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European Society for Vascular Surgery (ESVS) 2019 Clinical Practice Guidelines on the Management of Abdominal Aorto-iliac Artery Aneurysms

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LIST OF ABBREVIATIONS

3D	Three dimensional
AAA	Abdominal Aortic Aneurysm
ACS	Abdominal Compartment Syndrome
ACT	Activating Clotting Time
ADAM	American Aneurysm Detection And Management study
AOB	Aortic Occlusion Balloon
ARA	Accessory renal arteries
AUI	Aorto-Uni-Iliac
AXR	Abdominal Xray
bEVAR	Branched EVAR
BP	Blood Pressure
CAD	Coronary Artery Disease
chEVAR	Chimney EVAR
CIN	Contrast Induced Nephropathy
CIA	Common Iliac Artery
COPD	Chronic Obstructive Pulmonary Disease
CPR	Cardio-pulmonary Resuscitation
CRP	C-reactive Protein
CT	Computed Tomography
CTA	Computed Tomographic Angiography
DSA	Digital Subtraction Angiography
DUS	Duplex Ultrasonography
DVT	Deep Venous Thrombosis
EIA	External Iliac Artery
eGFR	Estimated Glomerular Filtration Rate
EJVES	European Journal of Vascular and Endovascular Surgery
ERAS	Early Recovery after Surgery
ESC	European Society of Cardiology
ESR	Erythrocyte Sedimentation Rate
ESVS	European Society for Vascular Surgery
EVAR	Endovascular Aneurysm Repair
EVAS	Endovascular Aneurysm Sealing
FDG	Fluoro-deoxyglucose
FEV1	Forced Expiratory Volume in one second
fEVAR	Fenestrated EVAR
FVC	Forced Vital Capacity
GC	Guideline Committee
GWC	Guideline Writing Committee
Hb	Haemoglobin
HK	Horseshoe Kidney
IAA	Iliac Artery Aneurysm
IIA	Internal Iliac Artery
IMA	Inferior mesenteric artery
InflAAA	Inflammatory Abdominal Aortic Aneurysm
IAH	Intra-abdominal Hypertension
IAP	Intra-abdominal Pressure
ICU	Intensive Care Unit
IFU	Instructions For Use
IMH	Intramural Haematoma
ITI	Inner to Inner
JRAAA	Juxtarenal Abdominal Aortic Aneurysm
LDL	Low Density Lipoprotein
LDS	Loeys—Dietz syndrome
LELE	Leading Edge to Leading Edge
LMWH	Low Molecular Weight Heparin
MAA	Mycotic Aortic Aneurysm
MET	Metabolic Equivalent
MRA	Magnetic Resonance Angiography
MRI	Magnetic Resonance Imaging
OSR	Open Surgical Repair
OTO	Outer to Outer

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PAOD	Peripheral Arterial Occlusive Disease
PAU	Penetrating Aortic Ulcer
PET	Positron Emission Tomography
PFG	Patient focus group
PTFE	Polytetrafluoroethylene
QALY	Quality Adjusted Life Years
rAAA	Ruptured Abdominal Aortic Aneurysm
RCT	Randomised Controlled Trial
SAEF	Secondary Aorto-enteric Fistula
SMA	Superior Mesenteric Artery
SRAAA	Suprarenal Abdominal Aortic Aneurysm
SUVmax	Maximum Standard Uptake Value
TAAA	Thoraco-abdominal Aortic Aneurysm
UK	United Kingdom
UKSAT	UK Small Aneurysm Trial
US	Ultrasound
USA	United States of America
VED	Vascular Ehlers–Danlos Syndrome

Chapter 1

1. INTRODUCTION AND GENERAL ASPECTS

1.1. Introduction and methods

Members of this Guideline Writing Committee (GWC) were selected by the European Society for Vascular Surgery (ESVS) to represent physicians involved in the management of patients with abdominal aortic and iliac artery aneurysms. The members of the GWC have provided disclosure statements of all relationships that might be perceived as real or potential sources of conflict of interest. These disclosure forms are kept on file at the headquarters of the ESVS.

The ESVS Guidelines Committee (GC) was responsible for the endorsement process of this guideline. All experts involved in the GWC have approved the final document. The guideline document underwent the formal external expert review process and was reviewed and approved by the ESVS GC and by the *European Journal of Vascular and Endovascular Surgery* (*EJVES*). This document has been reviewed in three rounds by 23 reviewers including 11 members of GC and 12 external reviewers from Europe, America, Asia, and Australia. All reviewers assessed all versions and finally approved the final version of this document.

1.1.1. The purpose of these guidelines. The ESVS has developed clinical practice guidelines for the care of patients with aneurysms of the abdominal aorta and iliac artery, with the aim of assisting physicians in selecting the best management strategy.

The first ESVS abdominal aortic aneurysm (AAA) guideline was published as a supplement in *EJVES* in 2011, under the leadership of Frans Moll.[485] Since then it has been the most cited (396 citations during 2010–2014) and downloaded (>3000 in 2015) paper in the *EJVES* with a major impact on clinical practice and research. In 2015, the ESVS GC, under the leadership of Philippe Kolh, initiated a process to update the AAA guideline.

The present guideline is a complete makeover. Several new topics, not addressed in the previous 2011 guidelines, have been added, such as juxtarenal AAA, isolated iliac aneurysms, mycotic and inflammatory aneurysms, and concomitant malignant disease. Also, new treatment concepts, such as fenestrated endovascular aneurysm repair (EVAR), chimney EVAR (chEVAR) and endovascular aneurysm seal (EVAS) are covered. Furthermore, service standards and logistics of importance, including surgical volume requirements and acceptable waiting time for surgery, are addressed. The patient's perspective has been included for the first time in an ESVS guideline. For already established topics, several updated recommendations have been made based on new data/evidence, such as recommendations on an EVAR first strategy for ruptured AAA (rAAA), a stratified less frequent follow up regimen after EVAR, and an updated surveillance protocol for small AAAs and subaneurysms.

The guideline, written and approved by the 16 members of the GWC, who are all members of the ESVS, is based on scientific evidence completed with expert opinion on the matter. By summarising and evaluating the best available evidence, recommendations for the evaluation and treatment of patients have been formulated.

The recommendations represent the general knowledge at the time of publication, but technology and disease knowledge in this field may change rapidly; therefore, recommendations can become outdated. It is an aim of the ESVS to update the guidelines when important new insights in the evaluation and management of diseases of the abdominal aorta and iliac artery become available.

Although guidelines have the purpose of promoting a standard of care according to specialists in the field, under no circumstance should this guideline be seen as the legal standard of care in all patients. The document provides a guiding principle, but the care given to an individual patient is always dependent on many factors including symptoms, comorbidities, age, level of activity, treatment setting, available techniques, and other factors.

1.1.2. Methodology

1.1.2.1. Strategy. The GWC convened on January 18, 2016, during a meeting in Hamburg. At that meeting the tasks in creating the guideline were evaluated and distributed among the committee members. Following preparation of the first draft, GWC members participated in a second meeting in Uppsala in March 2017 to review the wording/grading of each recommendation. If there was no unanimous agreement, discussions were held to decide how to reach a consensus. If this failed, then the wording, grade, and level of evidence was secured via a majority vote of the GWC members. The final version of the guideline was submitted in June 2018.

These guidelines will be updated continuously.

1.1.2.2. Literature search and selection. Members of the committee, supported by clinical librarians performed the literature search for this guideline systematically in Medline (through PubMed), Embase, Clinical Trial databases, and the Cochrane Library up to December 31, 2016. Reference checking and hand search by the GWC members added

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other relevant literature. A second literature search for papers published between May 2016 and January 2018 was performed in May 2018. The members of the GWC performed the literature selection based on information provided in the title and abstract of the retrieved studies.

Criteria for search and selection were (1) Language: English. (2) Level of evidence: Selection of the literature was performed following the pyramid of evidence, with aggregated evidence at the top of the pyramid (systematic reviews, meta-analyses), then randomised controlled trials, then observational studies. Single case reports, animal studies, and in vitro studies at the bottom of the pyramid were excluded, leaving expert opinions at the bottom of the pyramid. The level of evidence per section in the guideline is dependent on the level of evidence available on the specific subject. (3) Sample size: Larger studies were given more weight than smaller studies. (4) Relevant articles published after the search date or in another language were included, but only if they were of paramount importance to this guideline.

1.1.2.3. Weighing the evidence. To define the current guidelines, members of the GWC reviewed and summarised the selected literature. Conclusions were drawn based on the scientific evidence. The recommendations in the guidelines in this document are based on the European Society of Cardiology (ESC) grading system. For each recommendation, the letter A, B, or C marks the level of current evidence (Table 1.1). Weighing the level of evidence and expert opinion, every recommendation is subsequently marked as either Class I, IIa, IIb, or III (Table 1.2).

1.1.2.4. The patient's perspective. The goals behind patient participation in healthcare decision making can be categorised as democratisation and increased quality of decisions.[725] Patient engagement improves the validity of clinical guidelines and is encouraged by international and national groups.[126,294,566]

In order to improve accessibility and interpretability for patients and the public the plain English summaries for these guidelines were subjected to a lay review process. Information for patients was drafted for each subchapter which was read and amended by a vascular nurse specialist and at least one lay person or patient, before going to the Leicester patient focus group (PFG) for their opinions.

Men with small AAA under surveillance in the Leicester (UK) Vascular Surgery Unit were invited to attend a focus group meeting. All men had previously attended a patient education event to provide information about the clinical management of small AAA. This included the rationale for intervention thresholds, measures to improve fitness in preparation for surgery, and how decisions between endovascular repair, open surgery, and optimal medical therapy are made when a patient is referred for consideration of surgery.

Eight men attended a focus group discussion in November 2016 and July 2017. The provisional plain English summaries for the guidelines had been sent to the group of men attending, one week prior to the meeting. The men had been asked to read the text in preparation for the meeting. At the meeting the background to the ESVS guideline development process was presented.

The main theme that arose from the discussions was that of clarity, consistency, and simplicity in the presentation of facts and recommendations in the plain English summaries. A recurring example raised by the men in the group was the requirement for contextualisation when presenting risk, which was incorporated into subsequent drafts. Other changes that were made in response to the input of the PFG were the combination of all plain English summaries into a single document with a strong focus on dispelling medical myths about AAA, the provision of more information about how an individual may reduce their risk from AAA/surgery and the generation of a list of key facts about AAA for public use.

The PFG activities were conducted in Leicester, UK and involved only men with small AAAs under surveillance. No women with AAA, or the partners of patients were involved in the exercise. These limitations should be taken into consideration when reviewing this report.

Table 1.1. Levels of evidence.

Level of evidence A	**Data derived from multiple randomised clinical trials or meta-analyses.**
Level of evidence B	**Data derived from a single randomized clinical trial or large non-randomised studies.**
Level of evidence C	**Consensus of opinion of the experts and/or small studies, retrospective studies, registries.**

Table 1.2. Classes of recommendations.

Classes of recommendations	Definition
Class I	**Evidence and/or general agreement that a given treatment or procedure is beneficial, useful, effective.**
Class II	**Conflicting evidence and/ or a divergence of opinion about the usefulness/efficacy of the given treatment or procedure.**
Class IIa	***Weight of evidence/opinion is in favour of usefulness/efficacy.***
Class IIb	***Usefulness/efficacy is less well established by evidence/opinion.***
Class III	**Evidence or general agreement that the given treatment or procedure is not usefull/ effective, and in some cases may be harmful.**

1.2. Service standards

Management and treatment of AAA is associated with risk for the patient and puts great demands on the organisation. This chapter discusses general recommendations concerning quality, availability, experience, and time frames that apply to contemporary management and treatment of AAA. The recommendations made herein are only valid as long as all parts of the chain have sufficient quality and availability. Whenever these requirements cannot be provided locally, patients should be transferred to an appropriate centre. Referral should take into account the patient's preference.

1.2.1. Quality control. The importance of quality control in vascular surgery is well established. More than 40 years ago,

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the American Heart Association's Committee on Vascular Surgery had already recommended as a minimum standard that "vascular surgeons keep standardised and detailed records so that their work may be readily judged by its results".[157] Local, regional, and national vascular surgical quality registries exist in many countries and allow for continuous assessment of aortic practice and its outcome in participating centres.[48,439,481] Clinical audit of key outcome parameters (e.g. peri-operative mortality after elective aortic repair) allows for identification of outliers, and appropriate intervention to improve outcomes.[220] This is particularly important in the era of rapid technical and medical development, such as the introduction of new endovascular technologies and screening. The increasing use of endovascular techniques has resulted in an ongoing change in indications with older and more comorbid patients being treated[401] and a continuing evolution of EVAR devices, which have been assessed with variable rigour for different periods of follow up. Centres performing surgical treatment of AAA should therefore preferably participate in registries which allow for continuous quality control assessment. To allow for meaningful evaluation of surgical quality, internal and external validity of such registries is of utmost importance.[700,740] Generally, cases that are not registered tend to have worse outcomes.[185] Population based prospective registries are also a dynamic complement to randomised controlled trials (RCT) in providing pilot data early on as well as later monitoring the generalisability of new treatment strategies and technologies. Both randomised and non-randomised sources of evidence have strengths and weaknesses.[116] High quality and validated registries have a low risk of bias and reflect the daily practice over a longer time period and are region, nation, or continentwide. Aggregated results from RCTs and prospective registries have the potential to be major assets in guiding the local vascular surgeon as well as nationwide policy makers.[32]

Patient reported outcome measures (PROMs) are questionnaires that provide a means of measuring health or quality of life (QoL) from the patient's perspective.[175] Recently, three disease specific questionnaires were developed to assess QoL, symptoms and treatment satisfaction in patient with AAA; The Aneurysm Dependent Quality of Life Questionnaire (AneurysmDQoL), The Aneurysm Symptom Rating Questionnaire (AneurysmSRQ), The Aneurysm Treatment Satisfaction Questionnaire (AneurysmTSQ).[546,547] So far they have only been used in a small pilot study; however, showing their potential for patients with small AAAs under surveillance as well as before and after surgical repair,[546,547] and in a systematic review and qualitative evidence synthesis they were superior to generic PROMs, such as Short Form 36 and the Australian Vascular Quality of Life Index, in assessment of items important to patients with an AAA.[175] Further evaluation and refinement of AAA specific PROMs and their implementation, preferably within the framework of vascular surgery quality registries, are warranted.

Recommendation 1	Class	Level	References
Centres performing aortic surgery are recommended to enter cases in a validated prospective registry to allow for monitoring of changes in practice and outcomes.	I	C	[48,157,220, 439,477]

1.2.2. Resources and availability. The management of AAA has changed profoundly with the introduction of endovascular treatment options. Studies have convincingly shown the benefit of EVAR in both elective and emergency AAA repair in patients with suitable anatomy. The continuously decreasing peri-operative mortality and simultaneous increase in the utilisation of EVAR (at the expense of open surgical repair (OSR)) observed in several large population based studies, representing real world data, has provided additional support for the use of EVAR as an essential part of modern AAA treatment. This is also reflected by the recommendations made in this updated guideline.

At the same time, it is evident that some patients are not suitable for standard EVAR or more complex new endovascular treatment options but should instead be offered open surgery. Furthermore, complications after EVAR are not uncommon and may require elective as well as acute open surgical treatment. Similarly, OSR may sometimes require adjuvant endovascular treatment.

Consequently, one technique cannot entirely replace the other, at least not yet. Compromising the anatomical requirements for standard EVAR or using complex and partially unexplored endovascular techniques to avoid an established open surgical solution at all costs, or just offering major open surgery when there are proven minimally invasive techniques just because it is outside office hours, is not only unscientific, it is also unethical. Thus, today it is not acceptable to perform aortic surgery without the ability to offer both technologies 24/7.[50,70,237,287–289,378,386,541,558,606]

Recommendation 2	Class	Level	References
It is recommended that centres or networks of collaborating centres treating patients with abdominal aortic aneurysms can offer both endovascular and open aortic surgery at all times.	I	B	[50,70,237,287–289,378,386,541, 558,606]

1.2.3. Surgical volume. The relationship between surgical volume (caseload) and outcome has been reported for a

range of surgical and interventional specialties and has attracted considerable debate. However, the evidence for vascular surgery is robust and an association has been repeatedly demonstrated between higher annual caseload and lower operative mortality for AAA repair.

In a study from 2002 including 140,000 AAA repairs in Medicare the 30 day mortality was 8% for low volume hospitals (<17/year) compared to 4% in high volume hospitals (>79/year).[64] Similarly, a 13% reduction in the odds of mortality for each additional 20 cases performed was observed in a UK audit.[279] A meta-analysis of international practice, including 421,229 elective AAA repairs, demonstrated significantly favourable outcomes from higher volume units with a pooled effect estimate for mortality of odds ratio 0.66 (95% CI 0.65–0.67) for units performing ≥ 43 AAA repairs per year.[278] A recent study including >120,000 Medicare patients undergoing elective EVAR found a threshold for optimal outcomes of 30 EVAR cases per year.[788] Others suggest a lower threshold of ≥10 EVAR cases in a setting with a total volume, including OSR, of ≥50 repairs per year.[378]

In addition to the relationship between hospital volume and mortality, a similar association has been observed for surgeons' caseload and outcome.[548] However, this is harder to interpret in the modern era, when AAA repair is performed by teams rather than individuals.[33]

The associations between volume and outcome have also been shown in the emergency setting, for ruptured AAA (rAAA) repair[526,174,124,99] and recent studies document that it is safe to transfer most rAAA patients to the nearest high volume specialised vascular centre and that such a policy may, in fact, decrease mortality.[435,531,277] In a recent international registry study, including 9273 patients from 11 countries treated for rAAA, the peri-operative mortality was lower in centres with a primary EVAR approach or with high caseload volume; 23% in centres >22 repairs per year versus 30% in centres with a caseload <22, $p < 0.001$. The observed difference in outcome was predominantly seen after OSR, while no significant difference in peri-operative mortality after EVAR between centres based on volume could be observed. With most repairs still performed in very low volume centres and in centres with a primary OSR mortality was lowest when operations were performed by vascular surgeons (2.2%), compared to cardiac surgeons (4%) and general surgeons (5.5%) ($p < 0.001$). AAA repair performed by a general surgeon increased the risk of death by 76% compared to repair performed by a vascular surgeon.[162] The likelihood of receiving EVAR rather than OSR was higher when vascular surgeons performed the operation compared with treatment by general surgeons and cardiac surgeons.[706] There is, however, no comparative study between vascular surgeons and interventional radiologists, who today represent the two specialities that perform most AAA operations. In addition, several operations are now being carried out by a multidisciplinary team, making it difficult to provide a clear recommendation. Even if no specific recommendation on the specialtyis made, the GWC advocates that AAA surgery should be done under the leadership of a vascular surgeon.

In summary, the firm evidence of a volume outcome relationship makes it necessary and justifiable to make a recommendation on surgical volume. No clear threshold has, however, been defined in the literature. Instead, various cut off levels have been suggested. Important methodological differences between the studies, such as different healthcare systems, study design, surgical techniques, and populations, make it difficult to perform a formal meta-analysis of the optimal surgical volume. In addition, this is a sensitive issue with political implications making it challenging to provide a recommendation that can be accepted by everyone. Based on the literature, the GWC concluded that there is enough evidence for a rather strong recommendation on the required minimum volume to perform aortic surgery at all, and a weaker recommendation on the desired minimum volume, which should also work in different healthcare settings and geographies and be accepted by most.

Although available data indicate that surgical volume has an important impact on the outcome after OSR and to a lesser extent after EVAR, when adding detail to Recommendation 2, no distinction is made between EVAR and OSR and both types of repair should be included in the total volume of cases.

Recommendation 3	Class	Level	References
Abdominal aortic aneurysm repair should only be considered in centres with a minimum yearly caseload of 30 repairs.	IIa	C	[64,278,328,788]

Recommendation 4	Class	Level	References
Abdominal aortic aneurysm repair should not be performed in centres with a yearly caseload <20.	III	B	[124,160,174, 277,329,378, 435,526,531]

strategy reorganisation of acute vascular surgical services has the potential to improve outcomes of rAAA repair.[99]

Surgeon speciality also has significance for the outcome of AAA repair. In a study from the USA elective AAA

1.2.4. Pathway for treatment. RCTs have demonstrated the safety of a policy of ultrasonographic surveillance for asymptomatic AAAs below the threshold for elective repair. Above this threshold, the risk of rupture increases

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exponentially, however, with significant individual variation.[533] There are limited data concerning a reasonable waiting time for treatment once the threshold for repair has been reached.

Based on a retrospective analysis of 361 patients assigned for elective AAA repair, Noronen et al. suggested that the period from referral to operation should vary by AAA diameter: urgent (within 48 h) for AAAs $>$ 9 cm, one month for AAAs 7–9 cm, two months for AAAs 6–7 cm, and three months for AAAs $<$ 6 cm.[511] In the EVAR 2 trial, a RCT evaluating the long-term outcomes in physically frail patients with AAA treated with either early EVAR or no intervention, about 5% ruptured after randomisation but before attempted surgery. The median aortic diameter was 6.4 cm and the median time between randomisation and repair was eight weeks.[192,193] That rate is probably on the borderline of what is acceptable and thus indicates a possible upper limit on the waiting time for surgery.

The AAA size also affects what is an acceptable waiting time to repair. In a retrospective study of 138 AAA patients not undergoing immediate repair, the cumulative rupture rate was 4% at one year, 16% at three years, and 36% at five years in patients with baseline diameter 5.5–6.9 cm AAAs versus 35%, 71% and 100% in those with $>$7 cm AAAs.[615] In a recent meta-analysis, including 11 studies with total 1514 patients reporting follow up of untreated large AAA, the annual rupture rates was 3.5% in AAAs 5.5–6.0 cm, 4.1% in AAAs 6.1–7.0 cm, and 6.3% in AAAs $>$7.0 cm.[533]

In addition, there are psychological consequences of living with a large AAA, which seem to be reversible by surgery,[275,407] which further underlines the need to keep the waiting time for referral and treatment at a minimum.

Although there is no strong evidence to support exact timings, it is reasonable to adopt a similar approach as for other potentially lethal diseases, such as malignant disease. A suggested upper limit for the total pathway from referral to treatment is eight weeks, once the intervention threshold has been reached. This applies, however, only to standard AAA cases, whereas in more complex aneurysms or comorbid patients a lengthier planning or work up time may be justified. Correspondingly, a shorter timeframe should be pursued for larger AAAs.

Management of aortic diseases includes dealing with true emergencies, such as rupture, requiring quick and efficient handling that places high demands on the organisation. Establishing a protocol or algorithm for managing these emergencies is important to obtain optimal outcomes.[467,489,651] A 35% relative risk reduction in 30 day mortality for managing rAAA, corresponding to an absolute risk reduction of 22.5%, was reported after implementation of a structured protocol.[651]

A dedicated protocol has the potential to ensure a rapid and safe diagnosis, routine use of permissive hypotension pre-operatively,[372,739] facilitate the use of EVAR,[705] local anaesthesia,[651] and aortic occlusion balloon (AOB) when necessary.[434] When and how to notify the endovascular team, and secure a suitable operating environment, preferably a hybrid room, should be defined. Protocolised management of life threatening post-operative complications, such as abdominal compartment syndrome (ACS) is also strongly recommended.[68,349]

Guidelines and an established plan are also of importance in case of urgent referral/transportation to a high level facility for complex aortic repair.[249,274,278,471]

Chapter 2

2. EPIDEMIOLOGY, DIAGNOSIS, AND SCREENING

2.1. Epidemiology

2.1.1. Definition of abdominal aortic aneurysms. Aneurysm, from the Ancient Greek word ἀνεύρυσμα, means a dilatation or widening of an artery, most commonly being fusiform in shape. This chapter focuses on infrarenal AAAs. The most widespread definition of an AAA is based on the diameter of the abdominal aorta: an abdominal aortic diameter of 3.0 cm or more, which usually is more than 2 standard deviations above the mean diameter for men, is considered to be aneurysmal.[186,388,409] This definition, based on external ultrasound diameters had a sensitivity of 67% and a specificity of 97% in predicting the need for AAA repair within 10 years.[210] A lower threshold might be more appropriate in women and some Asian populations.[399,672]

Recommendation 5	Class	Level	References
Once the intervention threshold has been reached, the waiting time for vascular surgical care is recommended to be kept to a minimum, with an eight week pathway as a reasonable upper limit from referral to elective treatment of abdominal aortic aneurysms.*	I	C	[192,193,275,407,511,533,615]

* A shorter timeframe should be considered for larger AAAs while a lengthier planning or work up time may be justified for more complex aneurysms or comorbid patients.

Recommendation 6	Class	Level	References
An established protocol for the management of aortic aneurysm emergencies is recommended.	I	C	[274,467,489,651,705]

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Diameter measurements vary according to imaging methodology, with inner to inner wall measurements being about 0.3–0.6 cm smaller than outer to outer wall measurements, with leading edge to leading edge measurements being intermediate.[246,260,682] Therefore, all studies should specify the site and plane of measurement of aortic diameter. Other researchers have suggested defining AAA as the maximum infrarenal aortic diameter being at least 1.5 times larger than the expected normal infrarenal aortic diameter or suprarenal aortic diameter to compensate for individual variation in the diameter of the adjacent aorta and the different diameters measured.[304,339] This 1.5 fold diameter increase also provides a useful basis for the definition of AAA in women, iliac artery and other aneurysms.

2.1.1.1. Suggested reporting standards for AAA.

- AAA in men of European origin can be defined as an abdominal aortic diameter of 3.0 cm in either antero-posterior or transverse planes. A lower threshold might be more appropriate in women and some Asian populations.
- AAA also can be defined when the maximum diameter is $\geq$ 50% greater than the suprarenal diameter.
- The calliper placement, plane, and site of all measurements must be reported. This is particularly relevant for CT measurements, where the diameter in a plane perpendicular to the centreline should be reported and for all measurements the position of calliper placement should be specified: see Chapter 2.2 for full details.

2.1.2. Prevalence of AAA. AAA prevalence and incidence rates have decreased over the last 20 years, which has been attributed partially to the decline in smoking.[597,627,663] Prevalence is negligible before the age of 55–60 years and thereafter prevalence increases steadily with age.[597] In 1990, the global prevalence in 75–79 year olds was 2423 per 100,000 population versus 2275 in 2010;[597] the incidence has declined in both developed and developing countries. At both time points the prevalence was highest in Australasia, North America, and Western Europe and lowest in Latin America and Central Asia. Population screening studies offer the best evidence regarding the contemporary prevalence of AAA. The current prevalence in 65 year old men is 1.7% in the Swedish Screening Programme with an additional 0.5% with an already known AAA[663] and 1.3% in the UK National Screening Programme[295,297] and 3.3% in a Danish screening programme targeting men aged 65–74 years.[241] In contrast, a programme in the USA which only offers screening to smokers reports a prevalence of over 5%.[392]

A corresponding 20–50% decline over the last two to three decades in rAAA hospital admissions and incidence of rAAA repair has been reported from many countries in Europe and the USA, despite an ageing population.[171,374,401,607]

Most studies show that the prevalence is up to fourfold less in women than men. A recent systematic review of publications between 2000 and 2015 indicates that the pooled prevalence of AAA in women over 60 years was 0.7%.[707]

2.1.3. Natural history of small AAA. The natural history of small AAA is progressive growth in the majority of patients. The RESCAN study, an individual patient meta-analysis of >15,000 patients with AAA, 3.0–5.5 cm in diameter, indicated that (1) there was no difference in aneurysm growth rates between men and women, both on average 2.2 mm/year, (2) smoking increased aneurysm growth rates by 0.35 mm/year (about 16%), and (3) diabetes was associated with decreased aneurysm growth rates by 0.51 mm/year (approximately 25% reduction).[668] Within the diameter range studied, there was an exponential increase in average growth rates from 1.3 mm/year for 3.0 cm aneurysms to 3.6 mm/year for 5.0 cm aneurysms. Aneurysm growth rates do not appear to have changed over the past 25 years.[522]

2.1.4. Risk factors for AAA. Smoking is the strongest risk factor for AAA, with an odds ratio of >3 for the association,[383,663] and higher in women.[298,647] A screening and validation study of USA veterans (between 50 and 79 years old n = 114,419) noted the highest prevalence of AAA $\geq$ 3.0 cm of 5.1% in white male smokers between 50 and 79 years.[383]

Other risk factors include age, atherosclerosis, hypertension, ethnicity, and family history of AAAs.[296,298,383,663] Unique twin registry studies from Sweden and Denmark suggest that the heritability may be as high as 70%.[751,307]

The risk of developing AAA in a person with diabetes, especially type II diabetes, is about half that in a person without diabetes.[384,620]

2.2. Diagnosis

This section assesses modalities used for the diagnosis of AAA. The suitability of different imaging modalities is discussed, and their ability to assess aneurysm size and extent is evaluated. In addition, imaging modalities providing for the incidental diagnosis of AAA are discussed.

2.2.1. Clinical signs. AAAs are usually clinically silent. Physical examination may reveal a pulsatile mass, but abdominal palpation has a sensitivity <50% for detection of AAA[320] and decreases in patients with an abdominal girth more than 100 cm.[51,388] Therefore, abdominal palpation is not reliable for the diagnosis of AAA.

Symptoms or signs of an intact AAA, if present, are mainly pain or tenderness on palpation, localised to the AAA or radiating to the back or to the genitals. Symptoms may be related to complications, either by compression of nearby organs (duodenal obstruction, lower limb oedema, ureteral obstruction) or distal embolism.

For rupture the signs are usually more dramatic (haemodynamic collapse, pallor, abdominal and/or back pain, abdominal distension, and rarely primary aorto-enteric or arterio-venous fistula).

2.2.2. Imaging techniques

2.2.2.1. Ultrasonography. Abdominal ultrasound (US) and duplex ultrasonography (DUS) are first line imaging tools for detection and management of small AAAs, with high

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sensitivity and specificity.[409,416] US may also be used to detect AAA in the emergency room[153,590] but there are no studies evaluating the accuracy of diameter measurement in the emergency setting. Limitations are (1) obesity or excess bowel gas; (2) variation of aortic diameters with the cardiac cycle; (3) the absence of serial image reconstruction to allow for stent graft planning; (4) methodological differences (in training and instrumentation), and (5) visualisation of the suprarenal aorta can be difficult and there is no visualisation of the thoracic aorta.

Some of these limitations can be resolved by training and reporting standards: measurement performed in diastole versus systole, may result in a 2 mm lower diameter.[240] The use of a standardised US protocol including ECG gating and subsequent offline reading with minute calliper placement reduces variability.[87] Measurements must be performed in a plane perpendicular to the aortic longitudinal axis, which will vary in the presence of aortic tortuosity.

Different diameters can be measured/reported: antero-posterior, transverse, maximum in any direction.

In a review by Beales, intra-observer coefficients of repeatability for the antero-posterior and transverse diameters vary from 1.6 to 7.5 mm and from 2.8 to 15.4 mm, respectively,[47] which supports the use of the antero-posterior diameter as the principal measuring plane.

Calliper positioning determines which aortic boundaries are selected to define diameter:[416] outer, inner or leading edge, or combinations of these (Fig. 2.1). The existing literature is unclear which method has the best reproducibility, although the inter-observer variability for outer to outer (OTO) measurement has often been reported as lower than for ITI and LELE measurements.[63,77,246,260,682] Furthermore, it is important to acknowledge that the measured aortic diameter significantly depends on the method used.[246] Given the variation of evidence, opinion and established routines, and the importance of training, it is not possible to specify the preferred method at this stage. Until international consensus is reached, it is important to use *one* method consistently within every clinical programme.

Insufficient attention to reporting standards (specifying plane and positioning of callipers) is an important cause of poor inter- and intra-observer reproducibility.[416] The acceptable standard for measurement repeatability is that the limits of agreement should be $\pm$ 5 mm (meaning that the mean difference between measurements is $<$ 5 mm for 95% of measurements).[416]

Recommendation 7	Class	Level	References
Ultrasonography is recommended for the first line diagnosis and surveillance of small abdominal aortic aneurysms.	I	B	[389,409,416, 770]

Recommendation 8	Class	Level	References
The antero-posterior measuring plane with a consistent calliper placement should be considered the preferred method for ultrasound abdominal aortic diameter measurement.	IIa	B	[47,240,246, 260,416,682]

2.2.2.2. Computed tomography angiography. Computed tomography (CT) angiography (CTA) plays a key role in assessing the extent of disease and therapeutic decision making and planning. CTA is also the recommended imaging

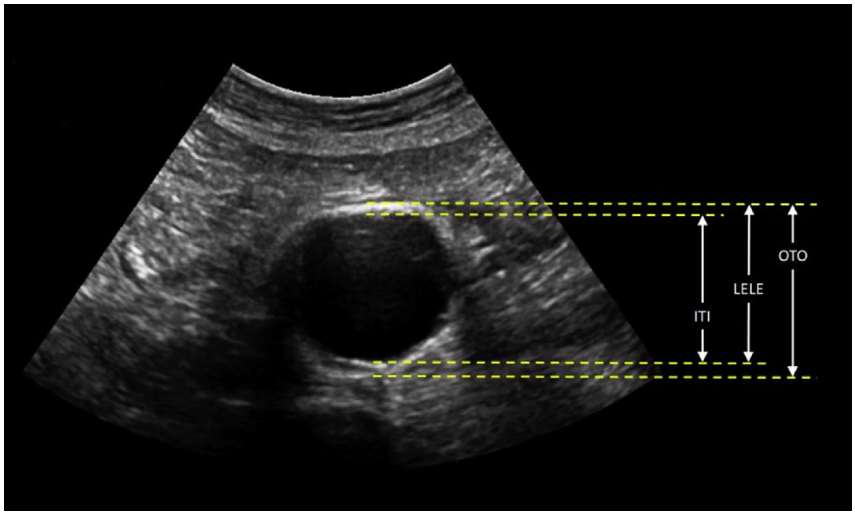

Figure 2.1. Caliper placement for measurement of aortic diameter. ITI = inner to inner; LELE = leading edge to leading edge; OTO = outer to outer.

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modality for the diagnosis of rupture and is an important tool in follow up after repair.[589]

Many of the same issues concerning measurement by US apply to CT measurement, for example axial versus orthogonal centreline diameters, changes with the cardiac cycle and details of calliper placement.[490,491] When applying predefined methodologies, intra-observer reproducibility can be within the clinically accepted range (±5 mm) in 90% AAA measurements, but the inter-observer reproducibility is poor, with 87% comparisons being outside ± 5 mm.[490] This variability is of particularly high clinical significance, since the number of patients considered for AAA repair, based on a diameter threshold, may vary from 11% to 24%, 5%—20%, and 15%—23% for three different radiologists.[490] There is no evidence whether this variability could be reduced with ECG gating, which carries the disadvantage of increased radiation dosage.[240]

CTA provides several advantages for intervention planning: it provides a complete data set of the entire aorta (including the thoracic aorta) and access vessels, which with dedicated post-processing software enables analysis in three perpendicular planes, construction of a centreline, and accurate diameter and length measurement. This reconstruction allows for pre-intervention planning for EVAR and three dimensional image fusion of CTA and angiography for real time peri-operative guidance. A prerequisite for a good reconstruction is CTA with ≤1 mm slice thickness. CTA provides additional information on patency/stenosis of arterial tributaries, position and/or duplication of the left renal vein, neck morphology, and aortic wall integrity at the level of the neck, useful for endovascular and OSR planning.

