Abdominal aortic aneurysms

The quest for meaningful biomarkers and opportunities to improve surgical care

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CHAPTER 8

Nationwide analysis of patients undergoing iliac artery aneurysm repair in the Netherlands

Submitted

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ABSTRACT

Objectives

The new 2019 guideline of the European Society for Vascular Surgery (ESVS) recommends to consider elective iliac artery aneurysm (eIAA) repair when the iliac diameter exceeds 3.5 cm. This recommendation is based on low-quality evidence. The current study assessed diameters at time of eIAA repair and ruptured IAA (rIAA) repair, and compared clinical outcomes after open surgical repair (OSR) and endovascular aneurysm repair (EVAR).

Methods

This retrospective observational study used the nationwide Dutch Surgical Aneurysm Audit (DSAA) registry and included all patients who underwent primary IAA repair between 2014 and 2018. Diameters at time of eIAA and rIAA repair were obtained from the DSAA registry. Patient characteristics and outcomes of OSR and EVAR were compared with appropriate statistical tests.

Results

A total of 851 patients were included. eIAA repair was carried out in 713 patients, rIAA repair in 102, and symptomatic IAA repair in 36. OSR was performed in 205, EVAR in 618, and hybrid repairs and conversions in 28. The median maximal IAA diameter at time of eIAA and rIAA repair was 43 (IQR 38-50) mm and 68 (IQR 58-85) mm, respectively. Mortality was 1.3% (95% CI 0.7-2.4) after eIAA repair and 25.5% (95% CI 18.0-34.7) after rIAA repair. Mortality was not significantly different between OSR and EVAR subgroups. Patients undergoing elective OSR had significantly more complications compared to EVAR (intraoperative: 9.8% vs 3.6%, postoperative: 34.0% vs 13.8% respectively).

Conclusions

In the Netherlands, most eIAA repairs are performed at diameters larger than recommended by the ESVS guideline. This appears to be safe, as the median IAA diameter at time of rupture is 2.5 cm larger than at time of elective repair. The results indicate that the threshold diameter for eIAA repair could possibly be raised to larger diameters.

INTRODUCTION

Iliac artery aneurysm (IAA) is a condition that accounts for a small proportion of all intra-abdominal aneurysms. Approximately 20% of patients with abdominal aortic aneurysms (AAAs) have concomitant IAA.[1] Similar to AAAs, IAAs are often operated electively to prevent future rupture. The introduction of endovascular aneurysm repair (EVAR) has resulted in a significant increase of elective IAA (eIAA) repair in recent years.[2]

No IAA-specific trials have been conducted to date. The small body of evidence regarding IAA management is in sharp contrast to that of AAA. Outcomes after AAA repair are well known and trials have demonstrated that it is safe to wait with elective AAA repair in men until a maximal diameter of 5.5 cm is reached.[3] As a result, 5.5 cm is widely used as a threshold diameter for elective AAA repair.[4,5] With respect to IAA, the clinical outcomes of patients have not been described extensively and there is no solid evidence with regard to a threshold diameter for elective repair. The recent 2019 guideline on abdominal aorto-iliac artery aneurysms from the European Society for Vascular Surgery (ESVS) recommends to consider eIAA repair when the iliac artery diameter exceeds 3.5 cm.[5] This recommendation is based on evidence of low quality (level C) and does not make a distinction between aneurysms of the common, external, or internal iliac artery (CIA, EIA, IIA, respectively). Others have suggested that the threshold diameter for eIAA repair should be raised to 4 cm.[6]

We used the Dutch Surgical Aneurysm Audit (DSAA) registry to evaluate the indications and outcomes of IAA surgery on a national level in the Netherlands.[7] The primary objective of this study was to determine the maximal diameters of IAA at time of eIAA repair and ruptured IAA (rIAA) repair. Other objectives were to present clinical outcomes after IAA repair, to compare outcomes after open surgical repair (OSR) and EVAR, and to determine risk factors for postoperative mortality.

MATERIALS AND METHODS

Study design and setting

This retrospective observational study used prospectively collected data from the DSAA registry, which is a nationwide prospective registry of all patients undergoing aortic or iliac aneurysm repair in the Netherlands. DSAA is one of the healthcare registries of the Dutch Institute of Clinical Auditing.[7] Registration of patients in the DSAA registry is mandatory for all hospitals carrying out aneurysm repair. Vascular surgeons prospectively register patients and their characteristics and outcomes in this registry. The scientific board of DSAA approved the study protocol (DSAA201707) prior to release of the data. This study included patients who underwent repair from 01-01-2014 until 01-01-2018. Patient consent was not required because the data was anonymized. This study complied with the Declaration of Helsinki and was carried out in accordance with the STROBE statement.[8]

Participants and study size

All patients who were registered in the DSAA for primary IAA repair were eligible for inclusion in this study. Patients were excluded when predefined variables labelled as essential were missing. These essential variables were age, sex, repair method (i.e. OSR, EVAR), and urgency of repair (elective, ruptured, or symptomatic non-ruptured IAA).

