National Institute for Health and Care Excellence

Abdominal aortic aneurysm: diagnosis and management

Evidence review H: Risk assessment tools for predicting surgical outcomes of patients who undergo elective abdominal aortic aneursym repair

NICE guideline <number>

Evidence reviews

May 2018

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5 Review question

6 7 What is the accuracy of available risk assessment tools in predicting poor and good surgical outcomes in people with unruptured abdominal aortic aneurysms?

8 Introduction

9 10 11 12 13 14 Various multifactorial risk models have been developed that aim to facilitate decision making before abdominal aortic aneurysm (AAA) repair; however, there is no consensus as to which tools should be used and when they should be used. This review question aims to determine which assessment tools are accurate in predicting surgical outcomes after elective AAA repair and might therefore inform patients in their decision to undergo surgery for an unruptured AAAs.

15 PICO table

16 **Table 1: Inclusion criteria**

Parameter	Inclusion criteria
Population	People who are being assessed for surgery for a confirmed unruptured AAA • Subgroups: by type of surgery
Assessment tools	• Vascular Study Group of New England Cardiac Risk Index (VSG-CRI) • Revised Cardiac Risk Index • British Aneurysm Repair (BAR) Score • Vascular Governance North West P Logistic risk model for mortality following elective AAA repair • Medicare risk prediction for perioperative mortality during AAA repair • Glasgow Aneurysm Scale (GAS) • POSSUM prediction models, including V-POSSUM score • Modified Customised Probability Index (m-CPI) • Customised Probability Index (CPI) • Surgical Risk Scale • Vascular Biochemistry and Haematology Outcome Models (VBHOM) • Estimation of Physiologic Ability and Surgical Stress (E-PASS) • EVAR Risk Assessment (ERA) model, also known as the 'Australasian model' • Co-morbidity Severity Score of the Society for Vascular Surgery and the American Association for Vascular Surgery (SVS/AAVS co-morbidity score) • Leiden/modified Leiden score • (John) Carlisle Calculator • Eagle score

Parameter	Inclusion criteria
	• Vanzetto score • George's score (aneurysm risk score)
Endpoints	• Mortality • Peri- and post-operative complications • Successful exclusion of the aneurysm, aneurysm rupture, or further aneurysm growth • Need for reintervention • Quality of life • Resource use, including length of hospital or intensive care stay, and costs

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 single broad search was used to identify all studies that examine the diagnosis, surveillance or monitoring of AAAs. This was a 'bulk' search that covered multiple review questions. The database was sifted to identify all studies that met the criteria detailed in Table 1. The relevant review protocol can be found in Appendix A.

Cohort studies in which multivariate models were used to assess the accuracy of risk assessment tools (risk prediction models) for predicting peri- and postoperative outcomes of patients undergoing EVAR or open repair procedures were considered for inclusion. Prospective and retrospective cohort studies with sample sizes greater than 500 participants were included.

The included studies all reported the area under the curve (AUC) of receiver operating characteristic (ROC) curves for each model. A ROC curve plots the sensitivity of a model against its specificity across the full range of possible thresholds scores. Accuracy, in terms of being able to discriminate between cases and non-cases, is then measured by the AUC. The committee interpreted AUCs in accordance with thresholds suggested by Hosmer and Lemeshow (2000). An AUC of 1 represents a perfect prediction while an area of 0.5 represents a worthless prediction (equivalent to 'chance'). An AUC below 0.7 and above 0.5 indicates that a model has poor discriminatory power. An AUC of 0.7 to 0.79 indicates acceptable model discrimination; values of 0.8 to 0.89 indicate excellent discrimination, and values greater than 0.9 indicate outstanding discrimination (Hosmer 2000).

It was not appropriate to pool AUCs from identified studies due to dissimilar definitions of outcome, factors, and mix of confounders between studies. Where a model was examined in two or more studies, we have reported the individual AUC with 95% CIs reported by each study, and a summary median and range of AUCs for the study sample. Where a model was examined in a single study we have reported the AUC with the reported 95% CIs.

Studies were excluded if they:

• were case-control or cross-sectional studies

• were not in English

• were not full reports of the study (for example, published only as an abstract)

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50 - were not peer-reviewed.

Clinical evidence

Included studies

From an initial database of 16,274 abstracts, 66 were identified as being potentially relevant.
Following full-text review of these articles, 10 studies were included. These included 4
prospective cohort studies and 6 retrospective cohort studies.

An update literature search was performed and provided by Cochrane, in December 2017.
The search found a total of 2,180 abstracts; of which, 5 full manuscripts were ordered. Upon
review of the full manuscripts, none of the studies met the inclusion criteria for this review
question.

Excluded studies

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

Summary of clinical studies included in the evidence review

Table 2: Included studies

Study	Details
Ambler Graeme K, Gohel Manjit S, Mitchell David C, Loftus Ian M, Boyle Jonathan R, Audit , Quality Improvement Committee of the Vascular Society of Great, Britain , and Ireland (2015) The Abdominal Aortic Aneurysm Statistically Corrected Operative Risk Evaluation (AAA SCORE) for predicting mortality after open and endovascular interventions. Journal of vascular surgery 61(1), 35-43	Study design: retrospective cohort study Location(s): UK Population: patients who underwent elective EVAR or open repair Sample size: 2,694 Outcome: in-hospital mortality Risk assessment tool(s): Vascular Biochemical and Haematological Outcome Model (VBHOM), Physiological and Operative Severity Score for enUmeration of Mortality (POSSUM), Vascular Governance North West (VGNW) risk model for mortality, and the Medicare risk prediction tool
Biancari F, Heikkinen M, Lepantalo M, and Salenius J P (2003) Glasgow Aneurysm Score in patients undergoing elective open repair of abdominal aortic aneurysm: A Finnvasc study. European Journal of Vascular and Endovascular Surgery 26(6), 612-617	Study design: retrospective cohort study Location(s): Finland, Netherlands, and UK Population: patients who underwent elective open repair of AAA Sample size: 1,911 Outcome: 30-day mortality, severe complications, cardiac complications ICU stay longer than 5 days Risk assessment tool(s): GAS
Biancari F, Hobo R, and Juvonen T (2006) Glasgow Aneurysm Score predicts survival after endovascular stenting of abdominal aortic aneurysm in patients from the EUROSTAR registry. The British journal of surgery 93(2), 191-4	Study design: retrospective cohort study Location(s): Finland, Netherlands, and UK Population: patients who underwent elective EVAR of aneurysms greater than 4.0 cm in diameter Sample size: 5,498 Outcome: 30-day mortality Risk assessment tool(s): GAS

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Study	Details
Choke E, Lee K, McCarthy M, Nasim A, Naylor A R, Bown M, and Sayers R (2012) Risk models for mortality following elective open and endovascular abdominal aortic aneurysm repair: A single institution experience. European Journal of Vascular and Endovascular Surgery 44(6), 549-554	Study design: prospective cohort study Location(s): UK Population: patients undergoing elective EVAR or open repair Sample size: 1,153 Outcome: The primary end point was the composite of 30-day and in-hospital death Risk assessment tool(s): Medicare risk prediction tool, VGNW risk model and GAS
Eslami Mohammad H, Rybin Denis, Doros Gheorghe, Kalish Jeffrey A, Farber Alik, Vascular Study Group of New, and England (2015) Comparison of a Vascular Study Group of New England risk prediction model with established risk prediction models of in-hospital mortality after elective abdominal aortic aneurysm repair. Journal of vascular surgery 62(5), 1125-33.e2	Study design: retrospective cohort study Location(s): UK Population: patients who underwent elective EVAR or open repair Sample size: 4,431 Outcome: in-hospital mortality Risk assessment tool(s): Medicare risk assessment tool, VGNW risk model and GAS
Faizer Rumi, DeRose Guy, Lawlor D Kirk, Harris Kenneth A, and Forbes Thomas L (2007) Objective scoring systems of medical risk: a clinical tool for selecting patients for open or endovascular abdominal aortic aneurysm repair. Journal of vascular surgery 45(6), 1102-1108	Study design: retrospective cohort study Location(s): Canada Population: patients who underwent elective EVAR or open repair Sample size: 862 Outcome: 30-day mortality Risk assessment tool(s): GAS, Leiden Scoring System, and Comorbidity Severity Score (CSS)
Giles Kristina A, Schermerhorn Marc L, O'Malley A James, Cotterill Philip, Jhaveri Ami, Pomposelli Frank B, and Landon Bruce E (2009) Risk prediction for perioperative mortality of endovascular vs open repair of abdominal aortic aneurysms using the Medicare population. Journal of vascular surgery 50(2), 256-62	Study design: retrospective cohort study Location(s): USA Population: patients older than 67 years, with at least 2 years of prior medical claims, who underwent elective EVAR or open repair Sample size: 22,860 Outcome: the primary endpoint was the composite of 30-day and in-hospital mortality Risk assessment tool(s): Medicare risk prediction tool
Grant S W, Grayson A D, Purkayastha D, Wilson S D, McCollum C, participants in the Vascular Governance North West, and Programme (2011) Logistic risk model for mortality following elective abdominal aortic aneurysm repair. The British journal of surgery 98(5), 652-8	Study design: prospective cohort study Location(s): UK Population: patients undergoing elective EVAR or open repair of AAA Sample size: 1,936 Outcome: 30-day mortality Risk assessment tool(s): VGNW risk model
Grant S W, Grayson A D, Mitchell D C, and McCollum C N (2012) Evaluation of five risk prediction models for elective abdominal aortic aneurysm repair using the UK	Study design: prospective cohort study Location(s): UK Population: patients undergoing elective EVAR or open repair

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Study	Details
National Vascular Database. The British journal of surgery 99(5), 673-9	Sample size: 10,891 Outcome: in-hospital mortality Risk assessment tool(s): Medicare risk prediction tool, VGNW risk model, GAS, VBHOM, Vascular-POSSUM (V-POSSUM)
Grant S W, Hickey G L, Carlson E D, and McCollum C N (2014) Comparison of three contemporary risk scores for mortality following elective abdominal aortic aneurysm repair. European Journal of Vascular and Endovascular Surgery 48(1), 38-44	Study design: prospective cohort study Location(s): UK Population: patients undergoing elective EVAR or open repair Sample size: 1,124 Outcome: in-hospital mortality Risk assessment tool(s): Medicare risk prediction tool and VGNW risk model for mortality

64   See Appendix D for full evidence tables.

65 Quality assessment of clinical studies included in the evidence review

66   The GRADE working group has not published criteria for assessing imprecision in relation to
67   AUC statistics. For the current review, the AUC classification categories referred to above
68   were used. Minimal important difference (MID) levels of 0.7 and 0.8 were chosen for the
69   assessment of imprecision, to be applied to the range of AUCs reported across contributing
70   studies (or to the 95% confidence interval where a model was evaluated by a single study).
71   When evidence on the prognostic utility of a risk assessment tool was obtained from a single
72   study, the evidence was downgraded one level if the 95% CI around an AUC crossed one
73   MID (0.7 or 0.8), or two levels if the 95% CI crossed both MIDs. When evidence on the
74   prognostic utility of a risk assessment tool was obtained from more than one study, the
75   evidence was downgraded one level if the AUC range crossed one MID (0.7 or 0.8), or two
76   levels if the AUC range crossed both MIDs.