Limitations include the use of nephrotoxic contrast agents and radiation. It is important to assess renal function before CT scan and to ensure adequate hydration for those with marginal renal function. Recent evidence does not suggest that there are clear advantages for any specific hydration protocol including whether hydration is oral or intravenous.[351,451]

Irradiation of the patient, especially with repeated CT scanning, may have an ensuing cancer risk. The mean estimated annual cumulative effective dose is 104 mSv per patient-year for EVAR, with a 0.8% average risk of exposure induced death.[86] The radiation risk during EVAR may be higher in younger patients.[72] Several methods are emerging to reduce the radiation dosage associated with CT scans.

Finally, there is often poor agreement between US and CTA diameters, particularly close to the treatment threshold. Again, much of this difference is probably attributable to inadequate reporting standards with respect to specification of aortic axis, plane of measurement and calliper placement, although differences in instrumentation also will be contributory. Most often, this results in a larger diameter on CTA compared with US, and it has been reported that for US diameters of 50—55 mm, up to 70% of AAAs exceed 55 mm on CTA.[207] US is recommended for surveillance of small AAA and CTA for pre-operative imaging, i.e. CTA should be performed when the size threshold for repair has been reached, as assessed by US.

2.2.2.3. Magnetic resonance imaging. Magnetic resonance imaging (MRI) is less widely available than CTA, with contraindications such as claustrophobia and some metal implants. However, MRI does not require radiation or injection of iodinated contrast agents, and therefore has an advantage over CTA when AAA management requires repeated imaging. There are few data concerning the use of MRI for routine AAA management in clinical practice, either for MRI or contrast enhanced MR angiography (CE MRA). Measurement comparisons with the gold standard CTA are scarce.[189]

2.2.2.4. Positron emission tomography-computed tomography (PET-CT). ^{18}Fluoro-deoxyglucose PET-CT localises and quantifies metabolic activity of cells, including inflammatory cells. ^{18}Fluoro-deoxyglucose PET-CT is a complementary imaging method for the diagnosis and follow up of aortic pathologies associated with inflammatory aneurysm,[596] aortic infection, including mycotic AAAs,[496] infected prostheses and stent grafts (see Chapter 6). Apart from these indications, PET-CT is primarily a research tool.

2.2.2.5. Incidental detection. Diagnostic imaging used for the investigation of other pathologies including back or chest pain, abdominal and genitourinary symptoms may also detect AAA. While US and CT scan are most commonly used, there are other imaging modalities including echocardiography, CT colonography, and spinal imaging which may diagnose an AAA.[8,231,341,539,774] There is little information about the sensitivity and specificity of these imaging modalities for the diagnosis of AAA. There also is the worrying observation that many of these incidentally diagnosed AAAs are ignored and not referred to vascular surgeons.[463,672,734]

Recommendation 9	Class	Level	References
In patients with abdominal aortic aneurysms computed tomography angiography is recommended for therapeutic decision making and treatment planning, and for the diagnosis of rupture.	I	C	[370,416,589]

Recommendation 10	Class	Level	References
Aortic diameter measurement with computed tomography angiography should be considered using dedicated post-processing software analysis in three perpendicular planes with a consistent calliper placement.	IIa	C	[490]

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Recommendation 11	Class	Level	References
It is recommended that patients with incidentally detected abdominal aortic aneurysm are referred to a vascular surgeon for evaluation, except for cases with very limited life expectancy.	I	C	[734]

2.3. Screening

This section aims to answer the following questions: (1) Does population screening for AAA reduce total AAA related mortality? (2) Does population screening for AAA reduce all cause mortality?, and (3) What is the evidence to support recommendations on AAA screening?

US can reliably image the infrarenal aorta in 98.5% of subjects[409] but visualising the aorta may be difficult in some cases (1–2%) and this should be recognised. In difficult cases the subject should be rescanned, after overnight fasting, in a hospital setting by an experienced sonographer.

2.3.1. Population screening for AAA in men

2.3.1.1. The benefits of ultrasonographic screening for AAA in older persons. There have been four randomised trials of population based screening for AAA in men in the UK, Denmark, and Australia (Table 2.1)[408,495,509,614,690,691] and one small trial of screening in women in the UK.[613] All the trials used population registers to identify potential participants of age 65 years or older and randomisation was either to an invitation for screening or no invitation to screening. The largest trial, MASS in the UK, excluded persons who were identified as having serious health problems or previous AAA repair, whereas the other trials had no exclusion criteria. Using Cochrane criteria,[132] all the trials were of reasonable quality, with MASS and the Danish trial being of good quality.[408,495] Three of the trials used prespecified surveillance and or referral protocols for those in whom an AAA was detected but the Australian trial referred patients to their primary care doctor. The primary outcome for all trials was AAA related mortality. Additionally, one similarity between the trials, not listed in Table 2.1, is that all trials were conducted in relatively advanced socioeconomic areas predominantly outside the largest cities and in persons of Caucasian origin.

The four screening trials in men have been summarised in a Cochrane Review and by the USA Preventive Services Task Force.[132,244] Overall there was a reduction in AAA specific mortality with the Cochrane review reporting the odds ratio in favour of screening for men as 0.60 (95% CI 0.47–0.78) and the USA Preventive Task Force reporting an odds ratio of 0.53 (95% CI 0.42–0.68). There was significant reduction in AAA related mortality in the MASS and Viborg trials at all time points from 3 to 15 years of follow up but not in the Australian trial.[458] This latter trial has recently published its long-term follow up and these data have been included in a meta-analysis in the associated editorial.[390] At the longest reported follow up from each trial, all cause mortality was significantly lower in the groups invited to screening, risk ratio 0.987 (95% CI 0.975–0.999, $p = 0.03$).[390] Therefore, aneurysm screening is almost unique in reducing both cause specific and all cause mortality. A recent Swedish nationwide study confirmed the result from the RCTs in a contemporary population based setting[758] and recent further support for AAA screening as part of multimodality screening in reducing all cause mortality comes from the Danish Viva trial.[410]

2.3.1.2. Harms, benefits and limitations of ultrasonographic screening for AAA in older persons. The principal harms of screening are associated with an increased rate of elective AAA repair (with its associated morbidity and mortality) and effects on quality of life. The number of

Table 2.1. Summary of randomised trials of population based screening for abdominal aortic aneurysm in men.

Trial characteristics	Chichester UK	Viborg Denmark	MASS UK	Western Australia
Number randomised	15,775	12,628	67,800	41,000
Gender	Men and women	Men	Men	Men
Age (year)	65–80	65–73	65–74	65–79
Period recruited	1988–1990	1994–1998	1997–1999	1996–1998
Year published	1995	2002	2002	2004
Attendance rate	68%	76%	80%	70%[a]
AAA detection rate	4% (7.6% in men)	4%	4.9%	7.2%
Place of screening	Hospital	Hospital	Community	Community
Intervention policy	At 6.0 cm	At 5.0 cm measured as external diameter	At 5.5 cm measured as internal diameter	none
Mean follow up (year)	4.1	13.0	13.1	12.8
AAA mortality, odds ratio (95% CI) Screened vs. not	0.59 men only (0.27–1.29)	0.31 (0.13–0.79)	0.58 (0.42–0.78	0.91 (0.68–1.21)
All cause mortality, odds ratio (95% CI) Screened vs. not	1.07 (men only) (0.93–1.22)	0.98 (0.95–1.02)	0.97 (0.93–1.02)	0.98 (0.96–1.01)

[a] As percentage of those alive when invitation for screening was sent: randomisation predated this invitation by several months in a large number of subjects.

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elective repairs increased approximately twofold in persons invited to screening, although this is partially offset by the reduction of emergency AAA repairs.[295,297,690,691,758] The high mortality associated with rupture combined with low elective peri-operative risk results in the number of men needed to screen of 667 and to treat with AAA repair of 1.5 in order to prevent one premature AAA related death.[758]

Quality of life has been assessed using generic questionnaires and the diagnosis of AAA appears to be associated with a transient small reduction in quality of life, with recovery by 12 months.[18,407,449,646] However, only generic tools were used which may not detect subtle changes in quality of life or psychological harms. A more recent study and systematic review suggested that both the physical the psychological harms are significant and further research is warranted.[44,133]

Detection of AAA, which may be the index cardiovascular disease, always warrants cardiovascular risk assessment and lifestyle advice, providing an opportunity to improve cardiovascular health. The benefits of smoking cessation, BP control, and other relevant lifestyle and therapeutic changes are discussed Chapter 3.

2.3.1.3. Contemporary evidence about population screening. There are several limitations in translating the results of these screening trials to contemporary practice. The trials all started in the last century when the prevalence of AAA was 4–7% in the men screened and most of the repairs were performed using open surgery. Today the population prevalence of AAA has reduced by two to threefold in several European countries and EVAR has become the treatment modality in elective and increasingly in emergency repairs too. In addition, with more widespread use of diagnostic imaging, the incidental detection rate of AAA is likely to have increased. Also, life expectancy has increased substantially. Therefore, it is appropriate to consider the contemporary evidence from two European countries with national aneurysm screening programmes for older men (UK and Sweden) and the Danish VIVA trial. These three studies indicate that screening remains cost effective in these health economies.[225,641,662,664,665,758] The national screening programmes offer screening to men age 65 years and the VIVA trial offered screening to men aged 65–74 years, but the optimum age at which there is greatest benefit in terms of lives saved and cost benefit has not been assessed formally. Screening programmes may take up to 10 years to reach maximum impact, so that conclusions reached at earlier time points could be misleading.[303]

2.3.1.4. Surveillance intervals and management of patients with screen detected aneurysm. These issues are discussed in the Chapter 3.1.

When the screening detected aneurysms are large enough to warrant repair (by either OSR or EVAR), the operative mortality appears to be very low, probably lower than for incidentally detected AAA.[411] In Sweden, the operative mortality was 0.9% for OSR and 0.3% for EVAR.[758] The operative mortality after OSR and EVAR in screen detected aneurysms in the UK was 0.9% and 0.7% respectively.[295,297]

Recommendation 12	Class	Level	References
Population screening for abdominal aortic aneurysm with a single ultrasound scan for all men at age 65 years is recommended.	I	A	[132,390,408, 410,495,509, 614,690,691, 758]

2.3.2. Subaneurysmal aortic dilatation. Subaneurysmal aortic dilatation (maximum aortic diameter 2.5–2.9 cm in men) is a topic of current interest and the early reports suggest that more than half of these aortas will exceed 3.0 cm within 5 years and one quarter will reach 5.5 cm within 10–15 years.[522,662,664,665,769]

In the final follow up of MASS the long-term protective effect of screening appeared to decline due to ruptures after ≥8 years among men initially screened normal (<3.0 cm). Approximately half of these ruptures occurred among those with subaneurysmal aortic dilatation at the time of screening.[686]

Although there is only limited evidence regarding the clinical relevance and cost effectiveness of surveillance of persons with subaneurysmal aortic dilatation,[252,641] current knowledge makes it justifiable to recommend that men with subaneurysmal aortic dilatation with a reasonable life expectancy may be considered for rescreening after 5–10 years. The fact that this group constitutes a small cohort (<5% of all men screened) means that such a measure does not require large resources.

Recommendation 13	Class	Level	References
Men with an aorta 2.5–2.9 cm in diameter at initial screening may be considered for rescreening after 5–10 years.	IIb	C	[252,522,641, 662,664,665, 686,769]

2.3.3. Screening in other subgroups. Consideration has been given to the merits of screening by different subgroups, including women and those relating to smoking, ethnicity, those having or having had relatives with AAA, those with other peripheral aneurysms, and those with other cardiovascular diseases.

2.3.3.1. Women. There is limited evidence for screening in women, with the only randomised trial being underpowered

(Scott BJS 2002). Nevertheless, based on the much lower AAA prevalence in women[661,707] population screening has not been considered.[395]

Recently, a discrete event simulation model was developed to provide a clinically realistic model of screening, surveillance, and elective and emergency AAA repair operations. Input parameters specifically for women were employed, and parameter uncertainty addressed by deterministic and probabilistic sensitivity analyses. The base case model adopted the same age at screening (65 years), definition of AAA (≥3.0 cm), surveillance intervals and AAA diameter for consideration of surgery (5.5 cm) as for men. The prevalence was low (0.43%) and operative mortality rates about twice as high as in men. The simulation model showed that the base case and all alternative scenarios (including screening at older ages, definition of AAA as 2.5 cm, intervention at lower thresholds) resulted in minimal gain in quality adjusted life years and would probably not be cost effective. The authors suggest that while population screening of women should not be considered at this time, further information is required about the aortic size distribution, definition of an AAA, and harms of screening in women.[671,672]

AAAs among women.[94] This may be counterbalanced by a lower life expectancy and higher operative risk in this subgroup, and, so far, there is no supporting evidence for screening these women.

2.3.3.3. Ethnicity. Ethnicity Studies from the UK, have reported a very low prevalence of AAA (0.2%) in subjects of Asian ethnic origin.[296] In the USA, the prevalence is lower in those of African American descent than whites.[298] However, few European studies consider ethnicity.

2.3.3.4. Family history of AAA. There are reports from several countries of an increased incidence of AAA among first degree relatives of AAA patients. In a Swedish population study, a family history of AAA increased the risk of AAA, odds ratio 1.9 (95% CI 1.6—2.20.[380] Family history of AAA is suggested to be associated with more rapid growth of the aneurysm and higher rupture rate[7,743] and rupture may occur at smaller aneurysm diameter and at lower age.[743] Although the benefit of AAA screening in those with a family history of AAA has not been assessed formally, it is recommended in all men and women aged 50 years and older with a first degree relative with an AAA.

2.3.3.5. Other peripheral aneurysms and cardiovascular diseases. Because of the high co-existence of AAA with other peripheral aneurysms (iliac, femoral, popliteal),[571] these patients are routinely screened for AAA as well as for other peripheral aneurysms. In a study of 190 patients operated on for popliteal artery aneurysm, 39% developed a new aneurysm during a mean 7 years' follow up, of which 43% were AAAs.[571]

Some relatively small studies have indicated a high incidence of AAA in patients with other cardiovascular disease: carotid stenosis,[12] coronary heart disease,[267] and PAD.[12] The benefit of AAA screening in patients with cardiovascular disease has, however, not been assessed formally, and the lower life expectancy and higher operative risks for these patients may counterbalance the potential benefit of a high prevalence.[759] Thus, there is no supporting evidence for such a strategy.

Recommendation 14	Class	Level	References
Population screening for abdominal aortic aneurysm in women is not recommended.	III	B	[395,613,671, 672]

Recommendation 15	Class	Level	References
All men and women aged 50 years and older with a first degree relative with an abdominal aortic aneurysm may be considered for abdominal aortic aneurysm screening at 10 year intervals.	IIb	C	[7,380,743]

2.3.3.2. Smoking. The dominant risk factor for AAA is smoking. It has been estimated that 75% of all AAA cases in the population are mainly attributable to smoking.[383,663] The USA Preventive Services Task Force has recommended AAA screening for men aged 65—75 years who have ever smoked, based on the strength of the association between smoking and AAA rather than evidence from randomised trials.[395] With a recommended screening strategy targeting all men aged 65 years there is currently no need for targeting screening based on smoking status.

There is an ongoing discussion about whether selective screening of smoking women may be worthwhile, based on the higher AAA prevalence in this subgroup of women[662,664,665,707] and the higher rupture rate of small

Recommendation 16	Class	Level	References
Screening for abdominal aortic aneurysm at 5—10 year intervals may be considered for all men and women with a true peripheral arterial aneurysm.	IIb	C	[571]

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Chapter 3

3. MANAGEMENT OF PATIENTS WITH SMALL AAA

This chapter focuses on infrarenal AAA cases that are amenable to treatment by a standard, commercially available stent graft, or by OSR utilising infrarenal aortic clamp placement. For juxta- and pararenal AAA, see Chapter 7.

3.1. Surveillance and medical management of small AAAs

At the time of diagnosis, particularly where screening is prevalent, most patients will have a small AAA. There is a consensus that US should be used for the surveillance of small AAAs, given its ease of use in the community and the greater cost as well as the radiation burden for the patient of CT scanning. The optimum frequency for surveillance scans of aneurysms 3.0–5.5 cm in diameter has not been determined by randomised trials but a large data synthesis (more than 15,000 patients) and modelling exercise has suggested that surveillance intervals should be stratified by AAA diameter.[578] For the smallest aneurysms (3–3.9 cm) a three year surveillance interval is safe (although a longer interval could be considered), for aneurysms 4.0–4.9 cm in diameter annual surveillance is safe and only when the diameter reaches 5.0 cm should the surveillance scans be increased to every 3–6 months.

3.1.1. Strategies to reduce the rate of aneurysm growth. Several different classes of drugs have been assessed for their ability to reduce the rate of small aneurysm growth in randomised trials. To date, no class of drug has been shown to be effective, including doxycycline, beta blockers, angiotensin converting enzyme inhibitors, and statins[63,352,469,591] and other trials are still ongoing.

Exercise also has not been proven to reduce the AAA growth rate.[498] Many of these trials may not have been adequately powered to assess either a small difference in growth rates or identify persons with rapid aneurysm growth. There are no trials investigating the efficacy of any agent to reduce the growth rate or rupture rate of large AAAs, which are not currently considered for intervention. In conclusion, there is no specific inhibiting drug or other therapy that can be recommended at this time.

All the observational studies show that current smoking is associated with an increased AAA growth rate and smoking cessation is probably associated with an approximately 20% reduction in growth rate, as well as halving the risk of aneurysm rupture.[668] Many randomised trials have shown that smoking cessation is most effective when supported by drugs and counselling.[259] Patients with diabetes also have a slower AAA growth rate than patients without diabetes, which has recently been suggested to be related to the metformin, used to treat type II diabetes.[212,228,668]

3.1.2. Reduction of cardiovascular risk. AAA patients have a high risk of future cardiovascular events. A systematic review has demonstrated that for patients with small AAAs, the annual risk of cardiovascular death was 3.0% (95% CI 1.7–4.3).[43] The European guidelines on cardiovascular disease prevention recommend that all patients with symptomatic peripheral vascular disease should use antiplatelet therapy, lipid lowering agents if low density lipoprotein (LDL) cholesterol $>$ 2.5 mmol/L ($>$97 mg/dL), and antihypertensives in the case of a systolic BP $>$ 140 mmHg, unless contraindicated.[2,233,551] The UK Heart Protection Study showed that for patients with peripheral arterial disease 40 mg of simvastatin reduced the incidence of a first major cardiovascular event by 22% versus those randomly assigned to placebo.[262] More specifically, a study examining the drugs taken by 12,485 UK patients with a recorded diagnosis of AAA showed that the five year survival rates were significantly improved for those taking statins (68% vs. 42%), antiplatelet therapy (64% vs. 40%), or antihypertensive agents (62% vs. 39%) compared with AAA patients not taking these medications.[31] More detailed analysis of the antihypertensive agents used indicated that diuretics may be less beneficial than other classes.[31]

Recommendation 17	Class	Level	References
Ultrasonography is recommended for aneurysm surveillance; every three years for aneurysms 3–3.9 cm in diameter, annually for aneurysms 4.0–4.9 cm, and every 3–6 month for aneurysms $\geq$5.0 cm.	I	B	[578]

Recommendation 18	Class	Level	References
Patients with a small abdominal aortic aneurysm are recommended to stop smoking (to reduce the abdominal aortic aneurysm growth rate and risk of rupture) and to receive help to do this.	I	B	[259,668]

Recommendation 19	Class	Level	References
No specific medical therapy has been proven to slow the expansion rate of an abdominal aortic aneurysm, and therefore is not recommended.	III	A	[352,591]

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Local guidelines, by country, may specify which antiplatelet drug, statin or antihypertensive agent(s) are recommended, and if so these local guidelines should be consulted.

Other healthy lifestyle strategies including smoking cessation (see above), exercise, and diet should be as recommended for any patient with cardiovascular disease, although there is little good quality specific evidence that such strategies are effective for patients with AAA, who are usually included in the peripheral arterial disease group.[683]

Recommendation 20	Class	Level	References
Strategies targetted at a healthy lifestyle, including exercise and a healthy diet, should be considered in all patients with abdominal aortic aneurysm.	IIa	B	[31,233,551]

Recommendation 21	Class	Level	References
Blood pressure control, statins and antiplatelet therapy should be considered in all patients with abdominal aortic aneurysm.	IIa	B	[2,31,233, 551,762]

3.2. Threshold for elective repair

Currently the evidence for the threshold for repair of small AAAs is based on aortic diameter, not volume measurements. The immediate decision about the size at which an aneurysm should be repaired is framed by the balance between the risk of aneurysm rupture (which is still fatal in >80% cases)[575,576] and the risk of operative mortality for aneurysm repair. Today, with the longevity of populations increasing, it also is necessary to consider the longer term prognosis, including surveillance and life expectancy after repair.

The management of fusiform, degenerative aneurysms 4.0–5.5 cm in diameter has been effectively determined by four randomised trials including two large multicentred randomised controlled trials of early open elective surgery versus surveillance, the UK Small Aneurysm Trial (UKSAT) and the American Aneurysm Detection And Management study (ADAM), and two smaller trials of endovascular repair versus surveillance, the Comparison of surveillance vs. Aortic Endografting for Small Aneurysm Repair (CAESAR) Trial and the Positive Impact of endoVascular Options for Treating Aneurysm early (PIVOTAL) study, with the data summarised in a Cochrane review, showing that surveillance was safe and cost effective.[204] All the trials had clearly defined intervention policies for the surveillance groups in addition to reaching the threshold diameter: these included rapid growths (>1 cm/year and the development of symptoms referable to the aneurysm). Only the UKSAT trial included a significant number of women. The trials used mainly OTO measurement using either US or CT to define the aortic diameter. The consensus from these trials is that aneurysms <5.5 cm in diameter should be managed conservatively. This has been proven to be extremely safe for men in two national screening programmes (England and Sweden).[295,297,662,664,665] Despite all this evidence, in several countries particularly those with privately funded healthcare, AAAs in men are still repaired below the 5.5 cm threshold (Beck Circulation 2016). A recent administrative registry based analysis showed a significantly lower population aneurysm related mortality in the USA, where more than 40% of repairs were performed on small AAAs <5.5 cm, as opposed to the UK, where the small AAA repair rate was less than 10%.[332] This paper has, however, been questioned for reasons relating to incidental detection rates, differences in coding systems, population structure, and total healthcare expenditure, as well as the indications for surgery and impact of population screening.[391,559,713] Although the 5.5 cm limit continues to create debate and compliance varies, the evidence is convincing. Patient information on the safety of following small AAAs is likely to be decisive to improve adherence to this recommendation; see Chapter 10 for more on this.

There is anecdotal evidence that rapid aneurysm growth (>1 cm/year) is associated with a higher risk of rupture. Some instances of presumed rapid aneurysm growth may relate to measurement errors and the first approach should be to re-measure the aneurysm diameter within 2 weeks.[369,626]

Unruptured symptomatic aneurysm has a variable definition, varying from tenderness on palpation to evidence of peripheral emboli, with no other obvious source, or unexplained back or abdominal pain. Such instances of aneurysms <5.5 cm diameter require urgent investigations to substantiate the symptomatic diagnosis. When surgery is indicated, delayed semi-elective (i.e. on the first available elective list) surgery with patient optimisation might be justified.[640,681]

The risk of rupture for small AAA is about four times higher in women than men.[578,668,685] In the RESCAN meta-analysis the rupture rate for women with a 4.5 cm AAA was approximately the same as that for a man with a 5.5 cm AAA, suggesting a threshold for surgery of 4.5 cm is appropriate in women.[578] On the other hand, the operative mortality is higher for women than men for both endovascular and open repair.[242,708] Therefore, there is no good evidence about the diameter threshold for repair in women, but it may be prudent to consider aneurysm repair at lower diameters, closer to 5.0 cm.[578,668,685]

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Recommendation 22	Class	Level	References
In men, the threshold for considering elective abdominal aortic aneurysm repair is recommended to be ≥5.5 cm diameter.	I	A	[204]

Recommendation 23	Class	Level	References
In women with acceptable surgical risk the threshold for considering elective abdominal aortic aneurysm repair may be considered to be ≥5.0 cm diameter.	IIb	C	[242,578,668, 685,708]

Recommendation 24	Class	Level	References
When rapid abdominal aortic aneurysm growth is observed (≥1 cm/year), fast track referral to a vascular surgeon with additional imaging should be considered.	IIa	C	[369,626]

Recommendation 25	Class	Level	References
Emergency referral to a vascular surgeon of patients with symptomatic abdominal aortic aneurysm is recommended.	I	C	[640,681]

3.2.1. Management of patients who have reached the diameter threshold for surgery but are not considered for early AAA repair. There are a significant number of persons with AAA who are not considered to be suitable for repair (including EVAR) because of other comorbidities or limited life expectancy.[295,297,330,708] There has been only one randomised trial to assess whether EVAR provided a survival benefit for patients too physically compromised to undergo OSR, the EVAR 2 trial. This trial showed that in these physically frail patients although EVAR prevented death from aneurysm rupture, operative mortality was high (7%) and it did not offer any benefit in terms of overall survival out to 12 years, with two thirds of both randomised groups being dead within five years.[670,709,710] However, there is likely to be a sliding scale for assessing fitness for repair as the aneurysm enlarges, with lower barriers for fitness for aneurysms >7 cm in diameter. For these reasons, it is important to both keep these patients under surveillance and refer patients to other relevant specialities to optimise their physical fitness.

For these patients, strategies to reduce cardiovascular risk will assume particular importance (see below). There are some observational data to suggest that statins may reduce the risk of rupture of large AAA[762,561] and that the risk of rupture is increased twofold in current smokers.[668]

Chapter 4

4. ELECTIVE AAA REPAIR

This chapter focuses on infrarenal AAAs for cases that are amenable to treatment by a standard, commercially available stent graft, or by OSR using an infrarenal aortic clamp. For juxtarenal AAAs, see Chapter 7.

4.1. Pre-operative management

4.1.1. Vascular anatomy assessment. Dedicated aortic imaging is crucial to determine an appropriate repair strategy and for optimal pre-operative planning. As the presence of synchronous aneurysms in other vascular beds may influence surgical decision making, screening of the whole aorta and the femoropopliteal segment is advocated.

The feasibility of EVAR and its early and long-term success depend on reliable baseline assessment of aortic morphology including landing zones for fixation and sealing, and correct measurements for appropriate stent graft selection.[238] Several criteria have been established that define patient suitability for EVAR according to the instructions for use (IFU) defined by the device manufacturers (Table 4.1).[115]

Although there is no randomised study on the best imaging modality, the consensus is that CTA including

Recommendation 26	Class	Level	References
Patients who initially are not candidates for abdominal aortic aneurysm repair should be considered for continued surveillance, referral to other specialists for optimisation of their fitness status and then reassessed.	IIa	C	[670,709,710]

Table 4.1. Cross sectional imaging criteria for planning of infrarenal abdominal aortic aneurysm repair.

1. Proximal neck to be cross clamped or used as landing zone, including; diameter and length, angulation, shape, presence and extent of calcification and athero-thrombosis.
2. Iliac arteries to be cross clamped or used for access and landing zone, including: patency; diameter and length; angulation/ tortuosity; extent of calcification and athero-thrombosis; patency of internal iliac arteries and pelvic circulation; presence of iliac artery aneurysms.
3. Access vessel and lower limb "runoff" vessels/circulation.
4. Anatomy and patency of visceral arteries and presence of accessory renal arteries.
5. Concomitant aneurysms in visceral arteries or thoracic aorta.
6. Other: Venous anomalies, including position and patency of inferior vena cava and left renal vein; organ position, including pelvic or horseshoe kidney; signs of concomitant disease potentially altering prognosis and, thereby, indication for repair.

multiplanar and curved three dimensional vascular reconstructions is the preferred pre-operative imaging modality, if permitted by renal function.[532] Alternatively, MRA may be used for this purpose, even though assessment of calcification may be more challenging.[595]

4.1.2. Operative risk assessment and optimisation. The ESC guidelines grade open aortic repair as a high risk intervention (defined as carrying a risk of cardiovascular death or myocardial infarction of 5% or more within 30 days), whereas EVAR is graded as an intermediate risk intervention with a cardiac risk between 1% and 5%[360]

There is extensive guidance on operative risk assessment and reduction[144,188,206,360,565,636,767] that has been summarised recently[350] and should be consulted for in depth information. This section aims to provide a broad overview of relevant factors to consider when performing aortic repair.

As a minimum, all patients should undergo a medical history and clinical examination, functional assessment, full blood count and electrolytes, including assessment of renal function, and electrocardiogram. Additional testing, including static echocardiogram and pulmonary function tests, depends upon the individual circumstances of the patient as described below.

4.1.2.1. Assessment and management of cardiac risk. Cardiac complications are estimated to cause more than 40% of peri-operative deaths after non-cardiac surgery[155] and the level of cardiac risk should therefore be assessed clinically.[326]

For cases with active cardiovascular disease, such as unstable angina, decompensated heart failure, severe valvular disease, and significant arrhythmia, further specialist assessment and management are required before AAA repair planning.

In the absence of active cardiovascular disease, clinical cardiovascular risk factors and the patient's functional capacity should be assessed. Risk scores may be used to quantify individual risk by integrating various risk factors (Table 4.2).[191,245,393] In clinical practice, functional capacity is estimated by the patient's ability to perform activities of daily living, assessed by metabolic equivalent (MET), which is estimated as the rate of energy expenditure while sitting at rest. By convention 1 MET corresponds to 3.5 mL O_2/kg/min.[728]

Patients capable of moderate physical activities (Table 4.3), such as climbing two flights of stairs or running a short distance (MET $\geq$ 4), will not benefit from further testing. Patients with poor functional capacity (MET $<$ 4) and/or with significant clinical risk factors should be referred to a specialist cardiologist for cardiac work up prior to AAA repair. Although poor capacity alone is only weakly associated with impaired outcomes after aortic repair,[768] cardiac prognosis is good if functional capacity is high, even in the presence of stable ischaemic heart disease or other risk factors.[493]

Table 4.2. Risk factors for cardiac, respiratory, and renal complications after abdominal aortic aneurysm repair, according to.[245,393]

Predictors of cardiac complications	Predictors of pulmonary complications	Predictors of renal complications
Age	Age $\geq$60 year	Pre-existing renal insufficiency
History of symptomatic ischaemic heart disease	Pre-existing chronic obstructive lung disease	Congestive heart disease
History of congestive heart failure	Congestive heart failure	Chronic obstructive lung disease
History of symptomatic cerebrovascular disease	Serum albumin level $\leq$35 g/L	Peripheral arterial occlusive disease
Creatinine clearance $<$60 mL/min or serum creatinine $>$170 μmol/L	FEV1 $<$ 70% of expected	Diabetes mellitus
Diabetes mellitus	FVC $<$70% of expected	Arterial hypertension
Functional status in terms of independent living	FEV1/FVC $<$0.65	
American Society of Anaesthesiology class 3/4		

FEV1 = forced expiratory volume in 1 s; FVC = forced vital capacity.

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Table 4.3. Functional capacity estimation based on physical activity, according to Ainsworth et al.[6]

Activity level	Example of activity
Poor (MET < 4)	Eating, getting dressed, light housework (washing dishes, cooking, making bed)
Moderate (MET 4–7)	Climbing two flights of stairs, walking up a hill, jogging < 10 min, heavy housework (scrubbing floor or moving furniture), hand mowing lawn, shovelling snow by hand
Good (MET 7–10)	Tennis, bicycling at moderate pace, leisure swimming, jogging > 10 min
Excellent (MET > 10)	Strenuous sports such as uphill mountain bicycling, football, basketball, karate, running 10 km/h or more

MET = metabolic equivalent.

Cardiac work up includes non-invasive evaluation of left ventricular dysfunction, heart valve abnormalities and stress induced myocardial ischaemia. Invasive coronary angiography, by contrast, should follow the same indications as in a non-surgical setting and not be routinely used for peri-operative risk assessment before aortic surgery.[360]

Cardiopulmonary exercise testing has gained popularity in many areas of major non-cardiac surgery to identify patients who may benefit from further cardiopulmonary optimisation prior to surgery. Despite many studies, there is little evidence to recommend routine work up of patients prior to AAA surgery.[782]

Biomarkers (e.g. troponins T and I, B-type natriuretic peptide) should not be used routinely in pre-operative risk stratification, but may be considered selectively in high risk patients,[360] for example with poor functional capacity or suspected relevant ischaemic heart disease.

Two randomised trials have demonstrated that patients with stable coronary artery disease (CAD) do not benefit from prophylactic revascularisation before vascular surgery,[461] even considering those with left main stem and triple vessel disease, or those with a left ventricular ejection fraction below 35%. Therefore, pre-operative coronary revascularisation should not be performed prophylactically but be reserved for patients with unstable CAD, acute myocardial infarction, or those considered with a prohibitive coronary risk for AAA repair.[206,360,461]

For patients undergoing interventional coronary revascularisation before AAA repair, the risk of in-stent thrombosis is highest during the first 6 weeks after coronary stenting, and dual antiplatelet therapy should not be discontinued. If bare metal stents have been used, reduction to antiplatelet monotherapy may be considered after 6 weeks. In contrast, if drug eluting stents have been used, dual antiplatelet therapy should not be discontinued for 6 months.[398] Therefore, elective AAA repair should usually be delayed if possible if dual antiplatelet therapy needs to be stopped for surgery. Alternatively, EVAR may be performed under dual antiplatelet therapy if AAA repair becomes necessary before. In patients with symptomatic AAA and complex coronary artery disease, simultaneous coronary artery bypass grafting (CABG) and open AAA repair is a theoretical option under specific circumstances, but usually EVAR performed under local anaesthesia would be preferred early after CABG.