Endpoints

The primary endpoint was maximal IAA diameter (in mm) at time of IAA repair. Secondary endpoints were the urgency of repair, method of repair, postoperative mortality, 30-day complications, and baseline patient characteristics (including age, sex and comorbidity). Urgency of repair was categorized as elective, ruptured, or symptomatic non-ruptured IAA (including repair of embolizing IAA). Postoperative mortality was defined as the combined 30-day and in-hospital mortality. The method of repair was categorized as OSR, EVAR (including iliac branched devices), hybrid repair or primary conversion. Definitions for the postoperative complications are listed in Supplemental table 1. Baseline patient characteristics and comorbidities 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.[9] The anatomical location of the IAA (CIA, EIA or IAA) was not registered in the DSAA and could not be analysed.

Statistical analysis

Missing data were not imputed. Categorical data are reported as numbers and percentages with 95% confidence intervals (CI). Normally distributed continuous data are reported as mean ± standard deviation (SD). Data with skewed distribution are reported as median with interquartile range (IQR). Differences between patients undergoing OSR and EVAR were tested with the Fisher's exact test for categorical variables, and with the unpaired t-test or Mann-Whitney U test for continuous variables. The test choice was based on the distribution of the data, which was tested with the Shapiro-Wilk test. Risk factors for postoperative mortality were identified by applying the same method. Differences were calculated between patients who did and did not survive the hospital stay. This was done separately for both eIAA and rIAA repair. A multivariable logistic regression analysis was not carried out because the absolute mortality numbers were low, and because some baseline variables were so rare that odds ratios could not be calculated, or were accompanied by very wide confidence intervals. All statistical analyses were carried out using IBM SPSS Statistics version 24 (IBM Inc., Armonk, NY, USA). A p value of < .05 was considered statistically significant.

RESULTS

Participants

The DSAA registry database contained 974 patients who underwent IAA repair between 01-01-2014 and 01-01-2018. A total of 851 patients were included in this study after exclusion of 119 patients who underwent revision surgery, and four patients with missing essential variables (age, sex, repair method and repair urgency – in one respectively). Some 91% of patients (n=778) were male and the mean age was 71.6 ± 8.9 years (Table 1). Other patient characteristics are listed in Supplemental table 2.

A total of 713 patients (84%) underwent eIAA repair, 102 underwent rIAA repair, 36 underwent sIAA repair. The method of repair was OSR in 205 patients, EVAR in 618 (including 100 iliac branched devices), and other methods in 28 (12 hybrid repairs, 5 primary conversions and 11 others). Patients undergoing rIAA repair were significantly older than patients undergoing eIAA repair (median 74 vs 72 years respectively; Table 1; p = 0.007). Patients who underwent EVAR were treated with devices of Medtronic (n=229), Gore (n=196), Cook (n=92), Vascutek (n=38), Endologix (n=30), and others (n=33).

Main outcomes

IAA diameter at time of repair

Elective IAA repair

Diameter data was available for 706 of 713 patients undergoing eIAA repair. The median maximal IAA diameter of 706 patients was 43 (IQR 38 - 50) mm. The diameters were not significantly different between OSR and EVAR subgroups (45 mm vs 43 mm in 152 and 531 patients respectively, p = 0.470; Table 1). A total of 72 of 706 IAAs (10.2%) were smaller than 35 mm at time of elective repair (Figure 1, Supplemental table 3).

Table 1. Characteristics of 851 patients undergoing primary IAA repair

	Total (n = 851)	**Elective (n = 713)**	**Rupture (n = 102)**	**Symptomatic (n = 36)**	**Total missing**
Age	71.6 ± 8.9 72 (66 - 78)	71.2 ± 8.7 72 (66 - 77)	74.0 ± 8.5 74 (68 - 81)	71.3 ± 12.9 73.5 (66 - 80)	0
Male sex	778 (91.4%)	656 (92.0%)	91 (89.2%)	31 (86.1%)	0
Cardiac disease	447 (53.7%)	378 (53.7%)	50 (53.8%)	19 (54.3%)	19
Pulmonary disease	173 (20.9%)	153 (21.6%)	13 (14.6%)	7 (21.9%)	23
Preoperative serum creatinine (mmol/L)	103.5 ± 61.6 90 (77 - 110)	99.9 ± 60.5 88 (76 - 105)	127.4 ± 56.7 116 (93 - 150)	107.9 ± 81.1 89 (77 - 116)	23
IAA diameter (mm)					
- Total	48.6 ± 15.5 45 (38 - 54)	45.4 ± 11.5 43 (38 - 50)	69.0 ± 21.5 68 (58 - 85)	60.4 ± 21.2 60 (42 - 75)	20
- EVAR	47.6 ± 14.1 45 (39 - 52)	45.2 ± 10.5 43 (38 - 50)	67.6 ± 22.3 61 (58 - 84)	61.0 ± 22.5 58 (43 - 74)	16
- Open repair (OSR)	52.2 ± 18.7 48 (38 - 64)	46.6 ± 14.4 45 (37 - 52)	72.3 ± 19.7 71 (60 - 87)	59.0 ± 19.0 65 (38 - 78)	4
Repair method					
- EVAR	618 (72.6%)	536 (75.2%)	57 (55.9%)	25 (69.4%)	0
- Open repair (OSR)	205 (24.1%)	154 (21.6%)	40 (39.2%)	11 (30.6%)	0
- Other	28 (3.3%)	23 (3.3%)	5 (4.9%)	0	0

