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Original Article

Short-term outcomes of open surgical abdominal aortic aneurysm repair from the Dutch Surgical Aneurysm Audit

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Abstract

Background: The sharp decrease in open surgical repair (OSR) for abdominal aortic aneurysm (AAA) has raised concerns about contemporary postoperative outcomes. The study was designed to analyse the impact of complications on clinical outcomes within 30 days following OSR.

Methods: Patients who underwent OSR for intact AAA registered prospectively between 2016 and 2019 in the Dutch Surgical Aneurysm Audit were included. Complications and outcomes (death, secondary interventions, prolonged hospitalization) were evaluated. The adjusted relative risk (aRr) and 95 per cent confidence intervals were computed using Poisson regression. Subsequently, the population-attributable fraction (PAF) was calculated. The PAF reflects the expected percentage reduction of an outcome if a complication were to be completely prevented.

Results: A total of 1657 patients were analysed. Bowel ischaemia and renal complications had the largest impact on death (aRr 12·44 (95 per cent c.i. 7·95 to 19·84) at PAF 20 (95 per cent c.i. 8·4 to 31·5) per cent and aRr 5·07 (95 per cent c.i. 3·18 to 8.07) at PAF 14 (95 per cent c.i. 0·7 to 27·0) per cent, respectively). Arterial occlusion had the greatest impact on secondary interventions (aRr 11·28 (95 per cent c.i. 8·90 to 14·30) at PAF 21 (95 per cent c.i. 14·7 to 28·1) per cent), and pneumonia (aRr 2·52 (95 per cent c.i. 2·04 to 3·10) at PAF 13 (95 per cent c.i. 8·3 to 17·8) per cent) on prolonged hospitalization. Small effects were observed on outcomes for other complications.

Conclusion: The greatest clinical impact following OSR can be made by focusing on measures to reduce the occurrence of bowel ischaemia, arterial occlusion and pneumonia.

Introduction

In the field of vascular surgery, registry data are being used increasingly as a tool for quality improvement[1]. Since 2013, all patients undergoing abdominal aortic aneurysm (AAA) surgery in the Netherlands have been recorded in the Dutch Surgical Aneurysm Audit (DSAA) to monitor and improve the quality of care[2,3]. Nowadays, AAA is predominantly treated by endovascular aortic aneurysm repair (EVAR) rather than open surgical repair (OSR)[4]. In about 25 per cent of elective infrarenal AAA repairs, OSR is still the preferred method[5,6]. Previous studies have shown the initial benefits of lower morbidity and mortality rates after EVAR, but this early advantage disappears during follow-up[5,7–9]. Quality improvement of perioperative care in vascular patients has become an important topic to prevent complications[10]. Yet, concerns have arisen that as OSR is now performed so infrequently, patient outcomes may be less favourable[11]. In order to optimize the current short-term outcomes after OSR, it is necessary to improve the quality of surgical postoperative care. Therefore, those postoperative complications that most affect outcomes need to be highlighted. Previous literature has demonstrated the prevalence of complications and outcomes after open AAA repair[5,7–9,12]. However, just reporting the prevalence of outcomes is not enough to measure the overall impact of complications on the population.

In order to define those complications most relevant to OSR, and to assess their impact on postoperative outcomes and the consequences of avoidance of a certain complication, the population-attributable fraction (PAF) can be used. The PAF is the proportion of events in the population that are attributable to the risk factor. The PAF is defined by the reduction of a disease

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(for example lung cancer) in the population that would occur if a certain risk factor was completely removed (for example no tobacco use)[13,14]. Furthermore, the PAF is a useful tool to assess the impact on public health of complications of several outcomes (such as death and secondary interventions), as it includes the frequency of a complication as well as the relative risk of a certain outcome related to that complication[14]. Complications after OSR lead to an increase in mortality rate and duration of hospital stay and significant increase in medical costs[15,16]. Furthermore, the 30-day intervention rate after OSR has been associated with increased postoperative mortality rate[16]. Reduction of complications is likely to result in lower postoperative morbidity and mortality rates, especially if those complications with the largest impact on mortality rate can be prevented.

The aim of this DSAA registry study was to identify the most frequently occurring complications following OSR, and subsequently to evaluate the impact of these complications on predetermined outcomes within 30 days by using the PAF.