Patients with heart failure (New York Heart Association Functional Classes III and IV: marked limitation in activity due to symptoms, and severe symptoms at rest respectively) should be optimised pharmacologically under expert guidance using beta blockers, angiotensin converting enzyme inhibitors or angiotensin receptor blockers, other antihypertensive drugs, and diuretics. Elective aortic repair should be deferred whenever possible until heart failure has been assessed and treated appropriately. A careful multidisciplinary meeting should evaluate the risk benefit of treatment for each individual patient.[11]

Aortic valve stenosis is the most relevant valvular heart disease in the context of AAA repair, because it increases the risk associated with blood loss, volume shifts, and arrhythmia. Patients with severe aortic valve stenosis (defined as mean gradient > 40 mmHg, valve area <1 cm^2, and peak jet velocity > 4.0 m/s) should be considered for aortic valve replacement prior to elective AAA repair.[206,360,377,461]

Applicable guidelines should be consulted for specific guidance on peri-operative management of patients with coronary, congestive and valvular heart disease.[206,360]

Recommendation 27	Class	Level	Reference
Routine referral for cardiac work up, coronary angiography and cardiopulmonary exercise testing is not recommended prior to abdominal aortic aneurysm repair.	III	C	[206,360]

Recommendation 28	Class	Level	References
In patients with poor functional capacity (defined as ≤ 4 metabolic equivalents) or with significant clinical risk factors (such as unstable angina, decompensated heart failure, severe valvular disease, and significant arrhythmia), referral for cardiac work up and optimisation is recommended prior to elective abdominal aortic aneurysm repair.	I	C	[206,360]

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Recommendation 29	Class	Level	References
In patients with stable coronary artery disease, routine coronary revascularisation before elective abdominal aortic aneurysm repair is not recommended.	III	B	[206,360,461]

Recommendation 30	Class	Level	References
In patients with unstable coronary artery disease or considered to be at high risk of cardiac events following abdominal aortic aneurysm repair, prophylactic pre-operative coronary revascularisation should be considered.	IIa	B	[206,360,461]

Recommendation 31	Class	Level	References
In patients with moderate to severe heart failure, pharmacological optimisation of heart failure under expert guidance should be considered before elective abdominal aortic aneurysm repair.	IIa	C	[11]

Recommendation 32	Class	Level	References
In patients with severe aortic valve stenosis, evaluation for aortic valve replacement prior to elective abdominal aortic aneurysm repair is recommended.	I	B	[206,360, 377,461]

Recommendation 33	Class	Level	References
In patients on dual antiplatelet therapy after interventional coronary revascularisation, delaying abdominal aortic aneurysm repair until reduction to monotherapy, may be considered. Alternatively, if AAA repair becomes necessary, EVAR may be considered under dual antiplatelet therapy.	IIb	C	[398]

4.1.2.2. Assessment and management of pulmonary risk. Pulmonary complications including atelectasis, pneumonia, respiratory failure, and exacerbation of underlying chronic lung disease may increase peri-operative morbidity and length of hospital stay to a similar extent as cardiac complications in patients after non-cardiac major surgery. Risk assessment strategies have been published previously[565,636] and certain risk factors indicate patients at risk (Table 4.2).

Pulmonary function testing with spirometry may identify patients who might be more suitable for minimally invasive treatment, or identify patients in whom respiratory function should be optimised pre-operatively.[565] Patients with a forced expiratory volume in one second (FEV_1) or forced vital capacity (FVC) of less than 70% of the expected value are at increased risk of peri-operative pulmonary complications as are those with a FEV_1/FVC of less than 0.65. Routine chest Xray prior to AAA repair is superfluous since CT of the entire aorta (including the chest) has usually been done and, furthermore, does not improve the pre-operative risk stratification and is not recommended.

Smoking cessation should be encouraged in every AAA patient (see Chapter 3) since cessation in the pre-operative period may reduce the risk of post-operative complications.[486,692] Furthermore, RCTs have shown a benefit of pre-operative chest physiotherapy before major abdominal surgery, including OSR of AAA.[76]

Recommendation 34	Class	Level	References
In all patients, pulmonary function testing with spirometry prior to elective abdominal aortic aneurysm repair should be considered.	IIa	C	[565]

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Recommendation 35	Class	Level	References
In patients with risk factors for pulmonary complications or a recent decline in respiratory function, specialist referral for respiratory work up and optimisation is recommended prior to elective abdominal aortic aneurysm repair.	I	C	[565,636]

Recommendation 36	Class	Level	References
Routine chest Xray prior to abdominal aortic aneurysm repair is not recommended.	III	C	[565,636]

4.1.2.3. Assessment and optimisation of kidney function. Post-operative impairment of kidney function prolongs hospital stay and is a known predictor of increased morbidity and long-term mortality.[144,727] Patients with pre-existing renal insufficiency, congestive heart disease, chronic obstructive pulmonary disease (COPD), peripheral arterial occlusive disease (PAOD), diabetes mellitus, or arterial hypertension are at particular risk[344,345] (Table 4.2). In the context of open or endovascular AAA repair pre-existing renal dysfunction is one of the most important predictors of peri-operative morbidity and mortality.[112,601]

Patients undergoing AAA repair should have their serum creatinine measured to assess pre-operative kidney function (i.e. estimated glomerular filtration rate (eGFR) according to the Modification of Diet in Renal Disease Study Group or Cockroft and Gault formula). Although there are no established criteria about the level of renal dysfunction that requires referral to specialist renal services, an eGFR of <60 mL/min can be classed as demonstrating significant renal compromise, and <30 mL/min to be severe and therefore warrant urgent referral.

Recommendation 37	Class	Level	References
In patients undergoing abdominal aortic aneurysm repair, assessment of pre-operative kidney function by measuring serum creatinine and estimating GFR is recommended, and those with severe renal impairment (estimated Glomerular Filtration Rate <30 mL/min/1.73 m^2) should be referred to a renal physician.	I	C	[112,144,601]

Patients with severe renal insufficiency (i.e. Chronic kidney disease Stages 4 or 5; eGFR <30 mL/min/1.73 m^2) should be evaluated by a specialist to optimise the renal function before elective aortic repair. Patients with mild to moderate renal failure (i.e. Chronic kidney disease Stages 2 or 3; eGFR <60 but >30 mL/min/1.73 m^2) should be adequately hydrated before AAA repair, especially when intravenous contrast media are to be used.[144]

Currently, no effective strategies besides appropriate hydration to prevent post-operative acute kidney injury after AAA repair exists (e.g. use of *N*-acetylcysteine, intravenous sodium bicarbonate, or fenoldopam).[37,144,488,760,766] Hence, urine output should always be monitored peri-operatively.

Recommendation 38	Class	Level	References
Patients with renal impairment should be adequately hydrated before elective abdominal aortic aneurysm repair, and estimated glomerular filtration rate, fluid input, and urine output should be monitored after abdominal aortic aneurysm repair to recognise and manage reduced kidney function.	I	C	[144]

4.1.2.4. Assessment and optimisation of nutritional status. Nutritional status is an important determinant of peri-operative mortality and morbidity. In an observational

analysis of 15,000 patients undergoing AAA repair, 30 day mortality and incidence of re-operations and pulmonary complications increased with hypoalbuminaemia after both open ($n = 4956$) and endovascular ($n = 10,046$) AAA repair.[292] Therefore, nutritional status should be assessed before aortic surgery for risk stratification.

An albumin level of <2.8 g/dL should be considered severe and is associated with significantly worse outcomes.[292] In this situation, nutritional deficiencies should be corrected before elective OR and elective EVAR, even though efficacy has not been assessed by RCT in AAA patients. Referral to a medical dietician may be advisable and should be evaluated depending on the degree and quality of nutritional deficiency.

Recommendation 39	Class	Level	References
In patients undergoing elective abdominal aortic aneurysm repair, assessment of pre-operative nutritional status by measuring serum albumin is recommended, with an albumin level of <2.8 g/dL as a threshold for pre-operative correction.	I	C	[292]

4.1.2.5. Assessment of carotid arteries. The prevalence of internal carotid artery stenosis is high among AAA patients because of similar risk factors. In the SMART study ($n = 2,274$, in which 147 were diagnosed with AAA) 8.8% of all AAA patients had an asymptomatic internal carotid artery stenosis of at least 70%.[368] In patients with a large AAA undergoing repair, the prevalence may be even higher. The presence of significant untreated internal carotid artery stenosis may have a negative effect on long-term prognosis after AAA repair.[400] Therefore, these patients are likely to benefit from best medical treatment before and particularly after AAA repair (but rarely prophylactic endarterectomy or stenting).

The benefit of carotid screening prior to AAA repair has not been assessed,[306] and current evidence does not support routine pre-operative screening. The ESVS Carotid guidelines have a weak recommendation (Class IIb) for selective screening for asymptomatic carotid stenoses in patients with multiple vascular risk factors to optimise risk factor control and medical therapy to reduce late cardiovascular morbidity and mortality, rather than identifying candidates for invasive carotid interventions.[501]

Patients with recently symptomatic internal carotid artery stenosis (<6 months) may require management of the carotid stenosis prior to AAA repair to reduce overall stroke risk. Applicable guidelines should be consulted for diagnostic and therapeutic management of symptomatic carotid disease.[501]

The efficacy of prophylactic intervention for internal carotid artery stenosis has not been evaluated in patients undergoing elective aortic repair. Prophylactic pre-operative carotid endarterectomy or stenting is not beneficial for patients with *asymptomatic* carotid artery stenosis, even if severe.[501]

Recommendation 40	Class	Level	References
Routine screening for asymptomatic carotid stenosis prior to abdominal aortic aneurysm repair is not recommended.	III	C	[306,501]

Recommendation 41	Class	Level	References
Patients with abdominal aortic aneurysms and concomitant symptomatic carotid stenosis within the last 6 months should be considered for carotid intervention before aneurysm repair.	IIa	A	[501]

Recommendation 42	Class	Level	References
Routine prophylactic carotid intervention for asymptomatic carotid stenosis prior to abdominal aortic aneurysm repair is not recommended.	III	C	[501]

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4.2. Peri-operative management

4.2.1. Peri-operative best medical treatment. Peri-operative beta blockade has been studied in RCTs. Randomised trials on newly initiated beta blockers within 24 h of vascular surgery either demonstrated no advantage in low risk patients (POBBLE trial,[85] MaVS study[775]), or showed increased all cause mortality, hypotension and stroke, despite reduced rates of peri-operative myocardial infarction (POISE trial[156]). Current ESC guidance suggests individual joint decision making between surgeon, cardiologist and anaesthetist.[360] Patients who already take an appropriate dose of beta blockers should continue this treatment.

Multiple observational studies have suggested that patients who take statins have lower rates of myocardial infarction and stroke after vascular surgery,[145,406] and two randomised trials confirmed that peri-operative statin usage (mean 30–37 days) reduced adverse cardiovascular events after vascular surgery.[177,610]

A recent UK RCT has shown that a period of pre-operative supervised exercise training is beneficial to patients undergoing open or endovascular aortic surgery by reducing cardiac, respiratory and renal complications post-operatively, as well as reducing the length of hospital stay.[35]

Recommendation 43	Class	Level	References
Commencement of beta blockers is not recommended prior to abdominal aortic aneurysm repair.	III	A	[85,156,775]

Recommendation 44	Class	Level	References
Statins are recommended before (if possible, at least 4 weeks) elective abdominal aortic aneurysm surgery to reduce cardiovascular morbidity.	I	A	[145,177, 406,610]

Recommendation 45	Class	Level	References
An established monotherapy with aspirin or thienopyridines (e.g. clopidogrel) is recommended to be continued during the peri-operative period after open and endovascular abdominal aortic aneurysm repair.	I	B	[101,170, 354,658]

4.2.2. Peri-operative management of antithrombotic therapy for other indications. Antiplatelet monotherapy with aspirin or thienopyridines (e.g. clopidogrel) does not pose an excessive bleeding risk during AAA repair.[256] Although associated with a greater risk of bleeding after non-cardiac surgery, there is no increase in severe bleeding episodes.[101] Therefore, antiplatelet monotherapy may be continued prior to endovascular or open repair to reduce thrombotic and cardiac risk.

Certain circumstances may necessitate continuation of dual antiplatelet agents (see "Assessment and management of cardiac risk" and Recommendation 33), but this is likely to be in high risk patients, in whom the balance of risks of AAA repair should be considered carefully.[137] Experience of dual therapy including more potent antiplatelet agents, such as prasugrel and ticagrelor, and AAA repair is very limited but is probably associated with a high risk of serious bleeding and should be avoided. Warfarin and new oral anticoagulants should be discontinued at least five days and two days respectively, prior to surgery to mitigate the risk of excessive bleeding. Depending on the indications for their use, anticoagulation may be bridged during the peri-operative period using a short acting agent such as low molecular weight heparin or unfractionated heparin.

In general, applicable guidelines should be consulted for specific guidance on antiplatelet and/or anticoagulant therapy during the peri-operative period of AAA repair.[170,354]

4.2.3. Antibiotic prophylaxis. Multiple randomised trials have shown the benefits of antibiotic prophylaxis during arterial reconstruction.[655] Therefore, peri-operative intravenous antibiotic prophylaxis is recommended prior to both open and endovascular AAA repair, with the choice of agent based on local institutional guidelines.

Recommendation 46	Class	Level	References
In all patients undergoing open or endovascular abdominal aortic aneurysm repair, peri-operative systemic antibiotic prophylaxis is recommended.	I	A	[655]

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4.2.4. Anaesthesia and post-operative pain management. Multimodal pain therapy, including the use of a non-opioid regimen should be instituted to maximise the efficacy of pain relief, while minimising the risk of side effects and complications.[632] This approach may include the use of epidural analgesia, patient controlled analgesia, and potentially placement of catheters for continuous infusion of local anaesthetic agents into the wound.

For open AAA repair, a Cochrane review analysed 1498 patients from 15 trials[243] and demonstrated that post-operative epidural analgesia provided better pain management when compared with systemic opioid based analgesia including reduced rates of myocardial infarction, faster endotracheal extubation with reduced incidence of post-operative respiratory failure, and shorter stays on the intensive care unit (ICU). However, there was no difference in 30 day mortality. In contrast, a retrospective study from the USA investigating 1540 patients undergoing elective AAA surgery found improved survival and a significantly lower risk of morbidity and mortality if general anaesthesia was combined with epidural anaesthesia.[36]

There is a wealth of evidence supporting the use of catheter based continuous wound analgesia in cardiothoracic, orthopaedic, general, urological, and gynaecological surgery, but there are no published data specific to aortic surgery.

There are no randomised trials comparing various methods of anaesthesia for endovascular aneurysm repair. The international multicentre ENGAGE study has examined the outcomes of 1231 patients undergoing EVAR under general (62% of patients), regional (27%), and local (11%) anaesthesia. The investigators concluded that the type of anaesthesia had no influence on peri-operative mortality or morbidity.[92] Locoregional anaesthesia, however, appeared to reduce procedure time, intensive care unit admissions, and post-operative hospital stay. In general, EVAR can be performed under local, locoregional, or general anaesthesia; therefore practice may follow local hospital routine and individual patient assessment and preference.

Recommendation 47	Class	Level	References
In patients undergoing open abdominal aortic aneurysm repair, peri-operative epidural analgesia should be considered, to maximise pain relief and minimise early post-operative complications.	IIa	B	[243]

4.2.5. Post-operative care. Delay in timely recognition and management of complications ("failure to rescue") is the principal determinant of peri-operative mortality after both open and endovascular AAA repair.[752] Therefore, patients undergoing open AAA repair should be routinely admitted to the ICU for advanced monitoring and early detection and management of complications. Local resources and policy will influence the selection of patients in whom ICU admission is deemed necessary, but usually all patients undergoing OSR and patients at increased peri-operative risk undergoing EVAR should be offered ICU surveillance. Also, AAA repair should be performed in hospitals with constant and immediate access to coronary catheterisation facilities.[360]

4.2.6. Early recovery after surgery (ERAS) after open AAA repair. Early or "enhanced" recovery after surgery (ERAS) programmes have been designed to accelerate the post-operative recovery of surgical patients by reducing the surgical stress response.[202] ERAS depends on an integrated, multidisciplinary common pathway including thorough pre-operative counselling to prepare the patient mentally, the use of epidural anaesthesia and minimised surgical access, optimal pain control with the avoidance of side effects, early post-operative mobilisation and oral nutrition as well as the avoidance (or early removal) of drains and urethral catheters. The methodology of ERAS has been well established in colorectal surgery and other areas of general surgery.[338,381] A limited number of studies have assessed ERAS protocols in the context of open AAA surgery and have reported shorter hospital stays and decreased pulmonary complications.[358,535]

4.2.7. Intra-operative imaging. EVAR depends on appropriate intra-operative imaging. Traditionally, digital subtraction angiography (DSA) has been used to ensure correct stent graft deployment and position, patency of side branches, and to detect the presence or absence of endoleaks. More recently, on-table (CT) has come to the forefront.[508] The C arm, which includes both the Xray source and detectors, rotates around the patient during the acquisition of images, thus creating a three dimensional (3D) set of images similar to CT. The use of cone beam CT combined with a completion angiogram has been shown to be highly accurate in detecting complications intra-operatively post EVAR.[694] Further data are, however, needed before the technique can be recommended in everyday practice.

Image fusion of CTA images with fluoroscopy can be achieved with automatic registration of the pre-operative CTA with an intra-operative non-contrast cone beam CT or with a 2D − 3D technique after acquiring two fluoroscopic images acquired at least 30° apart. "Fusion imaging" has been demonstrated to provide additional real time 3D guidance with reduced radiation, procedure time, and iodinated contrast doses during complex endovascular repairs.[269,462,673] Its value in standard EVAR is, however, limited.

4.2.8. Radioprotection measures. Xrays have their effect by ionising tissue at a molecular level. These effects may be described as deterministic or stochastic. Deterministic

effects, such as erythema of the skin, may occur when the threshold dose is exceeded. Stochastic effects, such as malignancy, have no particular threshold but the risk of occurrence increases as the dose increases. Numerous studies have shown that there is excess cancer mortality in individuals exposed to radiation. It has been estimated that an exposure of 100 mSv will confer an additional 1% lifetime risk of cancer related death in a 40 year old patient. To put this into perspective, effective radiation doses for common procedures are 15 mSv for a whole body CT, 20 mSv for an abdominal angiogram, and 5 mSv for a lower limb angiogram.[660]

It is essential that clinicians who work with radiation understand the risks involved (for patients, themselves, and other healthcare personnel) and the measures that can minimise this risk and the radiation dose.[176,268,484,552] Radiation during EVAR has been shown to cause DNA damage in operators, and research has highlighted the benefit of wearing full protective shielding.[183] A European diagnostic reference levels has been suggested through pooled European data.[703] Operators should know and apply the ALARA ("as low as reasonably achievable") principles[684] to protect the patient and team members.

Individual assessment should always ensure that the benefit of radiation outweighs the risk of the procedure. Radiation exposure can be quantified using automated programmes within the imaging equipment (patient dose information) and using real time dosimetry from personal dosimeters worn at the level of the neck (e.g. above and beneath the lead apron, and on a finger) for each individual involved in the procedure.[484]

Recommendation 48	Class	Level	References
During endovascular abdominal aortic aneurysm repair radiation dose reduction strategies are recommended, such as • Keeping as much distance as possible from the radiation source for both personnel and patient • Minimising the time of exposure, use of digital subtraction acquisitions and lateral angulations • Positioning the image intensifier close to the patient, with a well collimated beam • Using necessary magnification levels only • Diligent use and appropriate positioning of lead shields, including personal shields (apron, thyroid, shins and goggles) and mobile shields.	I	B	[176,183,268, 484,552]

4.2.9. Cell salvage. Intra-operative red blood cell salvage involves aspiration, washing, and filtration of patient blood during an operation to minimise blood loss by re-transfusion. Cell salvage has been shown to reduce the need for the intra-operative use of allogeneic blood during elective open AAA repair.[446,536]

Recommendation 49	Class	Level	References
Intra-operative cell salvage and re-transfusion should be considered during open abdominal aortic aneurysm repair.	IIa	B	[446,536]

4.3. Techniques for elective AAA repair

This section only covers elective repair of infrarenal AAA with suitable anatomy, while the management of rAAA is covered in Chapter 5 and juxtarenal AAA in Chapter 7.

4.3.1. Open repair

4.3.1.1. Types of grafts. Textile polyester material, specifically polyethylene terephthalate, commonly known by its brand name Dacron, has been the most frequently used material for 60 years. Different manufacturers employ different kinds of sealing impregnation (i.e. gelatin, albumin, etc.) to obtain zero porosity of the graft. Expanded polytetrafluoroethylene (ePTFE) is also used for aorto-iliac reconstruction. There are no data to suggest that any one graft would be superior to another. Vascular grafts with antimicrobial substances such as silver or triclosan are available but there is no evidence either supporting the routine use of these grafts to prevent aortic graft infection, or that prophylactic rifampicin soaking of the graft reduces graft infection.[655]

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4.3.1.2. Incision and approach. A midline incision through the linea alba from the xiphoid to the pubis is the widely used technique because of its flexibility and the possibility to access all abdominal organs with relative ease. An alternative access is the transverse subcostal incision below the ribcage allowing good access to the juxtarenal, suprarenal and coeliac portions of the aorta. A RCT on an AAA population showed a lower incidence of hernia after transverse incision than vertical incision.[199] A Cochrane review however found no clinically important difference between midline and transverse incisions for general abdominal surgery,[81] which was confirmed in a later RCT.[616] Therefore, the decision about the incision should be driven by surgeon preference and patient factors. Alternatively, a left retroperitoneal approach may be used providing access in more proximal aneurysm disease, inflammatory aneurysms, or in case of a "hostile" abdomen because of adhesions or a stoma. For exposure, the patient is positioned with the left shoulder rotated superiorly and to the right by 45°—60° and the left pelvis angled slightly. The operating table is fully broken head down. The incision runs from the lateral edge of the rectus abdominis muscle at the umbilicus to the costal margin.[704] The left kidney may either be left "in situ" or also be rotated to the right.

There is no major difference between the transperitoneal and the retroperitoneal route regarding operating time, blood loss, analgesia requirements, gastrointestinal function, morbidity, mortality, and length of ICU or hospital stay. In the long term, the retroperitoneal approach may be associated with more wound complications but fewer postoperative ileus, pneumonia, and incisional hernias than the transperitoneal approach.[78,423,629,704] For infrarenal AAA repair, the proximal landmark for exposure is the left renal vein, which often has to be mobilised to facilitate exposure of the aorta just below the renal arteries. If necessary, the left renal vein can safely be divided and ligated,[468,750] as long as important collaterals, including the adrenal, phrenic, gonadal, and lumbar veins, are preserved.[448] There is no evidence to support routine reconstruction of the left renal vein.[448]

The distal dissection depends on the extent of the aneurysmal disease. On the left side, an additional submesocolic peritoneal incision lateral to the sigmoid colon may be needed for better control of the external and internal iliac arteries. Severe disease of the iliac artery may jeopardise an adequate anastomosis in the abdomen, requiring isolation of the common femoral arteries at the groin to be able to perform an aortobifemoral bypass.

To prevent post-operative sexual dysfunction (e.g. retrograde ejaculation) it is important to avoid unnecessary injury to the peri-aortic tissues. Dissection should be minimal in the distal aorta/iliac bifurcation area. Distal bleeding control can also be achieved with balloon catheters.

4.3.1.3. Use of heparin. To minimise the risk of thrombosis due to stasis, heparin is usually administered systemically before cross clamping. Although, a systematic review found limited evidence for the efficacy of heparin in AAA repair,[765] it is a general vascular surgery principle. Accepted doses range between 50 and 100 IU/kg,[765] and heparin efficacy may be tested using an activated clotting time (ACT) test to ensure adequate anticoagulation.[227] Once peripheral perfusion has been re-established protamine sulphate may be administered to reverse heparinisation based on ACT test and the presence of diffuse bleeding or oozing.

Recommendation 50	Class	Level	References
Intravenous heparin (50—100 IU/kg) is recommended before aortic cross clamping.	I	C	[765]

4.3.1.4. Surgical repair. The proximal anastomosis should be sutured as close as possible to the renal arteries, even for long necks, to prevent later aneurysm development in the remaining infrarenal aortic segment. On a cellular level, advanced fibrillar degradation may also be present in seemingly healthy necks, leading to proximal aneurysm formation or anastomotic false aneurysm formation. Furthermore, the orientations of the medial fibres near the origin of the renal arteries provide improved mechanical properties.[108,413]

Recommendation 51	Class	Level	References
It is recommended to perform the proximal anastomosis as close as possible to the renal arteries to prevent later aneurysm development in the remaining infrarenal aortic segment.	I	C	[108,413]

The proximal end to end anastomosis is usually performed with a non-resorbable monofilament running suture (4—0 to 2—0). Pledgets (e.g. prosthesis, bovine pericardium, Teflon, etc.) may be employed to reinforce the suture in case of friable tissue. The distal anastomosis is performed in a similar fashion, after sufficient flushing of both iliac arteries and the graft to prevent distal embolisation.

Bifurcated grafts should be tailored to maintain sufficient body length to facilitate endovascular re-intervention

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should this be necessary in the future. At least one internal iliac artery (IIA) should be preserved or reimplanted when possible, to provide sufficient perfusion of pelvic organs and to reduce the risk of buttock claudication and colonic ischaemia.[49,65,66,443] Suture ligation of the inferior mesenteric artery (IMA) should be performed at its origin from the aneurysm sac to preserve left colic collaterals. There is no evidence in the literature to support reimplantation of a patent inferior mesenteric artery, but it may be considered occasionally in selected cases of suspected insufficient visceral perfusion with risk of colonic ischaemia, for example if the superior mesenteric artery is occluded and the IMA is an important collateral. Often, the need is only recognised intra-operatively when the sigmoid colon remains ischaemic after aortic repair. If in doubt, reimplantation should be performed using a small Carrel patch of aortic wall around the origin of the artery to reimplant it end to side to the graft or one of its limbs.[346,618]

Cross clamping time should be as short as possible to minimise lower body ischaemia, cellular damage and metabolic injury. Coordination with the anaesthesia team is particularly important at the time of declamping. The distal circulation should be checked and if necessary promptly corrected.

Recommendation 52	Class	Level	References
In selected cases of suspected insufficient perfusion of pelvic organs with risk of colonic ischaemia, reimplantation of the inferior mesenteric artery may be considered during open abdominal aortic aneurysm repair.	IIb	C	[346,618]

Recommendation 53	Class	Level	References
In open abdominal aortic aneurysm repair, it is recommended to preserve the blood flow to at least one internal iliac artery to reduce the risk of buttock claudication and colonic ischaemia.	I	C	[49,65,66,443]

4.3.1.5. Abdominal closure. Incisional hernia is a well known complication of laparotomy and requires treatment in 7–26% of patients.[15,265,674] The incidence of incisional hernias is higher after midline incision than after retroperitoneal access for OSR.[34,199] In addition to post-operative wound complications and obesity, AAA repair is an independent risk factor for the development of incisional hernia.[78]

The closure technique is crucial to reduce the rate of wound complications in midline incisions. Fascial closure with small bites and a suture length to wound length ratio higher than four is a generally recommended surgical technique.[149,479,497]

A recent meta-analysis based on several RCTs showed that prophylactic use of mesh reinforcement of midline laparotomies significantly reduces the risk of incisional hernia after open AAA repair. There was, however, no clear effect on the frequency of re-operation and long-term follow up data are still lacking. Despite these limitations it is reasonable to consider the technique for patients at increased risk of incisional hernia.[293,299]

Recommendation 54	Class	Level	References
In patients treated for abdominal aortic aneurysm by open repair, prophylactic use of mesh reinforcement of midline laparotomies may be considered for patients at high risk of incisional hernia.	IIb	A	[293,299]

Table 4.4. Anatomical requirements for the most commonly used stent grafts according to the latest instruction for use available to the authors.

Anatomical parameter	Endurant	Excluder	Zenith
Neck length	≥10 mm[a]	≥15 mm	≥15 mm
Neck diameter	19–32	19–29	18–32
Suprarenal neck angulation (α-angle)	≤45°	–	<45°
Infrarenal neck angulation (β-angle)	≤60°	≤60°	<60°
Distal fixation site length	≥15 mm	≥10 mm	>10 mm
Distal fixation site diameter	8–25 mm	8–25 mm	7.5–20 mm
Additional criteria	No significant or circumferential calcification or thrombus in proximal and distal landing zones No conical neck shape (<2–3 mm increase in neck diameter for each centimetre of length) Adequate femoral access		

[a] ≥ 15 mm with >60° to ≤75° infrarenal and >45° to ≤60° suprarenal neck angulation.

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4.3.2. Endovascular repair

4.3.2.1. Types of concept. Unlike OSR, a stent graft is meant to seal the sac from the inside of the aneurysm, while the aneurysm wall is left untouched. The paradigm is therefore changed from replacing the aneurysm to excluding it from the systemic circulation. Therefore, the anchoring segments need to provide both sufficient sealing and fixation. Most devices rely on some degree of oversizing of the stent graft to guarantee sealing and fixation. The degree of oversizing required, which ranges from 10% to 25%, varies between different devices.

Most stent grafts now adopt a modular design with two or three separate components including an aortic bifurcated main body and one or two iliac limbs. This has several important advantages. With a relatively limited stock, devices can be tailored precisely to the diameters and lengths of the vessels of the individual patient. Moreover, taking advantage of the overlap between components gives a degree of flexibility in planning.

Additional features that are specific to individual types of device include the possibility to reposition the proximal portion of the device during deployment, the presence of proximal bare stents for suprarenal fixation, hooks or barbs for additional fixation, and polymer filled rings for proximal sealing. There are no data that convincingly favour any of the above features or one particular EVAR device over another. Comparative studies are lacking and given the rapid technological development, even within the same branding, device specific studies are rapidly outdated. Pending further evidence, local preference and experience should therefore guide device selection.

There are several anatomical requirements specific to individual stent grafts and specified in their respective IFU (Table 4.4). Outside IFU the use of devices may have medicolegal implications in some countries, in such a way that the manufacturer's liability for the device quality no longer applies. Instead, responsibility is assumed by the operating surgeon or centre/hospital.

4.3.2.2. Access. Stent grafts are generally delivered through the femoral artery either through a surgical cut down or percutaneously. Surgical exposure may be obtained by means of a limited longitudinal or transverse incision (under general or local anaesthesia) and has the advantage of direct control of the artery and free choice of the ideal puncture site.

The percutaneous approach relies on artery "closure devices" which usually need to be inserted before the sheath is introduced.[182] This approach is less invasive and can be performed under local anaesthesia. Femoral calcification represents the only predictor of percutaneous access failure.[562]

A recent systematic review identified only two RCTs with a total of 181 participants comparing surgical cut down with total percutaneous access for elective EVAR. No significant differences were detected between the two methods regarding short-term mortality, major complications, wound infection, bleeding complications, and long-term (six month) complications. The percutaneous approach was, however, quicker than the cut down.[223]

In a comprehensive review including three RCTs and 18 observational studies, percutaneous access was associated with a lower frequency of access related complications, such as groin infection, lymphocoele, and a shorter procedure time and hospital length of stay, than open surgical access. Moreover, percutaneous endovascular aneurysm repair did not increase the risk of haematoma, pseudoaneurysm, and arterial thrombosis or dissection.[251]

In a systematic review and meta-analysis the utility of US guidance for femoral artery catheterisation was determined. A total of 1422 subjects from RCTs were included: 719 in the US guided group and 703 in the palpation guided group. US guidance was associated with a 49% reduction in overall complications, including haematoma and accidental venepuncture and a 42% improvement in the likelihood of first attempt success.[639]

Recommendation 55	Class	Level	References
An ultrasound guided percutaneous approach should be considered in endovascular aortic aneurysm repair.	IIa	B	[182,223,251, 562,639]

4.3.2.3. Use of heparin. A similar approach to heparin should be adopted in EVAR as in OSR, with administration once femoral access has been achieved (see Recommendation 50).

4.3.2.4. Accessory renal arteries. Accessory renal arteries (ARAs) are present in 9–16% of patients undergoing EVAR, with half likely to be covered.[379] Potential consequences are renal infarction with risk of deterioration of renal function (particularly with pre-existing renal insufficiency) and risk of persistent Type II endoleak.[594]

A recent systematic review found four studies that did not observe any significant changes of post-operative renal function, whereas one study reported an early transient increase in creatinine after ARA coverage. The frequency of renal infarction varied from 20% to 84%. Five studies did not observe endoleaks related to ARA coverage, whereas one reported the occurrence of Type II endoleaks in three of 18 patients who had ARA coverage. No significant change in blood pressure, mortality, and mean length of hospital stay was observed.[379]

Thus, current evidence supports the covering of ARAs located in the proximal fixation zone to achieve a seal in EVAR. It is recommended to try to preserve larger (>3 mm in diameter) or assumed significant ARAs (supplies > 1/3 of

the renal parenchyma), especially in cases with pre-operative renal insufficiency. Custom made fEVAR[117] or ChEVAR[3] are possible options to preserve ARA in patients not suitable for OSR.

There is currently no evidence to support pre-emptive embolisation of ARAs.[379,503]

Recommendation 56	Class	Level	References
Preservation of large accessory renal arteries (>3 mm) or those that supply a significant portion of the kidney (>1/3) may be considered in endovascular aneurysm repair.	IIb	C	[379]

4.3.2.5. Newer generation of stent grafts. In recent years, manufacturers have developed new stent grafts and delivery systems with lower profiles to allow an endovascular approach even in patients with small access vessels. Although there are some series reporting favourable mid-term outcomes for latest generation low profile stent grafts compared with standard profile stent grafts, more experience and longer term outcome data, especially on durability, are needed to confirm these findings.[638] When upgrades of existing platforms are used in clinical practice, the need for long-term follow up should be recognised, and evaluation in prospective registries, with complete follow up is recommended.[460,107]

An alternative endovascular concept, called endovascular aneurysm sealing (EVAS), is to completely seal the aortic aneurysm sac. This uses polymer filled polyurethane bags surrounding balloon expandable stents covered with PTFE. This approach was designed to prevent some of the complications of EVAR (see Chapter 7) including endoleak and stent graft migration. However, these devices have only been commercially available for a limited time, and their effectiveness and long-term durability are still under investigation.[75] The manufacturer recently issuing a hazard alert for the EVAS System due to higher than expected rates of leaks around the implant, device movement, and aneurysm enlargement[14,187] and significantly changed the IFU for EVAS (https://endologix.com/international/products/nellix). Currently, EVAS should only be used within studies approved by research ethics committees until adequately evaluated.[460]

Recommendation 57	Class	Level	References
For newer generations of stent grafts based on existing platforms, such as low profile devices, long-term follow up and evaluation of the durability in prospective registries is recommended.	I	C	[460,638,107]

Recommendation 58	Class	Level	References
New techniques/concepts (such as endovascular aneurysm sealing with endobags) are not recommended in clinical practice and should only be used with caution, preferably within the framework of studies approved by research ethics committees, until adequately evaluated.	III	C	[75,313,460, 638,687]

4.3.3. Laparoscopic aortic repair. Laparoscopic aortic surgery is a minimally invasive alternative to open surgery when EVAR is not indicated.[131,300]

Laparoscopic techniques for the treatment of AAA include a total laparoscopic approach, a laparoscopic assisted surgical approach (laparoscopic dissection with endo-aneurysmorrhaphy via mini-laparotomy), a hand assisted laparoscopic approach, or a robot assisted laparoscopic approach.