Continuous variables are presented as mean ± standard deviation and median (interquartile range).

Ruptured IAA repair

Diameter data was available for 90 of 102 patients undergoing rIAA repair. The median maximal diameter of 90 patients was 68 (IQR 58 - 85) mm and was not significantly different between OSR and EVAR subgroups (71 mm vs 61 mm in 38 and 47 patients respectively, $p = 0.313$). At time of rupture, 4 of 90 IAAs (4.4%) were < 30 mm, and 5 IAAs (5.5%) were 30 - 40 mm (Figure 1, Supplemental table 3). IAA diameters were significantly larger at time of rupture than at time of elective repair ($p < 0.001$).

Sex differences

Diameters at time of surgery were not different between men and women – both for eIAA repair (median 43.0 mm vs 42.5 mm, in 650 and 56 patients respectively, $p = 0.412$), and for rIAA repair (median 68.5 vs 63.0 mm, in 80 and 10 patients respectively, $p = 0.719$).

Postoperative outcomes

Elective IAA repair

Mortality was 1.3% (9/713; 95% CI 0.7% - 2.4%) after eIAA repair and was not

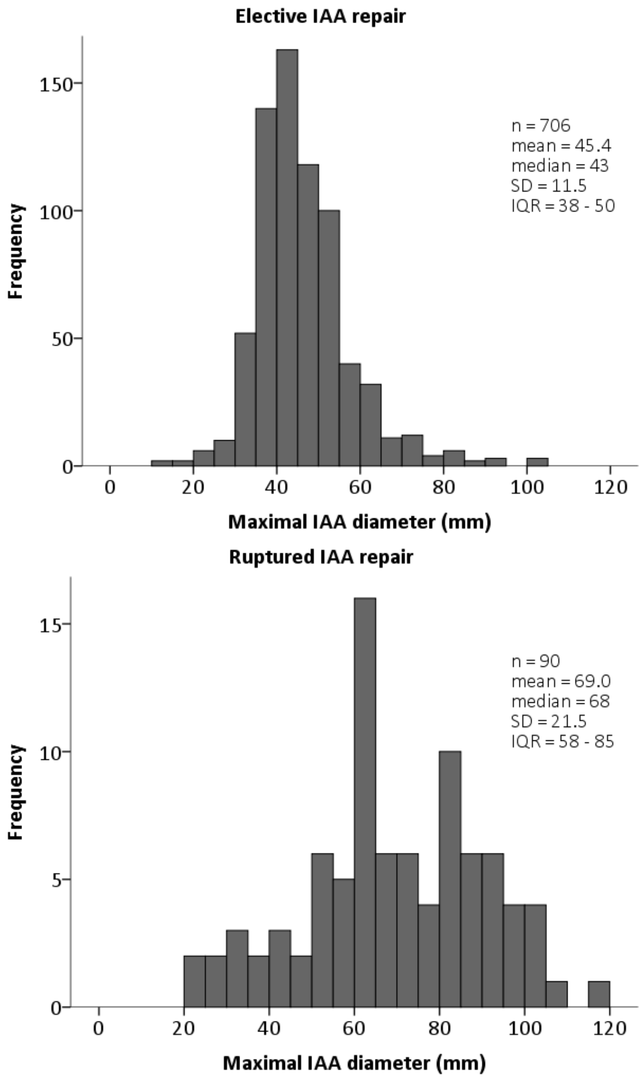

Figure 1. Distribution of IAA diameter at time of elective IAA repair and ruptured IAA repair

significantly different between OSR and EVAR subgroups (2.6% vs 0.9% respectively; p = 0.118). Complications occurred significantly more often after OSR compared to EVAR (intraoperative complications: 9.8% vs 3.6%, p = 0.005; postoperative complications: 34.0% vs 13.8%, p < 0.001). In total, 197 postoperative complications occurred in 130 patients (Table 2). The most frequent complications were arterial occlusions (in 25) and