77   See Appendix E for full modified GRADE tables.

78 Economic evidence

79 Included studies

80   A literature search was conducted jointly for all review questions by applying standard health
81   economic filters to a clinical search for AAA. This search returned a total of 5,173 citations.
82   Following review of all titles and abstracts, no studies were identified as being potentially
83   relevant to risk factors associated with AAA expansion or rupture. No full texts were
84   retrieved, and no studies were included as economic evidence.

85   An update search was conducted in December 2017, to identify any relevant health
86   economic analyses published during guideline development. The search found 814
87   abstracts; all of which were not considered relevant to this review question. As a result no
88   additional studies were included.

89 Excluded studies

90   No studies were retrieved for full-text review.

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91 Economic model

92 This review question does not lend itself to economic evaluation, and was not prioritised by
93 the committee for economic modelling. As such, no economic model was developed for this
94 review question.

95 Evidence statements

96 An area under the curve (AUC) of 1 represents a perfect prediction; an area of 0.5
97 represents a worthless prediction (equivalent to 'chance'). An AUC value below 0.7 indicates
98 poor model discrimination. Values of 0.7 to 0.79 indicates acceptable model discrimination;
99 values of 0.8 to 0.89 indicate excellent discrimination, and values greater than 0.9 indicate
100 outstanding discrimination (Hosmer 2000).

101 30-day mortality

102 *People undergoing EVAR or open repair*

103 Very low- to low-quality evidence from 4 cohort studies, including up to 8,271 people with
104 unruptured AAA, indicated that the Comorbidity Severity Score (CSS), Glasgow Aneurysm
105 Scale (GAS), modified Leiden score and the Vascular Governance North West (VGNW) risk
106 model had acceptable discriminatory power at predicting 30-day mortality after EVAR or
107 open surgical repair.

108 *People undergoing EVAR*

109 Very low-quality evidence from 1 cohort study, including 862 people with unruptured AAA,
110 indicated that the modified Leiden score had acceptable discriminatory power at predicting
111 30-day mortality after EVAR. Very low-quality evidence from 2 cohort studies, including up to
112 6,360 people with unruptured AAA, indicated that the CSS and the GAS had poor
113 discriminatory power at predicting 30-day mortality after EVAR.

114 *People undergoing open repair*

115 Very low-quality evidence from 1 cohort study, including up to 862 people with unruptured
116 AAA, indicated that the CSS and the modified Leiden score had acceptable discriminatory
117 power at predicting 30-day mortality after open surgical repair. Very low-quality evidence
118 from 2 cohort studies, including 2,773 people with unruptured AAA, indicated that the GAS
119 had poor discriminatory power at predicting 30-day mortality after open surgical repair.

120 In-hospital mortality in people undergoing EVAR or open repair

121 Very low- to moderate-quality evidence from 4 cohort studies, including up to 19,140 people
122 with unruptured AAA, indicated that the Medicare tool, Physiological and Operative Severity
123 Score for enUmeration of Mortality (POSSUM tool) and the VGNW risk model had
124 acceptable discriminatory power at predicting in-hospital mortality after EVAR or open
125 surgical repair. Very low- to moderate-quality evidence from 3 cohort studies, including up to
126 15,322 people with unruptured AAA, indicated that the GAS, Vascular-POSSUM tool and the
127 Vascular Biochemical and Haematological Outcome Model (VBHOM) had poor
128 discriminatory power at predicting in-hospital mortality after EVAR or open surgical repair.

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129 **Postoperative morbidity**

130 Low-quality evidence from 1 retrospective cohort study, including 1,911 patients with
131 unruptured AAA, indicated that the GAS had poor discriminatory power at predicting cardiac
132 complications (type of complications were not specified) after open surgical repair. Moderate-
133 quality evidence from the same study indicated that the GAS had poor discriminatory power
134 at predicting severe postoperative complications (including cardiac, cerebrovascular, renal,
135 pulmonary venous, and peripheral arterial complications, as well as sepsis) after open
136 surgical repair.

137 **Length of stay**

138 Moderate-quality evidence from 1 retrospective cohort study, including 1,911 patients who
139 underwent with unruptured AAA, indicated that the GAS had poor discriminatory power at
140 predicting prolonged length of stay (longer than 5 days) in intensive care after open surgical
141 repair.

142 **Recommendations**

143 H1. Do not use the following risk assessment tools in shared decision-making for repair of
144 unruptured AAA:

145 • Comorbidity severity score
146 • Glasgow Aneurysm Scale
147 • Medicare risk prediction tool
148 • Modified Leiden score
149 • Physiological and Operative Severity Score for enUmeration of Mortality (POSSUM)
150 • Vascular-POSSUM
151 • Vascular Biochemical and Haematological Outcome Model (VBHOM)
152 • Vascular Governance North West (VGNW) risk model

153 **Rationale and impact**

154 **Why the committee made the recommendations**

155 The evidence highlighted that none of the risk assessment tools had a high enough
156 predictive accuracy at predicting postoperative outcomes. This led the committee to conclude
157 that these tools would not improve decision-making and could potentially lead to
158 inappropriate decisions about patient management. They agreed that this could lead to harm,
159 and therefore advised that risk assessment tools should not be used.

160 **Impact of the recommendations on practice**

161 Risk assessment tools are not widely used outside the context of research. Therefore, the
162 recommendations will have little impact on practice.

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163 The committee's discussion of the evidence

164 Interpreting the evidence

165 *The outcomes that matter most*

166 The committee agreed that the outcomes which matter most are mortality and complications
167 that occur within 30 days of surgery. The committee considered that these outcomes were
168 more important than long-term outcomes because their clinical experience highlighted that
169 patients undergoing AAA surgery are at risk of experiencing more serious complications
170 soon after surgery.

171 *The quality of the evidence*

172 The committee only considered studies where a pre-existing risk assessment tool was tested
173 on a validation cohort. Studies in which risk assessment tools were developed using a
174 derivation cohort and tested on the same cohort were not considered in this review. This was
175 because these types of studies only assessed the internal validity of risk models (the degree
176 to which errors have been minimised within a study). The committee believed that it was
177 more important to evaluate the external validity (the degree to which a study's findings are
178 generalisable to wider populations and other settings) of risk models as it enabled them to
179 determine the prognostic utility of the tools.

180 The committee noted that investigators from the majority of included studies collected data
181 from national or international disease registries. It was considered that this type of approach
182 to data collection may have introduced bias to findings due to an inability to accurately record
183 and assess confounding. One study in particular (Giles et al., 2009) was considered to be at
184 high risk of bias because investigators assessed codes from a health insurance provider
185 database to ascertain the presence of risk factors, and subsequently used the data to
186 calculate risk scores.

187 *Benefits and harms*

188 The committee concluded that the assessed risk assessment tools had poor-to-acceptable
189 discriminatory power as pooled estimates of AUCs across included studies ranged from 0.65
190 to 0.75. It contrasted this with equivalent predictive statistics, such as QRISK2, which is
191 recommended by NICE for predicting cardiovascular disease (CG181), on the basis of AUCs
192 between 0.77 and 0.84, which would be classified as acceptable-to-excellent discrimination
193 using the rules of thumb adopted here. Therefore, the committee considered the AAA tools to
194 have insufficient discriminatory power for predicting postoperative outcomes of patients
195 undergoing elective AAA surgery. There was little confidence about the clinical utility of the
196 assessment tools as the committee could not see how using tools with AUCs of around 0.70
197 would lead to appropriate decisions about patient management and prognostic outcomes.

198 The committee considered that use of risk assessment tools with insufficient discriminatory
199 power could have potentially harmful effects on patient care. This is because such tools
200 could result in the decision to operate on a patient who shouldn't be operated on, or vice
201 versa. The committee discussed decision-making without the use of risk assessment tools.
202 They noted that most of the clinical data used to derive risk assessment tools are commonly
203 collected and are already available before surgery. They agreed that individual variables (as
204 opposed to risk models) can be still useful for making judgments of an individual's risk of
205 postoperative morbidity and mortality.

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206 **Cost effectiveness and resource use**

207 The committee considered that the recommendations were unlikely to have an impact on
208 costs or resource use within the NHS as risk assessment tools are not routinely used outside
209 the context of research.

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

211 The committee did not want to preclude development of tools for assessing postoperative
212 outcomes of AAA surgery. Thus, the committee chose to specify risk assessment that should
213 not be used rather than state that risk assessment tools should not be used, in general.

214 The committee decided against making a research recommendation because extensive
215 research into risk assessment tools for AAA surgery has already been performed over recent
216 decades and further research in this area is unlikely to be viewed as a priority.
217

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Appendices

Appendix A – Review protocols

Review protocol for risk assessment tools for predicting surgical outcomes of patients who undergo elective AAA repair

Review question 9	What is the accuracy of available risk assessment tools in predicting poor and good surgical outcomes in people with unruptured abdominal aortic aneurysms?
Objectives	To determine which assessment tools are accurate in predicting surgical outcome and might therefore inform patients in their decision to undergo surgery for an unruptured abdominal aortic aneurysms
Type of review	Prognostic
Language	English only
Study design	i) Prospective observational studies using multivariate analysis; population >500 ii) Prospective observational studies using smaller populations (>200) will be considered if insufficient evidence is identified
Status	i) Published papers only (full text) No date restrictions
Population	People who are being assessed for surgery for a confirmed unruptured abdominal aortic aneurysm Subgroups: by type of surgery
Assessment tools	Vascular Study Group of New England Cardiac Risk Index (VSG-CRI) Revised Cardiac Risk Index British Aneurysm Repair (BAR) score Vascular Governance North West P Logistic risk model for mortality following elective AAA repair Medicare risk prediction for perioperative mortality during AAA repair Glasgow Aneurysm Scale (GAS) POSSUM prediction models, including V-POSSUM score Modified Customised Probability Index (m-CPI) Customised Probability Index (CPI) Surgical Risk Scale Vascular Biochemistry and Haematology Outcome Models (VBHOM) Estimation of Physiologic Ability and Surgical Stress (E-PASS) EVAR Risk Assessment (ERA) model, also known as the 'Australasian model' Co-morbidity Severity Score of the Society for Vascular Surgery and the American Association for Vascular Surgery (SVS/AAVS co-morbidity score) Leiden/modified Leiden score (John) Carlisle Calculator Eagle score Vanzetto score George's score (aneurysm risk score)
Endpoint	Mortality Peri- and post-operative complications Successful exclusion of the aneurysm, aneurysm rupture, or further aneurysm growth