Methods

Study design

This observational study used data accessed from the DSAA, a mandatory national vascular audit in which every vascular medical centre has registered all AAA repairs in the Netherlands since 2013. The DSAA is one of the healthcare quality registries of the Dutch Institute of Clinical Auditing[2]. Verification of the DSAA data was executed in 2015 through a random sample of hospitals[17]. This study was approved by the scientific board of the DSAA (DSAA201907) and performed in accordance with the STROBE guidelines for observational studies[18].

Patients

All consecutive patients were eligible for inclusion if they had undergone a primary OSR for a non-ruptured (elective and symptomatic) infrarenal AAA between January 2016 and December 2019 at one of 60 medical centres in the Netherlands. Patients were excluded if predefined variables such as sex, age or 30-day or in-hospital death were missing.

Definitions

Baseline patient characteristics included age, sex, preoperative AAA diameter, cardiac co-morbidities (such as angina pectoris, hypertension), pulmonary co-morbidities (such as dyspnoea, chronic pulmonary diseases), and haemoglobin and creatinine concentrations. The definitions of registered co-morbidities can be found in *Table S1*. Up to 2018, baseline patient characteristics and co-morbidities were registered in the DSAA in accordance with the categorizations of the Physiological and Operative Severity Score for the enumeration of Mortality and morbidity (POSSUM) score, a mortality-risk-prediction model for surgical patients[19]. From 2019 onwards, the registration of co-morbidities has been based on International Classification of Diseases (ICD) codes. Postoperative complications registered in the DSAA are listed in *Table S2*. Postoperative morbidity was assessed, and the complications were distributed into the following categories: abdominal sepsis or abscess, bowel ischaemia, arterial occlusion (for example amputation, renal or other artery occlusion, trash foot), wound complications (such as deep wound infection), myocardial infarction or arrhythmia, congestive heart failure, pneumonia, other pulmonary complications (pulmonary embolism, pneumothorax), renal insufficiency (scored at surgeon's discretion; without or requiring haemodialysis), significant rebleeding (need for packed cells transfusion or secondary intervention), neurological complications (cerebrovascular accident or paraplegia), and other.

The primary outcome measure was the impact of postoperative complications within 30 days on mortality rate, secondary interventions and prolonged hospital stay. Postoperative death was defined as death within 30 days after the primary OSR, or within the same period of hospital admission. Secondary interventions were defined as all secondary interventions following primary OSR within 30 days that were registered in the DSAA. Prolonged hospital stay was specified as length of hospital stay of the surviving patients above the 75th percentile, registered in the DSAA and stratified by elective or urgent intact repair.

Statistical analysis

Patient characteristics were analysed by means of descriptive statistics. Normal distribution of the data was tested with histograms and Q-Q plots. Normally distributed continuous data were reported as mean with standard deviation. Data were reported as median with interquartile range if they did not follow normal distribution. Categorical variables were presented as proportions, and differences in proportions were assessed with the χ^2 test and Fisher's exact test, when appropriate. A two-sided $P < 0.050$ was considered to be statistically significant. The frequencies of all complications and outcomes were calculated. First, the adjusted relative risk (aRR) with 95 per cent confidence intervals was calculated for each complication–outcome pair using Poisson regression models with log link (exponentiates linear predictors) and robust error variance (to narrow confidence intervals) to estimate risk ratios for binary outcomes, while adjusting for confounders. Possible confounders included: age, sex, preoperative AAA diameter, cardiac status, pulmonary status, haemoglobin, creatinine and urgency of repair (elective or urgent intact). Subsequently, the PAF was determined to measure the impact of the complications. The PAF model takes into account the frequency and relative risk of a specific outcome whilst correcting for confounders and other complications. All PAF calculations were executed with the attributable fraction (AF) package in R software to estimate the adjusted attributable fraction in cohort studies[20]. In this study, the risk-adjusted PAF accounts for the proportional reduction in outcome (postoperative death, secondary intervention, prolonged hospital stay), if a given complication could be completely eliminated from the study population. All statistical calculations were performed with R (R Foundation for statistical computing, Vienna, Austria) version 4.0.2.

Results

Study population

In total, 16 335 patients were registered in the DSAA by 60 hospitals in the Netherlands between 1 January 2016 and 31 December 2019 (*Fig. 1*). Some 1660 patients (10·2 per cent) underwent primary OSR for an intact infrarenal AAA, of which 1657 (99·8 per cent) were eligible for inclusion. The majority of patients were male (1310 patients, 78·2 per cent) and the mean(s.d.) age was 70·6(7·51) years. The majority of the patients had cardiac co-morbidities (1074 patients, 64·8 per cent). Patient characteristics and co-morbidities are specified in *Table 1*.