Table 2. Postoperative outcomes after IAA repair

	Elective IAA repair			
	Total*	**EVAR**	**OSR**	**p value**
Mortality	9/713 (1.3%)	5/536 (0.9%)	4/154 (2.6%)	0.118
Patients with intraoperative Complications†	40/703 (5.7%)	19/527 (3.6%)	15/153 (9.8%)	0.005
Patients with postoperative complications†	130/712 (18.3%)	74/536 (13.8%)	52/153 (34.0%)	< 0.001
Postoperative complications	197	102	86	-
- Abdominal	23	5	16	-
- Arterial occlusion	25	16	9	-
- Prosthesis-related	15	15	0	-
- Wound	12	5	4	-
- Cardiac	18	9	8	-
- Pulmonary	23	8	15	-
- Neurological	11	5	5	-
- Renal	8	2	5	-
- Rebleeding	5	3	2	-
- Infection	12	7	5	-
- Other	45	27	17	-
Total admission days[X]	5.6 ± 20.7 3 (2 - 5)	4.5 ± 23.1 2 (2 - 3)	9.7 ± 10.3 7 (5 - 10)	<0.001
ICU admission days	0.9 ± 4.3 0 (0 - 1)	0.3 ± 2.1 0 (0 - 0)	2.8 ± 7.9 1 (1 - 2)	<0.001
Reinterventions within 30 days	46/455 (10.1%)	26/334 (7.8%)	19/101 (18.8%)	0.003
Readmissions	50/713 (7.0%)	38/536 (7.1%)	11/154 (7.1%)	1

* The 'Total' columns include other methods of repair than OSR and EVAR only (i.e. hybrid repair and primary conversion). † The sum of complications is more than the number of patients with complications. ▶

abdominal and pulmonary complications (both in 23). The number of hospital admission days were significantly higher after OSR (median 7 vs 2 days; p <0.001). Similar differences between OSR and EVAR were observed for ICU admission days (p < 0.001) and reintervention rates (p = 0.003; Table 2).

Ruptured IAA repair

Mortality after rIAA repair was 25.5% (26/102; 95% CI 18.0% - 34.7%). The difference between OSR and EVAR was not statistically significant (32.5% vs 17.5% respectively, p = 0.097). A total of 100 postoperative complications occurred in 57 patients. Intra- and postoperative complication rates were not statistically different between OSR and EVAR subgroups. However, the number of hospital admission days was significantly higher after

Ruptured IAA repair				Symptomatic IAA repair			
Total*	EVAR	OSR	p value	Total*	EVAR	OSR	p value
26/102 (25.5%)	10/57 (17.5%)	13/40 (32.5%)	0.097	2/36 (5.6%)	2/25 (8.0%)	0/11 (0%)	1
16/100 (16.0%)	7/56 (12.5%)	8/39 (20.5%)	0.392	1/36 (2.8%)	0/30 (0%)	1/11 (9.1%)	0.268
57/101 (56.4%)	27/56 (48.2%)	27/40 (67.5%)	0.065	12/36 (33.3%)	9/25 (36.0%)	3/11 (27.3%)	0.715
100	47	47	-	19	13	5	-
13	5	8	-	4	3	1	-
6	4	1	-	3	1	2	-
2	1	1	-	0	0	0	-
1	1	0	-	1	1	0	-
11	4	5	-	1	1	0	-
19	8	9	-	5	4	1	-
5	3	2	-	1	1	0	-
11	5	5	-	2	1	0	-
1	0	1	-	1	1	0	-
10	6	4	-	0	0	0	-
21	10	11	-	1	0	1	-
18.4 ± 44.6 8 (6 - 16)	19 ± 55.1 7 (5 - 13)	17.6 ± 20.3 10 (8 - 20)	0.003	8.7 ± 9.3 5 (2 - 11)	6.7 ± 9.5 3 (2 - 7)	12.9 ± 7.6 12 (7 - 19)	0.002
4.2 ± 9.4 2 (1 - 4)	3.0 ± 5.7 2 (1 - 3)	6.2 ± 13.3 2 (1 - 5)	0.067	1.7 ± 3.9 0 (0 - 2)	0.7 ± 1.8 0 (0 - 1)	4.0 ± 6.1 2 (1 - 3)	0.004
14/67 (24.1%)	7/37 (18.9%)	6/25 (24.0%)	0.753	2/27 (7.4%)	2/19 (10.5%)	0/8 (0%)	1
10/102 (9.8%)	5/57 (8.8%)	5/40 (12.5%)	0.736	3/36 (8.3%)	3/25 (12%)	0/11 (0%)	0.538

[x] Only includes patients surviving hospital stay. Continuous variables are presented as mean ± standard deviation and median (interquartile range).