Review question 9	What is the accuracy of available risk assessment tools in predicting poor and good surgical outcomes in people with unruptured abdominal aortic aneurysms?
	Need for re-intervention
	Quality of life
	Resource use, including length of hospital or intensive care stay, 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
	Comorbidities
Search strategies	See Appendix B
Review strategies	Double-sifting of randomly selected 20%.
	Appropriate NICE Methodology Checklists, depending on study designs, will be used as a guide to appraise the quality of individual studies. 20% will be appraised by a second reviewer.
	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	Patterson BO, Holt PJ, Hinchliffe R, Loftus IM, Thompson MM. Predicting risk in elective abdominal aortic aneurysm repair: a systematic review of current evidence. Eur J Vasc Endovasc Surg. 2008 Dec;36(6):637-45 – SYSTEMATIC REVIEW
	Bohm N, Wales L, Dunckley M, Morgan R, Loftus I, Thompson M. Objective risk-scoring systems for repair of abdominal aortic aneurysms: applicability in endovascular repair? Eur J Vasc Endovasc Surg. 2008 Aug;36(2):172-7
	Grant SW, Hickey GL, Carlson ED, McCollum CN. Comparison of three contemporary risk scores for mortality following elective abdominal aortic aneurysm repair. Eur J Vasc Endovasc Surg. 2014 Jul;48(1):38-44
	Grant SW, Sperrin M, Carlson E, Chinai N, Ntais D, Hamilton M, Dunn G, Buchan I, Davies L, McCollum CN, 2015. Calculating when elective abdominal aortic aneurysm repair improves survival for individual patients: development of the Aneurysm Repair Decision Aid and economic evaluation. Health Technology Assessment 19(32)
	Tang TY, Walsh SR, Fanshawe TR, Seppi V, Sadat U, Hayes PD, Varty K, Gaunt ME, Boyle JR. Comparison of risk-scoring methods in predicting the immediate outcome after elective open abdominal aortic aneurysm surgery. Eur J Vasc Endovasc Surg. 2007 Nov;34(5):505-13

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 9

Medline Strategy, searched 29th September 2016
Database: 1946 to September Week 3 2016
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 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.
4   or/1-3
5   prognosis.sh.
6   diagnosed.tw.
7   cohort.mp.
8   predictor:.tw.
9   death.tw.
10   exp models, statistical/
11   or/5-10
12   (sensitiv: or predictive value:).mp. or accurac:.tw.

Medline Strategy, searched 29th September 2016 Database: 1946 to September Week 3 2016 Search Strategy:
13   11 or 12
14   "signs and symptoms"/
15   ((sign or signs) adj5 symptom*).tw.
16   Risk Factors/
17   factor*.tw.
18   predict*.tw.
19   or/14-18
20   13 or 19
21   4 and 20
22   animals/ not humans/
23   21 not 22 (12444)
24   limit 23 to english language

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

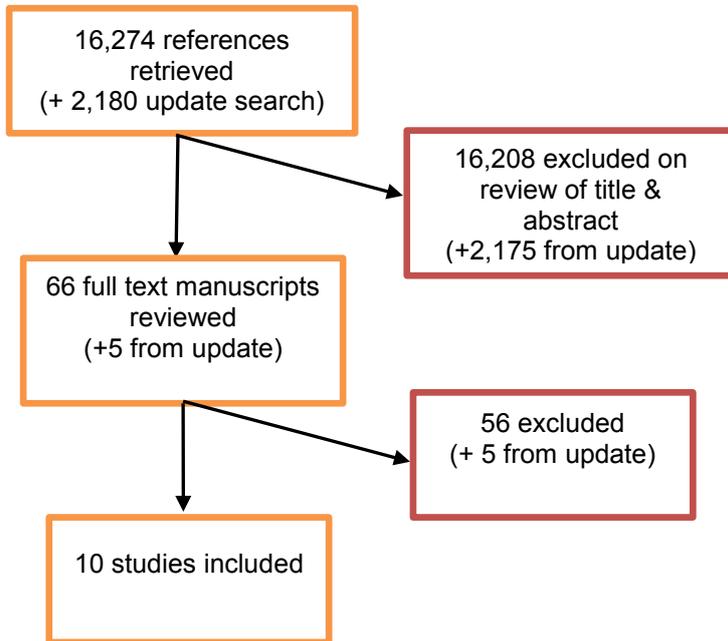| Medline Strategy |
| --- |
| Economic evaluations |
| 1   Economics/ |
| 2   exp "Costs and Cost Analysis"/ |
| 3   Economics, Dental/ |
| 4   exp Economics, Hospital/ |
| 5   exp Economics, Medical/ |
| 6   Economics, Nursing/ |
| 7   Economics, Pharmaceutical/ |
| 8   Budgets/ |
| 9   exp Models,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

Medline Strategy

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.
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

16,274 references
retrieved
(+ 2,180 update search)

16,208 excluded on
review of title &
abstract
(+2,175 from update)

66 full text manuscripts
reviewed
(+5 from update)

56 excluded
(+ 5 from update)

10 studies included

Appendix D – Clinical evidence tables

Full citation	Ambler Graeme K, Gohel Manjit S, Mitchell David C, Loftus Ian M, Boyle Jonathan R, Audit , Quality Improvement Committee of the Vascular Society of Great, Britain , and Ireland (2015) The Abdominal Aortic Aneurysm Statistically Corrected Operative Risk Evaluation (AAA SCORE) for predicting mortality after open and endovascular interventions. Journal of vascular surgery 61(1), 35-43
Study details	Study design: retrospective cohort study Location(s): UK Aim of the study: to develop a reliable risk model for in-hospital mortality after AAA surgery and compare it with established risk assessment tools Study dates: February 2010 to April 2011 Follow-up: not reported Sources of funding: not reported
Participants	Sample size: 8,088 patients in a derivation cohort and 2,694 in an external validation cohort (sex-specific proportions were not reported). For the purpose of this review, only analysis of the validation cohort will be considered. Inclusion criteria: patients who underwent elective EVAR or open repair (technique-specific proportions were not reported) Exclusion criteria: not reported Baseline characteristics • Mean age: 74.9 years • Sex: 84.8% male • Mean aneurysm diameter: not reported • Diabetes: 11.8% • Cardiac disease:42.4%
Methods	Data collection: data were obtained from a registry of prospectively recorded information called the UK National Vascular Database. The National Vascular Database collects clinical, demographic, and outcome data of patients undergoing key index vascular surgical procedures. Data entry exceeds 90% of cases in most regions. Multiple imputation was used to adjust for missing data. Analysis: multivariate logistic regression
Outcomes	Outcome: in-hospital mortality Risk assessment tools: Vascular Biochemical and Haematological Outcome Model (VBHOM), Physiological and Operative Severity Score for enUmeration of Mortality (POSSUM), Vascular Governance North West (VGNW) risk model for mortality, and the Medicare risk prediction tool
Study Appraisal using CASP (Critical appraisal	1. Did the study address a clearly focused issue? Yes 2. Was the cohort recruited in an acceptable way? Yes 3. Was the exposure accurately measured to minimise bias? No – investigators retrospectively reviewed data from a vascular society registry to ascertain the presence/absence of risk factors used in the risk prediction models assessed in this study.

skills programme)	4. Was the outcome accurately measured to minimise bias? Yes
	5. (a) Have the authors identified all important confounding factors? Unclear – retrospective cohort study in which confounding may not have been accurately assessed.
	(b) Have they taken account of the confounding factors in the design and/or analysis? Unclear
	6. (a) Was the follow up of subjects complete enough? Yes
	(b) Was the follow up of subjects long enough? Yes
	Overall risk of bias: Moderate
	Directness: directly applicable

Full citation	Biancari F, Heikkinen M, Lepantalo M, and Salenius J P (2003) Glasgow Aneurysm Score in patients undergoing elective open repair of abdominal aortic aneurysm: A Finnvasc study. European Journal of Vascular and Endovascular Surgery 26(6), 612-617
Study details	Study design: retrospective cohort study
	Location(s): Finland, Netherlands, and UK
	Aim of the study: to determine whether the GAS predicts postoperative outcomes after open repair of AAA
	Study dates: January 1991 to December 1999
	Follow-up: not reported
	Sources of funding: nor reported
Participants	Sample size: 1,911; 87.5% (1672/1911) male
	Inclusion criteria: patients who underwent elective open repair of AAA
	Exclusion criteria: not reported
	Baseline characteristics
	• Mean age: 68 years
	• Sex: 87.5% male
	• Mean aneurysm diameter: not reported
	• Comorbidities not reported
Methods	Data collection: data were retrospectively obtained from a Finnish surgical registry. Pre-, intra- and postoperative data were prospectively collected and entered into the registry's database. Severe complications included sepsis, as well as cardiac, cerebrovascular, renal, pulmonary venous, and peripheral arterial complications. These were defined according to the registry criteria.
	Analysis: multivariate logistic regression
Outcomes	Outcome: 30-day mortality, severe complications, cardiac complications ICU stay longer than 5 days
	Risk assessment tools: GAS

Study Appraisal using CASP (Critical appraisal skills programme)	1. Did the study address a clearly focused issue? Yes 2. Was the cohort recruited in an acceptable way? Yes 3. Was the exposure accurately measured to minimise bias? No – investigators retrospectively reviewed data from a surgical registry to ascertain the presence/absence of risk factors used in the risk prediction model assessed in this study. Authors acknowledge that risk factor definitions in the registry were country specific. 4. Was the outcome accurately measured to minimise bias? Yes 5. (a) Have the authors identified all important confounding factors? Unclear – retrospective cohort study in which confounding may not have been accurately assessed. (b) Have they taken account of the confounding factors in the design and/or analysis? Unclear 6. (a) Was the follow up of subjects complete enough? Yes (b) Was the follow up of subjects long enough? Yes Overall risk of bias: Moderate Directness: directly applicable

Full citation	Biancari F, Hobo R, and Juvonen T (2006) Glasgow Aneurysm Score predicts survival after endovascular stenting of abdominal aortic aneurysm in patients from the EUROSTAR registry. The British journal of surgery 93(2), 191-4
Study details	Study design: retrospective cohort study Location(s): Finland, Netherlands, and UK Aim of the study: to evaluate the efficacy of the GAS in predicting the survival of patients who underwent EVAR Study dates: October 1996 to March 2005 Follow-up: up to 30 days Sources of funding: not specified
Participants	Sample size: 5,498; 94.1% (5,173/5,498) male Inclusion criteria: patients who underwent elective EVAR of aneurysms greater than 4.0 cm in diameter were included Exclusion criteria: patients with aneurysms less than 4.0 cm in diameter and those treated with a withdrawn endograft were excluded Baseline characteristics - Median age: 72.7 years - Sex: 94.1% male - Median aneurysm diameter: 56 mm - Comorbidities not reported
Methods	Data collection: data were obtained from a database (EUROSTAR registry) containing demographic and risk factor details, as well as outcomes of patients who had underwent EVAR procedures across various vascular units in Europe Analysis: multivariate logistic regression
Outcomes	Outcome: 30-day mortality Risk assessment tools: GAS
Study Appraisal using CASP (Critical appraisal skills programme)	1. Did the study address a clearly focused issue? Yes 2. Was the cohort recruited in an acceptable way? Yes 3. Was the exposure accurately measured to minimise bias? No – investigators retrospectively reviewed data from a European EVAR registry to ascertain the presence/absence of risk factors used in the risk prediction model assessed in this study. 4. Was the outcome accurately measured to minimise bias? Yes 5. (a) Have the authors identified all important confounding factors? Unclear – retrospective cohort study in which confounding may not have been accurately assessed. (b) Have they taken account of the confounding factors in the design and/or analysis? Unclear 6. (a) Was the follow up of subjects complete enough? Yes