This technique is technically demanding and requires a large experience in laparoscopic surgery.[179] In a recent prospective comparative multicentre study, laparoscopic aortic surgery was associated with a significantly higher risk of death and adverse events compared with conventional open surgery, despite a highly experienced laparoscopic surgical team.[581]

Recommendation 59	Class	Level	References
Laparoscopic abdominal aortic aneurysm repair is not recommended in routine clinical practice, outside highly specialised centres, registries or trials.	III	C	[179,581]

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4.3.4. RCT comparing OSR and EVAR. Several RCT have compared open and endovascular treatment of AAA in patients with suitable anatomy, including the EVAR 1 trial,[237] DREAM,[71] OVER,[386] and ACE trials[50] (Table 4.5). They have shown a significant early survival benefit for EVAR of intact AAA. However, this benefit is lost during mid-term follow up.

4.3.4.1. EVAR 1 trial. The first RCT was the EVAR 1 trial. A total of 1082 patients with aneurysm diameter ≥5.5 cm were randomised between 1999 and 2003 in the UK to receive either elective EVAR or OSR. The trial demonstrated the benefits of EVAR for 30 day mortality (1.7% vs. 4.7%), but secondary interventions were more frequent in the EVAR group (9.8% vs. 5.8%).[237] Aneurysm related and total mortality were similar between the two groups after 6 months but after 4 years there was an increase in aneurysm related mortality in the EVAR, culminating after 8 years of follow up. The re-intervention rate was significantly higher in the EVAR group. An observed increased aneurysm related mortality in the EVAR group beyond 8 years of follow up (7% vs. 1%) was mainly attributable to secondary aneurysm sac rupture (7% vs. 1%). The inferior late overall survival after EVAR can be partly explained through a greater increase in late mortality from aneurysm related deaths in the EVAR group[541] and needs to be addressed by lifelong surveillance and adequate re-interventions.[545]

4.3.4.2. DREAM trial. The DREAM trial enrolled 351 patients in the Netherlands and Belgium with an aneurysm diameter ≥5 cm, between 2000 and 2003. The study findings suggested that EVAR provided an early survival advantage over OR and that this advantage was lost by the end of the first year. The operative mortality rate was 4.6% after OR versus 1.2% after EVAR,[563] and at 2 years the cumulative survival rate was 89.6% for OSR and 89.7% for EVAR. Cumulative rates of aneurysm related death were 5.7% for OSR and 2.1% for EVAR.[71] Very long-term follow up (12–15 years)[70] showed that the cumulative overall survival rates were 41.7% for OSR and 38.4% for EVAR. Freedom from re-intervention was significantly higher after OSR (86.4% vs. 65.1%).[70]

4.3.4.3. OVER trial. The OVER trial randomised 881 patients with an aneurysm diameter of 5 cm or more, between 2002 and 2008 in the USA, and followed them for a mean of 5.2 years. It showed low peri-operative mortality for both procedures, specifically lower for EVAR than OSR (0.5% vs. 3%). The reduction in peri-operative mortality with EVAR was sustained at two years and three years but not thereafter. There was no significant difference in the rates of secondary therapeutic procedures when laparotomy related re-interventions were included.[385,386] After 9 years of follow up, survival, quality of life, costs, and cost effectiveness did not differ between elective OSR and EVAR.[387] The 13 year results of this trial will be available shortly.

4.3.4.4. ACE trial. In France, the ACE trial randomised 316 patients with an aneurysm diameter of ≥5 cm, suitable for EVAR and at low to intermediate risk of OSR, between 2003 and 2008. After a median follow up of three years, no difference was found in the cumulative survival free of death or major events rates between OSR and EVAR (95.9% vs. 93.2% at one year and 85.1% vs. 82.4% at three years, respectively; $p = 0.09$). The re-intervention rate was higher in the EVAR group (16%, vs. 2.4% $p < 0.0001$) and there was a trend towards a higher aneurysm related mortality in the EVAR group (4%; vs. 0.7% $p = 0.12$).[50]

A recent meta-analysis[558] of individual patient data, reported data on mortality, aneurysm related mortality, and re-intervention considering the four RCTs of EVAR versus OSR mentioned above. This meta-analysis included 2783 patients, with 14245 person years of follow up. In the EVAR group, total mortality was lower between 0 and 6 months (46/1393 vs. 73/1390 deaths; pooled hazard ratio 0.61, $p = 0.010$), due to a lower 30 day operative mortality, but

Table 4.5. Summary of randomised controlled trials comparing elective endovascular and open repair for abdominal aortic aneurysm.

Study	Country	Recruitment period	*n* of pts	Main findings
EVAR 1	UK	1999–2003	1082	Better peri-operative survival after EVAR (1.7% vs. 4.7%) Early survival benefit lost after 2 years, with similar long-term survival Higher aneurysm related mortality in the EVAR group after 8 years, mainly attributable to secondary aneurysm sac rupture Higher re-intervention rate after EVAR
DREAM	The Netherlands and Belgium	2000–2003	351	Better peri-operative survival after EVAR (1.2% vs. 4.6%) Early survival benefit was lost by the end of the first year, with similar long-term survival Higher re-intervention rate after EVAR
OVER	USA	2002–2008	881	Better peri-operative survival after EVAR (0.5% vs. 3%) Early survival benefit sustained to 3 years but not thereafter No difference in re-intervention rate No difference in quality of life No difference in cost and cost effectiveness
ACE	France	2003–2008	316	No difference in peri-operative survival (1.3% vs. 0.6%) No difference in long-term survival up till 3 years Higher re-intervention rate after EVAR

UK = United Kingdom; USA = United States of America; EVAR = endovascular aneurysm repair.

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the advantage was lost in the long-term although total mortality for the two groups over the follow up period of the trials showed no significant differences. In terms of aneurysm related mortality, there was no difference between EVAR and OSR after 30 days and up to three years of follow up, but after three years the number of deaths was higher in the EVAR group (3 vs. 19 deaths). This study also showed that there were no early survival advantages after EVAR in patients with renal failure or previous CAD. The re-intervention rate was higher in the EVAR group but not all trials reported incision related complication after OSR. It was also shown that the efficacy of EVAR is not affected by age and sex. When taking incisional hernias, bowel obstructions, and other laparotomy based complications into account, as was done in the OVER trial,[386] the difference in secondary interventions between groups appear much less significant than that observed in the EVAR1[237] or DREAM trials.[70]

The cause of aortic rupture after EVAR relates principally to sac enlargement as the result of device failure or progression of native disease.[773] Aortic rupture has been proven to be an important cause of death in the RCTs that have a very carefully selected and followed-up population of patients. However, it should be noted that the rate of sac enlargement may be significantly higher in patients who undergo EVAR outside the IFU.[606]

Devices used in the EVAR 1, EVAR 2, DREAM, and OVER trials were mainly first or second generation EVAR devices. It is possible that newer devices and techniques currently in use may offer improved outcomes; however, only short-term results are available. Another confounding factor when analysing time trends is the type of anaesthesia: between 1999 and 2008 general anaesthesia was commonly used; today many EVAR procedures are performed under local anaesthesia and often using a percutaneous approach.

In the OVER trial, that evaluated cost and cost effectiveness, no difference was seen between EVAR and OSR.[386] This was confirmed in a model study from the Netherlands.[102] A recent systematic review noted, however, that published cost effectiveness analyses of EVAR do not provide a clear answer about whether elective EVAR is a cost effective solution and calls for cost effectiveness analysis of EVAR that incorporates more recent technological advances and the improved experience that clinicians have with EVAR.[717]

Owing to the rapid technological and medical developments, the existing RCTs comparing OSR and EVAR are partly outdated and thereby not entirely relevant for today's situation. It is therefore necessary to include more recent case series and registry studies in the overall valuation. Thus, despite data from multiple RCTs and meta-analysis, representing the highest level of evidence, the existing level of evidence is rated as mediocre (Level B).

4.3.5. Contemporary cohort studies comparing OSR and EVAR. Recent large population based registry studies from Europe and the USA have shown a sustained increased utilisation of EVAR with a continued decrease in mortality and morbidity, despite older and more comorbid patients being treated by EVAR.[48,401,437,698,779] The contemporary 30 day mortality after elective EVAR is around 1%, compared with a three to four times higher mortality after OSR.[100,401,779] The improved short-term outcome is sustained for at least five years.[401,436]

Also, a marked reduction in operating time, surgical complications, and ICU and hospital length of stay after EVAR have been observed in recent years[215,779] and when comparing stent grafts introduced after 2004 with those used prior to that time, the newer stent grafts have performed substantially better in terms of long-term rates of re-intervention, conversion, and AAA growth.[744]

The evidence from RCTs has the limitation that they predominantly apply to those under 80 years of age, whereas today the greatest increases in AAA repair appear to be those over 80 years.[100,401,510] This group has also seen the most pronounced improvement in outcome after AAA repair, which is likely to be related to the preferential use of EVAR for treatment of octogenarians. In a recent nationwide Swedish study the 30 day mortality after elective AAA repair among octogenarians was 2%, of which 80% were treated by EVAR.[401] In a report from the Vascular Quality Initiative database in the USA the 30 day and one year mortality after elective EVAR in octogenarians were 1.6% and 6.2% respectively. The corresponding mortality after OSR was 6.7% and 11.9% respectively.[270] Data from the ENGAGE registry suggest that octogenarians treated by EVAR have a higher incidence of complication with longer hospital stay and a longer than expected recovery time ($>$12 months) than younger patients.[556] Against this background, it is reasonable to consider elective AAA repair of patients over 80 years with reasonable life expectancy and QoL being well informed.

Therefore, data from modern cohort and registry studies indicate that there has been a continued development of treatment methods with the ability to offer treatment to more patients and at the same time with improved results. This information is an important complement to that from older RCTs when evaluating operating techniques today.

4.3.6. RCT comparing EVAR with no intervention in patients unfit for OSR. The EVAR 2 trial is the only RCT evaluating the patients for whom EVAR was originally designed, that is the frail patients not suitable for open surgery. A total of 404 patients, with an AAA $\geq$5.5 cm in diameter and physically ineligible for OSR were included between 1999 and 2004 in the UK.[709,710] Patients were divided into two groups: 197 patients were assigned to undergo EVAR, and 207 were assigned to have no intervention.

There was no benefit of early EVAR on AAA related or total mortality at four years of follow up, which was explained by a higher than expected peri-operative mortality (7.3%) after EVAR in this cohort of frail patients and a very high overall mortality. The overall rate of aneurysm rupture in the no intervention group was 12.4 per 100 person years.[192,193]

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After up to 10 years of follow up EVAR was associated with a significantly lower rate of aneurysm related mortality but also higher rates of complications and re-interventions and no difference in all cause mortality. During 8 years of follow up, EVAR was considerably more expensive than no repair.[709,710]

A very long-term follow up study, focused on the remaining fraction of the original EVAR 2 cohort that survived >8 years, and thus represents a subgroup of more fit patients than the overall EVAR 2 cohort, yet frail and deemed unfit for OSR of their AAAs (at that time). Up to 15 years' follow up, there was a significantly lower aneurysm related mortality in the EVAR group, however owing to a very high overall mortality no difference in overall life expectancy was seen. The authors concluded that "EVAR does not increase overall life expectancy in patients ineligible for open repair but can reduce aneurysm related mortality".[545,670]

4.3.7. Individual decision making process. It should be noted that this chapter refers to patients with an asymptomatic infrarenal AAA undergoing elective repair. Importantly, the present concepts should not be used to deduce recommendations for other situations. The choice of surgical technique should be discussed between the treating clinician and the patient and multiple factors should be considered when individualising a patient treatment plan. These include (1) anatomical suitability for EVAR, (2) physiological reserves and fitness for surgery, (3) life expectancy, (4) patient preferences, and (5) needs and expectations, including the importance of sexual function, and anticipated compliance with frequent lifelong surveillance and follow up.

The decision when and how an AAA is to be operated on is thus extremely complex, with multiple variables that should be considered. It is therefore not possible to provide very detailed recommendations, and important to allow some degree of freedom for individualised decision making, respecting patient choice whenever possible.[194,577]

Nearly all the evidence suggests a significant short-term survival benefit for EVAR over OSR, with a similar long-term outcome up to 15 years of follow up. Yet, there are indications that an increased rate of complications may occur after 8–10 years with earlier generation EVAR devices and uncertain durability of current devices, particular the low profile devices. Thus, although EVAR should be considered the preferred treatment modality in most patients, it is reasonable to suggest an OSR first strategy in younger, fit patients with a long life expectancy >10–15 years. The normal (average) survival after elective AAA repair is about 9 years.[436] Conversely, elective AAA repair is not recommended in patients with limited life expectancy, e.g. in patients with terminal cancer or severe cardiac failure. A pragmatic definition of "limited life expectancy" is less than 2–3 years.

Recommendation 60	Class	Level	References
In most patients with suitable anatomy and reasonable life expectancy, endovascular abdominal aortic aneurysm repair should be considered as the preferred treatment modality.	IIa	B	[48,70,71,78,100,192,193,194,237,270,385,386,387,401,447,541,545,558,563,577,698,709,710,779]

Recommendation 61	Class	Level	References
In patients with long life expectancy, open abdominal aortic aneurysm repair should be considered as the preferred treatment modality.	IIa	B	[50,70,71,237,385,386,387,541,545,558,563]

Recommendation 62	Class	Level	References
In patients with limited life expectancy, elective abdominal aortic aneurysm repair is not recommended.	III	B	[192,193,709,710]

Chapter 5

5. MANAGEMENT OF RUPTURED AAA

This chapter focuses on infrarenal AAA. For ruptured juxtarenal AAA, see Chapter 7.

Distinction between symptomatic and rAAA is crucial because results differ significantly between the two groups. A rAAA is defined as an acute haemorrhage from the AAA outside the true aortic wall with the presence of retroperitoneal and/or intraperitoneal blood. A contained rAAA is when the haematoma is temporarily sealed by the retroperitoneum. Symptomatic AAAs are those presenting with

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abdominal and/or back pain, tender AAA at palpation, or embolic events, but without breach of the aortic wall.

5.1. Pre-operative evaluation

The classical triad of hypotension, abdominal and/or back pain, and a pulsatile abdominal mass are present in about 50% of patients with a rAAA. A systematic review showed that a rAAA is misdiagnosed in 32% of patients.[22] The most common erroneous differential diagnoses were ureteric colic and myocardial infarction.

Emergency room US may be useful in identifying the presence of an AAA, but its sensitivity to detect retroperitoneal haemorrhage is low.[753] As a result, US cannot be used to identify a leak, but the presence of an AAA in an unstable patient is very suggestive of a rAAA. In the endovascular era, another drawback of US is that it lacks information about anatomical suitability for EVAR. Therefore, an immediate CTA as the key imaging modality is advocated for all patients with suspected rAAA.[60,612]

Most patients with a rAAA who reach the hospital alive are sufficiently stable to undergo CTA for consideration of EVAR.[83,289,414,637] Haemodynamic instability is defined as loss of, or reduced level of consciousness or systolic BP $<$ 80 mmHg.[13,322,489] Circulatory instability is however relative, and in most situations it is both preferable and feasible to have a CTA. A recent review and meta-analysis indicate that EVAR for haemodynamically unstable rAAA patients may be associated with decreased in hospital mortality compared with OSR: 37% versus 62%, $p = 0.009$.[789]

If, however, the patient is not stable enough for a CT scan, he or she should be transported directly to the operating room for emergency OSR or intra-operative imaging for determination of the suitability for EVAR. An intra-operative aortogram, with or without an AOB, may be an emergency compromise solution for determination of initial EVAR eligibility and device selection, with subsequent measurements obtained either fluoroscopically or via intravascular US.[569]

Recommendation 63	Class	Level	References
In haemodynamically stable patients with suspected ruptured abdominal aortic aneurysm, prompt thoraco-abdominal computed tomography angiography is recommended as the imaging modality of choice.	I	B	[83,414,575, 637,651]

Recommendation 64	Class	Level	References
In haemodynamically unstable patients with suspected ruptured abdominal aortic aneurysm, prompt thoraco-abdominal computed tomography angiography, allowing assessment for endovascular repair, should be considered before transferring the patient to the operating room.	IIa	B	[83,289,414,637]

5.1.1. Symptomatic non-ruptured AAA. For symptomatic non-ruptured AAA, optimal timing of treatment is debated. These aneurysms are thought to have a higher rupture risk than asymptomatic aneurysms, while emergency repair under less favourable circumstances is associated with a higher risk of peri-operative complications.[106,146,261,676,681] Some have suggested that delay in operative repair might improve outcome by allowing a more complete risk assessment, patient optimisation and avoiding out of hours operations by less experienced surgical and anaesthetic teams.[106,681] Therefore, the management of these cases should involve a brief period of rapid assessment and optimisation followed by delayed urgent repair under optimum conditions.[146,640] Careful monitoring with strict BP management awaiting repair is important.

Recommendation 65	Class	Level	References
Symptomatic non-ruptured abdominal aortic aneurysms should be considered for deferred urgent repair ideally under elective repair conditions.	IIa	B	[106,146,261, 640,676,681]

5.2. Peri-operative management

5.2.1. Permissive hypotension and transfusion protocol. There is considerable evidence that vigorous fluid replacement, known as the "normotensive resuscitation" strategy, may exacerbate bleeding and prejudice outcome. On the other hand, a "permissive hypotension" resuscitation strategy (otherwise known as "hypotensive haemostasis" or "delayed volume resuscitation") refers to a policy of delaying aggressive fluid resuscitation until proximal aortic control is achieved.[161,253] This may limit excessive haemorrhage by allowing clot formation and avoiding the development of iatrogenic coagulopathy. Although there are several published animal

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and human studies on the beneficial role of permissive hypotension in trauma, no direct comparative study exists on permissive hypotension vs. normotensive resuscitation strategies in the management of haemorrhagic shock in rAAA patients.[253,492] Nevertheless, nowadays permissive hypotension is considered a safe, well documented, and widespread practice in the management of rAAA patients.[161,263,454,455,520,583,726,738] Preferentially, resuscitation efforts should be managed with the use of blood and blood products with a suggested fresh frozen plasma/red blood cell ratio close to 1:1.[470,487] A step further is a policy of actively lowering BP using pharmacological agents. Some authors use the term "hypotensive haemostasis" to describe this active management and distinguish it from "permissive hypotension", the latter being more of a passive process of not responding to hypotension, as long as the patent remains conscious and stable albeit hypotensive. A Dutch study evaluated the feasibility of a protocol of hypotensive haemostasis using intravenous nitrates.[726] The aim was to limit prehospital intravenous fluid administration to 500 mL and to maintain systolic BP between 50 and 100 mmHg. The desired systolic BP range was reached in 46% of cases, whereas in 54%, a systolic BP $>$ 100 mmHg was recorded for $>$60 min. To date, whether pharmacological lowering of BP is beneficial remains unclear.[726]

Equally, the ideal BP that is allowed for permissive hypotension is debatable. There are increasing data that BP targets in elderly trauma patients should not be as low as in fit young patients (e.g. soldiers) from which type of population most of the data for permissive hypotension was generated. In the IMPROVE trial, the lowest systolic BP was strongly and independently associated with 30 day mortality and it was suggested that a minimum BP of 70 mmHg is too low a threshold for permissive hypotension in rAAA patients.[286] Nevertheless, most would recommend implementing a policy of permissive hypotension as long as the patient remains conscious, with a target systolic pressure 70–90 mmHg.

Recommendation 66	Class	Level	References
In patients with ruptured abdominal aortic aneurysm, a policy of permissive hypotension, by restricting fluid resuscitation, is recommended in the conscious patient.	I	B	[161,257,263, 286,455,492, 520,583,726, 738]

Recommendation 67	Class	Level	References
Local anaesthesia should be considered as the anaesthetic modality of choice for endovascular repair of ruptured abdominal aortic aneurysm whenever tolerated by the patient.	IIa	B	[286,322,371]

5.2.2. Anaesthesia. OSR requires general anaesthesia and the rAAA is approached via a midline transperitoneal or, less often, a left retroperitoneal incision.[633] Close cooperation between the anaesthetist and the surgeon is needed, since vasodilation on induction will often lead to sudden hypotension. Therefore, the surgical team should be scrubbed up and gowned, the surgical field should be prepped and draped, and all should be ready to start the operation prior to the induction of anaesthesia. This is important if delays are to be minimised and bleeding is to be controlled rapidly.

In contrast to OSR, one of the greatest advantages of EVAR for rAAAs is that it is feasible to perform the procedure under local anaesthesia, supplemented, if needed, by intravenous sedation.[371] Local anaesthesia has been advocated to prevent circulatory collapse caused by the induction of general anaesthesia and to promote peritoneal tamponade. Pooled data suggest that 29% of rAAA EVAR procedures were completed under local anaesthesia, and a further 24% of the procedures had been started under local anaesthesia and were later converted to general anaesthesia.[321] Common reasons for conversion to general anaesthesia were loss of consciousness during the operation because of severe hypovolaemic shock, severe discomfort from the rupture and the endovascular instrumentation of the aorta and iliac arteries, need for iliac artery access, and placement of a femoro-femoral bypass after deployment of an aorto-uni-iliac stent graft.[218,271,273,322,325] Movement artefact due to patient discomfort has been reported to be the reason for suboptimal stent graft deployment and inadvertent coverage of the renal arteries or more distal placement of the main body of the device. As a result, not all operators share the same enthusiasm for local anaesthesia.[273,778] Nevertheless, the use of local anaesthesia for EVAR for rAAAs has been associated with improved chances of survival.[322] In a post-hoc analysis of the IMPROVE trial, patients who received EVAR under local anaesthesia alone had a greatly reduced 30 day mortality compared with those who had general anaesthesia.[286]

5.2.3. Proximal aortic control and aortic occlusion balloon. Proximal aortic control during OSR is achieved either by infrarenal aortic cross clamping or by suprarenal or supracoeliac clamping followed by repositioning of the clamp to an infrarenal position as soon as feasible.

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Proximal aortic control can also be achieved by an endovascular AOB, during EVAR or as an alternative to conventional aortic cross clamping in haemodynamically unstable patients undergoing OSR.[154] Few reports on the effect of AOB related to open rAAA repair exist. One study showed that, compared with conventional aortic clamping, AOB was associated with reduced intra-operative mortality, but not in hospital mortality.[569]

Previous studies have demonstrated that approximately one third of rAAA patients undergoing EVAR are haemodynamically unstable and one in four experience complete circulatory collapse.[321,325,737] Such cases require immediate proximal occlusion of the aorta to control bleeding by rapidly inflating a compliant AOB. Maintaining balloon control continuously until the stent graft is fully deployed, and the rupture site excluded is crucial for survival. A meta-analysis of 39 studies documented that a total of 200 of 1277 patients (14.1%) required AOB.[324] Mortality was significantly lower in studies with a higher rate of AOB use, suggesting that the use of an AOB in unstable rAAA patients undergoing EVAR may improve the results.

Proximal aortic control during emergency EVAR can be achieved by a transfemorally placed AOB supported by a long sheath in the supracoeliac aorta using the dual balloon technique[57] or through a brachial approach.[434] Finally, when faced with a rAAA patient in circulatory collapse, some surgeons advocate placement of an AOB blind in the emergency room. However, whether such a manoeuvre is beneficial remains to be proven.

Recommendation 68	Class	Level	References
Aortic balloon occlusion for proximal control should be considered in haemodynamically unstable ruptured abdominal aortic aneurysm patients undergoing open or endovascular repair.	IIa	C	[57,263,321, 324,325,371, 432,434,455, 517,520,737, 738]

Recommendation 69	Class	Level	References
In patients undergoing endovascular repair for ruptured abdominal aortic aneurysms, a bifurcated device, in preference to an aorto-uni-iliac device, should be considered whenever anatomically suitable.	IIa	C	[286,321,323, 325,455]

5.2.4. Conventional graft and stent graft configuration. During OSR the diseased aortic segment is replaced by a prosthetic Dacron or ePTFE graft in a tube or bifurcated configuration in the same way as in elective repair (see Chapter 4). Every effort should always be taken to restore blood flow to at least one IIA, if patent (see Chapters 4 and 7).

Both aorto-uni-iliac (AUI) and bifurcated device configurations have been successfully used in EVAR for rAAAs.[321,323,325,464,575] The choice of a bifurcated over an AUI stent graft in the rAAA setting depends on several factors, such as the expertise and preference of the operator, stent graft availability, aneurysm anatomy and haemodynamic status of the patient.[321,325,464] A bifurcated option is more anatomically suited and avoids a femoro-femoral bypass, but a drawback is the time taken to cannulate the contralateral stump. The latter is a crucial factor in rAAA patients, and any delay in excluding the aneurysm may have a negative impact on survival. The AUI approach is easier and quicker, has a higher eligibility rate, requires fewer stent grafts in stock, but also requires a femoro-femoral graft. The latter has all the disadvantages of an extra-anatomical bypass plus the fact that local anaesthesia may have to be converted to general anaesthesia. A meta-analysis of published series on EVAR for rAAA documented that 60% of patients received bifurcated stent grafts.[323] Furthermore, single centre reports have suggested that a bifurcated stent graft may be associated with a lower mortality than AUI devices[325,323,371] and the IMPROVE trial has suggested that graft infection rates are lower with bifurcated devices.[290] It is important that the devices used for rAAAs should be the ones that the operator routinely uses for elective EVAR and with which the operating team has significant experience.

An important technical aspect of emergency EVAR is the degree of stent graft oversizing in the presence of existing hypovolaemia. The haemodynamic condition of the patient on presentation may influence this and, to avoid an intra-operative or late Type Ia endoleak, 30% oversizing is preferable when treating a rAAA assessed by CTA performed during permissive hypotension.[229,701]

5.2.5. Intravenous heparin administration. Whether to give intravenous heparin intra-operatively is a matter for debate. Although this is a universal policy during elective AAA repair, the intra-operative administration of intravenous heparin during open or endovascular rAAA repair is controversial. The risk of exacerbating bleeding should be balanced against the benefits of the thromboembolic protection provided by heparin.[232,376] Regardless of whether systemic anticoagulation is used at the outset, serious consideration should be given to heparin administration

and systemic anticoagulation during EVAR as soon as the aneurysm is fully excluded (with delivery system and sheaths still in place) or aortic control with an AOB is accomplished. Intravascular thrombosis requiring thrombectomy or open conversion may be needed if anticoagulation is withheld for the duration of the procedure.

5.2.6. Deep venous thrombosis prophylaxis. According to the American College of Chest Physicians, patients undergoing repair of a rAAA are categorised as high risk for the development of deep venous thrombosis (DVT).[247] However, they are also at increased risk of major bleeding. Therefore, when considering DVT prophylaxis, one should weigh the DVT risk against the bleeding risk. A reasonable approach is to use mechanical prophylaxis with sequential compression devices until the risk of major bleeding has subsided. Once the high risk of major bleeding has subsided, pharmacological prophylaxis with either low molecular weight heparin (LMWH) or unfractionated heparin can be started. In most patients, this can be safely initiated within 24–48 h of surgery unless there are signs of ongoing bleeding or a clinically significant coagulopathy.[364] This should be continued throughout the hospital stay and continued in selected patients after discharge based on individual risk factors and level of mobilisation.[247,364]

Recommendation 70	Class	Level	References
Selection of patients with ruptured abdominal aortic aneurysm for palliation based entirely on scoring systems or solely on advanced age is not recommended.	III	B	[4,59,128,147,322,367,436,586,621,625,671,675,689,715,747,748]

5.2.7. Non-operative management and palliation. Patients deemed unlikely to survive surgery may be turned down and managed palliatively. Non-intervention rates vary significantly across countries with some surgeons or centres being very selective and others adopting an all comers policy.[147,329] The decision to withhold treatment in patients who have a very low chance of survival is often difficult. Clinical judgements usually have to be made quickly, and a decision to operate is often taken despite a very low chance of success. To predict futility of open or endovascular intervention for rAAA and select patients for palliation, different scoring systems and algorithms have been tested, but, to date, none has proven significantly accurate.[671,748] Therefore, clinical decision making on withholding treatment or selection for palliation based entirely on a scoring system is not recommended.

Advanced age alone should not prevent the patient being offered surgery for rAAA. Good or, at least acceptable results can be achieved even in patients aged >80 years.[59,147,621] A meta-analysis of 36 studies showed an immediate post-operative mortality of 59% in patients >80 years old. Furthermore, intermediate survival data from six studies were available on 111 operative survivors with one, two, and three year pooled survival rates of 82%, 76%, and 69%, respectively. These acceptable immediate and intermediate survival rates in patients >80 years old after rAAA repair suggest a more confident approach toward emergency repair of rAAA in the very elderly.[59,147,436]

Finally, if cardiopulmonary resuscitation (CPR) is required before surgical repair, mortality rates may approach 100%. So, should CPR be continued, with such patients being offered repair, or should they be treated non-operatively? A recent multicentre study on 176 patients from the Netherlands concluded that a rAAA following pre-operative CPR is not necessarily a lethal combination.[90] Thirteen of these 176 patients (7.4%) needed CPR. Both CPR patients who received EVAR survived, whereas survival in the 11 CPR patients who underwent OSR was 27% (3 of 11). Therefore, rAAA patients needing CPR should not necessarily be denied intervention. However, it is reasonable to adopt a very restrictive and selective approach in this highly vulnerable patient group knowing the often dismal outcome.

5.3. Early outcome and post-operative complications

5.3.1. Mortality

5.3.1.1. Mortality after OSR of rAAA. For many years, the mortality rate of OSR for rAAAs was 50% or higher.[82] More recently, reports from multicentre studies, registries and RCTs have noted a decreasing trend in OSR mortality figures. The Swedvasc registry documented a decrease in mortality from 38% to 28% between 1994 and 2010 with almost entirely open surgery.[438] A collected world experience from the rAAA investigators (with data registered from 13 centres committed to EVAR whenever possible) reported 36% mortality for 763 patients (8–53%) who were offered OSR.[737] Furthermore, in the three recent RCTs on rAAA patients, the 30 day mortality was 25–40.6% after OSR.[154,286,575] In AJAX and ECAR trials, patients randomised in the OSR arm were all suitable for EVAR, whereas in the IMPROVE, they were not, as patients were randomised prior to CT into an endovascular strategy or an immediate OSR.

There are several prognostic risk factors for perioperative mortality after open rAAA repair. Pre-operative severe haemodynamic instability, cardiac arrest, deteriorated consciousness, renal impairment, congestive heart failure on admission and significant anaemia are known to be associated with increased mortality.[447,633] Intraperitoneal rupture, aortofemoral reconstruction, adjunctive vascular procedures, and total operating time are well established intra-operative factors associated with a worse outcome. Finally, post-operative multi-organ failure, respiratory and renal failure, post-operative bleeding, and

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cerebrovascular incidents increase mortality in the post-operative period. Significantly higher mortality is also seen in patients developing ACS.[190] Massive blood transfusion requirement is another poor prognostic factor in rAAA patients, with the blood product ratio influencing outcome.[470,487] Endovascular suitability is an independent and strongly positive predictor of survival in modern series of open rAAA repair.[160,287,288,359] Furthermore, in nationwide studies from the UK, USA and Sweden, lower mortality was seen in hospitals with larger bed capacity, in teaching hospitals, in hospitals with higher annual caseloads and when surgery was performed on weekdays rather than at weekends.[277,329,331] Finally, recent studies document that it is safe to transfer rAAA patients to the nearest high volume specialised vascular centre and that such policy may, in fact, decrease mortality.[435,531] Nationwide and regional surveys in the USA, however, suggest that this practice is not necessarily "safe", since transfer was associated with a lower operative mortality but an increased overall mortality when including transferred patients who died without surgery[471,472] (Mell JVS 2014) (see Chapter 1).

5.3.1.2. Mortality after EVAR for rAAA. The reported peri-operative (in hospital or 30 day) mortality rates after EVAR for rAAAs vary in the literature and range from 13% to 53%.[272,321,325,455,714,737] In general, reported figures from observational studies and administrative registries are much lower than those traditionally quoted for OSR with several studies reporting a mortality rate of 20% or less (Table 5.1).[23,29,30,91,122,181,222,236,272,277,321,325,331,439,455,465,483,679,697,714,737,757]

Four RCTs comparing OSR with EVAR for rAAA have been published to date[154,272,286,575] (Table 5.2). All four RCTs documented no statistical difference in peri-operative mortality between the two therapeutic options. Individual patient meta-analysis of the three recent RCTs (IMPROVE, AJAX, ECAR) showed, again, no differences in the 30 day and the 90 day mortality between EVAR and OSR.[667] Similarly, when summarising the world experience on the topic, there was a conspicuous contradiction between the pooled results of the observational studies, the administrative registries and the RCTs.[714] The observational studies and administrative registries showed that EVAR improved short-term survival, whereas the RCTs pooled together (ECAR, IMPROVE, AJAX) demonstrated no such advantage.[667] The disparate results are most likely explained by the differences in study quality and selection bias (in terms of patient confounders, aneurysm anatomy, haemodynamic instability, rejection rates, logistics, operator experience, etc.).[667] Specifically, observational studies and registries are more prone to selection bias. This is because patients must be stable enough for CTA to be considered for EVAR and, therefore, in these studies, there is likely to be a selection bias of more stable patients undergoing EVAR as opposed to OSR. Finally, one should keep in mind that the RCT results, especially in the IMPROVE trial, are given on an intention to treat basis, with some patients receiving a treatment different from the one intended.[286]

5.3.2. Morbidity

5.3.2.1. Complications after OSR of rAAA. The complication rate varies significantly between series. Indicative rates of post-operative complications were pulmonary in 42%, cardiac in 18%, acute kidney injury in 17%, ischaemic colitis in 9%, and wound complications in 7%.[633]

End organ ischaemia, such as post-operative colonic ischaemia and acute lower limb ischaemia are relatively infrequent but potentially serious complications of open (and endovascular) repair of rAAAs. Post-operatively, all rAAA patients should be closely monitored for signs of colonic ischaemia. When the diagnosis is suspected, frequent assessments, monitoring of intra-abdominal pressure (which has been found to have a strong correlation

Table 5.1. Comparison of peri-operative mortality figures between endovascular and open repair in administrative databases of patients with ruptured abdominal aortic aneurysm.

