysis.
			S: 2 years M: 6 mos.	£0.33	0.00004	£8,049		
			S: 2 years M: 3 mos.	£0.88	0.00006	£14,426		
			S: 1 year M: 6 mos.	£1.06	-0.00001	Dominated		
			S: 1 year M: 3 mos.	£1.51	0.00007	£41,452		
			S: 6 mos. M: 6 mos.	£1.70	-0.00007	Dominated		
			S: 6 mos. M: 3 mos.	£1.62	0.00008	£276,667		

a Populations other than screen-detected 65-year-old men were not considered.
b Relevant outcomes may have been omitted as patient quality-of-life is informed by population norms, with no differential associated with AAA or surgery.

Study, population, country and quality	Data sources	Other comments	Strategy	Incremental			Conclusions	Uncertainty
				Cost	Effect	ICER		

[c] The recalibration exercise, performed to make model outputs consistent with the observed data, appears to have failed in a number of key events, with notable differences in 10-year emergency operations and AAA-related deaths. The exercise appears to have focused on achieving incremental outputs and ICER results consistent with the observed data, rather than absolute outputs. Recalibration methods are not provided in sufficient detail.

[d] All comparisons between surveillance strategies are presented through comparing the incremental results of each strategy vs. a 'no screening' control arm. Absolute QALY results are not reported therefore a full incremental analysis can only be estimated using the incremental results vs 'no screening'.

[e] Probabilistic sensitivity analysis was not conducted.

Appendix F – Excluded studies

Clinical studies

Short Title	Title	Reason for exclusion
Bargellini (2005)	Type II lumbar endoleaks: hemodynamic differentiation by contrast-enhanced ultrasound scanning and influence on aneurysm enlargement after endovascular aneurysm repair	No relevant outcomes reported
Bengtsson (1993)	Natural history of abdominal aortic aneurysm detected by screening	Not a relevant intervention and/or comparator Published before 2000 or systematic review containing only papers published before 2000
Bihari (2013)	Strain measurement of abdominal aortic aneurysm with real-time 3D ultrasound speckle tracking	Not a relevant study design
Bonnard (2014)	Abdominal aortic aneurysms targeted by functionalized polysaccharide microparticles: a new tool for SPECT imaging	Not a relevant intervention and/or comparator Not a relevant study design
Boules (2006)	Can computed tomography scan findings predict "impending" aneurysm rupture?	Not a relevant intervention and/or comparator Not a relevant study design
Bown (2013)	Surveillance intervals for small abdominal aortic aneurysms: A meta-analysis	Not a relevant study design
Brady (2004)	Abdominal aortic aneurysm expansion: risk factors and time intervals for surveillance	Not a relevant study design
Bredahl (2013)	Reproducibility of ECG-gated ultrasound diameter assessment of small abdominal aortic aneurysms	Not a relevant intervention and/or comparator
Brekken (2006)	Strain estimation in abdominal aortic aneurysms from 2-D ultrasound	Not a relevant study design
Buijs (2013)	Current state of experimental imaging modalities for risk assessment of abdominal aortic aneurysm	Not a relevant study design
Callanan (2012)	Finite element and photoelastic modelling of an abdominal aortic aneurysm: a comparative study	Not a relevant study design
Canchi (2015)	A Review of Computational Methods to Predict the Risk of Rupture of Abdominal Aortic Aneurysms	Not a relevant study design