Full citation	**Biancari F, Hobo R, and Juvonen T (2006) Glasgow Aneurysm Score predicts survival after endovascular stenting of abdominal aortic aneurysm in patients from the EUROSTAR registry. The British journal of surgery 93(2), 191-4**
	(b) Was the follow up of subjects long enough? Yes Overall risk of bias: Moderate Directness: directly applicable

Full citation	**Choke E, Lee K, McCarthy M, Nasim A, Naylor A R, Bown M, and Sayers R (2012) Risk models for mortality following elective open and endovascular abdominal aortic aneurysm repair: A single institution experience. European Journal of Vascular and Endovascular Surgery 44(6), 549-554**
Study details	Study design: prospective cohort study Location(s): UK Aim of the study: to develop and validate an "in-house" risk model for predicting perioperative mortality following elective AAA repair and to compare this with other models Study dates: January 2000 to October 2010 Follow-up: not reported Sources of funding: the study was part funded by the British Society of Endovascular Therapy
Participants	Sample size: 1,153 patients in a derivation cohort and 343 in an external validation cohort (sex-specific proportions were not reported). For the purpose of this review, only analysis of the validation cohort will be considered. Inclusion criteria: patients undergoing elective EVAR or open repair. No further details were provided. Exclusion criteria: not reported Baseline characteristics • Mean age: not reported • Sex: 88.9% male • Mean aneurysm diameter: not reported • Myocardial infarction within the last 10 years: 17.3% • Respiratory disease: 18.0% • Diabetes: 8.6% • Previous transient ischaemic attack or stroke: 8.9%
Methods	Data collection: data were prospectively collected using a standardised proforma, adapted from a proforma produced by the UK National Vascular Database Analysis: multivariate logistic regression
Outcomes	Outcome: The primary end point was the composite of 30-day and in-hospital death

Full citation	Choke E, Lee K, McCarthy M, Nasim A, Naylor A R, Bown M, and Sayers R (2012) Risk models for mortality following elective open and endovascular abdominal aortic aneurysm repair: A single institution experience. European Journal of Vascular and Endovascular Surgery 44(6), 549-554
	Risk assessment tools: Medicare risk prediction tool, VGNW risk model, GAS and an "in-house" risk calculator. The in-house risk calculator will not be considered in this review as bespoke risk assessment tools are not included in this question's review protocol.
Study Appraisal using CASP (Critical appraisal skills programme)	1. Did the study address a clearly focused issue? Yes 2. Was the cohort recruited in an acceptable way? Yes 3. Was the exposure accurately measured to minimise bias? Yes 4. Was the outcome accurately measured to minimise bias? Yes 5. (a) Have the authors identified all important confounding factors? Unclear – minimal details were provided in the study manuscript. (b) Have they taken account of the confounding factors in the design and/or analysis? Unclear 6. (a) Was the follow up of subjects complete enough? Yes (b) Was the follow up of subjects long enough? Yes Overall risk of bias: Low Directness: directly applicable

Full citation	Eslami Mohammad H, Rybin Denis, Doros Gheorghe, Kalish Jeffrey A, Farber Alik, Vascular Study Group of New, and England (2015) Comparison of a Vascular Study Group of New England risk prediction model with established risk prediction models of in-hospital mortality after elective abdominal aortic aneurysm repair. Journal of vascular surgery 62(5), 1125-33.e2
Study details	Study design: retrospective cohort study Location(s): UK Aim of the study: to develop a risk prediction model using Vascular Study Group of New England (VSGNE) data and to compare it with established models Study dates: 2003 to 2013 Follow-up: not reported Sources of funding: not reported Baseline characteristics • Mean age: not reported • Sex: 77.5% male • Mean aneurysm diameter: people who underwent EVAR, 57.9 mm; people who underwent open surgery, 63.4 mm • Diabetes: 17.4% • Congestive heart failure: 8.8% • Myocardial disease: 32.5% • Vascular disease: 9.3%
Participants	Sample size: 4,431; 77.5% (3,432/4,431) male Inclusion criteria: patients who underwent elective EVAR or open repair were included (technique-specific proportions were not reported) Exclusion criteria: patients who underwent emergency AAA repair, had prior aortic surgery, patients who had missing information in their records, and those who had a supra celiac clamp during aortic repair were excluded
Methods	Data collection: data were obtained from a database developed by a regional cooperative (35 academic and community hospitals) to collect data on patients who undergo vascular procedures Analysis: multivariate logistic regression
Outcomes	Outcome: in-hospital mortality Risk assessment tools: Medicare risk assessment tool, VGNW risk model, GAS, and a risk prediction model derived from VSGNE data. **Note -** the VSGNE model assessed in this study is not the same as the Vascular Study Group of New England Cardiac Risk Index (VSG-CRI) model outlined in the review protocol. Furthermore, data relating to the VSGNE model cannot be considered as this is a seminal paper in which investigators created the model using a derivation cohort and did not validate it using an external validation cohort.
Study Appraisal using CASP	1. Did the study address a clearly focused issue? Yes 2. Was the cohort recruited in an acceptable way? Yes

Full citation	Eslami Mohammad H, Rybin Denis, Doros Gheorghe, Kalish Jeffrey A, Farber Alik, Vascular Study Group of New, and England (2015) Comparison of a Vascular Study Group of New England risk prediction model with established risk prediction models of in-hospital mortality after elective abdominal aortic aneurysm repair. Journal of vascular surgery 62(5), 1125-33.e2
(Critical appraisal skills programme)	3. Was the exposure accurately measured to minimise bias? No – investigators retrospectively reviewed data from a surgical registry to ascertain the presence/absence of risk factors used in the risk prediction model assessed in this study. 4. Was the outcome accurately measured to minimise bias? Yes 5. (a) Have the authors identified all important confounding factors? yes (b) Have they taken account of the confounding factors in the design and/or analysis? Unclear – retrospective cohort study in which confounding may not have been accurately assessed. 6. (a) Was the follow up of subjects complete enough? Yes (b) Was the follow up of subjects long enough? Yes Overall risk of bias: Moderate Directness: directly applicable

Full citation	**Faizer Rumi, DeRose Guy, Lawlor D Kirk, Harris Kenneth A, and Forbes Thomas L (2007) Objective scoring systems of medical risk: a clinical tool for selecting patients for open or endovascular abdominal aortic aneurysm repair. Journal of vascular surgery 45(6), 1102-1108**
Study details	Study design: retrospective cohort study Location(s): Canada Aim of the study: to assess the utility of comorbidity-based objective scoring systems for defining subgroups of patients who might most benefit from open or endovascular aneurysm repair Study dates: January 1999 to December 2004 Follow-up: up to 4 years Sources of funding: Not reported
Participants	Sample size: 862; 83% (716/862) male Inclusion criteria: patients who underwent elective EVAR (n=304) or open repair (n=558) of AAAs greater than 5.5 cm in diameter Exclusion criteria: Not reported
Methods	Data collection: data were obtained from a database of prospectively recorded information from a university-affiliated medical centre. The database contained patient demographic data, intervention modality, outcome and specific grading of a number of medical risk factors. All procedures were performed by one of four surgeons. Analysis: multivariate logistic regression Baseline characteristics • Mean age: EVAR group, 75 years; open surgery group, 71 years • Sex: EVAR group, 86.2% male; open surgery group, 81.2% male • Mean aneurysm diameter: not reported • Asymptomatic coronary artery disease: EVAR group, 18.1%; open surgery group, 39.4% • Congestive heart failure: EVAR group, 18.1%; open surgery group, 39.4% • COPD: EVAR group, 44.7%; open surgery group, 11.6% • Chronic renal failure: EVAR group, 2.3%; open surgery group, 2% • Cerebrovascular disease: EVAR group, 3%; open surgery group, 2.2% • Hypertension: EVAR group, 85.9%; open surgery group, 86%
Outcomes	Outcome: 30-day mortality Risk assessment tools: GAS, Leiden Scoring System, and Comorbidity Severity Score (CSS)

Study Appraisal using CASP (Critical appraisal skills programme)	1. Did the study address a clearly focused issue? Yes
	2. Was the cohort recruited in an acceptable way? Yes
	3. Was the exposure accurately measured to minimise bias? No – investigators retrospectively reviewed a database to ascertain the presence/absence of risk factors used in the risk prediction models assessed in this study.
	4. Was the outcome accurately measured to minimise bias? Yes
	5. (a) Have the authors identified all important confounding factors? Unclear – retrospective cohort study in which confounding may not have been accurately assessed.
	(b) Have they taken account of the confounding factors in the design and/or analysis? Unclear
	6. (a) Was the follow up of subjects complete enough? Yes
	(b) Was the follow up of subjects long enough? Yes
	Overall risk of bias: Moderate
	Directness: directly applicable

Full citation	Giles Kristina A, Schermerhorn Marc L, O'Malley A James, Cotterill Philip, Jhaveri Ami, Pomposelli Frank B, and Landon Bruce E (2009) Risk prediction for perioperative mortality of endovascular vs open repair of abdominal aortic aneurysms using the Medicare population. Journal of vascular surgery 50(2), 256-62
Study details	Study design: retrospective cohort study Location(s): USA Aim of the study: to developed a differential predictive model of perioperative mortality after AAA repair. Study dates: 2001 to 2004 Follow-up: not reported Sources of funding: This study was supported by Harvard-Longwood research training programme in vascular surgery
Participants	Sample size: 22,860 patients in a derivation cohort and 22,860 in an external validation cohort; 80.4% (18,400/22,860) male. For the purpose of this review, only analysis of the validation cohort will be considered. Inclusion criteria: patients older than 67 years, with at least 2 years of prior medical claims, who underwent elective EVAR (n=11,415) or open repair (n=11,415) were included Exclusion criteria: patients with a diagnosis of ruptured AAA, thoracic aneurysm, thoraco-abdominal aneurysms, or aortic dissection, as well as patients who had procedure codes for repair of the thoracic aorta or visceral bypass were excluded Baseline characteristics • Mean age: not reported • Sex: EVAR group, 80.7% male; open surgery group, 80.5% male • Mean aneurysm diameter: not reported • Chronic renal insufficiency: EVAR group, 4.0%; open surgery group, 3.8% • Myocardial infarction within 2 years: EVAR group, 8.2%; open surgery group, 8.0% • Vulvular heart disease: EVAR group, 11.3%; open surgery group, 10.5% • Congestive heart failure: EVAR group, 13.3%; open surgery group, 13.1% • Peripheral vascular diease: EVAR group, 21.0%; open surgery group, 20.4% • Cerebrovascular disease: EVAR group, 16.3%; open surgery group, 16.2% • Hypertension: EVAR group, 66.0%; open surgery group, 65.8% • Diabetes: EVAR group, 15.3%; open surgery group, 15.7% • COPD: EVAR group, 29.5%; open surgery group, 30.1%
Methods	Data collection: data were obtained from a database of prospectively recorded information from databases of the US medical healthcare provider (Medicare). Investigators obtained data relating to claims, patient demographic information, inpatient and outpatient and survival information. Analysis: multivariate logistic regression
Outcomes	Outcome: the primary endpoint was the composite of 30-day and in-hospital mortality