Postoperative clinical outcomes

All postoperative complications and clinical outcomes are shown in *Table 2*. Pneumonia (13·0 per cent), renal insufficiency (6·7 per cent) and myocardial infarction or arrhythmia (5·6 per cent) were

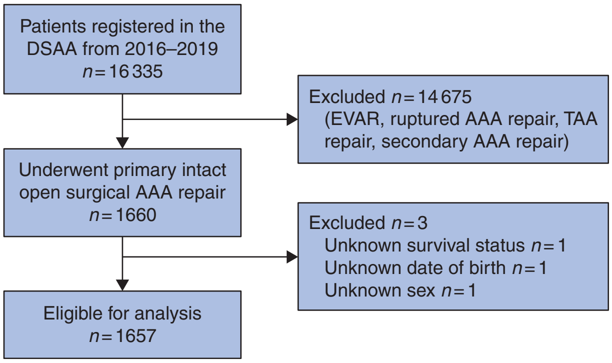

Fig. 1 Flow chart of included patients

DSAA, Dutch Surgical Aneurysm Audit; AAA, abdominal aortic aneurysm; EVAR, endovascular aortic aneurysm repair; TAA, thoracic aortic aneurysm

Table 1 Baseline characteristics

Variables	Overall (*n* = 1657)	Missing
Sex, female	327 (20·9)	0
Age (years)	70·6 (7·5)*	0
Cardiac co-morbidity	1074 (64·8)	30 (1·8)
Pulmonary co-morbidity	1231 (74·3)	30 (1·8)
Haemoglobin (mmol/l)	8·6 (1·0)*	40 (2·4)
Creatinine (μmol/l)	87 (74·0–106·0)†	57 (3·4)
Aneurysm diameter (mm)	62·6 (13·1)*	10 (0·6)
Urgency of repair, urgent intact	225 (13·6)	0
Year of surgery		0
2016	394 (23·8)	
2017	403 (24·3)	
2018	420 (25·3)	
2019	440 (26·6)	

Values in parentheses are percentages unless indicated otherwise; *values are mean(s.d.), †values are median (i.q.r.).

the most common complications after OSR. There were 72 deaths (4·3 per cent) within 30 days or in-hospital, 306 (18·5 per cent) patients had a prolonged hospital stay and 162 patients (9·8 per cent) underwent secondary intervention. Most of the secondary interventions were carried out via an open surgical procedure, that is relaparotomy (116 patients, 71·6 per cent). No differences were found between men and women in the incidence of specific complications (*Table S3*).

The risk-adjusted associations between postoperative complications and outcomes (death, secondary interventions, prolonged hospitalization) are shown in *Tables 3–5*. Most patients died with the complication abdominal sepsis or abscess (50 per cent). The occurrence of rebleeding most often led to a secondary intervention (90 per cent) and abdominal sepsis or abscess (71 per cent) to prolonged hospitalization. Abdominal sepsis or abscess, and bowel ischaemia were associated with the greatest relative risk of postoperative death (aRR 12·44 (95 per cent c.i. 7·95–19·48) and 8·87 (95 per cent c.i. 5·51 to 14·25) respectively). Apart from wound complications and pneumonia, all postoperative complications were significantly related to death. Arterial occlusion and bowel ischaemia were associated with the greatest relative risk of undergoing a secondary intervention (aRR 11·28 (95 per cent c.i. 8·90 to 14·30) and 10·21 (95 per cent c.i. 7·57 to 13·75) respectively). All postoperative complications were significantly associated with prolonged hospitalization, with the highest association for abdominal sepsis or abscess (aRR 3·84 (95 per cent c.i. 2·58 to 5·73)) and wound complications (aRR 3·58 (95 per cent c.i. 2·74 to 4·70)).

Table 2 Postoperative complications and clinical outcomes in 1657 patients

	Patients (*n* = 1657)	Missing
Postoperative complications		
Abdominal sepsis or abscess	14 (0·8)	4 (0·2)
Bowel ischaemia (transmural)	47 (2·8)	4 (0·2)
Arterial occlusion	52 (3·1)	2 (0·1)
Wound infection	52 (3·1)	5 (0·3)
Myocardial infarction or arrhythmia	92 (5·6)	6 (0·4)
Congestive heart failure	46 (2·8)	6 (0·4)
Pneumonia	215 (13·0)	2 (0·1)
Pulmonary (embolism, pneumothorax)	39 (2·4)	2 (0·1)
Renal insufficiency	111 (6·7)	2 (0·1)
Requiring haemodialysis	39 (2·4)	
Rebleeding	29 (1·8)	0
Cerebrovascular accident or paraplegia	11 (0·7)	2 (0·1)
Outcomes		
Death	72 (4·3)	0
Secondary interventions	162 (9·8)	1 (0·1)
Endovascular	9 (0·5)	
Percutaneous	6 (0·4)	
Endoscopic	1 (0·1)	
Thoracolaparoscopic	2 (0·1)	
Open	116 (7·0)	
Other	28 (1·7)	
Prolonged hospital stay	306 (18·5)	19 (1·1)