Short Title	Title	Reason for exclusion
Cook (1996)	A prospective study to define the optimum rescreening interval for small abdominal aortic aneurysm	Article not available
Courtois (2014)	Gene expression study in positron emission tomography-positive abdominal aortic aneurysms identifies CCL18 as a potential biomarker for rupture risk	Not a relevant intervention and/or comparator
Couto (2002)	Probabilities of progression of aortic aneurysms: estimates and implications for screening policy	Not a relevant study design
Erhart (2014)	Finite element analysis of abdominal aortic aneurysms: predicted rupture risk correlates with aortic wall histology in individual patients	Not a relevant intervention and/or comparator
Fillinger (2003)	Prediction of rupture risk in abdominal aortic aneurysm during observation: wall stress versus diameter	Not a relevant intervention and/or comparator
Forsythe (2017)	Magnetic resonance imaging using ultrasmall superparamagnetic particles of iron oxide in patients under surveillance for abdominal aortic aneurysms to predict rupture or surgical repair: the MA3RS study	Conference proceeding.
Ganten (2008)	Quantification of aortic distensibility in abdominal aortic aneurysm using ECG-gated multi-detector computed tomography	Not a relevant intervention and/or comparator
Gibbs (2010)	The ectatic aorta: no benefit in surveillance	Not a relevant intervention and/or comparator
Heng (2008)	Peak wall stress measurement in elective and acute abdominal aortic aneurysms	Not a relevant intervention and/or comparator
Hua (2001)	Simple geometric characteristics fail to reliably predict abdominal aortic aneurysm wall stresses	Not a relevant intervention and/or comparator
Khan (2015)	Assessing the potential risk of rupture of abdominal aortic aneurysms	Not a relevant study design
Khosla (2014)	Meta-analysis of peak wall stress in ruptured, symptomatic and intact abdominal aortic aneurysms (Provisional abstract)	Not a relevant study design
Kita (1993)	Abdominal aortic aneurysm and risk of rupture	Published before 2000 or systematic review containing only papers published before 2000

Short Title	Title	Reason for exclusion
Kok (2015)	Feasibility of wall stress analysis of abdominal aortic aneurysms using three-dimensional ultrasound	No relevant outcomes reported
Larsson (2011)	Analysis of aortic wall stress and rupture risk in patients with abdominal aortic aneurysm with a gender perspective	Not a relevant study design
Lindholt (2000)	Optimal interval screening and surveillance of abdominal aortic aneurysms	Not a relevant study design
Lindholt (2001)	[Optimal interval screening and observation of abdominal aortic aneurysms]	Not in English
Maier (2010)	A comparison of diameter, wall stress, and rupture potential index for abdominal aortic aneurysm rupture risk prediction	Not a relevant study design
McBride (2015)	MRI using ultrasmall superparamagnetic particles of iron oxide in patients under surveillance for abdominal aortic aneurysms to predict rupture or surgical repair: MRI for abdominal aortic aneurysms to predict rupture or surgery-the MA(3)RS study	No relevant outcomes reported Not a peer-reviewed publication
Merkx (2009)	Importance of initial stress for abdominal aortic aneurysm wall motion: dynamic MRI validated finite element analysis	Not a relevant study design
Powell (2013)	Should the frequency of surveillance for small abdominal aortic aneurysms be reduced?	Not a relevant study design
Shang (2015)	Local wall thickness in finite element models improves prediction of abdominal aortic aneurysm growth	Not a relevant intervention and/or comparator

Economic studies

Short Title	Title	Reason for exclusion
Bierig (2009)	Accuracy and cost comparison of ultrasound versus alternative imaging modalities, including CT, MR, PET, and angiography	Review article, no additional CUAs
Bluth (1996)	Ultrasonic evaluation of the abdominal aorta	Not a CUA
Campbell (2007)	The credibility of health economic models for health policy decision-making: the case of population screening for abdominal aortic aneurysm	Review article, no additional CUAs