Full citation	Giles Kristina A, Schermerhorn Marc L, O'Malley A James, Cotterill Philip, Jhaveri Ami, Pomposelli Frank B, and Landon Bruce E (2009) Risk prediction for perioperative mortality of endovascular vs open repair of abdominal aortic aneurysms using the Medicare population. Journal of vascular surgery 50(2), 256-62
	Risk assessment tools: Medicare risk prediction tool
Study Appraisal using CASP (Critical appraisal skills programme)	1. Did the study address a clearly focused issue? Yes 2. Was the cohort recruited in an acceptable way? Yes 3. Was the exposure accurately measured to minimise bias? No – investigators retrospectively reviewed healthcare insurance provider data to ascertain the presence/absence of risk factors used in the risk prediction model assessed in this study. 4. Was the outcome accurately measured to minimise bias? No – the endpoint (mortality) was established using ICD-9-CM codes. 5. (a) Have the authors identified all important confounding factors? Unclear – retrospective cohort study in which confounding may not have been accurately measured. (b) Have they taken account of the confounding factors in the design and/or analysis? Unclear 6. (a) Was the follow up of subjects complete enough? Yes (b) Was the follow up of subjects long enough? Yes Overall risk of bias: High Directness: directly applicable

Full citation	Grant S W, Grayson A D, Purkayastha D, Wilson S D, McCollum C, participants in the Vascular Governance North West, and Programme (2011) Logistic risk model for mortality following elective abdominal aortic aneurysm repair. The British journal of surgery 98(5), 652-8
Study details	Study design: prospective cohort study Location(s): UK Aim of the study: to develop a multivariable risk prediction model for 30-day mortality Study dates: September 1999 to October 2009 Follow-up: up to 30 days Sources of funding: This study was funded by Manchester Surgical Research Trust
Participants	Sample size: 1,936 patients in a derivation cohort and 829 in an external validation cohort (sex-specific proportions were not reported) For the purpose of this review, only analysis of the validation cohort will be considered. Inclusion criteria: patients undergoing elective EVAR or open repair of AAA (technique-specific proportions were not reported) Exclusion criteria: not reported Baseline characteristics • Mean age: not reported • Sex: 82.3% male • Maximal aneurysm diameter above 6 cm: 63.2% • Diabetes: 8.9% • History of myocardial infarction: 20.9% • Ischaemic heart disease: 39.3% • Respiratory disease: 28.2%
Methods	Data collection: prospective data were collected on consecutive AAA repairs performed across 22 hospitals in England. All data including patient demographics, aneurysm diameter, comorbidities, preoperative medications, investigations, procedural details and outcomes were entered into a central database. Confirmation of any deaths that occurred after discharge, but within 30 days, was obtained using the National Strategic Tracing service. Analysis: multivariate logistic regression
Outcomes	Outcome: 30-day mortality Risk assessment tools: VGNW risk model
Study Appraisal using CASP (Critical appraisal	1. Did the study address a clearly focused issue? Yes 2. Was the cohort recruited in an acceptable way? Yes 3. Was the exposure accurately measured to minimise bias? Yes 4. Was the outcome accurately measured to minimise bias? Yes 5. (a) Have the authors identified all important confounding factors? Yes

Full citation	Grant S W, Grayson A D, Purkayastha D, Wilson S D, McCollum C, participants in the Vascular Governance North West, and Programme (2011) Logistic risk model for mortality following elective abdominal aortic aneurysm repair. The British journal of surgery 98(5), 652-8
skills programme)	(b) Have they taken account of the confounding factors in the design and/or analysis? Unclear 6. (a) Was the follow up of subjects complete enough? Yes (b) Was the follow up of subjects long enough? Yes Overall risk of bias: Low Directness: directly applicable

Full citation	Grant S W, Grayson A D, Mitchell D C, and McCollum C N (2012) Evaluation of five risk prediction models for elective abdominal aortic aneurysm repair using the UK National Vascular Database. The British journal of surgery 99(5), 673-9
Study details	Study design: retrospective cohort study Location(s): UK Aim of the study: to evaluate the performance of five risk prediction models using the UK National Vascular Database Study dates: January 2008 to December 2010 Follow-up: not reported Sources of funding: the study was funded by the UK NIHR HTA programme
Participants	Sample size: 10,891; 87.3% (9,503/10,891) male Inclusion criteria: patients undergoing elective EVAR (n=5,938) or open repair (n=4,953) Exclusion criteria: records from hospitals in the North West of England, which were used in the development of one of the risk prediction models, were excluded. All variables with 20% or more of missing data were excluded from the analysis. Baseline characteristics - Mean age: 74.4 years - Sex: 82.8% male - Mean aneurysm diameter: 6.3 cm - Ischaemic heart disease: 31.8% - Previous myocardial infarction: 14.5% - Cardiac disease: 2.4% - Respiratory disease: 17.7% - Diabetes: 14.4%
Methods	Data collection: data were obtained from a vascular society registry called the UK National Vascular Database. The National Vascular Database collects data on a range of vascular surgical procedures from approximately 140 hospitals. Data included preoperative risk factors,

Full citation	**Grant S W, Grayson A D, Mitchell D C, and McCollum C N (2012) Evaluation of five risk prediction models for elective abdominal aortic aneurysm repair using the UK National Vascular Database. The British journal of surgery 99(5), 673-9**
	laboratory test results, operative details, postoperative morbidity and in-hospital mortality. When a patient factor was missing from the database record, the factor was assumed to be absent for categorical variables, or replaced with the median value for continuous variables.
Outcomes	Outcome: in-hospital mortality Risk assessment tools: Medicare risk prediction tool, VGNW risk model, GAS, VBHOM, V-POSSUM
Study Appraisal using CASP (Critical appraisal skills programme)	1. Did the study address a clearly focused issue? Yes 2. Was the cohort recruited in an acceptable way? Yes 3. Was the exposure accurately measured to minimise bias? No – investigators retrospectively reviewed data from a vascular society registry to ascertain the presence/absence of risk factors used in the risk prediction models assessed in this study. 4. Was the outcome accurately measured to minimise bias? Yes 5. (a) Have the authors identified all important confounding factors? Unclear – retrospective cohort study in which confounding may not have been accurately measured. (b) Have they taken account of the confounding factors in the design and/or analysis? Unclear 6. (a) Was the follow up of subjects complete enough? Yes (b) Was the follow up of subjects long enough? Yes Overall risk of bias: Moderate Directness: directly applicable

Full citation	**Grant S W, Hickey G L, Carlson E D, and McCollum C N (2014) Comparison of three contemporary risk scores for mortality following elective abdominal aortic aneurysm repair. European Journal of Vascular and Endovascular Surgery 48(1), 38-44**
Study details	Study design: prospective cohort study Location(s): UK Aim of the study: to perform a contemporary prospective validation of the Medicare risk prediction tool, VGNW risk model, and British aneurysm repair risk models Study dates: April 2011 to March 2013 Follow-up: not reported Sources of funding: the study was partly funded by the UK National Institute for Health Research Health Technology Assessment (NIHR HTA) programme
Participants	Sample size: 1,124; 87.8% (931/1,124) male Inclusion criteria: patients undergoing elective EVAR (n=759) or open repair (n=365) Exclusion criteria: patients undergoing thoraco-abdominal or isolated iliac aneurysm repairs were excluded

Full citation	Grant S W, Hickey G L, Carlson E D, and McCollum C N (2014) Comparison of three contemporary risk scores for mortality following elective abdominal aortic aneurysm repair. European Journal of Vascular and Endovascular Surgery 48(1), 38-44
	Baseline characteristics • Mean age: not reported • Sex: 87.3% male • Mean aneurysm diameter: not reported • Cardiac disease: 40.1% • Renal dialysis: 0.6%
Methods	Data collection: prospective data were collected on consecutive AAA repairs performed across 17 hospitals in England. Data were cleaned by removing duplicate records and correcting any transcriptional discrepancies and resolving any clinical and temporal conflicts. Missing data were imputed with the sample median (continuous or ordinal variables) or mode (dichotomous variables). Analysis: multivariate logistic regression
Outcomes	Outcome: in-hospital mortality Risk assessment tools: Medicare risk prediction tool, VGNW risk model for mortality, and the British Aneurysm Repair (BAR) score. The British aneurysm repair score will not be considered in this review as it is not specified in the review protocol.
Study Appraisal using CASP (Critical appraisal skills programme)	1. Did the study address a clearly focused issue? Yes 2. Was the cohort recruited in an acceptable way? Yes 3. Was the exposure accurately measured to minimise bias? Yes 4. Was the outcome accurately measured to minimise bias? Yes 5. (a) Have the authors identified all important confounding factors? Yes (b) Have they taken account of the confounding factors in the design and/or analysis? Unclear 6. (a) Was the follow up of subjects complete enough? Yes (b) Was the follow up of subjects long enough? Yes Overall risk of bias: Low Directness: directly applicable

Appendix E – GRADE tables

An area under the curve (AUC) of 1 represents a perfect prediction; an area of 0.5 represents a worthless prediction (equivalent to 'chance'). An AUC value below 0.7 indicates poor model discrimination. Values of 0.7 to 0.79 indicates acceptable model discrimination; values of 0.8 to 0.89 indicate excellent discrimination, and values greater than 0.9 indicate outstanding discrimination (Hosmer 2000).

30-day mortality

Predictor	No of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	No. of participants	Area under the ROC curve (95% CI)	Quality
30-day mortality in patients undergoing EVAR or open repair									
CSS	1 Faizer (2007)	Retrospective cohort study	Serious[1]	Serious[2]	Not serious	Serious[3]	862	0.69 [a] (Not reported) 0.74 [b] (Not reported) Median: 0.715 Range: 0.69 to 0.74	Very low
GAS	3 (Faizer 2007, Biancari 2006, Biancari 2003)	Retrospective cohort studies	Serious[1]	Very serious[4]	Not serious	Serious[3]	8,271	0.47 [a] (Not reported) 0.72 [b] (Not reported) 0.70 (0.66, 0.74) 0.67 (0.61, 0.72) Median: 0.71 Range: 0.47 to 0.72	Very low
Modified Leiden score	1 Faizer (2007)	Retrospective cohort study	Serious[1]	Not serious	Not serious	Serious[3]	862	0.70 [a] (Not reported) 0.71 [b] (Not reported) Median: 0.705 Range: 0.70 to 0.71	Low
VGNW risk model	1 Grant (2011)	Prospective cohort study	Not serious	N/A	Not serious	Very serious[5]	829	0.70 (Not reported)	Low
30-day mortality in patients undergoing EVAR									
CSS	1 Faizer (2007)	Retrospective cohort study	Serious[1]	N/A	Not serious	Very serious[5]	862	0.69 (Not reported)	Very low

Predictor	No of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	No. of participants	Area under the ROC curve (95% CI)	Quality
GAS	2 (Faizer 2007, Biancari 2006)	Retrospective cohort study	Serious[1]	Very serious[4]	Not serious	Serious[3]	6,360	0.47 (Not reported) 0.70 (0.66, 0.74) Median: 0.585 Range: 0.47 to 0.70	Very low
Modified Leiden score	1 Faizer (2007)	Retrospective cohort study	Serious[1]	N/A	Not serious	Very serious[5]	862	0.70 (Not reported)	Very low
30-day mortality in patients undergoing open repair									
CSS	1 Faizer (2007)	Retrospective cohort study	Serious[1]	N/A	Not serious	Very serious[5]	862	0.74 (Not reported)	Very low
GAS	2 (Biancari 2003, Faizer 2007)	Retrospective cohort studies	Serious[1]	Serious[2]	Not serious	Serious[3]	1,911 862	0.67 (0.61, 0.72) 0.72 (Not reported) Median: 0.695 Range: 0.67 to 0.72	Very low
Modified Leiden score	1 Faizer (2007)	Retrospective cohort study	Serious[1]	N/A	Not serious	Very serious[5]	862	0.71 (Not reported)	Very low

a. Data from the EVAR group of the Faizer (2007) trial
b. Data from the open repair group of the Faizer 2007 trial
1. Retrospective cohort study in which investigators retrospectively reviewed data from surgical registries, medical records or healthcare insurance provider databases to establish the presence or absence of risk factors, downgrade 1 level.
2. AUC range spans across 2 c-statistic classification categories, downgrade 1 level
3. AUC range crosses one minimal important difference (0.7 or 0.8), downgrade 1 level.
4. AUC range spans across 3 or more c-statistic classification categories, downgrade 2 levels. 3. 95% CI not reported, downgrade 2 levels.