OSR compared to EVAR (median 10 vs 7 days, p = 0.003). Outcomes after symptomatic (non-ruptured) IAA repair are also listed in Table 2. The small number of patients and events in the male and female subgroups did not allow other statistical assessments of mortality differences between men and women (Supplemental table 4).

Risk factors for mortality

None of the available baseline patient characteristics or preoperative measurements was associated with mortality after eIAA repair. The single measurement significantly associated with mortality after rIAA repair was preoperative serum creatinine (p = 0.003) (Supplemental table 5).

DISCUSSION

This nationwide analysis of surgery for IAA in the Netherlands demonstrated that elective IAA repair was carried out at a median maximal diameter of 43 mm. IAAs ruptured at a median maximal diameter of 68 mm. Mortality was 1.3% after elective repair and 25.5% after ruptured IAA repair. Mortality was not significantly different between OSR and EVAR subgroups. Patients undergoing elective OSR suffered from significantly more intra- and postoperative complications compared to patients undergoing elective EVAR.

With a median IAA diameter of 43 mm at time of elective repair, most patients in the Netherlands are electively operated when the recommended threshold diameter of 35 mm is exceeded. This appears to be safe, as the median IAA diameter at time of rupture is 2.5 cm larger than at time of elective repair. This also suggests that the threshold diameter for eIAA repair could be raised to larger diameters. Currently, only 10% of patients are operated before the IAA reaches a diameter of 35 mm. This is in line with practice in other countries. Boules et al. reported a mean diameter of 42 mm at time of elective repair in the United States between 1995 and 2004.[10] More recently, a survey among vascular surgeons from the United Kingdom revealed that two-third of surgeons would wait until a CIA aneurysm reached 40 mm in diameter before considering elective repair.[6]

The large difference between IAA diameter at time of eIAA repair and at time of rIAA repair supports the recent raise of the threshold diameter from 3.0 to 3.5 cm by the ESVS.[5] This is also confirmed when the current results are compared to previous AAA studies. A recent AAA study with DSAA data (of 1331 men) demonstrated that 8% of AAAs rupture below the threshold diameter of 5.5 cm.[11] If that 8th percentile would be translated to the current cohort of 90 ruptured IAAs, it would correspond to an IAA-equivalent diameter of 34 mm (Supplemental table 3). A 34-mm threshold for eIAA repair would result in 8% of IAAs rupturing below the threshold diameter. That would be equal to the currently accepted risk of rupture for AAA. This comparison between IAA and AAA only serves for hypothesis-generating purposes, and is only valid if the ratio between operation risk and rupture risk is similar for IAA and AAA. The peri-operative mortality risk in our study was 2.6% and 0.9% after elective OSR and EVAR respectively, which is slightly lower than the short-term mortality of 5.0 % and 0.9 % after elective OSR and EVAR of AAA in the Netherlands.[12] With regard to IAA rupture risk, evidence is unfortunately limited to very few studies that assessed expansion rates.[13,14] These studies did not detect sufficient ruptures to allow assessment of rupture risk. As randomized controlled trials on IAA are challenging to perform, evidence remains limited to observational studies and comparisons with similar conditions such as AAA.

A remarkable result of the current study was the good outcome after elective EVAR. Postoperative mortality was around 1%, and patients had significantly fewer complications and shorter hospital admissions compared to OSR. Our findings correspond to results from previous studies. Buck et al. consulted the Nationwide Inpatient Sample database from the United States (with 9016 elective EVARs for IAA) and demonstrated an in-hospital mortality of 0.5%, a complication rate of 6.7%, and a median hospital stay of 2.3 days after elective EVAR for isolated IAA.[2] Other smaller studies found similar results after EVAR and OSR.[10,15-18] However, as long-term outcomes after IAA repair are largely unknown, it remains premature to suggest an EVAR-first policy for all patients with suitable anatomy.