Author	Publication year	Country	Study period	*n* of pts (EVAR/OSR)	Mortality	
					EVAR	OSR
Greco	2006	USA	2000–2003	5798 (290/5508)	39%	48%
Wanhainen	2008	Sweden	1994–2005	3516 (92/3424)	15%	36%
Giles	2009	USA	2005–2007	567 (121/446)	24%	36%
Holt	2010	UK	2003–2008	4414 (335/4079)	32%	47%
Mani	2011	International	2005–2009	7040 (824/6216)	20%	33%
Chen	2013	Taiwan	1998–2009	537 (39/498)	44%	38%
Mohan	2013	USA	2001–2010	42,126 (8140/33,986)	26%	39%
Trenner	2013	Germany	1999–2010	4859 (575/4284)	23%	41%
Edwards	2014	USA	2001–2008	10,998 (1126/9872) 1099 propensity score matched patient pairs	34%*	48%[a]
Karthikesalingam	2014	England	2005–2010	6897 (569/6328)	32%	43%
		USA	2005–2010	19,174 (4003/15,171)	27%	46%
Karthikesalingam	2015	England	2003–2012	12,467 (1184/11,283)	28%	41%
		Sweden	2003–2012	2829 (464/2365)	21%	31%
Taylor	2016	New Zealand	2010–2014	285 (28/257)	18%	36%
Summary data				120,075	26.8%	39.6%

n = number; pts = patients; EVAR = endovascular aneurysm repair; OSR = open surgical repair.

[a] After propensity score matching. Result not included in summary data.

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Table 5.2. Peri-operative mortality figures in the four randomised controlled trials comparing endovascular and open repair of ruptured abdominal aortic aneurysm.

RCT	Country	Recruitment period	*n* of pts	30 day mortality	
				Randomised to EVAR	Randomised to OSR
Nottingham 2006	UK	2002–2004	32	53%	53%
AJAX 2013	The Netherlands	2004–2011	116	28%	29%
IMPROVE 2014	UK	2009–2013	613	35%	37%
ECAR 2015	France	2008–2013	107	18%	24%

n = number; pts = patients; EVAR = endovascular aneurysm repair; OSR = open surgical repair.

with colonic ischaemia), liberal use of colonoscopy, and early exploratory laparotomy are recommended to confirm the diagnosis and to help guide management.[49,164,165,482] Finally, acute lower limb ischaemia following open rAAA repair is not uncommon and may lead to amputation and death if not treated promptly. Haemodynamic instability, prolonged aortic cross clamp time, lack of heparin administration, and thrombo-embolic events may all play roles in its development. If lower limb ischaemia is suspected on table, immediate revascularisation is necessary depending on the aetiology.[123,290,715,716]

5.3.2.2. Complications after EVAR for rAAA. Emergency EVAR also carries the risk of several complications like those encountered after OSR. Whether EVAR is superior to OSR in terms of major morbidity remains to be seen,[427] however, a recent analysis of the Vascular Quality Initiative (2003–2013) database (514 EVAR, 651 OSR) suggested that EVAR is associated with lower in hospital morbidity than OSR.[10] Specifically, the incidence of cardiac complications (EVAR, 29% vs. OSR, 38%; $p = 0.001$), respiratory complications (28% vs. 46%; $p < 0.0001$), renal insufficiency (24% vs. 38%; $p < 0.0001$), lower extremity ischaemia (2.7% vs. 8.1%; $p < 0.0001$), and bowel ischaemia (3.9% vs. 10%; $p < 0.0001$) were significantly lower after EVAR than after OSR. Furthermore, median intensive care unit length of stay (EVAR, 2 days vs. OSR, 6 days; $p < 0.0001$) and hospital length of stay (6 vs. 13 days; $p < 0.0001$) were lower after EVAR.[10] Similar observations were made from the IMPROVE trial.[286]

In the most recent publication from the IMPROVE trial, the re-intervention rates were similar after EVAR and OSR for rAAA and most common in the first 90 days.[560] The rate of mid-term (between three months and three years) re-interventions after EVAR was high (9.5 per 100 person years) and most commonly performed for endoleak or other endograft related complications that occurred in 17% of patients. Endoleaks causing secondary rupture or requiring re-intervention consist mainly of Type IA and IB endoleaks which, when detected require immediate treatment. Type II endoleaks were not the cause of any secondary rupture in the IMPROVE trial, but the commonest reason for re-intervention in the mid-term.[560] This suggests that surveillance policies after rAAA repair need to be more strictly enforced and more intensive than those offered after elective repair.[560]

5.3.2.3. Intra-abdominal hypertension (IAH) and ACS. IAH is defined as a sustained or repeated pathological elevation in IAP $>$ 12 mmHg. ACS is defined as a sustained intra-abdominal pressure (IAP) $>$ 20 mm Hg (with or without an abdominal perfusion pressure $<$ 60 mmHg) that is associated with new organ dysfunction/failure. Abdominal perfusion pressure is defined as the mean arterial pressure minus the IAP.[349,428]

IAH/ACS is a common problem after both open and endovascular repair of rAAA. It is estimated that if measured consistently, an IAP $>$20 mmHg occurs in about half the patients after open rAAA repair, and 20% will develop ACS.[456] In Swedvasc, 6.8% of the 965 patients that underwent OSR and 6.9% of the 376 patients who had EVAR for rAAA developed ACS, with an additional 10.7% prophylactically left open after OSR.[190] In a meta-analysis of 39 series that were published between 2000 and 2012, the pooled ACS rate was calculated at 8% after EVAR for rAAA, but this figure exceeded 20% with improved awareness and vigilant monitoring.[323]

For patients undergoing EVAR for rAAA, risk factors for ACS include (1) use of an AOB; (2) severe coagulopathy; (3) massive transfusion requirements; (4) pre-operative loss of consciousness; (5) low pre-operative BP; and (6) the emergency conversion of modular bifurcated stent grafts to AUI devices.[190,466] Therefore, all such patients should be monitored closely so that early treatment can be initiated.

A management algorithm for IAH/ACS is summarised in Fig. 5.1.[68] When IAH/ACS is suspected, at first, non-surgical management (Table 5.3) should be attempted to reduce IAP.

If conservative measures prove unsuccessful and a full blown ACS has developed, decompression is indicated.[67,68,190,323,349,428,457,518,619] This is ideally performed by a midline laparotomy. Less invasive approaches, such as translumbar extraperitoneal decompression, have been reported, but the safety of these procedures has not been shown.[323,729]

The development of ACS after open or endovascular treatment for rAAAs is strongly associated with mortality. In the SwedVasc Registry, the 30 day, 90 day, and one year mortality after rAAA repair was 42.4%, 58.7%, and 60.7% in patients who developed ACS compared with 23.5%, 27.2%, and 31.8% in patients who did not develop ACS.[190] In a meta-analysis on ACS post-EVAR for rAAAs, data on outcomes of ACS were available for 76 patients, of whom 35 (47%) died.[323]

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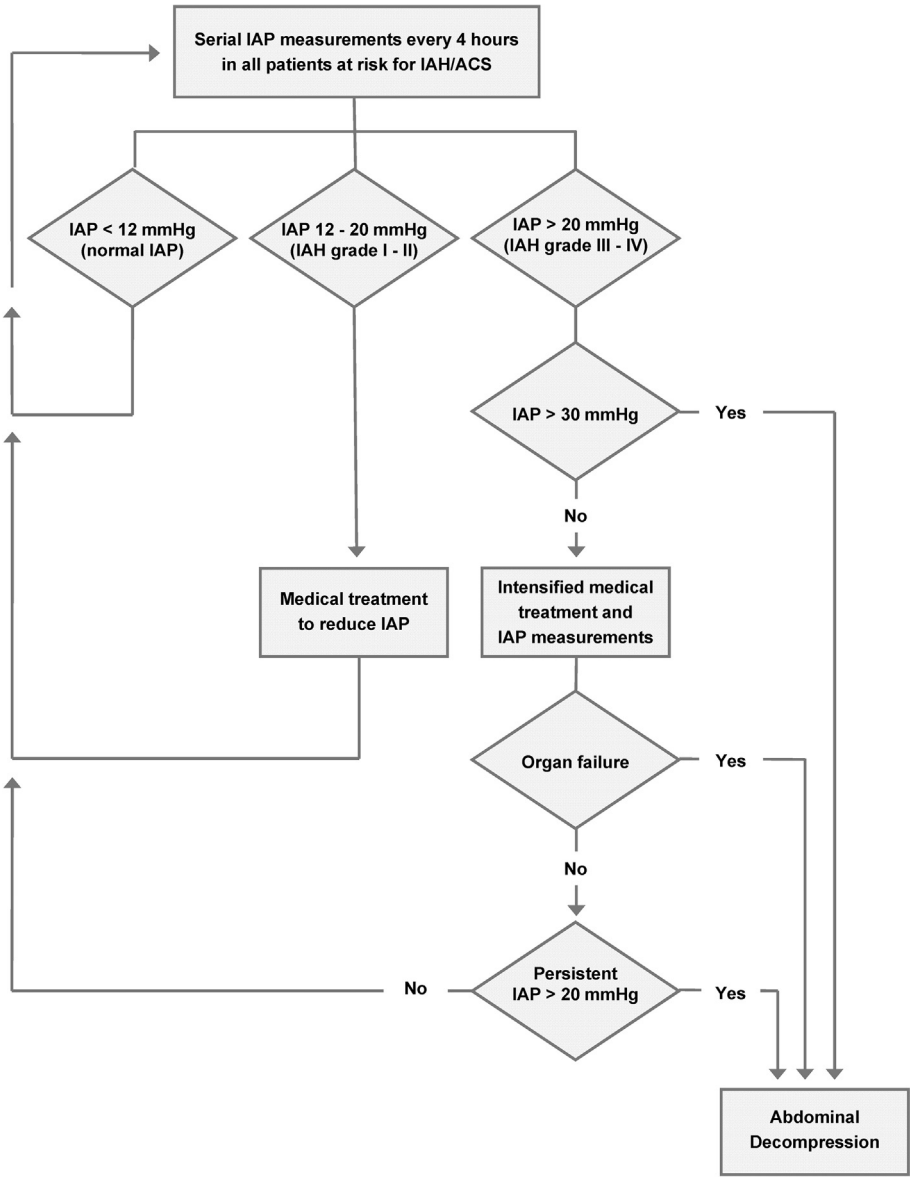

Figure 5.1. Algorithm for management of abdominal compartment syndrome after open or endovascular repair of ruptured abdominal aortic aneurysms.

The survivors after decompression for ACS may develop post-operative problems causing major morbidity, have a prolonged hospital stay, and require frequent re-interventions.[5,67,164] The management is challenging and delayed primary fascial closure should be performed as soon as possible to minimise the risk of large ventral hernias, intestinal fistulas, and graft infection. Different methods exist for temporary abdominal closure of the open

Table 5.3. Summary of medical treatment options for intra-abdominal hypertension/abdominal compartment syndrome.

Improve abdominal wall compliance	Pain relief (epidural anaesthesia) Avoid morphine Neuromuscular blockade (may reduce IAP by 50%)
Evacuate intra-luminal/abdominal content	Nasogastric decompression Paracentesis (seldom feasible)
Correct positive fluid balance	Avoid over resuscitation and crystalloids Whole blood and colloids (20% albumin) Diuretics (furosemide) Renal replacement therapy if indicated
Organ support	Optimize ventilation (PEEP) Vasopressors (APP $>$ 60 mmHg)

IAH = intra-abdominal hypertension; ACS = abdominal compartment syndrome; IAP = intra-abdominal pressure; PEEP = positive end expiratory pressure; APP = abdominal perfusion pressure.

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abdomen, such as the vacuum pack system with or without mesh bridge, the vacuum assisted wound closure, and the vacuum assisted wound closure with mesh mediated fascial traction.[5,164,323,455,456,619] According to a recent systematic review, the vacuum assisted wound closure with mesh mediated traction may achieve a high fascial closure rate without planned ventral hernia even after long-term open abdomen therapy.[5]

Recommendation 71	Class	Level	References
In all patients undergoing open or endovascular treatment for ruptured abdominal aortic aneurysm, monitoring of intra-abdominal pressure for early diagnosis and management of intra-abdominal hypertension/abdominal compartment syndrome is recommended.	I	B	[5,67,68,164, 190,323,349, 428,457,619]

Recommendation 72	Class	Level	References
In the presence of abdominal compartment syndrome after open or endovascular treatment of ruptured abdominal aortic aneurysm, decompressive laparotomy is recommended.	I	B	[5,148,164, 455,456,619]

Recommendation 73	Class	Level	References
In the management of open abdomen following decompression for abdominal compartment syndrome after open or endovascular treatment of ruptured abdominal aortic aneurysm, vacuum assisted closure system should be considered.	IIa	C	[5,456,619]

5.3.3. Mid- and long-term outcome after rAAA repair. High quality comparative long-term data on endovascular and open repair of rAAAs are scarce. Single centre or multicentre studies from Europe and the USA have shown no difference in the mid-term mortality between EVAR and OSR, after adjusting for patient and operative characteristics.[514,585,715,716] Other factors, such as patient comorbidities and indices of shock on admission seem to be the primary independent determinants of long-term outcomes.[585] The one year results from the IMPROVE trial suggested that an endovascular first strategy for rAAA does not offer an early survival benefit, but faster discharge with better quality of life and is cost effective (IMPROVE Trial Investigator[288] ;36:2061–9). When pooled together, the one year results of the three recent RCTs (IMPROVE, AJAX, ECAR) suggest that there is a consistent but non-significant trend for lower mortality post EVAR.[669] The recently published three year results of the IMPROVE trial suggest that, compared with OSR, an endovascular strategy for suspected rAAA was associated with a survival advantage, a gain in quality adjusted life years, similar levels of re-intervention, and reduced costs, and that this strategy was cost effective. These findings support the increasing use of an endovascular strategy, with wider availability of emergency endovascular repair.[289] This is also supported by a large Medicare study including >10,000 rAAA patients, of whom 1126 underwent EVAR. After propensity score matching, the peri-operative mortality was 33.8% after EVAR and 47.7% after OSR ($p < 0.001$), a difference that persisted for > 4 years. The authors concluded that EVAR for rAAA is associated with lower peri-operative and long-term mortality and that the increasing adoption of EVAR for rAAA is associated with an overall decrease in mortality of patients hospitalised for rAAA.[181]

Aortic anatomy seems to play an important role regarding the outcome, both for OSR and EVAR for rAAA. In the IMPROVE trial, short aneurysm necks adversely influenced mortality after OSR of rAAA and precluded conventional EVAR.[287,288] This explains why observational studies, but not randomised trials, have shown an early survival benefit for EVAR. When considering emergency EVAR only, single centre studies from experienced units document good results even in rAAA patients with hostile aortic neck anatomy.[89,365,528,529] When patients are grouped based on aortic anatomy and whether EVAR is performed inside or outside the IFU, increased long-term mortality and complications after EVAR for rAAAs are associated with hostile aneurysm anatomy.[27]

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Recommendation 74	Class	Level	References
In patients with ruptured abdominal aortic aneurysm and suitable anatomy, endovascular repair is recommended as a first option.	I	B	[288,289,669]

Chapter 6

6. LONG-TERM OUTCOME AND FOLLOW UP AFTER AAA REPAIR

This chapter focuses on long-term outcome after infrarenal AAA repair both by OSR and EVAR, including indications for medical management after AAA repair, complications occurring after surgery, and their implications for follow up. Specific issues related to long-term management of patients post EVAR are discussed separately in Section 6.4. For juxtarenal AAA, see Chapter 7.

6.1. Long-term survival after AAA repair

The peri-operative mortality after AAA repair has decreased over the past decades because of the introduction of EVAR and improved peri-operative care. Patients undergoing AAA repair have an increased atherosclerotic burden, resulting in an increased mortality risk compared with the general population. In a meta-analysis of survival after elective AAA repair in 36 studies including 107,814 patients, the five year survival rate was 69%.[32] The long-term survival among those surviving the peri-operative period (90 days) does not differ significantly between rAAA and intact AAA repair.[436] The long-term survival after AAA repair is affected by patient age at the time of repair, AAA size, gender, comorbidities, and regional differences.[32,331,342] Severe renal disease and COPD result in a significant reduction in long-term survival in AAA patients.[342] In a case control analysis of 19,505 AAA patients operated on in the UK, the five year freedom from adverse cardiovascular event was 86% among AAA patients and 93% for controls.[327] The annual risk of myocardial infarction, stroke, and death was increased approximately twofold compared with a matched population in a Danish cohort of AAA patients.[184] The most common causes of late death post-AAA repair include ischaemic heart disease, lung cancer, and pulmonary disease.[230] Although the risk of late aneurysm related death is difficult to assess due to the uncertainty in cause of death registration and lack of adequate long-term cohorts, it has been reported to be <3% in historic and modern studies.[230,284,305] Despite the increased risk of late cardiovascular death after AAA repair, no randomised trials have been performed to assess whether medical management modifies the risk of cardiovascular events in these patients.[584]

6.2. Medical management after AAA repair

Most patients requiring AAA repair suffer from advanced artherosclerotic disease and other smoke related comorbidities.[611,736] To optimise the outcome of AAA repair, risk factor optimisation and medical treatment of the underlying cardiovascular disease should be continued post-operatively.[184] The best medical treatment includes antihypertensive therapy (i.e. angiotensin converting enzyme inhibitors, beta blocking agents), lipid modifying therapy (i.e. statins), and antiplatelets[141,262,340,534,790] although evidence about single drugs may be conflicting[603,605]. Applicable guidelines should be consulted for specific guidance on which atherosclerotic manifestation warrants which secondary prophylaxis.[2]

Recommendation 75	Class	Level	References
In all patients after abdominal aortic aneurysm repair, cardiovascular risk management, with blood pressure and lipid control as well as antiplatelet therapy, is recommended.	I	B	[2,184,262,340, 343,534,584, 790]

6.3. Late complications and follow up after AAA repair

Late complications after AAA repair occur after both open and endovascular surgery. While some complications are unique to one of the techniques (e.g. incisional hernias after OSR or endoleak after EVAR), others may occur irrespective of the technique used (e.g. graft infection). A summary of frequent late complications after OSR is presented in Table 6.1, and after EVAR in Table 6.2.

Table 6.1. Long-term complications after open abdominal aortic aneurysm repair, and their incidence within 5 and 10–15 years.

Complication	Estimated frequency during 5 year follow up	Estimated frequency during 10 year follow up
Para-anastomotic aneurysm formation	1%	12% (15 years)
Limb occlusion	1%	5% (15 years)
Incisional hernia	5–12%	5–21%
Graft infection	0.5–5%	
Secondary aorto-enteric fistula	<1%	

References: [55,61,127,265,674].

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Table 6.2. Long-term graft related complications after endovascular aneurysm repair.

Complications	Definition	Estimated frequency during 5 year follow up
Type I endoleak	Peri-graft flow occurring from attachment sites	5%
A	proximal end of stent graft	
B	distal end of stent graft	
C	iliac occluder	
Type II endoleak	Perigraft flow occurring from collateral branches to the aneurysm; inferior mesenteric artery (IIA) and lumbar arteries (IIB)	20–40%, 10% persistent at 2 years
	Categorised as early or late/delayed (before or after 12 months) and as transient or persistent (resolved or not resolved $\leq$6 months)	
Type III endoleak	Peri-graft flow occurring from stent graft defect or junction sites	1–3%
A	leak from junctions or modular disconnection	
B	fabric holes	
Type IV endoleak	Peri-graft flow occurring from stent graft fabric porosity $<$30 days after placement	1%
Endotension	AAA sac enlargement without visualised endoleak	$<$1%
Migration	Movement of the stent graft in relation to proximal or distal landing zone	1%
Limb kinking and occlusion	Graft thrombosis or stenosis	4–8%
Infection	Stent graft infection	0.5–1%
Rupture	Aortic rupture	1–5%

References: [20,125,328,375,430,485,628,764].

6.3.1. Para-anastomotic aneurysm formation. Para-anastomotic aneurysm formation may occur after open AAA repair, and may be either a true aneurysm developing adjacent to the anastomosis, or a false aneurysm caused by disruption of the anastomosis. Graft infection may be the underlying cause of secondary aneurysm formation and needs to be excluded, especially in proximal aortic para-anastomotic aneurysm. The incidence of para-anastomotic aneurysm is up to 10% after 10 years in both aortic and femoral anastomoses. The diagnosis can be established by physical examination and DUS in femoral lesions, and by MRI or CT in aortic or iliac para-anastomotic aneurysms. Indications for therapy depend on para-anastomotic aneurysm size and clinical symptoms. While true aortic or iliac aneurysms proximal or distal to the anastomosis can be treated at a diameter threshold equivalent to that for elective therapy, a lower threshold diameter should be considered for false or saccular aneurysms. Either endovascular or open repair may be used to treat aortic or iliac para-anastomotic aneurysms, while open surgery is mostly used in femoral artery aneurysms.[61,180,593,780]

Recommendation 76	Class	Level	References
In patients treated for abdominal aortic aneurysm with new onset or worsening of lower limb ischaemia, immediate evaluation of graft related problems, such as limb kinking or occlusion, is recommended.	I	C	[129,200,440]

6.3.2. Limb occlusion. After open surgery with a bifurcated prosthesis, limb occlusion develops in 1–5%[61,127] leading to acute or chronic limb ischaemia. Post-EVAR re-intervention due to limb occlusion or kinking occurs in 1.4–8% of patients in modern series.[38,125,129,200,328,440,473,656] Approximately one third of stent graft limb occlusions are noted within the first 30 days post-EVAR, and about half of the patients present with symptoms of acute limb ischaemia.[125,200,440,678] Risk factors for limb occlusion include iliac artery angulation, tortuosity, and calcification, as well as stent graft oversizing $\geq$15% in the iliac landing zone.[200,440,678] Landing of the stent graft in the external iliac artery (EIA) is the strongest predictor of limb occlusion.[129,200,608]

Graft kinking prior to occlusion may be detected due to symptoms, or on routine follow up imaging with CTA or DUS. Intervention is required for symptomatic limb occlusion or as a preventive measure. Treatment options include graft thrombectomy with adjunctive stenting in the presence of kinking, extra-anatomical bypass, or endovascular thrombolytic treatment. There is no evidence in the literature regarding superiority of one treatment option over the other, and the treatment strategy can thus be decided individually.

6.3.3. Graft infection. Prosthetic graft infection is a serious late complication after open as well as endovascular AAA repair. It occurs between 0.3% and 6% after OSR[418] and

0.2–1% after EVAR.[198,624,745] The presence of prosthetic material in the groin increases the rate of infection to 2–4%. Other risk factors are surgical revision, immunosuppression, diabetes, bacteraemia at the primary operation or post-operatively, pre-operative hospitalisation, and various surgical factors, such as surgery duration, emergency surgery, intestinal injury, tissue trauma, and in EVAR use of an aorto-uni-iliac graft with extra-anatomical bypass.[422,580,745,754]

Because of the high morbidity and mortality of aortic graft infections (20–75% combined morbidity and mortality in various series) early diagnosis and aggressive treatment are important.[396] Diagnosis is based on clinical symptoms and laboratory findings in combination with imaging. A wide spectrum of clinical presentations can be observed including generalised sepsis, groin purulence, pseudoaneurysm formation, and graft occlusion.[219] Back pain (66%) and fever (66%) are the most frequent symptoms of graft infection on presentation.[635] Early graft infections ($\leq$3 months) are more often associated with clear signs of infections, such as fever and sepsis, wound infections, and signs of peri-graft infection. Late graft infections (>3 months) are usually low grade infections predominantly with local symptoms, such as fistula and peri-aortic gas and pseudoaneurysm formation, often with normal laboratory parameters.

CT provides information about the anatomical location, extent of infection, and other associated abnormalities (peri-aortic mass, fistula, presence of psoas abscess, or peri-aortic gas). CT has a sensitivity of 94% and a specificity of 85–100% in advanced graft infection.[419,445] For low grade graft infection CT is, however, less accurate with a sensitivity and specificity of 64%.[213] ^{18}Fluoro-deoxyglucose PET combined with CT scanning is a reliable non-invasive imaging modality for the diagnosis and follow up of prosthetic infection with a sensitivity of 77–93% and a specificity of 70–89%.[54,97] A focal fluoro-deoxyglucose (FDG) uptake with a SUV value > 8 in agreement with the clinical picture > 4–6 months post-operatively is a strong indicator of graft infection.[213] Staphylococcal organisms are most frequently identified in late infections, but any type of bacteria or fungi may be the cause of infection.

Surgical management is required to eliminate the infection.[143] Many patients require urgent treatment, 19% in a multicentre study from USA.[635] Treatment of graft infection should aim to remove the complete graft and debride the operative field extensively. Reconstruction options include in situ repair using autologous vein, cryopreserved allograft, xenopericardial graft, impregnated prosthetic graft, or extra-anatomical reconstruction.[136,139,169,258] Omentoplasty is used with any of the reconstructive materials mentioned. In the literature, there is no clear picture as to the optimal reconstruction method. All techniques carry high morbidity (including sepsis, renal failure, and major amputation) as well as a re-infection risk of 25% and a five year mortality of 46–60%.[119] Prosthetic graft replacement is associated with higher risk of re-infection than autogenous reconstructions, while prosthetic grafts impregnated with silver and/or antibiotics fared better than standard prosthetic grafts.[515,635] Long-term systemic antibiotic treatment is recommended in all patients treated for graft infection in collaboration with infectious disease consultants, with a minimum treatment duration of 6 weeks.[119] The exact duration of antibiotic treatment, which may be lifelong, needs to be managed individually.

In patients, unlikely to survive radical surgical therapy, a semi-conservative approach with partial graft removal or a conservative/palliative management strategy may be considered.[624,630,635]

There is no evidence of relationship between aortic graft infections and dental or other surgical procedures, and thus routine use of secondary antibiotic prophylaxis during dental procedures is not recommended in this setting.[26,263,504] In line with the current guidelines for endocarditis prophylaxis, antibiotic prophylaxis should be considered in procedures at high risk of infectious complications. This includes abscess drainage, dental procedures involving manipulation of gingival tissue or the peri-apical region of the teeth, or breaching of the oral mucosa. Additionally, antibiotic prophylaxis should be considered in immuno-compromised patients undergoing surgical or interventional procedures. It is important to underline that adequate evidence is lacking in this field. Recommendations regarding antibiotic prophylaxis after aortic surgery generally follow the guidelines provided for endocarditis prophylaxis after prosthetic valve placement. Therefore, changes in such guidelines would affect the use of antibiotics for patients with prosthetic aortic grafts.

Recommendation 77	Class	Level	References
For radical treatment of aortic graft or stent graft infection complete graft/stent graft explantation is recommended.	I	C	[624,635]

Recommendation 78	Class	Level	References
In selected high risk patients with graft/stent graft infection, conservative and/or palliative options should be considered.	IIa	C	[624,635]

Recommendation 79	Class	Level	References
In situ reconstruction with prosthetic material is not recommended in heavily contaminated or infected areas.	III	C	[635]

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Recommendation 80	Class	Level	References
In patients with previous abdominal aortic aneurysm repair routine use of antibiotic prophylaxis in conjunction with dental or other surgical procedures for prevention of graft infection is not recommended.	III	C	[26,263,504]

Recommendation 81	Class	Level	References
In patients with previous abdominal aortic aneurysm repair antibiotic prophylaxis should be considered in conjunction with high risk infectious procedures, including abscess drainage, dental procedures requiring manipulation of the gingival or peri-apical region of the teeth or breaching the oral mucosa, as well as in immuno-compromised patients undergoing surgical or interventional procedures.	IIa	C	[26,263,504]

6.3.4. Secondary aorto-enteric fistula. SAEF is a rare complication after aortic surgery, which may occur after OSR and EVAR, with a frequency of 0.3—0.5%.[61,382,635] This complication presents a mean of 6 years after the primary operation and is associated with high morbidity and mortality (21—77%).[17,431,587] Diagnosis is clinical (sepsis, massive gastrointestinal bleeding, shock) and established by gastroduodenoscopy and CT scanning.

Recommendation 82	Class	Level	References
In any patient with an aortic prosthesis presenting with gastrointestinal bleeding, prompt assessment to identify a possible secondary aortoenteric fistula is recommended.	I	C	[382,587]

Recommendation 83	Class	Level	References
In patients with a suspected or confirmed secondary aorto-enteric fistula, emergency referral to a high volume vascular surgical centre for treatment decision is recommended.	I	C	[314,431]

Recommendation 84	Class	Level	References
In patients with secondary aorto-enteric fistula and bleeding, staged endovascular stent grafting as a bridge to open surgery may be considered.	IIb	C	[314,431]

Emergency treatment of SAEF is usually required[314,431] and referral to a high volume vascular surgical centre for treatment decision is necessary.[314] Synchronous and staged procedures using in-situ or extra-anatomical strategies and autologous, homologous, or prosthetic material have been used for vascular repair.[119,198] Enteric repair can be performed with duodenorrhaphy, with or without omental interposition and with or without enterostomy, or duodenal resection/reconstruction. A literature review including 331 SAEF cases suggests that the use of omental interposition and in situ vascular reconstruction may be advantageous, and that duodenal derivation is preferable to the simple closure of fistula.[587] A review and pooled data analysis of 823 SEAF cases suggests that staged endovascular (bridge) to open surgery, for bleeding control, is associated with better early survival.[314]

Overall, there are insufficient data to provide clear recommendations about the exact treatment of SAEF, and therefore local preferences and the patient's condition should determine the therapeutic strategy.

6.3.5. Sexual dysfunction. Patients with AAA have a high baseline prevalence of sexual dysfunction. Up to 75% of patients report problems such as erectile dysfunction and retrograde ejaculation, often because of advanced age and comorbidities.[564] In a recent prospective single centre study from Germany, 27% of the patients reported erectile dysfunction before OSR increasing to 53% one year after surgery. The corresponding frequencies after EVAR were 43% and 59% respectively. The prevalence of erectile dysfunction one year after surgery did not differ significantly between the two groups ($p = 0.412$).[426] After EVAR

the reported rate of sexual dysfunction ranges up to 17% in patients with intra-operative unilateral internal iliac artery occlusion and up to 24% in bilateral occlusion.[79,572] Long-term prospective data analysing operative strategies, risk factors, and therapeutic options are currently not available. It is, however, important to inform patients about this complication and be aware of the pre-operative prevalence of sexual dysfunction in all male patients undergoing open and endovascular aortic repair.

6.3.6. Post-operative imaging after open repair for AAA. In a study of 1112 patients undergoing open AAA repair between 1970 and 1976, 5% developed new aortic aneurysms (including anastomotic aneurysms) a mean of five years after the initial repair.[555] In a single centre report including 102 patients with multiple aortic aneurysms, 31% of the aneurysms were located in the abdominal aorta, 23% thoraco-abdominal aorta, 27% descending thoracic aorta, and 19% ascending aorta or arch.[226] An incidence of femoral or popliteal aneurysms of up to 14%[163] and of thoracic aortic aneurysms of 12.6%[114] has been reported after OSR for AAA.

No randomised studies are available regarding the potential benefit of post-operative imaging surveillance after OSR of AAA. Nevertheless, the risk of late para-anastomotic aneurysm and recurrent aortic aneurysm and peripheral aneurysm formation makes it reasonable to consider imaging surveillance of all patients after OSR of AAA, who are fit for treatment if a new aneurysm is detected.

MRI or CT scanning is the method of choice to detect para-anastomotic aneurysms and new true aortic aneurysms early[593] method *of* choice for peripheral aneurysms.

Recommendation 85	Class	Level	References
In all patients after open repair for abdominal aortic aneurysm, imaging follow up of the aorta and peripheral arteries may be considered every five years.	IIb	C	[114,163]

6.4. EVAR specific late complications and implications for follow up

6.4.1. Long-term complications of EVAR. Patients treated by EVAR are more likely to experience aortic complications and re-interventions than those operated on by open surgery.[652]

This section focuses on EVAR related complications and their implications for follow up. It should be underlined that the long-term complications and failures discussed here relate to standard devices for the treatment of infrarenal AAA. The long-term outcome of fenestrated and branched stent grafts, EVARs performed with parallel grafts to the visceral arteries, and new concepts, such as aneurysm sealing[721] may differ from that of standard devices. Consequently, modified follow up schedules may be necessary for these complex EVAR procedures and newer technologies.

6.4.2. Endoleak. Endoleak signifies the presence of flow in the aneurysm sac outside the graft after EVAR,[764] and occurs in up to one third of cases,[375] although the prevalence depends on the type of stent graft used as well as the imaging performed during follow up. Endoleaks are classified into primary (present at the time of repair) or secondary (occurring after a prior negative imaging), as well as on the cause of perigraft flow (Table 6.2). The presence of an endoleak on follow up affects AAA sac shrinkage over time.[375] Approximately half of the endoleaks (mainly Type II) resolve spontaneously, without any re-intervention.[375] Anticoagulant therapy may increase the risk of endoleak development post EVAR.[74] The importance of endoleaks in relation to the risk of AAA rupture is related to the pressure the aneurysm sac is exposed to, and management of endoleaks therefore varies based on the cause.[609,773]

6.4.2.1. Type I endoleak. Persistent direct flow in the aneurysm sac due to inadequate proximal (Type IA) or distal (Type IB) seal of the stent graft is dangerous and associated with a high risk of aneurysm rupture.[209,609] Direct flow may also occur because of lack of seal in an iliac plug (Type IC), in aorto-uni-iliac repair and crossover graft. Type I endoleak should be treated promptly, with the aim of excluding the aneurysm from pressurised circulation. Endovascular options include graft balloon dilation or insertion of a bare metal stent or apposition of the stent graft fabric with endovascular staples against the aortic wall if the graft is adequately sized, has not migrated, and there is an appropriate landing zone to achieve a seal.[312,348,500] More commonly, extension of the landing zone is required with proximal tubular or fenestrated cuff insertion, or distal iliac extension.[337,500] If an endovascular option is not available in reasonable time and the patient is fit for OSR, open conversion can be performed with acceptable results.[604]

Recommendation 86	Class	Level	References
In patients with Type I endoleak after endovascular abdominal aortic aneurysm repair, re-intervention to achieve a seal, primarily by endovascular means, is recommended.	I	B	[209,609]

6.4.2.2. Type II endoleak. Endoleaks originating from collateral vessels are the most common type of endoleak and can be detected early after EVAR or occur later during

follow up. Often, these resolve spontaneously and the risk of rupture is low (<1%).[375,415,628] In the presence of sac expansion because of a suspected Type II endoleak, adequate imaging should be performed to rule out other causes of growth like inadequate sealing or Type III endoleak (connection, graft integrity or suture holes).[628] Different imaging modalities used for EVAR follow up and their benefits and downsides in detecting and classifying endoleaks are presented below.