In-hospital mortality

Predictor	No of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	No. of participants	Area under the ROC curve (95% CI)	Quality
In-hospital mortality in patients undergoing EVAR or open repair									
GAS	2 (Grant 2012, Eslami 2015)	Retrospective cohort studies	Serious[1]	Not serious	Not serious	Not serious	15, 322	0.60 (0.56, 0.63) 0.69 (Not reported) Median: 0.645 Range: 0.60 to 0.69	Moderate
Medicare tool	4 (Grant 2012, Ambler 2015, Eslami 2015, Grant 2014)	Prospective and retrospective cohort studies	Serious[1]	Not serious	Not serious	Not serious	19,140	0.71 (0.69, 0.74) 0.72 (Not reported) 0.77 (Not reported) 0.78 (0.70, 0.86) Median: 0.745 Range: 0.71 to 0.78	Moderate
POSSUM	1 Ambler (2015)	Retrospective cohort study	Serious[1]	N/A	Not serious	Very serious[2]	2,694	0.73 (Not reported)	Very low
V-POSSUM	1 Grant (2012)	Retrospective cohort study	Serious[1]	N/A	Not serious	Not serious	10,891	0.62 (0.59, 0.65)	Moderate
VBHOM	2 (Grant 2012, Ambler 2015)	Retrospective cohort studies	Serious[1]	Serious[3]	Not serious	Serious[4]	13,585	0.61 (0.58, 0.64) 0.74 (Not reported) Median: 0.675 Range: 0.61 to 0.74	Very low
VGNW risk model	4 (Ambler 2015, Grant 2012,	Prospective and retrospective cohort studies	Serious[1]	Not serious	Not serious	Serious[4]	19,140	0.70 (Not reported) 0.71 (0.68, 0.74) 0.75 (0.65, 0.84) 0.77 (Not reported)	Low

Predictor	No of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	No. of participants	Area under the ROC curve (95% CI)	Quality
	Grant 2014, Eslami 2015)							Median: 0.73 Range: 0.70 to 0.77	

1. The majority of evidence was obtained from retrospective cohort studies in which investigators retrospectively reviewed data from surgical registries, medical records or healthcare insurance provider databases to establish the presence or absence of risk factors, downgrade 1 level.
2. 95% CI not reported, downgrade 2 levels.
3. AUC range spans across 2 c-statistic classification categories, downgrade 1 level.
4. AUC range crosses one minimal important difference (0.7 or 0.8), downgrade 1 level.

Postoperative morbidity

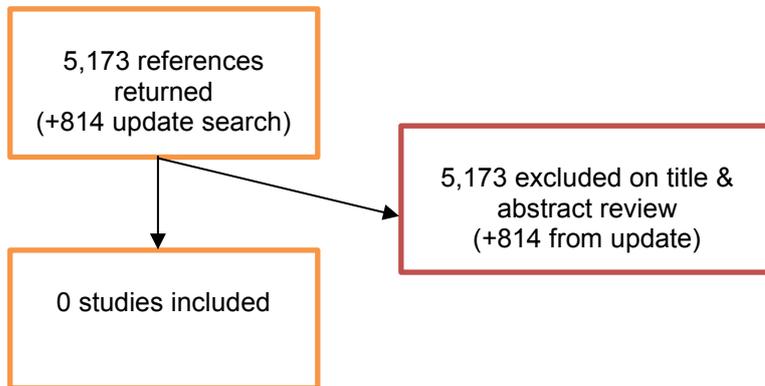| Predictor	No of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	No. of participants	Area under the ROC curve (95% CI)	Quality
Cardiac complications (not specified) in patients undergoing open repair									
GAS	1 Biancari (2003)	Retrospective cohort study	Serious[1]	N/A	Not serious	Serious[2]	1,911	0.69 (0.65, 0.73)	Low
Severe complications in patients undergoing open repair (complications included cardiac, cerebrovascular, renal, pulmonary venous, and peripheral arterial complications, as well as sepsis)									
GAS	1 Biancari (2003)	Retrospective cohort study	Serious[1]	N/A	Not serious	Not serious	1,911	0.65 (0.62, 0.68)	Moderate

1. Retrospective cohort study in which investigators retrospectively reviewed data from surgical registries, medical records or healthcare insurance provider databases to establish the presence or absence of risk factors, downgrade 1 level.
2. AUC 95% CI crosses one minimal important difference (0.7 or 0.8), downgrade 1 level.

Length of stay

Predictor	No of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	No. of participants	Area under the ROC curve (95% CI)	Quality
ICU length of stay longer than 5 days in patients undergoing open repair									
GAS	1 Biancari (2003)	Retrospective cohort study	Serious[1]	N/A	Not serious	Not serious	1,911	0.63 (0.59, 0.68)	Moderate

1. Retrospective cohort study in which investigators retrospectively reviewed data from surgical registries, medical records or healthcare insurance provider databases to establish the presence or absence of risk factors, downgrade 1 level.

Appendix F – Economic evidence study selection

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┌─────────────────────────┐
│   5,173 references      │
│       returned          │        ┌──────────────────────────┐
│ (+814 update search)    │───┐    │  5,173 excluded on title & │
└─────────────────────────┘   │    │     abstract review       │
            │                  └──▶ │   (+814 from update)      │
            │                       └──────────────────────────┘
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┌─────────────────────────┐
│   0 studies included    │
│                         │
└─────────────────────────┘
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Appendix G – Excluded studies

Clinical studies

No.	Study	Reason for exclusion
1	Amaranto Daniel J, Wang Edward C, Eskandari Mark K, Morasch Mark D, Rodriguez Heron E, Pearce William H, and Kibbe Melina R (2011) Normal preoperative white blood cell count is predictive of outcomes for endovascular procedures. Journal of vascular surgery 54(5), 1395-1403.e2	Not specific to AAA: Study included a mixed population of patients with carotid stenosis, peripheral arterial disease and aortic aneurysms (location unspecified).
2	Arya Shipra, Kim Sung In, Duwayri Yazan, Brewster Luke P, Veeraswamy Ravi, Salam Atef, and Dodson Thomas F (2015) Frailty increases the risk of 30-day mortality, morbidity, and failure to rescue after elective abdominal aortic aneurysm repair independent of age and comorbidities. Journal of vascular surgery 61(2), 324-31	Risk assessment tool (modified frailty index) is not included in the review protocol.
3	Baas Annette F, Janssen Kristel J. M, Prinssen Monique, Buskens Eric, and Blankensteijn Jan D (2008) The Glasgow Aneurysm Score as a tool to predict 30-day and 2-year mortality in the patients from the Dutch Randomized Endovascular Aneurysm Management trial. Journal of vascular surgery 47(2), 277-81	Sample size less than 500 participants.
4	Bertges Daniel J, Goodney Philip P, Zhao Yuanyuan, Schanzer Andres, Nolan Brian W, Likosky Donald S, Eldrup-Jorgensen Jens, Cronenwett Jack L, Vascular Study Group of New, and England (2010) The Vascular Study Group of New England Cardiac Risk Index (VSG-CRI) predicts cardiac complications more accurately than the Revised Cardiac Risk Index in vascular surgery patients. Journal of vascular surgery 52(3), 674-683.e3	Sample size less than 500 participants.
5	Bohm N, Wales L, Dunckley M, Morgan R, Loftus I, and Thompson M (2008) Objective Risk-scoring Systems for Repair of Abdominal Aortic Aneurysms: Applicability in Endovascular Repair?. European Journal of Vascular and Endovascular Surgery 36(2), 172-177	Sample size less than 500 participants.
6	Ballotta E, Da Giau , G , Gruppo M, Mazzalai F, Spirch S, and Terranova O	This systematic review did not assess the accuracy of risk assessment tools for

No.	Study	Reason for exclusion
	(2009) Elective abdominal aortic aneurysm repair in the very elderly: a systematic review. Minerva medica 100(1), 95-103	predicting postoperative outcomes. Instead investigators compared death and complication rates between patients who received EVAR and those who received open repair.
7	Bang J Y, Lee J B, Yoon Y, Seo H S, Song J G, and Hwang G S (2014) Acute kidney injury after infrarenal abdominal aortic aneurysm surgery: a comparison of AKIN and RIFLE criteria for risk prediction. British journal of anaesthesia 113(6), 993-1000	This retrospective study compared the ability of Acute Kidney Injury Network (AKIN) criteria and Risk, Injury, Failure, Loss, and end-stage (RIFLE) criteria in predicting mortality in patients undergoing infrarenal AAA surgery. This is out of scope of this review question.
8	Beck Adam W, Goodney Philip P, Nolan Brian W, Likosky Donald S, Eldrup-Jorgensen Jens, Cronenwett Jack L, Vascular Study Group of Northern New, and England (2009) Predicting 1-year mortality after elective abdominal aortic aneurysm repair. Journal of vascular surgery 49(4), 838-4	No risk assessment tools were assessed. This study explored risk factors which could be used to develop a risk prediction model.
9	Carlisle J B, Danjoux G, Kerr K, Snowden C, and Swart M (2015) Validation of long-term survival prediction for scheduled abdominal aortic aneurysm repair with an independent calculator using only pre-operative variables. Anaesthesia 70(6), 654-65	No multivariate analysis was performed. Investigators used univariate analysis (Kaplan-meier curves) to establish the discrimination and calibration of a bespoke survival calculator (not specified in the review protocol).
10	de Bruin , Jorg Lucas, Karthikesalingam Alan, Holt Peter J, Prinssen Monique, Thompson Matt M, Blankensteijn Jan D, Dutch Randomised Endovascular Aneurysm Management Study, and Group (2016) Predicting reinterventions after open and endovascular aneurysm repair using the St George's Vascular Institute score. Journal of vascular surgery 63(6), 1428-1433.e1	No multivariate analysis was performed. Investigators used Kaplan meier curves (univariate analysis) to assess whether St Georges Vascular Institute Scores could be used to predict the need for re-intervention.
11	De Martino , Randall R, Nolan Brian W, Goodney Philip P, Chang Catherine K, Schanzer Andres, Cambria Robert, Bertges Daniel J, Cronenwett Jack L, Vascular Study Group of Northern New, and England (2010) Outcomes of symptomatic abdominal aortic aneurysm repair. Journal of vascular surgery 52(1), 5-12.e1	Study does not assess that predictive capacity of risk assessment tools. Instead, investigators report descriptive statistics of outcomes of patients who underwent surgical repair of symptomatic AAAs.
12	DeMartino R R, Huang Y, Mandrekar J, Goodney P P, Oderich G S, Kalra M, Bower T C, Cronenwett J L, and Gloviczki P (2017) External validation of a 5-year survival prediction model after elective abdominal aortic aneurysm repair. Journal of Vascular Surgery ,	Risk assessment tool is not included in the review protocol. Investigators used data from the VSGNE database but the tool assessed is not the same as the Vascular Study Group of New England Cardiac Risk Index (VSG-CRI) specified in the review protocol. Furthermore, it is unclear whether multivariate analysis was performed.