Strengths and limitations

The strength of this study lies in the large sample size and the national coverage. It is the largest study to date that has reported diameters at time of IAA repair. Nevertheless, this study is subject to some major limitations. As other retrospective studies using administrative databases, there is a possibility of coding errors and missing data. Furthermore, the included patients were registered for undergoing primary IAA repair, and not for undergoing isolated IAA repair. Therefore, the proportion of patients undergoing concomitant AAA repair is unknown. The unavailability of some relevant and interesting data was another limitation. This prevented us from characterizing the cohort in more detail. The most important unavailable variable was the aneurysm location – i.e. CIA, EIA or IIA. CIAs with normal anatomy have diameters that are two times larger than IAA.[19] Ideally, the suggested threshold diameter would therefore be tailored to aneurysms of specific iliac locations. Our current study could unfortunately not make this anatomic distinction – similar to the ESVS guideline that only provided recommendations for IAA in general.[5] Another limitation was posed by the low absolute mortality rates and some infrequent baseline variables (Supplemental table 2). As a consequence, we only identified one baseline characteristic (i.e. serum creatinine prior to rIAA repair) that was significantly associated with postoperative mortality. In addition, we were unable to carry out a multivariable logistic regression analysis that could identify independent risk factors for mortality. Another limitation was the fact that DSAA only consists of patients who have undergone repair. Diameters at time of rupture are therefore unknown for patients who are not operated for ruptured IAA. Furthermore, the DSAA only contains outcomes up to 30 days after IAA repair. Mid-term and long-term outcomes of this cohort are therefore unknown. Information on endoleaks, graft patency and reinterventions is needed to determine all benefits and harms of OSR and EVAR, which in turn are needed to determine the best treatment strategy for patients with IAA.

Future perspectives

Since no IAA-specific trials are expected in the near future, evidence for clinical management comes from the results of observational studies. Large registries that include both postoperative outcomes and IAA diameters could provide data for these future studies. With statistical methods such as standardization or inverse probability weighting, trials can be mimicked to estimate causal effects.[20] Yet, this would require a larger amount of patient-specific data than available for the current study. Furthermore, considering the positive outcomes after EVAR, more research should be conducted on improving EVAR-suitability. Future studies should also investigate the long-term outcomes after IAA repair – and EVAR specifically – since the long-term outcomes after IAA repair are unknown.

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Collaborators

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SUPPLEMENTS

Supplemental table 1. Definitions of complications registered in the DSAA registry

Abdominal	Abdominal abscess, abdominal sepsis, ileus, spleen injury, bowel ischemia, bowel injury, stoma placement, other abdominal complications
Arterial occlusion	(major) amputation, renal artery occlusion, other arterial occlusion (including trash foot)
Prosthesis-/reconstruction related	Prosthesis infection, Prosthesis migration, other prosthesis-/reconstruction related complications
Wound	Deep wound infection, fascia dehiscence, other wound complications
Cardiac	Myocardial infarction, cardiac decompensation (failure), cardiac rhythm disturbances, other cardiac complications
Pulmonary	Pneumonia, pulmonary embolism, pneumothorax, other pulmonary complications
Neurological	Cerebrovascular accident, paraplegia, delirium, other neurological complications
Renal	Renal insufficiency requiring hemodialysis
Rebleeding	Rebleeding
Infection	Infections other than pulmonary and surgical
Other	Other postoperative complications

Supplemental table 2. Patient characteristics according to POSSUM

	Total (n = 851)	**Elective (n = 713)**	**Rupture (n = 102)**	**Symptomatic (n = 36)**
Age				
- <61	82 (9.6%)	72 (10.1%)	5 (4.9%)	5 (13.9%)
- 61 - 70	275 (32.3%)	238 (33.4%)	28 (27.5%)	9 (25%)
- >70	494 (58.0%)	403 (56.5%)	69 (67.6%)	22 (61.1%)
- Missing (%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Cardiac disease				
- No abnormalities	385 (45.2%)	326 (45.7%)	43 (42.2%)	16 (44.4%)
- Diuretic, digoxin, med. for angina or hypertension	357 (42.0%)	304 (42.6%)	39 (38.2%)	14 (38.9%)
- Peripheral oedema, warfarin, borderline cardiomegaly	73 (8.6%)	60 (8.4%)	10 (9.8%)	3 (8.3%)
- Raised JVP, cardiomegaly	17 (2.0%)	14 (2.0%)	1 (1.0%)	2 (5.6)
- Missing (%)	19 (2.%)	9 (1.3%)	9 (8.8%)	1 (2.8%)
Pulmonary disease				
- No dyspnoea	655 (77.0%)	554 (77.7%)	76 (74.5%)	25 (69.4%)
- Dyspnoea during exercise	141 (16.6%)	124 (17.4%)	11 (10.8%)	6 (16.7%)
- Disabling dyspnoea	26 (3.1%)	25 (3.5%)	1 (1.0%)	0 (0%)
- Dyspnoea at rest	6 (0.7%)	4 (0.6%)	1 (1.0%)	1 (2.8%)
- Missing (%)	23 (2.7%)	6 (0.8%)	13 (12.7%)	4 (11.1%)
Preoperative ECG				
- No abnormalities	401 (47.1%)	355 (49.8%)	33 (32.4%)	13 (36.1%)
- Atrial fibrillation	66 (7.8%)	53 (7.4%)	9 (8.8%)	4 (11.1%)
- Other abnormal rhythm, Q or ST/T wave changes	276 (32.2%)	232 (32.5%)	34 (33.3%)	10 (27.8%)
- No preoperative ECG done	105 (12.3%)	72 (10.1%)	25 (24.5%)	8 (22.2%)
- Missing (%)	3 (0.4%)	1 (0.1%)	1 (1.0%)	1 (2.8%)