In a follow up study of 2367 EVAR patients, 18% had early Type II endoleaks which resolved spontaneously, 5% had persistent Type II endoleaks, and 11% developed new onset Type II endoleak during follow up.[415] Approximately half of the patients with persistent or late endoleaks developed sac growth, with a 50% re-intervention rate at 2 years. Factors associated with persistent or recurrent Type II endoleak include coil embolisation of internal iliac arteries, distal graft extension, age ≥80 years, and anatomical factors such as number of patent side branches arising from the aneurysm, sac thrombus, and the diameter of the lumbar and inferior mesenteric arteries.[134,415,442,525] Pre-operative sac embolisation in selected patients has been suggested as a technique to reduce risk of Type II endoleak development during follow up[453,550] but the benefit of a reduced number of late re-interventions or decreased incidence of rupture remains to be proven.

Although most Type II endoleaks are benign, rupture has been described due to flow from a Type II endoleak.[609] In a systematic review, < 1% of the Type II endoleaks resulted in a rupture. This low rupture rate is however based on retrospective studies where intervention has often been performed for persistent Type II endoleak with sac expansion, and thus the true natural history of Type II endoleaks is unknown. Although most ruptures due to Type II endoleak seem to occur in the presence of sac expansion, rupture has also been reported without sac expansion.[628] Based on the above, there is no evidence for when intervention is indicated for Type II endoleak.[628] Some centres treat Type II endoleaks if the sac has expanded >1 cm, and others at 5 mm as this is the lower limit for definite detection of sac expansion between two imaging events using the same modality.

Various techniques for the treatment of Type II endoleak have been described. Endovascular treatment consists of transarterial, translumbar, transcaval, or transsealing (between iliac graft and iliac arterial wall) embolisation of the aneurysm sac and feeding vessels. Multiple embolisation materials have been used for treatment of Type II endoleak.[600] Endovascular treatment is successful in 60–80% of the cases; however, a clear definition for successful intervention is lacking, and may affect the interpretation of these results. According to a systematic review, translumbar embolisation may have a higher success rate with a lower rate of complications.[628] Surgical treatment options include laparoscopic or open ligation of side branches feeding the endoleak, suturing of the ostia of the leaking branch after opening the aneurysm sac or stent graft explantation with conversion to OSR. This is obviously more invasive and reserved for cases where endovascular intervention has failed.

Recommendation 87	Class	Level	References
Expansion of sac diameter ≥1 cm detected during follow up after endovascular abdominal aortic aneurysm repair using the same imaging modality and measurement method may be considered as a reasonable threshold for significant growth.	IIb	C	[628]

Recommendation 88	Class	Level	References
Re-intervention for Type II endoleak after endovascular abdominal aortic aneurysm repair should be considered in the presence of significant aneurysm growth (see Recommendation 87), primarily by endovascular means.	IIa	C	[628]

6.4.2.3. Type III endoleak. Endoleak resulting from stent graft component separation or fabric tear is classified as Type III. These endoleaks may occur due to maldeployment of stent grafts with inadequate overlap, proximal or distal stent graft migration, or material fatigue. Just as Type I endoleaks, these endoleaks expose the aneurysm to direct aortic pressure with subsequent risk of rupture.[609] Therefore, prompt intervention is warranted, primarily by partial or total endovascular relining. Open conversion may become necessary if endovascular options have failed.

Recommendation 89	Class	Level	References
In patients with Type III endoleak after endovascular abdominal aortic aneurysm repair, re-intervention is recommended, primarily by endovascular means.	I	C	[609]

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6.4.2.4. Type IV endoleak. Leakage of blood through the stent graft due to material porosity in the early post-operative period is defined as Type IV endoleak. According to a review of post-EVAR ruptures reported in the literature up to 2008, no cases of rupture due to Type IV endoleak were found.[609] Type IV endoleak is rare with most modern devices and does not require any re-intervention.

6.4.2.5. Endotension. Endotension (sometimes called Type V endoleak) signifies the presence of sac expansion without any visible endoleak. Several possible mechanisms for endotension have been suggested, including increased graft permeability, resulting in direct transmission of pressure through the graft to the aortic wall.[402] Given the definition, it is possible that cases classified as endotension are due to an endoleak that cannot be defined with current imaging modalities.[103,781] Historically, the first generation Gore Excluder stent grafts had a high rate of re-intervention due to endotension caused by graft permeability issues.[429] Endotension may result in AAA rupture, although this is exceedingly rare with only anecdotal cases in the literature.[609]

As with Type II endoleak, treatment is indicated for significant sac growth (>1 cm), and consists of stent graft relining or explantation and open replacement. In a series of 100 patients requiring stent graft explantation, endotension was the reason in only six cases.[702]

Cranial migration may also occur at the distal landing zone of the stent graft, due to changes in aneurysm morphology or shrinkage of the aneurysm sac after EVAR. An iliac fixation length of >20 mm or preferably down to the IIA has been suggested to reduce the risk of proximal stent graft migration.[42,58,588,749] EVAR with flared iliac limbs is associated with a higher risk of distal endoleaks.[42,235,588]

6.4.4. Follow up imaging after EVAR. The aim of post-operative imaging is to predict or detect complications. Various imaging modalities can be used during EVAR follow up. A list of imaging modalities and their pros and cons is presented in Table 6.3. Generally, CTA and/or DUS form the basis for EVAR follow up imaging.[480]

6.4.4.1. Abdominal X-ray. Traditionally, AXR with antero-posterior and lateral projections has been used during follow up for detection of stent fracture and migration.[201] This imaging technique is however highly limited in its detection of possible EVAR complications, and is therefore not suitable as the sole imaging modality for follow up. With migration and stent fractures being rare in modern endovascular practice, as well as development of 3D CT imaging, the role of AXR as follow up imaging modality is limited.

6.4.4.2. Duplex ultrasound. DUS offers the possibility of repeated and reliable measurement of maximum aneurysm diameter at low cost and without exposing the patient to ionising radiation or nephrotoxic contrast. Diameter measurements with DUS cannot be directly compared with CT measurements,[756] and thus to assess sac dynamics post-EVAR, repeat examinations with the same imaging modality are required. The addition of colour duplex imaging offers the possibility of detecting endoleaks, including flow direction and waveform.[52] In a meta-analysis of 21 studies comparing DUS with CT, the sensitivity of DUS detecting endoleaks was 0.77 and specificity 0.97.[480] Addition of microbubbles as US contrast increases the sensitivity of DUS to 0.98, but reduces specificity to 0.88. With further development of US imaging, combination of 3D volume measurement and contrast enhanced US may further increase the role of DUS in EVAR follow up imaging.[1] The downside of DUS is that it is dependent on the operator and patient related factors (e.g. obesity, hernias, presence of calcification), and current DUS imaging does not offer the possibility of reliably assessing sealing zone length, stent graft overlap and device migration.

Recommendation 90	Class	Level	References
Significant aneurysm sac growth after endovascular abdominal aortic aneurysm repair, without visible endoleak on standard imaging, should be considered for further diagnostic evaluation with alternative imaging modalities to exclude the presence of an unidentified endoleak, and should be considered for treatment.	IIa	C	[103,609, 702,781]

6.4.3. Migration. Stent graft migration is usually defined as movement of the stent graft >10 mm compared with fixed anatomical landmarks verified on flow centreline CT reconstructions, or any migration resulting in symptoms or re-intervention.[110,485] While stent graft migration was a common event with the early generation stent grafts, the development of active supra- or infrarenal fixation in modern stent grafts has reduced its prevalence.[40,433,693,731] Migration may result in Type I endoleak, stent graft separation, kinking, and graft occlusion. Risk factors for proximal migration include short proximal fixation, angulated neck, large aneurysm size, and stent graft type.[9,110,553,693] The role of oversizing is controversial, but there are indications that stent graft oversizing of >30% may contribute to the risk of migration.[654,733] Disease progression with neck dilatation may be a cause of late migration, and is related to initial neck diameter.[109] It is important to note, however, that most studies concerning risk factors for proximal device migration are performed on case series with previous generation stent grafts when migration was a relatively common issue.

6.4.4.3. Computed tomography. CTA permits the assessment and detection of most EVAR complications (Table 6.2). CT imaging can be performed either as single scan (native or

Table 6.3. Imaging techniques applicable to detection of endovascular aneurysm repair complications and used during follow-up. (Modified from Dellagrammaticas et al.[152]).

	Imaging modality AXR	DUS	CE-DUS	CT	CTA	MRA	PET-CT
Detection of possible EVAR complication							
Aneurysm sac enlargement	No	Yes	Yes	Yes	Yes	Yes	Yes
Endoleak	No	Yes	Yes	No	Yes	Yes	No
Sealing zone and component overlap	Yes	Limited	Limited	Yes	Yes	No	Yes
Migration	Yes	Limited	Limited	Yes	Yes	No	Yes
Limb kinking or occlusion	No	Yes	Yes	Kinking	Yes	Yes	Kinking
Stentgraft infection	No	Limited	Limited	Limited	Yes	Yes	Yes
Risks	Ionizing radiation	None known	None known	Ionizing radiation	Ionizing radiation. Contrast nephropathy.	Risk for nephrogenic systemic fibrosis if eGFR<30	Ionizing radiation
Technical aspects	Reproducibility difficult due to changes in patient position	Operator and patient dependent	As DUS	None	Timing of contrast administration important	Unsuitable for ferromagnetic stents & pacemaker bearers. Artefacts.	Non-specific markers for inflammation/cell proliferation, risk of false positive findings.
Suitable as sole modality for EVAR follow-up	No — combined with DUS/CE- DUS	No — combined with CT or AXR ± CE-DUS	No — combined with CT or AXR	No — combined with DUS/CE- DUS	Yes	No — as complement to CT/AXR + DUS/CE-DUS	No - only in case of suspected infection

EVAR = endovascular aneurysm repair; AXR = abdominal Xray; DUS = duplex ultrasound; CE-DUS = contrast enhanced duplex ultrasound; CT = computerised tomography; CTA = CT angiography; MRA = magnetic resonance angiography.

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arterial phase contrast), two scans (native + arterial phase or arterial + delayed phase contrast), or three scans (native, arterial, and delayed phase contrast imaging).[319] Delayed phase contrast imaging (venous and/or portal sequences) is important to rule out flow in the aneurysm when searching for endoleaks. The negative aspects of CT include the risks associated with ionising radiation, which may become an issue especially when frequently repeated imaging is required, and the use of nephrotoxic contrast in patients who may have pre-existing renal dysfunction. In addition, CT may result in detection of other incidental findings.[695]

6.4.4.4. Magnetic resonance imaging. MRI can be used in EVAR follow up in selected patients. Aneurysm diameter measurements can be performed reliably with MR and are comparable to measurements performed with CT.[21] In a systematic review of eleven studies comparing MR and CT examinations post-EVAR, MRI was more sensitive in detecting Type II endoleaks.[248] MRI may therefore have a specific role in imaging of patients with post-EVAR sac growth where CTA is negative or inconclusive. Ferromagnetic stent grafts will result in significant artefacts, which make image analysis difficult.

6.4.4.5. PET-CT. Imaging using PET-CT with the nucleotide tracer FDG can be used to guide the diagnosis of suspected stent graft infection.[592,680] Increased FDG uptake is a marker of increased cell metabolism, which may be due to infection. However, the risk of false positive and negative findings must be assessed in the clinical context of individual patients.

6.4.5. EVAR follow up. Owing to the risk of graft related complications and rupture after EVAR, regular imaging follow up has been regarded as mandatory. Current stent graft IFUs include recommendations regarding regular follow up with up to five CT examinations during the first post-operative year.[130,475] These intensive follow up routines were modified in previous version of the ESVS guidelines.[485]

The true value of prophylactic regular follow up imaging after EVAR is however uncertain. Routine surveillance seldom identifies significant findings requiring re-intervention.[69,159] Most patients who require re-intervention after EVAR present with symptoms.[328] Compliance with annual prophylactic imaging guidelines is suboptimal and lack of adherence to follow up does not seem to affect long-term mortality or the post-implantation rupture rate.[214,239] Despite clear guidelines, follow up routines vary significantly between centres.[537] There are possibilities to stratify patients based on early imaging findings regarding risk of late failure.[28,39,41,744] Regular prophylactic follow up imaging incurs a significant cost, which has implications for the lifetime cost of EVAR and health economic evaluations. Therefore, further patient stratification and reduction of unnecessary EVAR follow up imaging is desirable.

6.4.5.1. Early post-operative follow up. Early post-operative clinical and imaging follow up after EVAR is required to assess the success of the intervention. The aim of the first follow up examination is to clinically assess patient recovery, access related complications, and reliable aneurysm exclusion. An early CTA in addition to clinical examination covers these aspects. DUS examination can verify the absence of endoleaks and assess limb patency and flow. As DUS does not assess stent graft overlap, seal length, and kink, it may need to be augmented by CT without contrast. With further development, intra-operative angiography combined with cone beam CT for completion assessment could possibly replace the post-operative CTA[694] but further investigations are required.

6.4.5.2. Patient stratification during follow up. After the first post-operative examination, a stratification of patients based on risk of late complications would reduce the overall burden of EVAR follow up. Presence of endoleak at early follow up is an important indicator of possible late complications or need for re-intervention.[730] Although the significance of Type II endoleak is questioned, it is known that persistent Type II endoleak may result in sac expansion and loss of adequate seal.[507] Therefore, it is reasonable that patients with Type II endoleak on first post-operative CT are followed, focusing on assessment of sac size with duplex scans. An increase in sac size of $\geq$1 cm should prompt further imaging with CTA and re-intervention when appropriate.

Risk of EVAR failure is also significantly associated with the adequacy of the stent graft in relation to the patient's anatomy. Patients undergoing EVAR outside the manufacturer's IFU have an increased risk of late failure, presumably because of lack of adequate seal (Schanzer Circulation 2011).[606] The long-term success of EVAR relies on an adequate seal of the stent graft against the normal arterial wall above and below the aneurysm. Therefore, the above findings indicate the importance of an adequate seal in the long-term success of EVAR. The prognostic value of the first post-operative CT scan and assessment of adequate seal ($\geq$10 mm proximally and distally) in predicting late EVAR outcome has been established in several studies.[28,41,538]

Sac shrinkage during follow up indicates successful exclusion of the aneurysm from arterial pressure, and has been shown to be a predictor of low risk of EVAR failure during the first five post-operative years.[39,280] Sac shrinkage is more likely to occur in patients with favourable aneurysm anatomy and adequate seal, as well as in those without endoleaks.[280]

6.4.5.3. EVAR follow up algorithm. Based on the above literature, a modern follow up algorithm after EVAR would include early post-operative imaging aiming to identify presence of endoleak, and assess the stent graft seal against arterial wall. Patient stratification into three groups would thereafter be possible based on this initial imaging (Fig. 6.1):

- The low risk group (no endoleak, anatomy within IFU, adequate overlap and seal of $\geq$10 mm proximal and distal stent graft apposition to arterial wall) could be considered for limited follow up, with delayed imaging until five years after repair.

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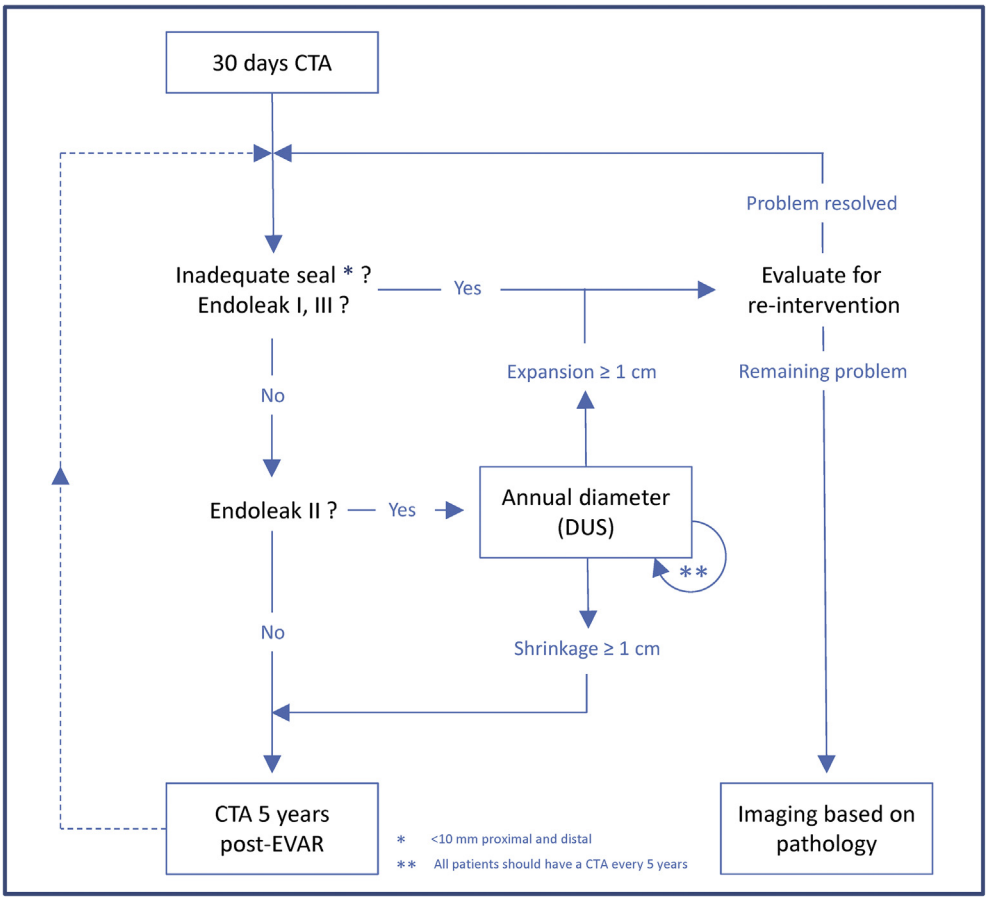

Figure 6.1. This figure offers an example of follow up algorithm post-endovascular aneurysm repair with patient stratification based on initial imaging. All patients should be offered lifelong follow up, including a CT scan at least every 5 years. If necessary more frequent imaging may be performed with CT or duplex ultrasound, and will depend on the aim of the imaging (evaluation of seal length and stent graft integrity requires CT, evaluation of endoleak and sac size can be performed with duplex ultrasound). US = ultrasound; 30 d = within 30 days postoperatively.

- The intermediate risk group (adequate overlap and seal, but presence of Type II endoleak). This group of patients would require follow up examination to assess for expansion or shrinkage. Patients with sac shrinkage $\geq$1 cm in the presence of a Type II endoleak can be regarded as low risk of failure, with limited follow up according to the low risk group.
- The high risk group (presence of Type I or III endoleak, inadequate overlap or seal $<$ 10 mm). In these patients, need for re-intervention should be assessed based on the findings, and is recommended for Type I or III endoleak or kinking. For patients with inadequate overlap or seal $<$10 mm, who do not show any signs of endoleak, repeat imaging is recommended, primarily with CTA to accurately assess overlap, seal, endoleaks and expansion during follow up.

The clinical success of EVAR beyond five years after repair is less studied, as most current reports focus on 5 year results.[39,41,69,606] There are indications of risk of increased rate of late ruptures after EVAR,[541] possibly due to disease progression. Therefore, repeat aortic imaging is recommended in all patients post EVAR five years after initial repair, as per Recommendation 85.

This EVAR follow up scheme is indicated for standard EVAR devices. Complex EVAR procedures, such as fenestrated/branched EVAR, patients treated with chimney grafts, or new EVAR device systems based on non-standard technology, require individualised follow up based on device, repair, and perceived risk of late failure.

Recommendation 91	Class	Level	References
Early (within 30 days) post-operative follow up after endovascular aortic repair including imaging of the stent graft to assess presence of endoleak, component overlap and sealing zone length is recommended.	I	B	[39,41,95,328]

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Recommendation 92	Class	Level	References
Patients considered at low risk of endovascular aortic repair failure after their first post-operative CTA, may be considered for stratification to less frequent imaging follow ups.	IIb	C	[28,39,41, 538,606]

Chapter 7

7. MANAGEMENT OF JUXTARENAL AAA

7.1. Definition and epidemiology

There is no general agreement on how to define aneurysms with short necks and/or involving the visceral arteries.[115,205,567] For the purpose of these guidelines the GWC propose the following definition:

> Juxtarenal AAA (JRAAA) is defined as an aneurysm extending up to but not involving the renal arteries, necessitating suprarenal aortic clamping for OSR, i.e. a *short neck* (<10 mm).[135,205] Another name sometimes used is pararenal AAA.[115,304]

Suprarenal AAA (SRAAA) is defined as an aneurysm that extends up to the superior mesenteric artery, involving one or both renal arteries to be repaired, i.e. *no neck*. Another name sometimes used is paravisceral AAA, usually when the splanchnic arteries are involved. The distinction between a SRAAA and a Crawford type IV thoraco-abdominal aortic aneurysm (TAAA) is not clearly defined.[135,205]

This chapter predominantly deals with JRAAA. For advice on SRAAA/type IV TAAA the ESVS guidelines on the Management of descending thoracic aorta disease should be consulted.[579]

There are no data available from the literature on rupture risk and natural history of patients with a JRAAA. In most case series patients were treated by open or endovascular repair when the mean or median diameter of the aneurysm was 6 cm. The peri-operative mortality after both open and endovascular repair is reported to be around 4%.[88,568] Based on the RCTs on AAA repair a threshold for repair of 5.5 cm may also be considered for JRAAA. However, because of the lack of evidence for this specific subgroup and the fact that patients with JRAAA may be at higher surgical risk, an individualised approach regarding threshold for repair is appropriate. This is reflected in the recommendation that states that in patients with acceptable surgical risk, a minimum threshold of 5.5 cm for elective repair for JRAAA may be considered (Class IIb), whereas in practice a larger threshold may be more appropriate in patients with increased comorbidities.

Most JRAAA will be asymptomatic and detected incidentally during imaging for other reasons. Patients with small aneurysms will be kept under surveillance according to the protocol for infrarenal AAA, with the modification that CTA is often preferable since the perirenal area is not always well imaged using US.

For accurate pre-operative planning CTA with 1 mm slices is recommended, allowing for 3D reconstructions, accurate measurement of distances to, and angles of target vessels etc.

7.2. Preservation of renal function and circulation

Since the aneurysm is close to or involves the renal arteries, and patients often have renal dysfunction, measures for preservation of renal function are of great importance. Several adjunctive methods have been reported, such as reducing suprarenal clamp time in open surgery, medication, and cold renal perfusion.

A Cochrane review found no evidence from RCTs for the efficacy of dopamine and its analogues, diuretics, calcium channel blockers, angiotensin converting enzyme inhibitors, *N*-acetyl cysteine, atrial natriuretic peptide, sodium bicarbonate, antioxidants, and erythropoietin to preserve renal function in patients undergoing surgery.[786]

Of note, there are no data from randomised studies to assess the efficacy of measures to preserve renal function during repair of juxta- or suprarenal aneurysms. Although mannitol is frequently used in complex aneurysm surgery, there are only limited data from underpowered studies. One RCT comparing mannitol versus saline infusion in 28 patients with an infrarenal AAA did not find a clinically relevant effect of mannitol on preservation of renal function.[502] In another RCT comprising 60 patients with open infrarenal AAA repair, no difference was found in renal failure in patients allocated to fenoldopam versus dopamine and sodium nitroprusside.[521] In a pilot RCT in patients undergoing JRAAA repair, renal dysfunction occurred in three of 26 (12%) patients with pre-operative administration of prostaglandin E1 in combination with cold saline renal perfusion as opposed to nine of 24 (38%) patients without prostaglandin E1 or cold perfusion.[696] This difference may be attributed to cold renal perfusion rather than prostaglandin E1. Two slightly larger RCTs from the TAAA field investigated the effect of cold crystalloid perfusion on renal function. Some three of 74 (21%) patients who had renal perfusion with 4 °C Ringer's lactate developed renal dysfunction as opposed to 10 out of 16 (63%) who had continuous perfusion with blood ($p = 0.03$).[353] Cold renal perfusion with crystalloid was as efficacious as perfusion with cold blood. In another RCT 21 of 81 (21%) of patients with TAAA repair who had renal perfusion with 4 °C Ringer's lactate had renal dysfunction as opposed to 27 of 86 (31%) in those with perfusion with 4 °C cold blood ($p = 0.4$).[397] In a small non-controlled study in patients undergoing OSR for ruptured JRAAA, two of 10 patients with renal cooling died in contrast to eight of 11 patients without renal cooling.[777] In conclusion, there is no compelling evidence in favour of pharmacological protection of renal function, whereas cold renal perfusion may be

beneficial. Finally, keeping suprarenal clamp time as short as possible (<25 min) is crucial to reduce ischaemic damage to the kidney.[172] There are no data comparing the effect of trans-abdominal or retroperitoneal exposure on suprarenal clamp time.

In patients undergoing endovascular JRAAA repair, strategies to reduce the risk of contrast induced nephropathy (CIN) should be implemented. In addition to dose reduction of iodine contrast media, withdrawal of nephrotoxic drugs and ensuring adequate hydration may also lower the risk of CIN.[513] Intravenous hydration with 0.9% saline is the prophylactic intervention best supported by evidence, to decrease the risk of CIN[105,732]. Several other prophylactic regimens to lower the risk of CIN have been proposed, for example acetylcysteine and hydration with sodium bicarbonate instead of saline, but none has been convincingly proven to be effective.[648] A recent large RCT found no benefit of intravenous sodium bicarbonate over intravenous sodium chloride or of oral acetylcysteine over placebo for the prevention of contrast associated acute kidney injury[760,766].

7.3. Treatment

7.3.1. Open surgery. Traditionally, elective JRAAA repair is done by open surgery, via a trans-abdominal or retroperitoneal approach. Since open surgery involves suprarenal clamping, the mortality and morbidity, especially renal dysfunction, are higher than OSR of an infrarenal AAA. Transection of the left renal vein entails better exposure and creation of the proximal anastomosis on the juxtarenal aorta. Alternatively, exposure can be improved by transection of the adrenal, gonadal, and lumbar veins, which facilitates mobilising the left renal vein. There are several systematic reviews that provide a benchmark for open surgery.[309,335,568] In the most recent systematic review of 21 case series comprising 1575 patients, 30 day or in hospital mortality after open JRAAA repair was 4.1%. The mean AAA diameter at surgery was 6.1 cm; the mean age was 71 years. Fourteen per cent of the patients had post-operative renal dysfunction whereas permanent dialysis was necessary in 3% of patients.[568] Interpretation of the data is hampered because of the wide range of definitions for renal dysfunction applied in the various studies included in the review. In a contemporary series of patients included in the Vascular Study Group of New England registry, peri-operative mortality was 3.6% in 443 patients after elective OSR for a JRAAA or PRAAA, with 20% renal complications and 1% need for permanent dialysis.[150] The mean diameter at surgery was 6.2 cm, 40% of the patients had a retroperitoneal approach, and mannitol was used in 73% of the cases. The mean suprarenal clamp time was 24 min and cold renal perfusion was used in 15% of the patients.

7.3.2. Fenestrated and branched EVAR. Technical improvements and growing experience in endovascular repair have offered the possibility to extend the proximal landing zone for stent grafts by incorporating the renal and visceral arteries in the graft, allowing endovascular repair of juxta- and suprarenal aneurysms. Although the endovascular technique has today become the dominant treatment modality in many centres, not all JRAAAs are suitable for endovascular repair because of arterial anatomy. In fenestrated EVAR (fEVAR) side branches are incorporated in the stent graft by means of extending separate stent grafts through fenestrations (holes) in the fabric into the side branches that need to be spared. Visceral arteries can be incorporated by means of scallops, or extra separate grafts if needed. Branched EVAR (bEVAR) is a similar technique with extra branches woven onto the fabric of the stent graft through which an extra stent graft can be entered into the renal and/or visceral arteries. The main advantage f/bEVAR lies in the avoidance of aortic cross clamping and subsequent lower risk of renal dysfunction, less surgical trauma and faster recovery, which may be advantageous for patients at high risk of open surgery. f/bEVAR are technically challenging techniques that have been developed in specialised centres and should be done by highly specialised and experienced surgical teams.

Several systematic reviews have summarised the safety and efficacy of fEVAR.[335,337,412,568] In the review of highest quality 14 case series of fEVAR were included comprising 751 patients.[568] The 30 day or in hospital mortality was 4.1%. The prevalence of transient post-operative renal impairment was 11% whereas 2% of all patients needed permanent dialysis. The GLOBALSTAR collaborators included 318 patients treated with fEVAR between 2007 – 2010 in 14 UK centres, with an experience of >10 procedures.[88] The mean age of the patients was 74 years, the mean AAA diameter was 6.2 cm, and peri-operative mortality was 4.1%. Freedom from secondary interventions was 90%, 86%, and 70%, at one, two, and three years post-operatively, respectively.

The risk of peri-operative mortality and morbidity seems to increase with the need for more proximal extension of the landing zone. Patel et al. found a difference in peri-operative mortality after f/bEVAR from 2% in patients with two fenestrations to 24% in patients with 4 fenestrations.[542,543] This finding was corroborated (although not statistically significant) in the GLOBALSTAR cohort with mortality rates in patients with renal fenestrations alone of 2.7%, 2.9% when including the SMA and 9.4% in patients needing four fenestrations.[88] Also, in the WINDOWS cohort, peri-operative mortality was 6.5% in patients with JRAAA, as opposed to 14.3% in those with a SRAAA or TAAA.[452] In a small series of 42 patients there was no significant difference in mortality in patients with more than two fenestrations (4.2%) versus those with renal fenestrations only (2.8%).[476] In the largest single centre series there was also no difference in mortality between patients with more than two fenestrations (1/185, 0.5%) versus one of 199 (0.5%) in patients with renal fenestrations only.[336]

7.3.3. Parallel grafts. While some graft types have developed systems for fEVAR or bEVAR, others have explored and developed other ways to extend the (infrarenal) aortic neck

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by means of parallel grafts in a chimney or snorkel configuration (chEVAR). This technique has the advantage that it does not use custom made devices that may take time to be manufactured, whereas a disadvantage might be the formation of gutters and subsequent endoleaks.[167] The interpretation of research is hampered by the high risk of bias in many studies regarding patient selection, definition, and ascertainment of patency and completeness of follow up,[404] and long-term outcome data are scarce.

Most of the data has been collected in the PERICLES registry in which some 95% of the 517 patients had a JRAAA.[166] The reported 30 day mortality for elective cases was 18 of 488 (3.7%). The incidence of transient renal failure was 28%, whereas 3% of the patients needed permanent dialysis. Fifteen patients (2.9%) had a persistent endoleak, for a technical success of 97.1%. The overall survival was 79% after a mean follow up of 17 months. Chimney graft patency in patients who had imaging after a mean of 17 months follow up was 94% and was estimated to be 89% and 87% after two and three years, respectively. Mean aneurysm sac regression was 4.4 mm, while no data were given on the proportion of patients with a growing aneurysm. The recommended new sealing zone after chimney graft placement was 2 cm and the best results were achieved if a maximum of two chimneys were placed. In a systematic literature review of JRAAA repair the incidence of post-operative Type Ia endoleaks was 7.6% after chEVAR, compared with 3.7% after fEVAR[784]

The best results with parallel grafts are obtained in properly selected patients with a proximal landing zone of $\geq$15 mm, proper stent graft oversizing of 30%, and if the use of chimneys can be restricted to a maximum of two.[474,784] In a further analysis of the PERICLES cohort the hazard ratio of chimney graft occlusion increased by 1.8 (95% CI 1.2—2.9) for each additional chimney graft. The risk of chimney graft occlusion and Type Ia endoleak was similar for all combinations of balloon expandable covered stents and endografts.[602]

7.3.4. Novel and adjunctive techniques. In a series of 28 patients with a juxta- or suprarenal aneurysm, the feasibility and safety of parallel grafts in conjunction with EVAS to extend the proximal landing zone was demonstrated.[142] One patient died and there was one Type I endoleak and one Type II endoleak. Since median follow up was limited to 123 days, no conclusions can be drawn on the durability of this technique in treating JRAAA. The ASCEND registry included 154 patients operated in eight centres who had EVAS combined with 1—4 parallel grafts.[688] The median follow up was three months (range 0.1—27.5 months, mean 5.6 months). Estimated freedom from re-intervention at one year was 89%, but follow up is again too short to draw meaningful conclusions. There are few studies on EVAS conducted completely independent from the manufacturer.

Endostaples have been developed to provide a better alignment of stent grafts if proximal sealing after EVAR is expected to be insufficient because of a short or angulated neck. Use of endostaples may thus extend the indication for EVAR, without the need for fenestrations or parallel grafts. In a multicentre registry of 208 cases of primary prophylactic use of endostaples, technical failure (3/57, 5.3%) and Type I endoleaks (2/45, 4.4%) were more prevalent in patients with an aortic neck $<$ 10 mm as opposed to necks $>$ 10 mm: one of 95 (1.1%) and one of 73 (1.4%), respectively.[313] After a mean follow up of 14 months in 130 patients, the prevalence of Type Ia endoleaks was 1.5% ($n = 2$). A limitation of this study is incomplete follow up, and the absence of a control group. The literature on endostaples is mainly limited to company sponsored reports. Until further data on durability are available the use of standard EVAR with endostaples as primary treatment of JRAAA repair should be limited to studies approved by research ethics committees with informed consent from the patients.[460]

Laser generated in situ fenestration of standard stent grafts is an off label technique mainly aimed at emergency treatment. The technology is still in its infancy, with only limited clinical data from technical and case reports. Long-term data remain scarce and the technique is not recommended outside investigational studies.[224]

7.3.5. Comparison of outcomes. It is important to realise that, in published reports, patients were treated in highly specialised centres with ample experience in open or endovascular surgery (or both) and that the outcomes may not be generalisable. In addition, outcomes are influenced by case selection, technical experience in the centre and follow up protocols. Finally, the lack of independent long-term follow up data makes it difficult to evaluate the durability of all complex endovascular techniques.

There are no direct comparisons of the outcomes of OSR, fEVAR, and chEVAR, and it is unlikely that a randomised comparative study will ever be performed. Meta-analyses attempting to compare outcomes from case series are flawed since the choice for a specific surgical approach is multifactorial, and there is no methodological or statistical technique that can correct for confounding by indication. Propensity matched analysis is an established technique to correct for differences in available confounding variables. In a recent analysis of the American College of Surgeons National Surgical Quality Improvement Program database, mortality after fEVAR and chEVAR for JRAAA and PRAAA ($n = 263$) was 2.7% and not significantly different from the 5.7% after open surgery ($n = 263$): odds ratio 0.45 (95% CI, 0.18—1.13). Significantly fewer patients had peri-operative morbidity after endovascular surgery (16% vs. 35%), mostly driven by heart failure and renal insufficiency.[524] These findings are in contrast with a study that matched 42 fEVAR to 147 open surgery patients (where fEVAR was limited to high risk patients), in which mortality was significantly higher after fEVAR, 9.5% versus 2.0%.[570] Morbidity was also higher, 41% versus 23%.