No.	Study	Reason for exclusion
13	Deery Sarah E, Lancaster Robert T, Baril Donald T, Indes Jeffrey E, Bertges Daniel J, Conrad Mark F, Cambria Richard P, and Patel Virendra I (2016) Contemporary outcomes of open complex abdominal aortic aneurysm repair. Journal of vascular surgery 63(5), 1195-200	No risk assessment tools were assessed.
14	Dijkstra M L, Van Sterkenburg , S M M, Lardenoye J W, Zeebregts C J, and Reijnen M M. P. J (2016) One-year outcomes of endovascular aneurysm repair in high-risk patients using the endurant stent-graft: Comparison of the ASA classification and SVS/AAVS medical comorbidity grading system for the prediction of mortality and adverse events. Journal of Endovascular Therapy 23(4), 574-582	No multivariate analysis was used to assess the predictive capacity of the risk assessment tool. Instead, descriptive statistics were used to highlight mortality rates of patients categorised as low, medium or high risk according to the risk assessment tool.
15	Egorova Natalia, Giacovelli Jeannine K, Gelijns Annetine, Greco Giampaolo, Moskowitz Alan, McKinsey James, and Kent K Craig (2009) Defining high-risk patients for endovascular aneurysm repair. Journal of vascular surgery 50(6), 1271-9.e1	Risk assessment tool development: logistic regression was performed to identify independent risk factors which could be used for developing a bespoke risk assessment tool (not specified in the review protocol). The tool was not tested against a validation cohort.
16	Eslami Mohammad H, Rybin Denis V, Doros Gheorghe, and Farber Alik (2017) Description of a risk predictive model of 30-day postoperative mortality after elective abdominal aortic aneurysm repair. Journal of vascular surgery 65(1), 65-74.e2	Risk assessment tool development: logistic regression was performed to identify independent risk factors which could be used for developing a risk assessment tool (not specified in the review protocol). The tool was not tested against a validation cohort.
17	Eslami Mohammad H, Rybin Denis V, Doros Gheorghe, Siracuse Jeffrey J, and Farber Alik (2017) External validation of Vascular Study Group of New England risk predictive model of mortality after elective abdominal aorta aneurysm repair in the Vascular Quality Initiative and comparison against established models. Journal of vascular surgery ,	Conference abstract
18	Forbes Thomas L, Steiner Stefan H, Lawlor D Kirk, DeRose Guy, and Harris Kenneth A (2005) Risk-adjusted analysis of outcomes following elective open abdominal aortic aneurysm repair. Annals of vascular surgery 19(2), 142-8	Study did not assess the predictive capacity of risk assessment tools. Instead authors describe a method of categorising patients at risk of mortality following elective open AAA repair.
19	Fowkes F G. R, Greenhalgh R M, Powell J T, et al. (1998) Length of hospital stay following elective abdominal aortic aneurysm repair. European Journal of Vascular and Endovascular Surgery 16(3), 185-191	No risk assessment tools were assessed. Instead, investigators assessed which patient-related factors were associated with increased length of stay.

No.	Study	Reason for exclusion
20	Goncalves F B, Ultee K H. J, Hoeks S E, Stolker R J, and Verhagen H J. M (2016) Life expectancy and causes of death after repair of intact and ruptured abdominal aortic aneurysms Presented in the Plenary Rapid Pace Session at the 2015 Vascular Annual Meeting of the Society for Vascular Surgery, Chicago, Ill, June 17-20, 2015. Journal of vascular surgery 63(3), 610-6	No risk assessment tool was assessed. Instead, authors assessed risk factors independently associated with mortality.
21	Goueffic Yann, Becquemin Jean-Pierre, Desgranges Pascal, and Kobeiter Hisham (2005) Midterm survival after endovascular versus open repair of infrarenal aortic aneurysms. Journal of endovascular therapy : an official journal of the International Society of Endovascular Specialists 12(1), 47-57	Study does not assess that predictive capacity of risk assessment tools. Instead, investigators report descriptive statistics of outcomes of patients who underwent surgical repair of unruptured AAAs.
22	Grant S W, Hickey G L, Grayson A D, Mitchell D C, and McCollum C N (2013) National risk prediction model for elective abdominal aortic aneurysm repair. The British journal of surgery 100(5), 645-53	Risk assessment tool development: logistic regression was performed to identify independent risk factors which could be used for developing a bespoke risk assessment tool (not specified in the review protocol). The tool was not tested against a validation cohort.
23	Hadjianastassiou V G, Tekkis P P, Goldhill D R, and Hands L J (2005) Quantification of mortality risk after abdominal aortic aneurysm repair. The British journal of surgery 92(9), 1092-8	Risk assessment tool development: logistic regression was performed to identify independent risk factors which could be used for developing a bespoke risk assessment tool which is not mentioned in the review protocol. Additionally, the study sample included patients who underwent elective and emergency aneurysm surgery.
24	Hadjianastassiou V G, Franco L, Jerez J M, Evangelou I E, Goldhill D R, Tekkis P P, and Hands L J (2006) Optimal prediction of mortality after abdominal aortic aneurysm repair with statistical models. Journal of Vascular Surgery 43(3), 467-473	Risk assessment tool development: logistic regression was performed to identify independent risk factors which could be used for developing a bespoke risk assessment tool (not specified in the review protocol). The tool was not tested against a validation cohort.
25	Hicks Caitlin W, Black James H, 3rd , Arhuidese Isibor, Asanova Luda, Qazi Umair, Perler Bruce A, Freischlag Julie A, and Malas Mahmoud B (2015) Mortality variability after endovascular versus open abdominal aortic aneurysm repair in a large tertiary vascular center using a Medicare-derived risk prediction model. Journal of vascular surgery 61(2), 291-7	No multivariate analysis was used to assess the predictive capacity of the risk assessment tool. Instead, descriptive statistics were used to highlight mortality rates of patients categorised as low, medium or high risk according to the risk assessment tool.
26	Hirzalla Osama, Emous Marloes, Ubbink Dirk Th, and Legemate Dink (2006) External validation of the Glasgow Aneurysm Score to predict outcome in elective open abdominal aortic	Sample size less than 500 participants.

No.	Study	Reason for exclusion
	aneurysm repair. Journal of vascular surgery 44(4), 712-717	
27	Lalys Florent, Durrmann Vincent, Dumenil Aurelien, Goksu Cemil, Cardon Alain, Clochard Elodie, Lucas Antoine, and Kaladji Adrien (2017) Systematic Review and Meta-Analysis of Preoperative Risk Factors of Type II Endoleaks after Endovascular Aneurysm Repair. Annals of vascular surgery 41, 284-293	Study explores risk factors associated with endoleaks after EVAR; however it is not clear whether this is after elective or emergency EVAR. Individual studies were reviewed to ascertain I they were relevant to this review question.
28	Kertai Miklos D, Steyerberg Ewout W, Boersma Eric, Bax Jeroen J, Vergouwe Yvonne, van Urk , Hero , Habbema J Dik F, Roelandt Jos R. T. C, and Poldermans Don (2003) Validation of two risk models for perioperative mortality in patients undergoing elective abdominal aortic aneurysm surgery. Vascular and endovascular surgery 37(1), 13-21	Sample size less than 500 participants.
29	Kodama A, Narita H, Kobayashi M, Yamamoto K, and Komori K (2011) Usefulness of POSSUM physiological score for the estimation of morbidity and mortality risk after elective abdominal aortic aneurysm repair in Japan. Circulation Journal 75(3), 550-556	Sample size less than 500 participants.
30	Khashram M, Williman J A, Hider P N, Jones G T, and Roake J A (2016) Systematic review and meta-analysis of factors influencing survival following abdominal aortic aneurysm repair. European Journal of Vascular and Endovascular Surgery 51(2), 203-215	Risk assessment tool (American Society of Anaesthesiologist score) not included in the review protocol.
31	Kim Jihoon T, Kim Min-Ju, Han Youngjin, Choi Ji Yoon, Ko Gi-Young, Kwon Tae-Won, and Cho Yong-Pil (2016) A new risk-scoring model for predicting 30-day mortality after repair of abdominal aortic aneurysms in the era of endovascular procedures. Annals of surgical treatment and research 90(2), 95-100	Risk assessment tool development: logistic regression was performed to identify independent risk factors which could be used for developing a bespoke risk assessment tool which is not mentioned in the review protocol.
32	Mani K, Venermo M, Beiles B, Menyhei G, Altreuther M, Loftus I, and Bjorck M (2015) Regional differences in case mix and peri-operative outcome after elective abdominal aortic aneurysm repair in the vascunet database. European Journal of Vascular and Endovascular Surgery 49(6), 646-652	Study did not assess the predictive capacity of risk assessment tools. Instead authors reported descriptive statistics. Additionally multivariate analysis was only performed to assess which risk factors were associated with mortality
33	Markar Sheraz R, Walsh Stewart R, Griffin Kathryn, Khandanpour Nader, Tang Tjun Y, and Boyle Jonathan R	Risk assessment tool (Postoperative Pneumonia Risk Index) not specified in the review protocol. Furthermore, it is unclear