Values in parentheses are percentages.

Population-attributable fraction

Risk-adjusted PAFs were estimated for each complication–outcome pair (for example, complication–death, complication–secondary intervention) to characterize the effect of each complication of the respective outcome measure (see *Tables 3–5*). In the study population, bowel ischaemia and renal complications had the greatest overall impact on short-term postoperative death. Prevention of these complications would result in a decrease in mortality rate of 19·97 (95 per cent c.i. 8·40 to 31·53) per cent due to bowel ischaemia, and 13·86 (95 per cent c.i. 0·69 to 27·02) per cent for renal complications. Elimination of arterial occlusion and bowel ischaemia would result in a reduction of secondary interventions of 21·36 (95 per cent c.i. 14·66 to 28·06) per cent and 13·66 (95 per cent c.i. 7·99 to 19·34) per cent, respectively. Postoperative complications such as congestive heart failure and renal complications had the least impact on undergoing a secondary intervention, 0·34 and 0·14 per cent respectively. Pneumonia had the highest overall impact on prolonged hospital stay at 13·05 (95 per cent c.i. 8·29 to 17·81) per cent. The other postoperative complications were observed to have less impact on prolonged hospital stay.

Discussion

This registry cohort study provided an overview of current morbidity and mortality rates following OSR in the Netherlands. The impact of relevant postoperative complications on clinical outcomes was assessed by means of the PAF. Bowel ischaemia and renal complications had the strongest association with postoperative death. Arterial occlusion and bowel ischaemia were shown to have the highest impact on secondary interventions, and pneumonia on prolonged hospitalization.

Originally PAF was used to define contributory risk factors and the impact of medical interventions on the health status of a population[13,14]. The strength of PAF is that it merges the frequency of the risk factor with the relative risk of a certain

Table 3 Risk-adjusted associations and population-attributable fraction between postoperative deaths and complications after open surgical repair of abdominal aortic aneurysm

Postoperative complication	No. died/survived*	Risk-adjusted association‡		Risk-adjusted PAF§	
		aRr†	P	PAF†	P
Abdominal sepsis or abscess	7/7 (50)	12·44 (7·95, 19·48)	<0·001	7·19 (1·05, 13·34)	0·022
Bowel ischaemia	20/27 (43)	8·87 (5·51, 14·25)	<0·001	19·97 (8·40, 31·53)	<0·001
Arterial occlusion	11/41 (21)	6·92 (3·99, 11·97)	<0·001	11·05 (2·85, 19·25)	0·008
Wound infection	2/50 (4)	1·08 (0·27, 4·35)	0·909		
Myocardial infarction or arrhythmia	14/78 (15)	3·44 (1·98, 6·00)	<0·001	12·90 (2·15, 23·65)	0·019
Congestive heart failure	11/35 (24)	4·21 (2·14, 8·29)	<0·001	10·95 (1·80, 20·11)	0·019
Pneumonia	16/199 (7)	1·51 (0·86, 2·64)	0·147		
Pulmonary	12/27 (31)	6·94 (3·88, 12·41)	<0·001	12·19 (3·65, 20·72)	0·005
Renal	23/88 (21)	5·07 (3·18, 8·07)	<0·001	13·86 (0·69, 27·02)	0·039
Rebleeding	6/23 (21)	4·83 (2·07, 11·27)	<0·001	3·89 (−2·24, 10·02)	0·214
Cerebrovascular accident or paraplegia	4/7 (36)	5·64 (2·07, 15·34)	<0·001	3·91 (−1·23, 9·05)	0·136

*Values in parentheses are percentage that died; †values in parentheses are 95 per cent confidence intervals. Patients can have multiple complications and thus fall into multiple categories. P values were obtained via Multivariable Poisson regression. ‡Multivariable Poisson regression. §Logistic regression-based estimate of confounder-adjusted attributable fractions. aRR, adjusted relative risk; PAF, population-attributable fraction.