In conclusion, decision making is complex and should be tailored to each individual patient and local health economies. Stratification of cases by anatomy and surgical risk may be useful in patients with JRAAA. OSR with an anastomosis below the renal arteries with a short renal clamping time may be a preferable and durable option for fit patients with a short aortic neck. With more complex anatomy or

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high surgical risk because of comorbidities an endovascular solution may be preferable.

7.3.6. Patient perspective and quality of life. None of the studies on the treatment of JRAAA have focused on the patient's perspective or quality of life. Current decision making can only be based on the outcomes of patients treated in centres of expertise, which are biased by patient selection, above average performance by very experienced operators and reports of low scientific value in heterogeneous populations and indications for a certain technique. In addition, although survival, target vessel patency, renal function, and re-interventions are well reported, there are no data on the impact on quality of life for a single technique, let alone a comparison of different techniques, including OSR. This limitation should be overcome because patients should be informed about the advantages and disadvantages of the various treatment options, as well as the consequences of conservative treatment

7.3.7. Logistic and economic considerations. In the only cost effectiveness analysis published to date on data from the WINDOWS registry, costs were €38,212 for f/bEVAR as compared to €16,497 for open surgery.[477] After two years follow up from the same study there were no differences in mortality between the endovascular and OSR groups (11.2% vs. 11.4%).[478] The total hospital costs were €41,786 for f/bEVAR versus €21,142 for OSR.

In a cost effectiveness analysis commissioned by the National Health Service in the UK no evidence for the superiority of open surgery or complex endovascular repair for juxtarenal or thoraco-abdominal aneurysms could be established.[16] In addition, as it was difficult to estimate costs because of the rapidly evolving endovascular technology a cost effectiveness analysis was not deemed possible. They proposed a RCT to estimate the effect of f/bEVAR compared with open surgery or conservative management.

Given the rarity and complexity of JRAAA treatment centralisation to specialised high volume centres that can offer both open and endovascular repair seems justified.

7.4. Ruptured JRAAA

One important limitation of the EVAR technology is in ruptured JRAAA, cases that are traditionally treated by OSR. Nevertheless, more complex rAAAs with short or no neck, not suitable for standard EVAR, could still be treated by endovascular means using adjunctive procedures, such as the parallel (chimney, periscope, sandwich) stent grafts. A study assessing rAAA cases documented that approximately 30% of rAAA were suitable for endovascular repair, that chimney grafts in one or both renal arteries could increase overall suitability by 12%, further increasing to 60% when iliac access issues could be overcome.[158] In a combined series from two centres, the authors practically eliminated open rAAA surgery by using adjunctive endovascular procedures in 17 of 70 patients (24%). These were chimney in three, open iliac debranching in one, coiling in eight, onyx in three, and chimney plus onyx in two.[454]

Other adjuncts or novel therapeutic tools that could potentially expand the endovascular options to include rAAA cases with inadequate proximal neck include an off the shelf fenestrated device,[362] back table modification of standard stent grafts to create scallops and fenestrations[603,605,650] the use of endostaples to secure proximal fixation,[313] or the use of in situ laser fenestration.[224]

Finally, since EVAS has already been used for infrarenal rAAA,[574] it could also be an option for JRAAAs when used in conjunction with chimney stent grafts.[142] The results of this new technology in the ruptured JRAAA setting are awaited.

7.5. Follow up after JRAAA repair

Since endovascular repair of complex aneurysms is an evolving technique, it is imperative that follow up of patients is robust. All patients should be included in a thorough follow up programme including annual CTA to collect information on the durability of endovascular repair. The focus of most research has been on the patency of branches, and survival. Surprisingly few data are available on the post-operative anticoagulation regimen and the association with branch or parallel graft patency. No studies have addressed long-term follow up after OSR for JRAAA, but it may be regarded as self evident that these patients should be followed at least as frequently as patients operated on by OSR for infrarenal AAAs.

Although all patients with AAA should receive antiplatelet therapy, many large studies on complex endovascular repair did not specify their post-operative anticoagulation regimen,[79,88,165,336] whereas others used aspirin[452] or dual antiplatelet therapy.[142]

Recommendation 93	Class	Level	References
In patients with juxtarenal abdominal aortic aneurysm and acceptable surgical risk, the minimum threshold for elective repair may be considered to be 5.5 cm diameter.	IIb	C	[204]

Recommendation 94	Class	Level	References
Centralisation to specialised high volume centres that can offer both complex open and complex endovascular repair for treatment of juxtarenal abdominal aortic aneurysm is recommended.	I	C	[162,278]

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Recommendation 95	Class	Level	References
In patients with juxtarenal abdominal aortic aneurysm, open repair or complex endovascular repair should be considered based on patient status, anatomy, local routines, team experience, and patient preference.	IIa	C	[524,570]

Recommendation 96	Class	Level	References
In complex endovascular repair of juxtarenal abdominal aortic aneurysm, endovascular repair with fenestrated stent grafts should be considered the preferred treatment option when feasible.	IIa	C	[568]

Recommendation 97	Class	Level	References
In complex endovascular repair for juxtarenal abdominal aortic aneurysm, using parallel graft techniques may be considered as an alternative in the emergency setting or when fenestrated stent grafts are not indicated or available, or as a bailout, ideally restricted to $\leq$2 chimneys.	IIb	C	[165]

Recommendation 98	Class	Level	References
In patients with juxtarenal abdominal aortic aneurysm, new techniques/concepts, including endovascular aneurysm seal, endostaples, and in situ laser fenestration, are not recommended as first line treatment, but should be limited to studies approved by research ethics committees, until adequately evaluated.	III	C	[142,224,313, 460,687]

Recommendation 99	Class	Level	References
In patients with ruptured juxta/pararenal abdominal aortic aneurysm open repair or complex endovascular repair (with a physician modified fenestrated stent graft, off the shelf branched stent graft, or parallel graft) may be considered based on patient status, anatomy, local routines, team experience, and patient preference.	IIb	C	[362,574,605]

Recommendation 100	Class	Level	References
In patients undergoing open repair of juxtarenal abdominal aortic aneurysm a strategy to preserve renal function by means of cold crystalloid renal perfusion may be considered.	IIb	C	[105,777]

Recommendation 101	Class	Level	References
In patients treated for juxtarenal abdominal aortic aneurysm by endovascular repair, a thorough long-term follow up programme including annual computed tomography angiography is recommended.	I	C	[165]

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Chapter 8

8. MANAGEMENT OF ILIAC ARTERY ANEURYSM

8.1. Definition

The most accepted definition of iliac artery aneurysm (IAA) is dilatation of the vessel to more than 1.5 times its normal diameter.[304] In general, a common iliac artery (CIA) $\geq$ 18 mm in men and $\geq$15 mm in women, and an internal iliac artery (IIA) $\geq$ 8 mm is considered aneurysmal.[304,373] IAAs are commonly associated with aneurysmal dilatation of the abdominal aorta as aorto-iliac aneurysms in about 10% of AAA.[363,582] Isolated IAA is an aneurysm of the iliac arteries without an aneurysm of the infrarenal abdominal aorta. This definition includes aneurysms of the CIA, the IIA, the EIA, and combinations of those. Aneurysms of the EIA, which has a different embryological origin, are rare.

Several classifications for isolated IAA have been proposed.[195,573,598] Reber's anatomical classification into type I — IV appears well suited to compare outcomes of different anatomical entities (Fig. 8.1), while Fahrni's classification depends on neck suitability for endovascular repair, which may change with time, device, and operating technique.

8.2. Natural history and threshold for repair

The reported growth rate of IAA is similar to AAA, about 1—4 mm/year depending on aneurysm diameter.[459,599] The incidence of rupture and its association with size and growth rate of the isolated IAA is not as well established as in AAA, with only case series available.

Most reported ruptured IAAs in the literature are larger than 5 cm, and rarely below 4 cm.[113,208,283,334,363,373]

As solid data are lacking, the patients' operative risk as well as suitability for open and/or endovascular repair should be considered to determine the individual threshold for repair. However, conservative treatment appears safe in most patients with a maximum diameter below 3.5 cm.[334] A recent retrospective multicentre study on the diameter of ruptured IAA aneurysms recommended surveillance of IAA aneurysms in elderly men until a diameter of 4 cm.[373] There are no available data on medical therapies in terms of blood pressure control or treatment with platelet inhibitors, beta blockers, or statins in patients with isolated IAA. Conservative management should therefore be according to recommendations for AAA (see Chapter 3.1).

Recommendation 102	Class	Level	References
The threshold for elective repair of isolated iliac artery aneurysm (common iliac artery, internal iliac artery and external iliac artery, or combination thereof) may be considered at a minimum of 3.5 cm diameter.	IIb	C	[113,208,283, 334,363,373]

The underlying pathology and type of isolated IAA is similar to AAA and includes degenerative aneurysm, pseudoaneurysm, penetrating ulcer, post-dissection aneurysm, mycotic aneurysm, and traumatic aneurysm.[24]

Isolated IAAs are most frequently confined to the CIA (Reber I) and least frequent in the EIA (Reber IV).[113,363,540] Their overall frequency is reported in up to 7% of all aorto-iliac aneurysms and 12—48% of all isolated IAA are bilateral.[80,363,540] The majority of patients with isolated IAA are male (90%) and diagnosed in the seventh and eighth decade.[80,113,121]

8.3. Clinical presentation and imaging

While most individuals with isolated IAA are asymptomatic, symptoms can result from local compression of the ureter, sacral plexus, or iliac vein.[598]

Physical examination and DUS are less reliable and may frequently overlook IAA, while CTA is highly accurate in detecting IAA.[598] With the increased use of cross sectional imaging, IAAs are increasingly detected at an asymptomatic stage.

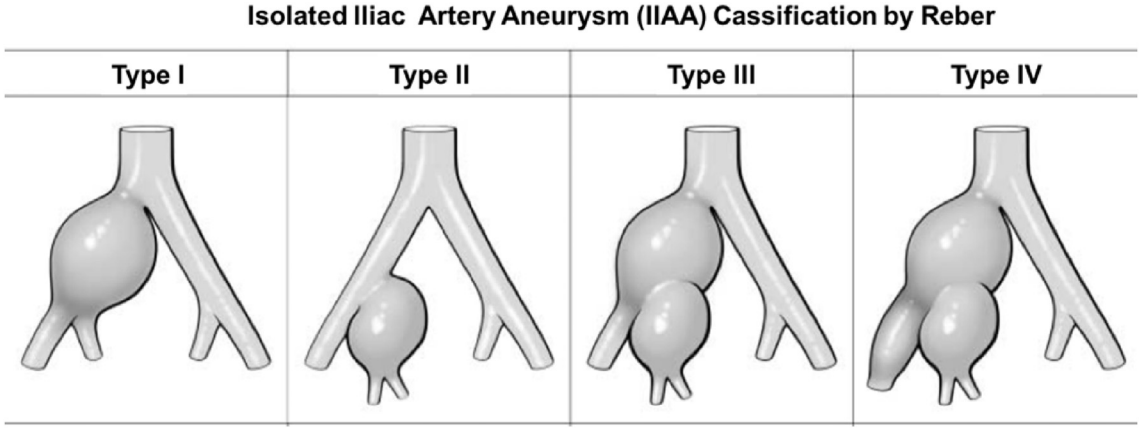

Figure 8.1. Isolated iliac aneurysm classification by Reber. Permission to reproduce granted from Springer *Nature*.

There are no data regarding follow up intervals for small isolated IIAs. Suggested surveillance intervals extrapolated from AAA surveillance may be every three years for IIAs IAAs with diameter 2.0—2.9 cm and annually for 3.0—3.4 cm. Surveillance of a known IAA can preferably be done by means of DUS, and CTA in case of visualisation problems.

8.4. Surgical treatment

The aim of surgical treatment of IAAs is to exclude the aneurysm from the circulation to prevent further growth and rupture. Before the advent of endovascular repair in the early 1990s OSR was the mainstay of treatment of IAA. The steady shift towards endovascular techniques since 2000 was associated with a significant decrease in operative morbidity and mortality[98] and with fewer complications and a shorter length of hospital stay.[113,540] While this trend was initially partly explained by differences in case mix, with a higher number of emergency cases in the OSR group, recent experience indicates significant advantages for endovascular repair in both the elective and the emergency setting.[98,540,554] However, as pathology, anatomy, disease extent, and patient fitness differ widely between individual patients, both techniques should be available in centres managing patients with IAA.

Endovascular techniques have further evolved in recent years from routine embolisation of the IIA in most cases to side branch techniques preserving IIA patency.[285] Results of the iliac side branch technique have not been specifically reported for isolated IAA, but results from aortoiliac aneurysms indicate a high technical success rate and high mid-term patency of the target vessel.[355,631] In a retrospective Danish analysis including 112 patients treated for aorto-iliac aneurysms by endovascular means, gluteal claudication developed in 38% after IIA exclusion compared with none after treatment with iliac side branch stent grafts.[677] Iliac side branch endografts have received approval (CE-mark, Conformité Européenne) in the European Union for use in aorto-iliac aneurysm and isolated IAA. The most common anatomical factor limiting the use of iliac side branched stent graft is an aneurysmal IIA.[234]

Other, less well studied, alternative techniques of endovascular repair to preserve IIA perfusion in IAA have been proposed, such as the bell bottom technique, the sandwich technique and hybrid repair including femoral crossover bypass.[53]

Especially in ruptured isolated IAA the possibility to operate under local anaesthesia appears to be a significant advantage of endovascular repair. The necessity to convert to OSR is reported to be uncommon.[167,208]

Recommendation 103	Class	Level	References
In patients with iliac artery aneurysm endovascular repair may be considered as first line therapy.	IIb	B	[98,113,285,355]

8.4.1. Open surgical repair. OSR is usually performed under general anaesthesia, using retroperitoneal or transabdominal access. Depending on the extent of the aneurysmal disease the reconstruction is done by iliac tube graft repair or by bifurcated graft repair including the infrarenal aorta, with or without revascularisation of the IIA. A less invasive technique in selected cases is ligation of the iliac artery with reperfusion of the contralateral femoral artery and/or IIA by a crossover bypass.[276] The necessity of ligating the IIA during OSR for IAA has been inconsistently reported.

Owing to the deep pelvic location, OSR of IAA can be technically challenging with an increased risk of iatrogenic injuries of veins, ureter, or nerve, resulting in peri-operative blood loss, morbidity, and mortality.[113]

8.4.2. Endovascular repair. Endovascular treatment of IAA originally involved embolisation of the IIA and stent graft coverage extending from the CIA to the EIA. Involving the infrarenal aorta and the contralateral iliac artery into the repair is sometimes necessary to obtain a proper proximal seal.[113,121,598] Consequently, occlusion of lumbar arteries and the inferior mesenteric artery is more frequently associated with endovascular repair and should be considered. In contrast, OSR of isolated IAAs may allow leaving the infrarenal aorta and contralateral iliac arteries untouched.

8.4.3. Preservation of pelvic circulation. Interruption of IIA perfusion is normally well compensated for by collateral artery perfusion via pathways from the contralateral IIA, mesenteric, and femoral arteries. If not, it may lead to symptoms such as buttock claudication, colonic ischaemia, pelvic necrosis, or erectile dysfunction.[302] Buttock claudication is the most frequent complication of endovascular treatment of IAA, with a reported frequency of up to 28%.[79,80,113,355,540] The likelihood and severity of these complications are more frequent with bilateral IIA occlusion,[79,355] but cannot easily be predicted. Therefore, preservation of blood flow to at least one IIA is recommended, if it does not compromise the primary treatment goal of aneurysm exclusion.

The availability of iliac side branch stent grafts now allows preservation of IIA flow in most cases, leading to a reduced incidence of buttock claudication in the treatment of aorto-iliac AAA and IAA involving the IIA.[355,677] Even in cases of IIA aneurysms without a proper landing zone within the main stem of the IIA, iliac side branch devices have successfully been used outside their IFU, landing distally in the gluteal arteries to preserve IIA flow to one of its major gluteal branches.[19,506]

Whenever embolisation of the IIA is necessary to exclude an IAA, the embolising material should preferably be placed in the proximal portion of the IIA to maintain

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communication between its anterior and posterior divisions.[79,302] Distal embolisation increases the risk of buttock claudication.[79,302] In case of bilateral IIA occlusion it has become common practice in many centres to stage the treatment to allow collateral development.

In cases with extensive aortic coverage by stent grafts, with occlusion of segmental arteries, preservation of IIA flow plays an important role in the prevention of spinal cord ischaemia as this territory contributes to flow into the collateral network of the spinal cord.[178]

Recommendation 104	Class	Level	References
Preserving blood flow to at least one internal iliac artery during open surgical and endovascular repair of iliac artery aneurysms is recommended.	I	B	[302]

Recommendation 105	Class	Level	References
In patients where internal iliac artery embolisation or ligation is necessary, occlusion of the proximal main stem of the vessel is recommended if technically feasible, to preserve distal collateral circulation to the pelvis.	I	C	[302]

8.5. Follow up after IAA repair

To date no studies have specifically addressed follow up after IAA repair, which depends on the type of repair as well as the presence of other concomitant aneurysmal and other disease. For this reason, follow up should be done according to the recommendations for AAA (see Chapter 6).

Chapter 9

9. MISCELLANEOUS AORTIC PROBLEMS

9.1. Mycotic AAA

Mycotic or primary infected aortic aneurysms (MAAs) are caused by septic emboli to the vasa vasorum, by haematogenous spread during bacteraemia or by direct extension of an adjacent infection leading to an infectious degeneration of the arterial wall and aneurysm formation. The term "mycotic" was coined by Osler in 1885 because of their mushroom like appearance, which is misleading because most MAA are caused by common microorganisms including Gram positive, mostly staphylococcal and enterococcus species as well as *Streptococcus pneumoniae* and *Clostridium* species. Among Gram negative bacilli, *Salmonella* species are mostly involved but *Coxiella burnetti*, mycobacterium, and fungi may also be identified.

The incidence of MAA is up to 1.3% of all aortic aneurysms in Western countries and reportedly higher in East Asia.[281,645] Most patients are male and tend to be younger (mean age 69–70 years) than those with a degenerative non-infected aneurysm (74–78 years).[424,597,644]

There is no clear consensus on how to define a MAA.[643] In most recent publications the diagnosis of MAA is based on a combination of (1) clinical presentation, (2) laboratory tests, and (3) CT findings (Table 9.1). In addition, a typical medical history is often seen, with the presence of concomitant infections (e.g. osteomyelitis, urinary, tuberculosis, gastroenteritis, and soft tissue) and immunosuppressive disease or medications (e.g. cancer, renal failure with dialysis, human immunodeficiency virus (HIV), diabetes, or steroid treatment).[151,421,424,617,644,645,771]

The source of infection is not identified in one third of the patients nor is the causative organism in 21–40%.[96,308,317] Empirical antibiotic treatment against *Staphylococcus aureus* and Gram negative rods, such as *Salmonella* should be initiated as soon as cultures have been secured, and continued in cases with negative blood and tissue cultures. Clinical results of antibiotic therapy alone or surgery alone remain poor.[417,642,282]

9.1.1. Open surgical repair. Early diagnosis, immediate administration of systemic antibiotics, and timely surgical treatment is crucial to improve early outcomes. Despite lack of evidence, OSR is regarded as the gold standard for definitive treatment of MAA. OSR includes resection of the aneurysm, extensive local debridement, and revascularisation by extra-anatomical bypass or in situ reconstruction. Options for in situ conduits include preferably autologous vein (femoral or long saphenous vein – neo-aorto-iliac system), cryopreserved arteries, bovine pericardium, or if unavailable prosthetic grafts (PTFE, Dacron or antibiotic soaked Dacron grafts) based on surgeon's preference.[173,266,494,761] Operative cultures should be obtained, extensive debridement should occur, and the infectious

Table 9.1. Suggested diagnostic criteria of mycotic aortic aneurysm.[645]

Combination of the following factors:	
1. Clinical presentation	Abdominal/back pain Fever Sepsis/shock
2. Laboratory and culture	C-reactive protein ↑ Leucocytes ↑ Positive blood culture or aortic tissue culture
3. Radiologic findings on CT	Saccular/multi-lobular/eccentric Peri-aortic gas/soft tissue mass Rapid expansion (days) and/or rupture Atypical location (e.g. para-visceral) or multiple aneurysms in different locations

process should be separated from the graft with omentum. Mortality rates up to 5—49% after in situ grafting versus 24—50% after extra-anatomical bypass have been reported.[173,254,394,494,783] Infection related complications may occur in 0—20% after in situ grafts and older data suggest an equally high complication rate after extra-anatomical bypass, with the most feared being late aortic stump rupture in up to 20%.[25] No reliable comparative data exist between the various open surgical techniques. Finally, the anatomical location of the aneurysm sometimes makes OSR very demanding in SRAAA.

9.1.2. Endovascular repair. In the last 15 years MAAs have been increasingly treated successfully by endovascular means. EVAR has been regarded with scepticism because of major concerns about leaving the infected tissue in place, including the aneurysm itself, and the risk of recurrent/persistent infection. On the other hand, EVAR is a less invasive alternative than conventional OSR of MAA, enabling treatment of fragile and comorbid patients with challenging aneurysm anatomy and avoidance of major surgical trauma (aortic cross clamping, heparinisation, and massive blood transfusion). In emergency situations EVAR may be a bridge to later definitive surgery and for those unfit for OSR be a permanent or palliative treatment.[317] A recent large European multicentre study including 123 patients with 130 MAAs (38% rupture and 52% suprarenal/thoracic) showed that EVAR may offer a durable treatment (55% five year survival) if associated with long-term antibiotic therapy (6—12 months or possibly lifelong)[645] but additional open and percutaneous procedures may be necessary to remove secondary lesions.[617,644] Late infection related complications do occur especially within the first year and are often lethal (European study 19% of total cohort), especially in patients with non-*Salmonella* positive blood cultures (41% five year survival), with immunodeficiency (40% five year survival), with peri-aortic/intrathrombus gas on pre-operative CT scan (36% five year survival)[645,282] or with fever or rupture at the time of the operation.[317,644]

A recent Swedish nationwide comparative study of OSR and EVAR for MAA, including 132 patients with 144 abdominal MAAs, showed a significant early survival benefit for EVAR (up till 4 years) with no late disadvantages in terms of rates of late infection or aneurysm related complications or survival,[644] suggesting that endovascular repair is an acceptable alternative to OSR.

The antibiotic regimen should be formulated on a case by case basis in close collaboration with the microbiology and infection specialists based on clinical, laboratory parameters, and imaging studies. Surveillance and duration of antibiotic therapy (ranging from 4 — 6 weeks to lifelong) are influenced by the identified organism, type of surgical repair, and immunological status of the patient. Some endovascular therapy review articles propose favourable outcomes with delayed surgery when antibiotics are being administered until clinical manifestations of the infection are controlled in haemodynamically stable patients. The point is to eradicate bacteria from the aorta and bloodstream before deploying a foreign body stent graft.[317,318] However, there is likely to be selection bias in those reports and the high growth and rupture rate observed for MAA makes deferred surgery risky unless rigorous surveillance is in place. Rupture and suprarenal aneurysm location are significant risk factors for death within five years.[644]

In summary, MAA is a rare and life threatening disease. Early detection and treatment with antibiotics followed by surgical repair is central to their management. The largest and most recent studies with long-term follow up suggest that EVAR may have a short-term benefit over OR, with no late disadvantages. However, because of the rarity of MAA strong evidence is lacking, which makes firm recommendations difficult.

Recommendation 106	Class	Level	References
It is recommended that the diagnosis of a mycotic aortic aneurysm is based on a combination of clinical, laboratory, and imaging parameters.	I	C	[151,424,644]

Recommendation 107	Class	Level	References
Treatment of patients with a suspected mycotic aortic aneurysm with intravenous antibiotics is recommended; empirical antibiotic treatment against *Staphylococcus aureus* and Gram negative rods should be initiated as soon as cultures have been secured, and continued in those with negative cultures.	I	C	[317,644,282]

Recommendation 108	Class	Level	References
Mycotic aneurysm repair is recommended irrespective of aneurysm size.	I	C	[516,644]

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Recommendation 109	Class	Level	References
Surgical techniques used in mycotic aneurysm repair should be considered based on patient status, local routines, and team experience, with endovascular repair being an acceptable alternative to open repair.	IIa	C	[173,317,617, 644]

Recommendation 110	Class	Level	References
Long-term post-operative antibiotic treatment (6—12 months or lifelong) and surveillance should be considered after mycotic aneurysm repair.	IIa	C	[173,644]

9.2. Inflammatory AAA

Another aortic entity, first described by Walker et al. in 1972,[755] is inflammatory abdominal aortic aneurysm (InflAAA), representing 4—7% of all AAAs.[653,746,785] An InfAAA is defined by (1) an unusually thickened aneurysm wall, (2) shiny white peri-aneurysmal and retroperitoneal fibrosis, and (3) dense adhesions of adjacent intra-abdominal structures.

The pathogenesis of InflAAA remains unknown. Autoimmune mechanisms are likely to be important in inducing this chronic inflammatory reaction either by a local disease process based on an inflammatory reaction to components of atherosclerotic plaques or as a manifestation of a systemic disease.[111] Based on immunological studies on inflammation, a classification of InflAAAs as immunoglobulin (Ig)G4 related and IgG4 non-related has been proposed, emphasising an immunological role in the development of the disease.[333]

Most InflAAA belong to the group of chronic peri-aortitis (idiopathic peri-aneurysmal retroperitoneal fibrosis). These patients are 62—68 years old at presentation, about 5—10 years younger than patients with a degenerative AAA. The majority are males (M:F ratio (6—30):1), heavy smokers (85—90%), and may have arterial hypertension, CAD, and PAOD.

The diagnosis of InflAAA is based on a combination of clinical, laboratory, and imaging parameters including CTA.[264]

InflAAAs are associated with a higher frequency of aneurysm related symptoms (65—90%) than ordinary degenerative AAAs and have a triad of chronic pain (50—80% abdomen, back, pelvic), weight loss (20—50%), and moderately elevated inflammatory markers (ESR and CRP 60—90%). Clinical examination may reveal a tender pulsatile AAA (15—71%).[264,505,512,657]

CTA is the method of choice to detect the inflammation around the enlarged aorta with thickening of the adjacent tissues and potential entrapping of adjacent organs: duodenum and sigmoid colon (60%) or ureteral obstruction (20—44%) with hydro-uretero-nephrosis (15—30%) and left renal/caval vein involvement (18—21%).[62,291] InflAAA is mostly documented in the infrarenal aorta but chronic inflammatory processes may also be noted in the thoracic aorta, IIA (43%), femoral artery (13%)[347,311] and other medium sized vessels (mesenteric, renal arteries and veins).[712] CTA detects the typical anatomical feature "the mantle sign" a thickened wall from chronic inflammatory cells and dense peri-aneurysmal fibrosis sparing the posterior wall, with possible involvement of adjacent structures such as ureters, bowel, vessels.[58,505] Multidetector CTA, ^{18}F-FDG PET/CT, MRI, and diffusion weighted MRI have emerged as potential tools to diagnose and follow up InflAAAs.[211,316]

The differential diagnosis from MAAs is facilitated by negative bacterial blood cultures, negative skin test (tuberculosis), negative serological tests (syphilis), the localisation to the abdominal aorta, and the typical anatomical features on CTA. Biopsy may be warranted to exclude malignancy.

There is no consensus how to measure the diameter of an InflAAA, whether it should include the thickened wall or not.[291]

9.2.1. Medical management. The optimal management of patients with InflAAAs remains uncertain and it is recommended that all patients with InflAAA are managed by a multidisciplinary team with close surveillance.

Non-operative medical management with corticosteroids may be considered in symptomatic aneurysms with a diameter below the threshold for repair with severe pain and weight loss, associated with intense hydronephrosis and mantle sign suggesting peri-operative difficulties.[120] Optimal dose and duration of medical treatment are still unclear since controlled clinical trials that have evaluated the long-term efficacy of steroids in InflAAAs are lacking.

Other immunosuppressive agents (azathioprine and methotrexate) have been used as steroid sparing agents because of the side effects of steroids or in steroid refractory cases.[634,711,719,720,722]

Tamoxifen (a selective oestrogen receptor modulator) has been used in the treatment of idiopathic retroperitoneal fibrosis, based on its usefulness in pelvic desmoid tumours. In a prospective single centre study, 19 patients with non-malignant retroperitoneal fibrosis were treated with tamoxifen, 20 mg orally twice daily. After a median treatment duration of 2.5 weeks 15 of 19 patients reported substantial resolution of symptoms, improved acute phase reactants, and signs of regression on gallium and CT scanning.[718] Tamoxifen in combination with steroids has been suggested to be effective in inflAAA.[720]

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Acute phase reactants (ESR, CRP) alone are not reliable for management and follow up as they are often not concordant with metabolic assessment of the disease. A prospective trial on retroperitoneal fibrosis imaging has shown that ^{18}F-FDG PET may help to guide decisions about initiation or cessation of steroid treatment based on a maximum standard uptake value (SUV_{max}). If $SUV_{max} \geq 4$, the patients are 10 times more likely to respond to steroid therapy than those with a value < 4, but a scoring system for retroperitoneal fibrosis activity measurement is pending.[203]

9.2.2. Surgical management. The lifetime risk of rupture is low, $< 5\%$.[549] The same threshold for repair as for standard degenerative AAA is indicated. Infrequently in symptomatic refractory cases in spite of medical treatment, invasive treatment may be indicated to control the inflammatory process.[405] Double J ureteric stents may be inserted preoperatively if significant hydronephrosis is present.

OSR is complicated by the inflammatory adhesions to duodenum, left renal vein, inferior vena cava, and ureters.[405] A transperitoneal approach with limited dissection of the proximal neck, leaving the duodenum attached to the thickened peel and proximal aortic clamping distant from the thickened parts of the aneurysmal wall may reduce surgical injury to the adherent organs, and associated surgical mortality (6–11%).[405,530] After OSR of the InflAAA, peri-aneurysmal fibrosis tends to regress but this process is not necessarily related to normalisation of ESR, which occurs earlier during follow up than regression of fibrosis which may take several years.[505,512,653]

EVAR is gaining increasing popularity to exclude InflAAAs with lower 30 day mortality rates (2.4%)[530] and fewer major complications.[657] In case series, peri-aneurysmal fibrosis post EVAR in most cases remains stable or decreases at midterm follow up but long-term follow up is warranted.[62,530]

Hydronephrosis and peri-aortic fibrosis may persist and even progress despite OSR or EVAR.[530] Therefore, continued immunosuppressive therapy[711,720] and close post-operative surveillance is indicated to decrease or stabilise this peri-aortic inflammation but sometimes ureteric stents, pyelostomy, or lysis by means of open surgery may still be required.

9.3. Penetrating aortic ulcer, pseudoaneurysm, intramural haematoma, local dissection, and saccular aneurysm

Penetrating aortic ulcer (PAU), first described in 1934,[735] is defined as ulceration of an atherosclerotic plaque that penetrates through the aortic intima resulting in a variable amount of haematoma within the aortic wall. These lesions typically occur in elderly patients with systemic atherosclerosis and associated comorbidities. Based on a literature review, the estimated incidence is 1% in the vascular population, with abdominal PAU (11–24%) being less common than thoracic PAU (76–86%) but multiple lesions and associated aneurysms may be noted.[45,649] Progression of PAU may lead to intramural haematoma (IMH), pseudoaneurysm formation (dilatation of the aorta due to disruption of all wall layers, which is only contained by peri-aortic connective tissue), rupture (extra-aortic haematoma), and lower limb embolisation.[45,58] PAU are symptomatic in 18–70% causing pain (52%) or acute lower limb ischaemia because of distal embolism (12%) or rupture (4.1–6.9%).[45,216,217,499]

Isolated abdominal aortic dissections (IAAD) are rare and much less common than abdominal aortic dissection associated with thoracic aortic dissection.[699] The dissection is related to a tear in the intimal layer and subsequent blood flow through the tear into the media creating a false lumen. The entry tear generally originates below or at the level of the renal arteries (82%).[196] A concomitant AAA is present in 41% of patients with symptomatic IAAD.[699]

IMH represents blood in the aortic wall without an intimal tear or entry point on imaging[579] and rarely exists in the abdominal aorta alone.

If IAAD, IMH, or pseudoaneurysms are detected in the abdominal aorta, trauma, iatrogenic injury or PAU as an underlying cause should be excluded.[310] The most common complaint is abdominal or back/flank pain (57–62%), sometimes associated with acute lower limb ischaemia 5%.[301,699]

Saccular AAA are regarded as a separate entity defined as spherical aneurysms involving only a portion of the aortic circumference.[361] Infection should always be excluded, and if present managed accordingly (see Chapter 9.1).[644] The optimal management of non-infected saccular AAA, including when to intervene,[623] requires further research

Recommendation 111	Class	Level	References
All patients with symptomatic inflammatory abdominal aortic aneurysms should be considered for medical anti-inflammatory treatment.	IIa	C	[264,512,530, 720]

Recommendation 112	Class	Level	References
In patients with inflammatory abdominal aortic aneurysm with a threshold diameter of 5.5 cm and suitable anatomy, endovascular repair should be considered as a first option.	IIa	C	[315,530,657]

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and should currently be based on individual risk assessment. Owing to the uncertainty about a possible increased rupture risk[361,623] early treatment may be considered.

Both CT and MRI enable the diagnosis of PAU, IMH, and IAAD with a high degree of accuracy.[255] PAUs are characterised by a contrast filled crater that communicates with the aortic lumen. IMH is a crescentic area of smooth high attenuation within the aortic wall, detected on unenhanced CT. Intramural blood pools are frequently observed but are not associated with poor prognosis and should be distinguished from ulcer like projections.[58,772] Dissection presents as a linear filling defect in the aortic lumen with the true lumen often smaller than the false lumen. The cranio-caudal extent of a PAU is much shorter than an IAAD or primary IMH.

Serial imaging surveillance by cross sectional imaging (CTA or MRA) is justified since the natural course is largely unknown[216,217]. The assessment of an ulcer includes the measurement of the maximum aortic diameter at the ulcer site, the depth of the ulcer, and the length of the intimal defect (width) at the ulcer site. The growth rate in abdominal PAU is about 3 mm/year.[221]

Complicated PAU refers to a co-existing extra-aortic haematoma (pseudoaneurysm), embolisation symptoms, recurrent pain, a PAU that initially measures $>$ 20 mm in width or $>$ 10 mm in depth or progression of total abdominal aortic diameter.[216,217,221] Likewise, complicated IMH/IAAD means the presence of recurrent pain, expansion of the IMH, peri-aortic haematoma, intimal disruption, or malperfusion.