No.	Study	Reason for exclusion
	(2009) Assessment of a multifactorial risk index for predicting postoperative pneumonia after open abdominal aortic aneurysm repair. Vascular 17(1), 36-9	whether multivariate analysis was performed.
34	Mastracci Tara M, Greenberg Roy K, Hernandez Adrian V, and Morales Catherine (2010) Defining high risk in endovascular aneurysm repair. Journal of vascular surgery 51(5), 1088-1095.e1	Risk assessment tool development: logistic regression was performed to identify independent risk factors which could be used for developing a bespoke risk assessment tool (not specified in the review protocol).
35	Matsumura Jon S, Katzen Barry T, Sullivan Timothy M, Dake Michael D, Naftel David C, Excluder Bifurcated Endoprosthesis, and Investigators (2009) Predictors of survival following open and endovascular repair of abdominal aortic aneurysms. Annals of vascular surgery 23(2), 153-8	No risk assessment tools were assessed. Instead investigators assessed which individual factors were independently associated with survival following EVAR.
36	Nesi F, Leo E, Biancari F, Bartolucci R, Rainio P, Satta J, Rabitti G, and Juvonen T (2004) Preoperative risk stratification in patients undergoing elective infrarenal aortic aneurysm surgery: Evaluation of five risk scoring methods. European Journal of Vascular and Endovascular Surgery 28(1), 52-58	Sample size less than 500 participants.
37	Mousa Albeir Y, Bozzay Joseph, Broce Mike, Yacoub Michael, Stone Patrick A, Najundappa Aravinda, Bates Mark C, and AbuRahma Ali F (2016) Novel Risk Score Model for Prediction of Survival Following Elective Endovascular Abdominal Aortic Aneurysm Repair. Vascular and endovascular surgery 50(4), 261-9	Risk assessment tool development: logistic regression was performed to identify independent risk factors which could be used for developing a bespoke risk assessment tool (not specified in the review protocol). It is unclear whether an external validation cohort was used.
38	Patterson B O, Holt P J. E, Hinchliffe R, Loftus I M, and Thompson M M (2008) Predicting Risk in Elective Abdominal Aortic Aneurysm Repair: A Systematic Review of Current Evidence. European Journal of Vascular and Endovascular Surgery 36(6), 637-645	Systematic review including prospective and retrospective observational studies. Additionally, some studies had sample sizes of less than 500 patients. Individual studies were assessed to determine whether they met the protocol's inclusion criteria.
39	Patterson Benjamin Oliver, Karthikesalingam Alan, Hinchliffe Robert J, Loftus Ian M, Thompson Matt M, and Holt Peter J. E (2011) The Glasgow Aneurysm Score does not predict mortality after open abdominal aortic aneurysm in the era of endovascular aneurysm repair. Journal of vascular surgery 54(2), 353-7	No multivariate regression was performed to assess the predictive capacity of the Glasgow Aneurysm Score (GAS). Instead, investigators used univariate analysis to assess which components of the GAS were independently associated with death.
40	Pisimisis George T, Bechara Carlos F, Barshes Neal R, Lin Peter H, Lai Win S, and Kougias Panagiotis (2013) Risk factors and impact of proximal fixation on acute and chronic renal dysfunction	No risk assessment tools were assessed. Instead, investigators used multivariate regression to identify which factors were associated with acute kidney injury and chronic kidney disease.

No.	Study	Reason for exclusion
	after endovascular aortic aneurysm repair using glomerular filtration rate criteria. Annals of vascular surgery 27(1), 16-22	
41	Png Chien Yi M, Tadros Rami O, Beckerman William E, Han Daniel K, Tardiff Melissa L, Torres Marielle R, Marin Michael L, and Faries Peter L (2017) An anatomic risk model to screen post endovascular aneurysm repair patients for aneurysm sac enlargement. The Journal of surgical research 217, 29-35.e1	Risk assessment tool development: logistic regression was performed to identify independent risk factors which could be used for developing a bespoke risk assessment tool (not specified in the review protocol). Furthermore, the study included less than 500 participants.
42	Prytherch D R, Ridler B M. F, Ashley S, Audit Research Committee of the Vascular Society of Great, Britain , and Ireland (2005) Risk-adjusted predictive models of mortality after index arterial operations using a minimal data set. The British journal of surgery 92(6), 714-8	No multivariate analysis was performed: instead the descriptive statistics (chi-square test) was used to test the predictive power of the risk assessment tool.
43	Prytherch D R, Sutton G L, and Boyle J R (2001) Portsmouth POSSUM models for abdominal aortic aneurysm surgery. The British journal of surgery 88(7), 958-63	No multivariate analysis was performed. Instead, the descriptive statistics (chi-square test) was used to test the predictive power of the risk assessment tool.
44	Ramanan Bala, Gupta Prateek K, Sundaram Abhishek, Gupta Himani, Johanning Jason M, Lynch Thomas G, MacTaggart Jason N, and Pipinos Iraklis I (2013) Development of a risk index for prediction of mortality after open aortic aneurysm repair. Journal of vascular surgery 58(4), 871-8	Risk assessment tool development: logistic regression was performed to identify independent risk factors which could be used for developing bespoke a risk assessment tool (not specified in the review protocol). It is unclear whether an external validation cohort was used.
45	Samy A K, Murray G, and MacBain G (1994) Glasgow aneurysm score. Cardiovascular Surgery 2(1), 41-44	Risk assessment tool development: logistic regression was performed to identify independent risk factors which could be used for developing a risk assessment tool. No external validation cohort was used.
46	Samy A K, Murray G, and MacBain G (1996) Prospective evaluation of the Glasgow Aneurysm Score. Journal of the Royal College of Surgeons of Edinburgh 41(2), 105-107	No multivariate regression was performed to assess the predictive capacity of the Glasgow Aneurysm Score (GAS). Instead, investigators reported proportions of patients who survived, according to different GAS ranges.
47	Scali Salvatore T, Beck Adam W, Chang Catherine K, Neal Dan, Feezor Robert J, Stone David H, Berceli Scott A, and Huber Thomas S (2016) Defining risk and identifying predictors of mortality for open conversion after endovascular aortic aneurysm repair. Journal of vascular surgery 63(4), 873-81.e1	No risk assessment tools were assessed. Instead investigators assessed independent risk factors associated with conversion to open surgical repair.
48	Schlosser Felix J. V, Vaartjes Ilonca, van der Heijden , Geert J M. G, Moll Frans L, Verhagen Hence J. M, Muhs	No risk assessment tools were evaluated. Investigators assessed which risk factors

No.	Study	Reason for exclusion
	Bart E, de Borst , Gert J, Tiel Groenestege, Andreas T, Kardaun Jan W. P. F, de Bruin , and Agnes (2010) Mortality after elective abdominal aortic aneurysm repair. Annals of surgery 251(1), 158-64	were associated with mortality after elective AAA repair.
49	Sconfienza Luca Maria, Santagostino Ilaria, Di Leo , Giovanni , Piazza Raffaella, Gozzi Gino, Trimarchi Santi, and Sardanelli Francesco (2013) When the diameter of the abdominal aorta should be considered as abnormal? A new ultrasonographic index using the wrist circumference as a body build reference. European journal of radiology 82(10), e532-6	No risk assessment tools were evaluated. Additionally, multivariate analysis was not performed.
50	Setacci F, Sirignano P, Galzerano G, De Donato , G , Ceriello D, Paroni G, Cappelli A, and Setacci C (2012) Siena EVAR Score. The Journal of cardiovascular surgery 53(2), 229-34	Study did not assess the predictive value of a risk assessment tool. Instead, logistic regression was performed to identify independent risk factors which could be used to develop a bespoke risk assessment tool. It is unclear whether an external validation cohort was used
51	Steyerberg E W, Kievit J, de Mol Van Otterloo, J C, van Bockel , J H, Eijkemans M J, and Habbema J D (1995) Perioperative mortality of elective abdominal aortic aneurysm surgery. A clinical prediction rule based on literature and individual patient data. Archives of internal medicine 155(18), 1998-2004	Not an observational study (RQ9). This study combined results from literature data with individual patient data to assess risk factors which could be used to produce a clinical prediction rule. No external validation cohort was used.
52	Stone David H, Goodney Philip P, Kalish Jeffrey, Schanzer Andres, Indes Jeffrey, Walsh Daniel B, Cronenwett Jack L, Nolan Brian W, Vascular Study Group of New, and England (2013) Severity of chronic obstructive pulmonary disease is associated with adverse outcomes in patients undergoing elective abdominal aortic aneurysm repair. Journal of vascular surgery 57(6), 1531-6	No risk assessment tool was assessed. Instead, authors assessed risk factors independently associated with in-hospital and long-term mortality.
53	Tang T Y, Walsh S R, Prytherch D R, Wijewardena C, Gaunt M E, Varty K, and Boyle J R (2007) POSSUM models in open abdominal aortic aneurysm surgery. European journal of vascular and endovascular surgery : the official journal of the European Society for Vascular Surgery 34(5), 499-504	Wrong population: the study sample included patients with ruptured aneurysm who underwent emergency open repair (for ruptured aneurysms). This is out of scope of the review question.
54	Tang T Y, Walsh S R, Fanshawe T R, Seppi V, Sadat U, Hayes P D, Varty K, Gaunt M E, and Boyle J R (2007) Comparison of Risk-scoring Methods in Predicting the Immediate Outcome after Elective Open Abdominal Aortic	Sample size less than 500 participants.

No.	Study	Reason for exclusion
	Aneurysm Surgery. European Journal of Vascular and Endovascular Surgery 34(5), 505-513	
55	Tang Tjun, Walsh Stewart R, Fanshawe Thomas R, Gillard Jonathan H, Sadat Umar, Varty Kevin, Gaunt Michael E, and Boyle Jonathan R (2007) Estimation of physiologic ability and surgical stress (E-PASS) as a predictor of immediate outcome after elective abdominal aortic aneurysm surgery. American journal of surgery 194(2), 176-82	Unclear if multivariate analysis was performed.
56	Ultee Klaas H. J, Soden Peter A, Zettervall Sara L, Darling Jeremy, Verhagen Hence J. M, and Schermerhorn Marc L (2016) Conversion from endovascular to open abdominal aortic aneurysm repair. Journal of vascular surgery 64(1), 76-82	No risk assessment tool was assessed. Instead, authors assessed risk factors associated with conversion to open surgical repair during EVAR.
57	van Beek , Sytse C, Blankensteijn Jan D, Balm Ron, Dutch Randomised Endovascular Aneurysm Management trial, and collaborators (2013) Validation of three models predicting in-hospital death in patients with an abdominal aortic aneurysm eligible for both endovascular and open repair. Journal of vascular surgery 58(6), 1452-1457.e1	Sample size less than 500 participants.
58	Vande Geest, Jonathan P, Di Martino , Elena S, Bohra Ajay, Makaroun Michel S, and Vorp David A (2006) A biomechanics-based rupture potential index for abdominal aortic aneurysm risk assessment: demonstrative application. Annals of the New York Academy of Sciences 1085, 11-21	Wrong study design. This was a study which aimed to predict postoperative aneurysm rupture through evaluation of 13 three-dimensional computer simulations.
59	Vogel Todd R, Dombrovskiy Viktor Y, and Graham Alan M (2009) Elective abdominal aortic aneurysm repair: relationship of hospital teaching status to repair type, resource use, and outcomes. Journal of the American College of Surgeons 209(3), 356-63	No risk assessment tools were assessed. Instead, investigators assessed the relationship between type of hospital and type of AAA surgery performed.
60	Wisniowski Brendan, Barnes Mary, Jenkins Jason, Boyne Nicholas, Kruger Allan, and Walker Philip J (2011) Predictors of outcome after elective endovascular abdominal aortic aneurysm repair and external validation of a risk prediction model. Journal of vascular surgery 54(3), 644-53	Sample size less than 500 participants.
61	Yuo Theodore H, Sidaoui Joseph, Marone Luke K, Avgerinos Efthymios D, Makaroun Michel S, and Chaer Rabih A (2014) Limited survival in dialysis	No risk assessment tool was assessed. Instead, authors assessed risk factors independently associated with mortality.

No.	Study	Reason for exclusion
	patients undergoing intact abdominal aortic aneurysm repair. Journal of vascular surgery 60(4), 908-13.e1	

Economic studies

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

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.