Table 4 Risk-adjusted associations and population-attributable fraction between secondary interventions and complications after open surgical repair of abdominal aortic aneurysm

Postoperative complication	No. with/without intervention*	Risk adjusted association‡		Risk-adjusted PAF§	
		aRr†	P	PAF†	P
Abdominal sepsis/abscess	12/2 (86)	9·84 (7·40, 13·08)	<0·001	5·01 (1·47, 8·56)	0·006
Bowel ischaemia	33/14 (70)	10·21 (7·57, 13·75)	<0·001	13·66 (7·99, 19·34)	<0·001
Arterial occlusion	42/10 (81)	11·28 (8·90, 14·30)	<0·001	21·36 (14·66, 28·06)	<0·001
Wound infection	31/21 (60)	7·95 (5·94, 10·65)	<0·001	13·11 (7·53, 18·69)	<0·001
Myocardial infarction or arrhythmia	15/77 (16)	1·64 (0·98, 2·75)	0·057		
Congestive heart failure	9/37 (20)	2·02 (1·05, 3·90)	0·036	0·34 (−1·60, 2·29)	0·729
Pneumonia	26/189 (12)	1·31 (0·89, 2·0)	0·184		
Pulmonary	9/30 (23)	2·64 (1·44, 4·82)	0·002	1·33 (−1·26, 3·91)	0·314
Renal	29/82 (26)	3·12 (2·16, 4·54)	<0·001	0·14 (−5·31, 5·59)	0·961
Rebleeding	26/3 (90)	9·65 (7·43, 12·53)	<0·001	11·32 (6·39, 16·25)	<0·001
Cerebrovascular accident or paraplegia	4/7 (36)	3·31 (1·43, 7·63)	0·005	1·09 (−1·57, 3·76)	0·422

*Values in parentheses are percentage that had intervention; †values in parentheses are 95 per cent confidence intervals. Patients can have multiple complications and thus fall into multiple categories. P values were obtained via Multivariable Poisson regression. ‡Multivariable Poisson regression. §Logistic regression-based estimate of confounder-adjusted attributable fractions.aRR, adjusted relative risk; PAF, population-attributable fraction.

Table 5 Risk-adjusted associations and population-attributable fraction between prolonged hospitalization and complications after open surgical repair of abdominal aortic aneurysm

Postoperative complication	No. with/without prolonged hospitalization*	Risk-adjusted association‡		Risk-adjusted PAF§	
		aRr†	P	PAF†	P
Abdominal sepsis or abscess	10/4 (71)	3·84 (2·58, 5·73)	<0·001	1·23 (−0·14, 2·59)	0·079
Bowel ischaemia	26/21 (55)	2·72 (2·05, 3·61)	<0·001	2·59 (0·27, 4·91)	0·029
Arterial occlusion	20/32 (39)	2·31 (1·58, 3·37)	<0·001	0·92 (−1·38, 3·21)	0·434
Wound infection	33/19 (64)	3·58 (2·74, 4·70)	<0·001	4·84 (2·44, 7·25)	<0·001
Myocardial infarction or arrhythmia	48/43 (53)	2·75 (2·17, 3·48)	<0·001	7·04 (3·93, 10·15)	<0·001
Congestive heart failure	25/20 (56)	2·65 (1·94, 3·63)	<0·001	3·28 (0·76, 5·79)	0·011
Pneumonia	88/125 (41)	2·52 (2·04, 3·10)	<0·001	13·05 (8·29, 17·81)	<0·001
Pulmonary	19/19 (50)	2·46 (1·70, 3·59)	<0·001	2·18 (−0·04, 4·42)	0·055
Renal	63/47 (57)	3·25 (2·59, 4·06)	<0·001	5·86 (2·19, 9·53)	0·002
Rebleeding	15/14 (52)	2·36 (1·61, 3·46)	<0·001	1·21 (−0·28, 2·70)	0·112
Cerebrovascular accident or paraplegia	5/6 (46)	2·24 (1·12, 4·50)	0·022	0·05 (−1·04, 1·14)	0·926

*Values in parentheses are percentage that had prolonged hospitalization; †values in parentheses are 95 per cent confidence intervals. Patients can have multiple complications and thus fall into multiple categories. ‡Multivariable Poisson regression. §Logistic regression-based estimate of confounder-adjusted attributable fractions. P values were obtained via Multivariable Poisson regression. aRR, adjusted relative risk; PAF, population-attributable fraction.

outcome relating to that risk factor. PAFs have already been shown to be useful in analysis of the impact of postoperative complications on clinical outcomes after major vascular surgery[21]. Complications such as bleeding and pneumonia were found to have the largest overall impact, and it was suggested they should be prioritized as targets for improvement of the quality of surgical vascular care[21]. This emphasizes the relevance of using the PAF in gaining understanding of the current outcomes after OSR, as the PAF identifies opportunities for prevention of a disease in patients and the incidence of exposure in the population.