	Total (n = 851)	Elective (n = 713)	Rupture (n = 102)	Symptomatic (n = 36)
Systolic BP (mmHg)				
- 110 - 129	206 (24.2%)	181 (25.4%)	17 (16.7%)	8 (22.2%)
- 130 - 170 or 100 - 109	522 (61.3%)	466 (65.4)	34 (33.3%)	22 (61.1%)
- >170 or 90 - 99	62 (7.3%)	42 (5.9%)	17 (16.7%)	3 (8.3%)
- <90	31 (3.6%)	2 (0.3%)	28 (27.5%)	1 (2.8%)
- Missing (%)	30 (3.5%)	22 (3.1%)	6 (5.9%)	2 (5.6%)
Pulse rate (bpm)				
- 50 - 80	522 (64.9%)	495 (69.4%)	36 (35.3)	21 (58.3%)
- 81 - 100 or 40 - 49	213 (25.0%)	167 (23.4%)	32 (31.4%)	14 (38.9%)
- 101 - 120	37 (4.3%)	20 (2.8%)	17 (16.7%)	0 (0%)
- >120 or <40	9 (1.1%)	3 (0.4%)	6 (5.9%)	0 (0%)
- Missing (%)	40 (4.7%)	28 (3.9%)	11 (10.8%)	1 (2.8%)
Haemoglobin (g/dl)				
- 13.0 - 16.0	522 (61.3%)	479 (67.2%)	22 (21.6%)	21 (58.3%)
- 11.5 - 12.9 or 16.1 - 17.0	193 (22.7%)	155 (21.7%)	30 (29.4%)	8 (22.2%)
- 10.0 - 11.4 or 17.1 - 18.0	65 (7.6%)	38 (5.3%)	23 (22.5%)	4 (11.1%)
- <10.0 or >18.0	56 (6.6%)	28 (3.9%)	25 (24.5%)	3 (8.3%)
- Missing (%)	15 (1.8%)	13 (1.8%)	2 (2.0%)	0 (0.0%)
WBC count (/nL)				
- 4.0 - 10.0	397 (46.7%)	354 (49.6%)	25 (24.5%)	18 (50.0%)
- 10.1 - 20.0 or 3.1 - 3.9	169 (19.9%)	97 (13.6%)	60 (58.8%)	12 (33.3%)
- >20.0 or <3.1	20 (2.4%)	3 (0.4%)	13 (12.7%)	4 (11.1%)
- Missing (%)	265 (31.1%)	259 (36.3%)	4 (3.9%)	2 (5.6%)
Sodium (mmol/L)				
- >135	728 (85.5%)	618 (86.7%)	79 (77.5%)	31 (86.1%)
- 131 - 135	50 (5.9%)	30 (4.2%)	16 (15.7%)	4 (11.1%)
- 126 - 130	5 (0.6%)	2 (0.3%)	3 (2.9%)	0 (0%)
- <126	3 (0.4%)	2 (0.3%)	0 (0%)	1 (2.8%)
- Missing (%)	65 (7.6%)	5 (8.6%)	4 (3.9%)	0 (0%)
Potassium (mmol/L)				
- 3.5 - 5.0	747 (87.8%)	637 (89.3%)	78 (76.5%)	32 (88.9%)
- 3.1 - 3.4 or 5.1 - 5.3	40 (4.7%)	25 (3.5%)	12 (11.8%)	3 (8.3%)
- 2.9 - 3.1 or 5.4 - 5.9	11 (1.3%)	5 (0.7%)	5 (4.9%)	1 (2.8%)
- <2.9 or >5.9	3 (0.4%)	1 (0.1%)	2 (2.0%)	0 (0%)
- Missing (%)	50 (5.9%)	45 (6.3%)	5 (4.9%)	0 (0%)
Glasgow Coma Scale				
- 15	794 (93.3%)	689 (96.6%)	73 (71.6%)	32 (88.9%)
- 12 - 14	19 (2.2%)	3 (0.4%)	14 (13.7%)	2 (5.6%)
- 9 - 11	1 (0.1%)	0 (0%)	1 (1.0%)	0 (0%)
- <9	7 (0.8%)	2 (0.3%)	5 (4.9%)	0 (0%)
- Missing (%)	30 (3.5%)	19 (2.7%)	9 (8.8%)	2 (5.6%)

Percentages for missing data are based on the total sample. EVAR = endovascular aneurysm repair, ECG = electrocardiogram, BP = blood pressure, WBC = white blood cell, bpm = beats per minute.
Urea is also an item of the physiological POSSUM score but was not available in the DSAA registry.