Although the natural history of these processes has not been clearly described, for every patient with PAU, IMH, or IAAD medical management should be initiated and is essentially based on of the same concept used for type B aortic dissections, with reduction of the BP, management of atherosclerotic risk factors and optimal pain control.[579] A complicated PAU/IMH/IAAD requires invasive treatment, as do IAADs which are associated with concomitant aneurysms even for lesions with a diameter $<$5 cm[301] although some have advocated a more aggressive approach if the overall aortic diameter is $>$ 3 cm.[196,356,441]

The focal nature of these pathologies renders them ideal targets for endovascular repair with stent grafts. This can be achieved with high technical success rates in complicated cases, but the procedure may be associated with high in hospital mortality (10%) because of the frailty of the population affected.[216,217,356]

Recommendation 113	Class	Level	References
In all patients with penetrating aortic ulcer, isolated abdominal aortic dissection, aortic pseudoaneurysm, or intramural haematoma, medical treatment, including blood pressure control, is recommended.	I	C	[301,499,579]

Recommendation 114	Class	Level	References
In uncomplicated penetrating aortic ulcer, dissection, or intramural haematoma of the abdominal aorta, serial imaging surveillance is recommended.	I	C	[499,579]

Recommendation 115	Class	Level	References
In patients with complicated penetrating aortic ulcer, dissection, or intramural haematoma, and in pseudoaneurysm in the abdominal aorta, repair is recommended.	I	C	[499,579]

Recommendation 116	Class	Level	References
Early treatment may be considered for saccular abdominal aortic aneurysms, with a lower threshold for elective repair than for standard fusiform abdominal aortic aneurysms.	IIb	C	[361,623]

Recommendation 117	Class	Level	References
In patients with complicated penetrating aortic ulcer, dissection, intramural haematoma, or pseudoaneurysm of the abdominal aorta, endovascular repair should be considered as a first option.	IIa	C	[45,216,217, 301,499,699]

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9.4. Concomitant malignant disease

The reported incidence of concomitant malignant diseases and AAA is 5.4–6.7%.[425,742] It represents a challenging issue in terms of treatment priority, timing, and expected outcome.

Most published papers consist of small case series. Hence, decisions should be made based on clinical judgement applied individually in a multidisciplinary setting. Being a prophylactic procedure AAA repair is only worthwhile if the lifetime risk of rupture exceeds the risk of treatment in patients with a reasonable life expectancy. The prognosis of concomitant cancer is therefore central in the decision making process together with other comorbidities (age, physiological well being) and patient preference. Other considerations are a perceived increased risk of AAA rupture following abdominal cancer surgery[46] versus a significant delay in the treatment of cancer if AAAs are treated by OSR first, and the risk of graft infection. Cytotoxic chemotherapy did not increase aneurysm growth compared with patients not undergoing treatment for malignancy in a retrospective analysis.[450] Furthermore, only six patients with AAA and concomitant cancer receiving chemotherapy in the literature needed urgent aneurysm surgery possibly due to under reporting or representing the normal biological variability observed in aneurysm disease.[450,527,666,787]

Two recently published meta-analyses[357,366] focusing on management of AAA and concomitant abdominal neoplasms, included different studies but came to the same conclusion "treat what is most threatening or symptomatic first" (large AAA, obstructing colonic cancer, bleeding gastric cancer, etc.).

Since open AAA repair prior to resection of a gastrointestinal cancer may result in a delay of months in comparison to days post EVAR,[46,357,403,425,557] the AAA should preferably be considered for EVAR if anatomically suitable followed by staged cancer surgery within 2 weeks. This would allow for a minimum delay in the treatment of both the aneurysm and the cancer, as well as a reduced risk of graft infection. A high procedure related mortality and morbidity has been observed when open AAA repair is carried out prior to gastrointestinal cancer resection, often weeks or months later, as opposed to cancer surgery first: 19% and 42% versus 9% and 26%, respectively.[403]

If both lesions are life threatening (e.g. large aneurysm with advanced obstructing malignancy) and the anatomy is not suitable for endovascular repair, a synchronous open approach may be chosen, providing very high attention to detail (patient selection, blood supply to avoid bowel necrosis, irrigation, and omental wrap to avoid infection) realising that cumulative morbidity and mortality are higher in these single stage operations.[403]

The overall survival rates post EVAR in patients treated for concomitant cancer are naturally poorer because of progression of the neoplastic disease and are influenced by type, stage, and grading of the malignancy: 50–66% at three years for colorectal cancer[425,776] and 15% at three years for lung cancer.[73] In lung cancer and pancreatic cancer, staging is crucial before considering AAA treatment because the overall survival correlates closely with the stage of these cancers.[73,741]

As with any patient with severe concomitant comorbidities and underlying chronic disease with a poor prognosis, management of rAAA in a patient with advanced cancer disease, previously deemed inappropriate for elective repair, should be discussed with the patient and the family, with emphasis on the futility of attempting repair and the patient's wishes should be made clear to family or other parties involved.

There may be a perceived increased risk of deep vein thrombosis and pulmonary embolism, as well as limb thrombosis post EVAR (up to 7%), possibly because of hypercoagulability, thrombophilia, para-neoplastic syndrome, chemotherapy, and lithotomy position.[357,366,425,557] Prolonged low molecular weight heparin (LMWH) prophylaxis up to four weeks should be considered post EVAR in patients with concomitant cancer.[197]

Recommendation 118	Class	Level	References
Patients with abdominal aneurysm and concomitant cancer are not recommended prophylactic aneurysm repair on a different indication (diameter threshold) from patients without cancer, including cases of chemotherapy.	III	C	[73,450]

Recommendation 119	Class	Level	References
In patients with concomitant malignancy, a staged surgical approach, with endovascular repair of a large or symptomatic abdominal aortic aneurysm first, to allow for treatment of malignancy with minimal delay, is recommended.	I	C	[357,366,425]

Recommendation 120	Class	Level	References
In patients with concomitant cancer, prolonged low molecular weight heparin prophylaxis up to four weeks after abdominal aortic aneurysm repair should be considered.	IIa	C	[197,425]

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9.5. Genetic syndromes

Although classic cardiovascular risk factors are the leading cause of AAA, in young patients (<60 years) a specific diagnostic approach is needed to look for underlying genetic or connective tissue disorders, or both. More than 30 heritable conditions have been described that can potentially manifest with aortic or arterial aneurysms. The same heritable aortic disease usually associated with the thoracic aorta can also affect the abdominal aorta, but to a much lesser extent, such as Marfan syndrome, vascular Ehlers—Danlos syndrome (VED), Loeys—Dietz syndrome (LDS), arterial tortuosity syndrome, and aneurysm osteoarthritis syndrome.[579,724]

Mutations in genes encoding for extracellular matrix components (e.g. Fibrillin 1, Collagen Type III Alpha 1 Chain, Collagen Type IV Alpha 5 Chain); the smooth muscle cell contractile apparatus (e.g. actin alpha 2 smooth muscle aorta, Protein Kinase Cyclic guanosine monophosphate (cGMP) Dependent Type I); Transforming Growth Factor Beta 3 signalling pathway (e.g. TGFBR 1, 2, Small Mothers against decapentaplegic homolog 3, TGFB3) are known to be associated with increased risk of abdominal aortic pathology and aneurysm formation. Variability in clinical presentations among individuals with identical mutations can be significant.[84]

Genetic counselling involves a thorough clinical examination with emphasis on skeletal, ocular, cutaneous, and craniofacial features, detailed mapping of family history with construction of a three generation pedigree, and collection of clinical data in first degree relatives.[93] Diagnostic vascular imaging should not only focus on the known pathological features but also provide a complete overview of the cerebral, thoracic, and abdominal vasculature using MRA and transthoracic echocardiography.[444] Appropriate genetic counselling and testing of the patient and family members should be initiated early, not only to establish proper medical/surgical management in the individual patient but also to uncover implications for family members.

Management strategies including imaging surveillance (CTA/MRA/DUS), medical treatment, or surgical intervention for the individual patient should be discussed within a multidisciplinary aortic team.

An individual approach is paramount since the rupture risk is higher at smaller aortic diameters in for example LDS (TGFBR1,2) and aneurysm osteoarthritis syndrome (Small Mothers against decapentaplegic homolog 3) than in Marfan (Fibrillin 1) patients, and surgical repair is more challenging in VED owing to the increased arterial wall fragility than in Marfan's syndrome.

If surgical treatment is considered OSR is generally to be preferred using specific repair techniques due to vessel friability, for example delicate and atraumatic handling of tissues and sewing of anastomoses with pledgeted sutures, and use of supporting cuffs and glues. More recently, particularly in patients with an increased surgical risk because of redo procedures or in emergencies as a bridging procedure, a gradual move towards endovascular repair has been observed, but this approach cannot be recommended for routine use in the elective treatment of AAA with underlying genetic causes.[420]

VED (Collagen Type III Alpha 1 Chain) is a dominant inherited rare and most serious connective tissue disorder with inherent vessel friability that causes arterial dissection and ruptures with high mortality. Treatment with the beta blocker celiprolol was shown in a RCT to be associated with a threefold decrease in arterial rupture in VED patients.[523] Experience of invasive treatment is limited to case reports and small case series.[56] A recent international consensus report on the diagnosis, natural history, and management of VED concluded that non-contained ruptures or clinically unstable aneurysms (pre-rupture) or false aneurysms often require intervention. Depending on the location, endovascular treatment (embolisation of the bleeding artery), or open surgery (aorta and iliac vessels) may be indicated although invasive procedures may provoke further morbidity. Ideally management of patients with VED should be centralised at centres of excellence when feasible.[104] International multicentre collaborations such as the European Reference Network on Rare Multisystemic Vascular Diseases (http://vascern.eu/) may play an important role in improving the knowledge of the management of this rare disease.

Recommendation 121	Class	Level	References
In patients with abdominal aortic aneurysm in whom the disease cannot be solely explained by a non-genetic cause, such as patients <60 years or in patients with a positive family history, genetic counselling is recommended prior to genetic testing.	I	C	[93,140,723]

Recommendation 122	Class	Level	References
Referral to a multidisciplinary aortic team at a highly specialised centre is recommended to manage patients with an aortic disorder suspected of having an underlying genetic cause.	I	C	[444,544,622,763]

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Recommendation 123	Class	Level	References
In young patients with suspected connective tissue disorders and abdominal aortic aneurysms, open surgical repair is recommended as first option.	I	C	[250,544]

9.6. Co-existent horseshoe kidney

Horseshoe kidney (HK) is the most common congenital kidney anomaly, with a prevalence of 0.25%. A medial fusion of the kidneys anterior to the aorta is the main characteristic of this anomaly. The co-existence of AAA and HK is rare, occurring only in 0.12% of patients. The ventrally positioned renal isthmus poses a technical challenge during AAA repair. Surgical repair is further complicated by arterial anomalies commonly associated with HK.[138,519]

The literature on AAA with co-existing HK is limited to case reports and small case series, susceptible to publication bias.[118,138,519,659] Owing to the limited state of knowledge, no firm recommendations can be made. The surgeon should choose open or endovascular methods based on patient factors as well as according to personal preference and expertise.

When the aortic morphology is suitable and no dominant renal arteries originate from the aneurysm, the placement of a stent graft may be considered. EVAR in patients with co-existing HK, however, often requires covering of ARAs to achieve an adequate proximal seal zone, with resulting partial renal infarction. It is recommended that all anomalous renal arteries larger than 3 mm in diameter should be preserved.[118,138]

If dominant renal arteries arise from the aneurysm, the retroperitoneal approach seems to be a valuable method to preserve the overlying renal isthmus to prevent renal necrosis, haemorrhage, urinary leakage and fistula formation, sepsis, and post-operative renal insufficiency.[138,659] As many accessory renal arteries as possible should be reanastomosed to the prosthesis.[519,659]

Recommendation 124	Class	Level	References
A retroperitoneal approach for patients requiring open surgical repair or endovascular repair if anatomically feasible may be considered as preferred options for the surgical treatment of abdominal aortic aneurysm with a co-existing horseshoe kidney.	IIb	C	[118,519,659]

Recommendation 125	Class	Level	References
Preservation of the renal isthmus and anomalous renal arteries >3 mm in diameter should be considered during both open and endovascular repair of abdominal aortic aneurysm with a co-existing horseshoe kidney.	IIa	C	[118,138,659]

Chapter 10

10. UNRESOLVED ISSUES

The GWC identified key issues relating to the management of abdominal aorto-iliac artery aneurysms that need to be addressed to better define future guidelines. These include the following.

10.1. Organisation

- How should, and can the future care of patients with aorto-iliac aneurysmal disease be organised? Particularly important but also controversial are the issues of centralisation and surgical volume. There is clearly a strong relationship between volume and outcome, but the exact threshold for AAA repair has not yet been defined. Other important aspects that have to be taken into account are population density and geographical distance.
- Likewise, how can open surgical skills be acquired and maintained as more cases are treated with endovascular technology especially since surgical volume seems to be paramount in OSR outcomes (vs. EVAR). Should open surgery be centralised in the near future?
- A strategic issue for the vascular surgery specialty is whether only vascular surgeons should perform the operations? Although supported by some data, more information is needed before a recommendation can be made.
- What is a safe and acceptable waiting time to repair an AAA? There is limited evidence about AAA but in a time of limited resources when different patient groups are weighed against each other it is important to defend the AAA patients' needs with well founded arguments. Modern cancer care often has very well structured treatment pathways with clearly defined deadlines and may serve as a role model.
- What key outcomes should be reported? Systematic reviews have been consistent in demonstrating the large number and heterogeneity of outcome reporting in

trials, registries, and other research studies: this heterogeneity being particularly important in times of rapid technological advance. This has the effect of making clinically relevant comparisons between trials and pooling of results in meta-analyses difficult, which leads to potential outcome reporting bias. Therefore Core Outcome Sets for AAA need to be developed and used. This is a minimum set of outcome criteria that all stakeholders, including patients, agree on. Core Outcome Sets for abdominal aortic aneurysm would allow consistency in the future reporting of outcomes and the increased efficiency of clinical research in this field.

10.2. Screening

- The changing epidemiology has challenged the future of AAA screening. General screening of all 65 year old men is highly cost effective today, but what if the prevalence continues to decline? Can targeted high risk screening in smokers or in patients with established atherosclerotic cardiovascular disease be a cost effective alternative? Screening of first degree relatives of AAA patients also needs to be better evaluated.
- A recurring criticism for screening is the uncertainty about possible psychosocial harm and decreased quality of life. Although existing data do not give cause for major concern, research should evaluate and guide how to prevent any potential negative psychosocial and quality of life effects.
- Existing literature indicates that subaneurysmal aortic dilatation may become an aneurysm, that often reaches the size threshold for repair. A weak recommendation to rescreen these patients after 5—10 years has been included. More data are, however, needed about long-term clinical and health economic effect of subaneurysm surveillance.
- Secondary cardiovascular prevention combined with AAA screening could have a major impact on the overall health promoting effect of an AAA screening programme, and need to be evaluated properly. In addition, extended screening programmes, targetting multiple disease processes, have recently been proposed and need further assessment.

10.3. Imaging

- Currently, we were unable to recommend a preferred detailed US (and CT) measurement method. Harmonisation of the US and CT imaging and measurement methodology has clinical and scientific consequences, and should be identified and implemented in the near future.
- Radiation exposure has emerged as a potentially major occupational hazard in modern vascular surgery, causing safety concerns for healthcare workers and patients. How to improve radiation safety behaviour is a key question demanding great attention.

10.4. Non-surgical management of AAA

- The development of better predictive tools for individual rupture risk including bio-markers, functional imaging, and morphology based indicators should be the subject of long-term research projects.
- Another ambitious research initiative focuses on medical treatment to slow AAA growth. A number of projects in the early stages of animal models are ongoing. A potential candidate drug for imminent clinical trials is metformin.
- The impact of cardiovascular secondary preventive medical treatment in AAA patients and refinement of pre-operative assessment should be studied in close collaboration with other societies and GL groups.
- The size threshold for AAA repair in women and specific ethnic groups is an area of uncertainty requiring further research and high quality long-term follow up cohort data may be the basis for better substantiated future recommendations.

10.5. Surgical treatment of AAA

- The debate about OSR vs. EVAR is a never ending story. The rapid technological development is an inherent challenge within the endovascular field. Constant upgrades/modifications and the several actors involved, make it extremely difficult to get reliable data about durability, which is of utmost importance. Device related complications or problems are rare and difficult to detect and study in single centre environments. RCTs although representing the highest level of evidence will eventually become outdated under these circumstances, and therefore cohort data and registry data will be the main means of continuously updating our knowledge. The behaviour of the later generation of low profile stent grafts is an ongoing research area of great importance.
- The endovascular pioneers have advanced the endovascular field but often took risks, which today is no longer acceptable. In the future, a more responsible introduction of new products is important, for ethical reasons as well as for the credibility of our vascular surgical discipline. CE marking (or approval) is a certification mark for products sold within the European Economic Area (EEA), namely the European Union (EU) and European Free Trade Association (EFTA). Unlike the rigorous evaluation of efficiency and safety required for Food and Drug Administration (FDA) approval in the USA, CE marking has nothing to do with efficiency or safety. There are many unproven, ineffective, or even inappropriate medical devices that are CE marked. So, it is up to the profession (ESVS) to make proper recommendations based on science (or lack of science) and experience. The role for several new innovative CE marked technologies on the market is still unclear and further data are needed before these can be recommended for use in routine clinical practice.

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10.6. Post-operative follow up

- Annual imaging after EVAR for all patients is neither evidence based nor feasible. It is believed there is sufficient evidence to recommend a more far reaching risk based stratified follow up routine. However, this change needs to be carefully monitored and evaluated but setting up a RCT is not realistic because of the low frequency of the main endpoint (aneurysm rupture) after EVAR. Instead, we have to rely on careful monitoring of the long-term outcome, preferably in prospective cohort studies and registry studies with complete reporting.

10.7. Miscellaneous aortic problems

- Endovascular techniques, such as fEVAR, have emerged as promising alternatives to OSR for the treatment of JRAAA. However, comparative studies/data on long-term outcome and health economics are still missing and needed. When looking for papers reporting specifically on outcomes for SRAAA we ended up in confusion and despair. Confusion, because of the heterogeneous definitions of SRAAA (if provided) and despair because results are usually reported for a mixture of pathologies, including JRAAA, SRAAA, type IV and sometimes also extensive TAAA. Uniform reporting standards with respect to definitions and outcomes for specific subgroups of JRAAA and SRAAA is crucial.
- The threshold for repair of asymptomatic iliac aneurysms was difficult to determine. Owing to the limited evidence, we agreed to a weak recommendation suggesting 3.5 cm as a minimum threshold to consider repair. More data are needed to either confirm or modify this limit.
- Rare diseases require multicentre and probably international collaborations. Therefore, we support the creation of international registries for MAA, InflAAA, PAU, IMH, pseudoaneurysms, saccular aneurysms, and isolated dissection, focusing on epidemiology, medical treatment, indications for treatment, surveillance in patients with genetic disorders, and outcome after OSR and EVAR.
- The patient's perspective has been included for the first time in an ESVS GL. The text should be translated into different languages and its contents evaluated in other patient populations. Key patient related outcome measures across Europe should be defined and incorporated into reporting metrics, particularly Core Outcome Sets.

Chapter 11

11. INFORMATION FOR PATIENTS

This information has been developed by the European Society for Vascular Surgery (ESVS). In order to provide guidance for healthcare professionals involved in the care of patients with abdominal aortic aneurysm (AAA) the ESVS produces guidelines and recommendations. The ESVS guidelines committee for AAA has produced a full set of guidelines for professionals, which is the main part of this document.

The next part of the document contains the same information but is presented in a format for non experts. Details of the process used to develop this information, and how strong the evidence is for each piece of information, are given at the end of this section. Where very good evidence for the management of people with AAA has been found, it has been included in the information presented here.

11.1. What is an abdominal aortic aneurysm?

Abdominal aortic aneurysm is a swelling or ballooning out of the main artery in the body as it takes blood through the belly to supply the legs (Fig. 11.1). These aneurysms are very rare before the age of 60 years. They are more common in people who have ever smoked (current smokers or ex-smokers) than in those who have never smoked. They are also more common in men than in women. Rarely, there may be a genetic cause for the abdominal aortic aneurysm.

Most aneurysms do not cause any symptoms and patients with an aneurysm usually do not realise they have one until it is found by a doctor, as a result of other medical tests or in the event that it bursts.

11.2. How is an abdominal aortic aneurysm diagnosed?

Occasionally, an aneurysm is found by a doctor while examining a patient. This is not a reliable way to diagnose an aneurysm however. If someone is suspected of having an abdominal aortic aneurysm the best way to confirm the diagnosis is by using a special type of ultrasound (US) examination (Duplex ultrasonography). This is a good non-invasive method for checking the aorta at the back of the abdomen (where aneurysms most commonly form). US does not involve any radiation and is quick and simple.

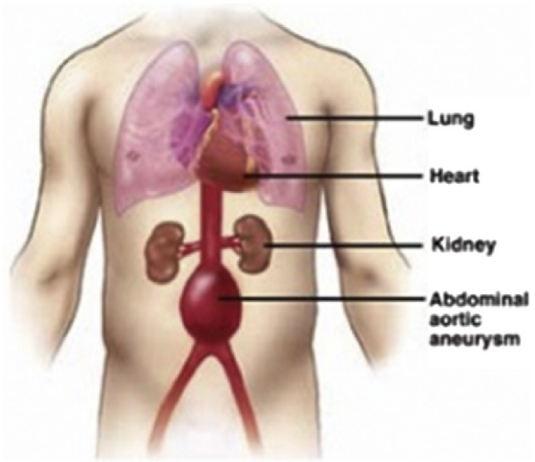

Figure 11.1. An abdominal aortic aneurysm.

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Many aneurysms are not suspected before they are diagnosed and most people who have an aneurysm diagnosed are usually having a scan for another reason, or as part of a screening programme (see below).

More detailed information can be obtained about an aneurysm using computerised tomography scanning (CT scan). This involves the injection of dye into a vein in your body that can be seen on the scan. This dye clearly reveals the details of the arteries and the aneurysm. It is a good method for seeing the blood vessels and parts of the aneurysm that cannot be seen on US (such as the parts of the aorta in your chest). CT scans are most commonly used when an operation to repair an aneurysm is being considered, or if your doctor wants to make sure your aneurysm has not burst. A doctor may suspect a burst aneurysm if someone who is known to have an aneurysm develops sudden and severe abdominal or back pain, or if they collapse.

11.3. What about screening for abdominal aortic aneurysm?

Offering US screening to men aged 65 years (or older) reduces the risk of dying from an aneurysm by finding aneurysms before they burst. Offering screening does increase the number of people who require operations to repair an aneurysm, but these operations are much safer than leaving an aneurysm alone. Screening has been shown to be cost-effective in men, but presently there is no information about whether women would benefit from screening.

We recommend that all men, at the age of 65 years should be offered a one time US screening examination of their belly to look for the presence of an abdominal aortic aneurysm.

11.4. What happens if I am diagnosed with an abdominal aortic aneurysm?

If you are diagnosed with an abdominal aortic aneurysm you will be told whether it is small (between 3 cm and 5.4 cm) or large (5.5 cm or bigger). The size of an aneurysm is usually measured by US from the front to the back. If it is measured on a CT scan the size is usually slightly bigger than when measured by US. It is, however, the US measurement that is the most important one.

While your aneurysm remains small, it is very unlikely to cause you any problems, but you will need to have the size of your aneurysm monitored on a regular basis, even though this may be only every three years for the smallest aneurysms.

11.5. If I have an abdominal aortic aneurysm what is the risk of it bursting?

If your aneurysm is small, the risk of it bursting is extremely small. The risk of aneurysm rupture increases as the size of the aneurysm increases. For a 3.0 cm aneurysm the risk of it bursting within one year is about one in 2000 (0.005%) for men and one in 500 (0.02%) for women. For a 5.0 cm aneurysm the risk is about one in 150 (0.66%) for men and one in 30 (3.3%) for women. It is known that the risks of aneurysm rupture increase for aneurysms larger than 5.5 cm, but because most patients with large aneurysms are offered surgery, we do not know what the risk of rupture is for patients with large aneurysms. For aneurysms above 5.5 cm the risk is about one in 10 per year, but higher for very large aneurysms.

11.6. What can I do to stop an aneurysm progressing?

At the moment there is no good evidence that any specific treatment (drug, diet, or exercise) will stop your aneurysm growing larger (see Recommendation 3.3). However, if you are a smoker, this will cause your aneurysm to grow more quickly. Stopping smoking will reduce the chance of your aneurysm growing quickly.

11.7. If I have an aneurysm will it affect other parts of my body or my general health?

Having an AAA is often a warning signal of disease in other blood vessels, including those supplying the heart. This is not a direct effect of having an aneurysm. It is just that the same things that cause aneurysms such as smoking also cause disease in other blood vessels. Therefore your doctor may recommend that, in addition to improving your physical fitness, you take one or more drugs to reduce your chance of having heart problems or a stroke in the future. We recommend that all people diagnosed with an AAA should be prescribed a cholesterol lowering drug (statin) to reduce the risk of other cardiovascular diseases (see Recommendation 4.11).

11.8. What happens if I have a small aneurysm and it gets bigger?

If your aneurysm grows and becomes a large aneurysm, your doctor is likely to recommend an operation to repair it. For many patients this will not happen in their lifetime. We recommend that for men, if their AAA grows to the size of 5.5 cm or more, they should be referred to a surgeon for consideration of surgery to repair it (see Recommendation 3.6).

For women it has been traditional to use the same size of 5.5 cm as the threshold to refer for surgery. Some experts recommend referral for women at 5.0 cm. At present there is no evidence for or against a different recommendation for women and this should be decided in consultation with your doctor or surgeon. It is known that aneurysms in women are more likely to burst than in men, but surgery to repair an aneurysm is riskier for women than for men.

11.9. What happens if I am referred to a vascular surgeon to discuss surgery?

When you are seen by a vascular specialist to discuss your abdominal aortic aneurysm, the main question that will be considered, is whether you would benefit from an operation or not. Not everyone with an abdominal aortic aneurysm benefits from having it repaired. This is because there

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are risks associated with abdominal aortic aneurysm repair. If these risks are greater than the risk of the aneurysm bursting, then surgery is not recommended.

Two forms of surgery are commonly performed: open operations and endovascular (keyhole) operations. We recommend that in people who are fit for both open repair and endovascular repair, the decision about which type of operation to have should be based on the personal preference of the patient (see Recommendation 4.24). This decision should be made in consultation with a vascular surgeon. In patients who are at slightly higher risk than standard because they have other health problems we recommend that endovascular repair should be performed (see Recommendation 4.26).

For men, the risk of dying from a complication during or immediately after planned surgery is about 1 in 25 (4%) for open repair and 1 in 140 (0.7%) for endovascular repair. Risks of surgery are higher in women, about 1 in 15 (6.9%) for open repair and 1 in 55 (1.8%) for endovascular repair.

11.10. How is an operation to repair an abdominal aortic aneurysm performed?

An open operation to repair an abdominal aortic aneurysm is performed through a large cut in the abdomen. The aorta is identified at the back of the abdomen and the blood flow through the aorta temporarily stopped. The aneurysm is then replaced with a material graft that is stitched in place and the blood flow through the aorta then restored (Fig. 11.2A).

An endovascular operation is carried out through smaller cuts in the groin. Using Xray control a spring loaded graft (also called stent) is passed up from the arteries in the groin into the aorta (Fig. 11.2B). Once the graft is in the right place it is released. Often three or four graft pieces are required but once completed the endovascular graft takes the strain off the wall of the aneurysm. Not everyone can have an endovascular aneurysm repair. One of the things surgeons assess, when seeing patients with abdominal aortic aneurysms, is their suitability for an endovascular repair. About 70%–80% of people with aneurysms are suitable for an endovascular repair.

11.11. What are the main advantages and disadvantages of an open and an endovascular abdominal aortic aneurysm repair?

The main advantage of an endovascular repair, compared with an open repair, is a shorter time in hospital at the time of the operation and a lower risk at the time of the operation. The main disadvantage of an endovascular repair is that after surgery, you will need to be monitored by your surgeon to make sure the endovascular repair graft does not move or leak. Some patients need additional surgery in the future to repair or prevent failure of an endovascular stent and this represents additional risks as time goes by. When groups of patients who have had open and endovascular aneurysm repair are compared over long periods of time (years) the risks are the same. The monitoring performed after surgery sometimes requires CT scanning that requires Xray radiation and this has a very small theoretical risk of causing cancer and kidney disease.

In the past many surgeons thought that is was not necessary to see people, after they had recovered from

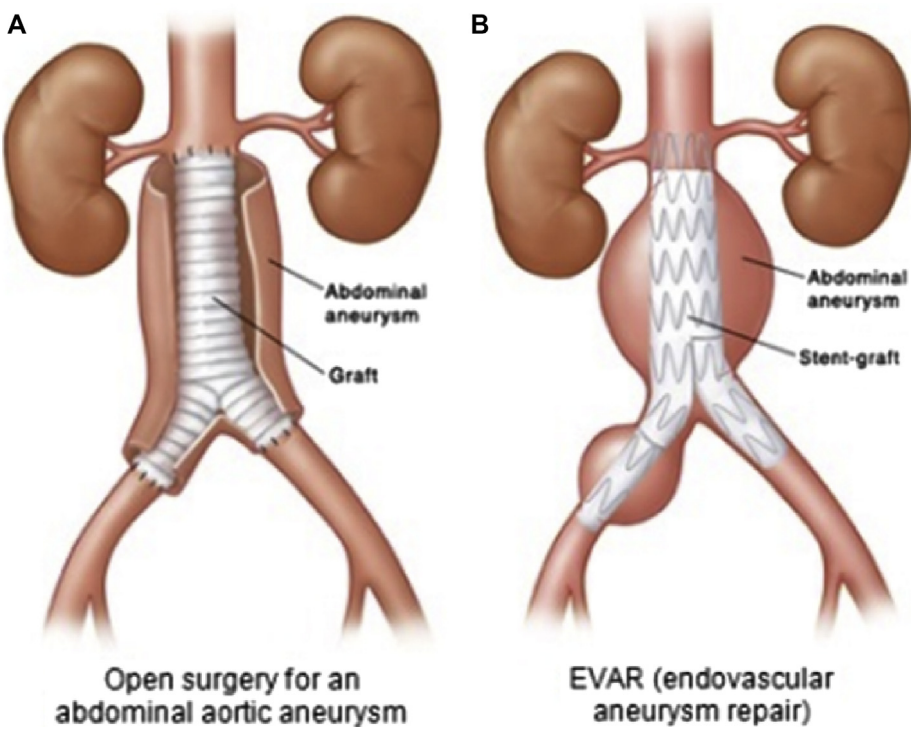

Figure 11.2. >(A) Open AAA repair. The affected segment of the aorta is replaced with a material graft stitched in place. (B) Endovascular AAA repair. A stent graft is placed inside the aneurysm to reline the aorta and prevent the aneurysm bursting.

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open surgery. This was thought to be one of the advantages of open surgery and many patients decided to have an open operation because of this. Our ESVS Guidelines Committee, however, recommends that, after repair of an abdominal aortic aneurysm, whether done by endovascular or open surgery, patients should be offered regular follow up examinations of their belly to look for the effectiveness of the repair, and for additional new aneurysms of adjacent arteries.

11.12. What happens if I am not fit enough to have an operation to repair my aneurysm?

In some people the risks of surgery to repair an aneurysm are higher than usual. For example people with lung disease or kidney problems are more likely to suffer complications after surgery than those without. When the risk of surgery is greater than the risk of an aneurysm bursting surgeons will normally recommend that an operation is delayed until the aneurysm gets bigger or that it is not done at all (see Recommendation 4.26).

There is very limited evidence about the best way to care for you, if your physical fitness for surgery cannot be improved. In patients who are unfit, having an aneurysm repaired is likely to stop it bursting, but there is no evidence that such an operation will prolong life. If you are a smoker, then stopping smoking will reduce the risk of your aneurysm growing and bursting.

If the patient insists on going ahead with an aneurysm repair, the average risk of dying from the operation is about 7% (1 in 14, compared to between 1 in 50 or 1 in 100 in physically fit patients). It should be noted that this average risk is for all "unfit" patients. Many people will have risks higher than this and a decision about surgery will have to be made based on the advice from a surgeon and an anaesthetist at the time an operation is being considered.

11.13. What happens if an aneurysm bursts?

If an aneurysm bursts (ruptures) this is a medical emergency. If you have an aneurysm and suddenly develop severe back or abdominal pain, or collapse it is important to seek medical help immediately and make sure you inform the people treating you that you have an aneurysm. Unfortunately many people do not survive aneurysm rupture. In those people who reach hospital an emergency operation can be performed. This is much higher risk than planned surgery; around one in three people who have an operation for a ruptured AAA will not survive. Many people who do survive will take many months to recover or suffer long-term physical disability. Because of these risks some patients choose not to have a ruptured aneurysm repaired despite the fact that almost all patients with a ruptured aneurysm will die from this within a few days.

Ruptured aneurysms can be treated using the same operations as for planned surgery. Based on recent evidence we recommend that patients with ruptured aneurysm who are suitable for an endovascular repair should have this as a first option wherever possible (see Recommendation 5.13).

11.14. Rare causes of abdominal aortic aneurysm

Most aneurysms are caused by a combination of factors, such as an individual's genetic background, that predispose certain groups to the development of an AAA and environmental factors, such as smoking, that in combination lead to damage of the structure of the aortic wall and the formation of an aneurysm. In some rare cases an aneurysm can be caused by other factors. It is harder to recommend treatments for these rare aneurysms because we generally know less about diseases that are uncommon.

Some genetic conditions cause aneurysms. These are usually treated by experts in clinical genetics in combination with surgeons, if there is a need to repair the aorta. For most of these patients open repair is better than endovascular surgical repair.

Most rare aneurysms that occur later in life are due to infection, inflammation, or form as a result of other diseases of the aorta. The treatment for these aneurysms can be different from the usual sort of aneurysm and the recommendations above may not apply to you. If your doctor thinks your aneurysm is due to one of these causes they will tell you this and tell you about what treatment would be best for you.

11.15. How was this information developed and what should I know before reading the full document?

The above information is a summary of the overall guidelines for clinicians, which has been produced by the European Society for Vascular Surgery (ESVS) AAA Guidelines Committee. This committee was set up to review all the available medical evidence about AAA and make recommendations about how AAA should be managed. As part of this process all pieces of evidence are considered. A decision is then made by the committee whether the evidence is something that is strong enough to make a firm recommendation that all doctors should follow, or if the evidence is not strong enough to make a recommendation. In some areas there is no, or little, evidence available on which to make a recommendation.

The committee therefore makes a decision about whether one particular treatment is one that "experts" would agree is the best. For each treatment being considered the committee then awards a grade from A (best quality evidence) to C (no real evidence) as well as a class of recommendation from I (strong recommendation and an agreement among experts that the treatment is beneficial, useful or effective) to III (agreement that the treatment is not effective, or even harmful).

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