The postoperative mortality rate was 4.3 per cent in this registry for open repair of intact AAA and comparable to the 4.4 per cent from vascular registries in 11 countries[22]. Complete elimination of bowel ischaemia would lead to a reduction of 20 per cent, and prevention of renal insufficiency to a reduction of 14 per cent in mortality rate following OSR. The 2.8 per cent incidence of bowel ischaemia following OSR is in line with the 1.9–3.6 per cent reported in previous studies[23,24]. Although the PAF of bowel ischaemia was lower than that of arterial occlusion after secondary interventions, it showed the highest clinical impact on two of the three outcomes in the present study. The origin of postoperative bowel ischaemia is multifactorial, but patient factors (age, female gender, hypertension) as well as longer operating time, and increased blood loss are proven risk factors[20,24,25]. Surgical quality-improvement programmes should prioritize the prevention of these risk factors. This can be achieved by initiating AAA repair quality-improvement programmes where the continued focus should be on associated risk factors such as blood loss and operating time[23–26].

Postoperative renal failure is also a well known risk factor for death following open AAA repair[27,28]. Multiple reasons for the development of renal insufficiency following OSR have already been explored: several types of medication[29], patients with AAA with a history of smoking resulting in atherosclerosis which leads to cardiovascular and renal disease[30], and clamping time during OSR[31]. Preoperative assessment by a nephrologist can be helpful for risk prediction of postoperative renal insufficiency[28,31]. Further research is necessary to analyse whether concentration of care should be considered at least for OSR, because proficiency in OSR is declining due to the ever-increasing use of EVAR. Therefore the European Society for Vascular Surgery guidelines recommend 30 elective AAA repairs per year per centre[31].

Prevention of arterial occlusion would lead to a reduction of 21 per cent of secondary interventions within 30 days of OSR. Prophylactic perioperative heparinization is routine in open AAA surgery, yet the evidence that this has a beneficial effect is not compelling[32] and is currently being investigated[33]. Wound infections were also found to have a large impact on the need for secondary intervention. Several studies have recorded possible risk factors for wound infections after major vascular surgery and suggested strategies for preventing this[34,35]. Perioperative recommendations to prevent this were use of chlorhexidine, antibiotic prophylaxis, maintenance of normothermia and glucose control[35].

Finally, pneumonia had the greatest effect on prolonged hospitalization with a PAF rate of 13 per cent. Open repair of AAA increases the risk of postoperative complications, and has also been proven to be an important cause of prolonged hospitalization[36]. Enhanced recovery after surgery may contribute to preventing pulmonary complications, as improvements following OSR have been previously observed in duration of hospital stay, intake and ambulation[36].

A recent international Delphi study among vascular surgeons analysed the nature and severity of complications following surgery for AAA, carotid artery disease and peripheral artery disease[37]. For patients undergoing open AAA repair, bowel ischaemia and acute myocardial infarction were the two major complications on which consensus was reached. This finding is in concordance with the present study, as these complications (bowel ischaemia, 20 per cent, and myocardial infarction or arrhythmia, 13 per cent) had a great impact on mortality rate.

There are some limitations that apply to this study. First, the DSAA is a national registry, and the possibility of under-reporting of complications exists (registration bias). However, the DSAA registry is mandatory for all national medical centres, and each mandatory variable should be registered before completing a patient's record. Variables to prevent complications, such as antiplatelet medication and postoperative physiotherapy, unfortunately could not be assessed in this study, as the DSAA registry contains no information on these. Second, it was not absolutely evident if a particular complication (for example, arterial occlusion) resulted in a particular outcome (prolonged hospitalization). Third, long-term outcomes (greater than 30 days) were not examined and thus could have underestimated the number of postoperative complications that occur later, such as wound infections.

The strengths of this cohort study are its prospectively registered population-based nationwide set-up, the use of the PAF model while correcting for confounders, large sample size and a complete and validated database.

Collaborators

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Supplementary material

Supplementary material is available at *BJS Open* online.

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