Short Title	Title	Reason for exclusion
Connelly (2002)	The detection and management of abdominal aortic aneurysm: a cost-effectiveness analysis	Not a relevant intervention and/or comparator
Frame (1993)	Screening for abdominal aortic aneurysm in men ages 60 to 80 years. A cost-effectiveness analysis	Not a CUA
Hassan (2008)	Computed tomographic colonography to screen for colorectal cancer, extracolonic cancer, and aortic aneurysm: model simulation with cost-effectiveness analysis	Not a CUA
Health Quality Ontario (2006)	Ultrasound screening for abdominal aortic aneurysm: an evidence-based analysis	Review article, no additional CUAs
Lee (2002)	The cost-effectiveness of a "quick-screen" program for abdominal aortic aneurysms	Not a relevant intervention and/or comparator
Pickhardt (2008)	Computed tomographic colonography to screen for colorectal cancer, extracolonic cancer, and aortic aneurysm: model simulation with cost-effectiveness analysis	Not a CUA
Russell (1990)	Is screening for abdominal aortic aneurysm worthwhile?	Not a CUA
Sogaard (2012)	Cost effectiveness of abdominal aortic aneurysm screening and rescreening in men in a modern context: evaluation of a hypothetical cohort using a decision analytical model	Not a relevant intervention and/or comparator
Stather (2013)	International variations in AAA screening	Review article, no additional CUAs
Thanos (2008)	Vascular ultrasound screening for asymptomatic abdominal aortic aneurysm	Not a CUA

Appendix G – Research recommendation

Research recommendation	**What are the most effective and cost effective frequencies for monitoring people with unruptured abdominal aortic aneurysms (AAA) of different diameters, and what is the optimal threshold for repair?**
Population	People with a confirmed unruptured abdominal aortic aneurysm • Stratified by: aneurysm diameter, sex, ethnicity & comorbidities
Intervention(s)	Varying intervals of monitoring • For example: 3 month. 6 month, 1 year and 2 year intervals
Comparator(s)	Each other
Outcome(s)	1. AAA rupture • Unplanned (non-elective/emergency) repair of an abdominal aortic aneurysm surgery in relation to (referral for) elective surgery • Mortality; survival • Acceptability to patients • Resource use and cost 2. Abdominal aortic aneurysm expansion • Abdominal aortic aneurysm rupture • Unplanned (emergency or non-elective) repair
Study	Systematic review and modelling

Potential criterion	**Explanation**
Importance to patients, service users or the population	More frequent monitoring increases the chances of identifying aneurysms that have grown large enough to need repair. However, monitoring requires resources and the absolute risk of AAA rupture is relatively low, so there are opportunity costs to consider. Effective planning is important to maximise surgical outcomes and to ensure that the greatest benefit is obtained for the person with an AAA whilst posing the least potential harm. It is important to establish how often aneurysms should be monitored to keep the risk of rupture as low as possible while making the best use of NHS resources
Relevance to NICE guidance	High priority: the research would fill notable gaps in the evidence base as no risk models dedicated to postoperative surveillance are currently available.
Current evidence base	Literature searches found no clinical studies and only 1 cost-utility analysis that assessed the cost effectiveness of different frequencies for monitoring people with unruptured AAA. The study was considered partially applicable with potentially serious limitations. Authors reported that, at a value of £20,000 per QALY gained, the optimal strategy is to monitor small (3.0–4.4cm) AAAs once every 2 years and medium-sized (4.5–5.4cm) AAAs once every 3 months. Monitoring medium-sized AAAs less frequently than once every 3 months provides only small cost savings relative to the QALY losses incurred. Monitoring small AAAs more frequently than once every 2 years provides only small QALY gains relative to the additional costs incurred. Compared with the optimal approach, the strategy currently adopted – 1-yearly surveillance for small AAAs and 3-monthly surveillance for medium AAAs – is associated with an ICER of £41,452 per QALY gained. Probabilistic sensitivity analysis was not conducted, and populations other than screen-detected 65-year-old men were not considered. Overall, the committee considered that more, directly-

Potential criterion	Explanation
	applicable evidence would be useful in informing future guideline recommendations.
Equality	No specific equality concerns are relevant to this research recommendation.
Feasibility	There is a sufficiently large and well defined population available that systematic reviews and health economic modelling, using high-quality evidence should be feasible.

Appendix H – 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.