Supplemental table 3. Distribution of IAA diameter at time of elective IAA repair and ruptured IAA repair

IAA diameter (mm)	Elective IAA repair, n (%)		Ruptured IAA repair, n (%)	
	Per diameter category	Cumulative	Per diameter category	Cumulative
< 20	4 (0.6%)	4 (0.6%)	0 (0.0%)	0 (0%)
20 - 24	6 (0.9%)	10 (1.4%)	2 (2.2%)	2 (2.2%)
25 - 29	10 (1.4%)	20 (2.8%)	2 (2.2%)	4 (4.4%)
30 - 34	52 (7.4%)	72 (10.2%)	3 (3.3%)	7 (7.8%)
35 - 39	140 (19.9%)	212 (30.0%)	2 (2.2%)	9 (10.0%)
40 - 44	163 (23.1%)	375 (53.1%)	3 (3.3%)	12 (13.3%)
45 - 49	118 (16.7%)	493 (69.8%)	2 (2.2%)	14 (15.6%)
50 - 54	100 (14.2%)	593 (84.0%)	6 (6.7%)	20 (22.2%)
55 - 59	40 (5.7%)	633 (89.7%)	5 (5.6%)	25 (27.8%)
60 - 64	32 (4.5%)	665 (94.2%)	16 (17.8%)	41 (45.6%)
65 - 69	11 (1.6%)	676 (95.8%)	6 (6.7%)	47 (52.2%)
70 - 74	12 (1.7%)	688 (97.5%)	6 (6.7%)	53 (58.9%)
75 - 79	4 (0.6%)	692 (98.0%)	4 (4.4%)	57 (63.3%)
80 - 84	6 (0.9%)	698 (98.9%)	10 (11.1%)	67 (74.4%)
85 - 89	2 (0.3%)	700 (99.2%)	6 (6.7%)	73 (81.1%)
90 - 94	3 (0.4%)	703 (99.6%)	6 (6.7%)	79 (87.8%)
95 - 99	0 (0.0%)	703 (99.6%)	4 (4.4%)	83 (92.2%)
100 - 104	3 (0.4%)	706 (100.0%)	4 (4.4%)	87 (96.7%)
105 - 109	0 (0.0%)	706 (100.0%)	1 (1.1%)	88 (97.8%)
110 - 114	0 (0.0%)	706 (100.0%)	0 (0.0%)	88 (97.8%)
115 - 119	0 (0.0%)	706 (100.0%)	1 (1.1%)	89 (98.9%)
≥ 120	0 (0.0%)	706 (100.0%)	1 (1.1%)	90 (100%)
Total	706 (100%)	706 (100.0%)	90 (100%)	90 (100%)

Supplemental table 4. Mortality stratified by sex

	Total	Men	Women	p-value
Elective IAA repair				
- total	9/713 (1.3%)	8/656 (1.2%)	1/57 (1.8%)	n.s.
- EVAR	5/536 (0.9%)	5/502 (1.0%)	0/34 (0%)	n.s.
- OSR	4/154 (2.6%)	3/132 (2.3%)	1/22 (4.5%)	n.s.
Ruptured IAA repair				
- total	26/102 (25.5%)	25/91 (27.5%)	1/11 (9.1%)	n.s.
- EVAR	10/57 (17.5%)	10/51 (19.6%)	0/6 (0%)	n.s.
- OSR	13/40 (32.5%)	12/35 (34.3%)	1/5 (20.0%)	n.s.

n.s.: not significant

Supplemental table 5. Differences between survivors and non-survivors

	Elective IAA repair			Ruptured IAA repair		
	Survivors	Non-survivors	p-value	Survivors	Non-survivors	p-value
Age	71.2 ± 8.8	76.0 ± 5.6	0.08	73.3 ± 8.5	76.1 ± 8.5	0.16
Female sex	56/704	1/9	0.53	10/76	1/26	0.28
Cardiac history	371/695	7/9	0.19	34/69	16/24	0.16
Respiratory history	149/698	4/9	0.11	9/71	4/18	0.29
Malignancy, present or previous	143/704	1/9	0.70	5/72	5/26	0.12
Systolic blood pressure (mmHg)	138.3 ± 18.9	142.7±31.3	0.24	117.3 ± 36.5	104.5 ± 39.2	0.14
Pulse rate (per minute)	73.0 ± 13.6	72.7±26.5	0.25	87.2 ± 21.1	92.7 ± 26.2	0.38
Preoperative serum haemoglobin (mmol/L)	8.7 ± 1.0	8.7 ± 1.0	0.79	7.3 ± 1.2	6.5 ± 1.4	0.07
Preoperative serum creatinine (µmol/L)	99.9 ± 60.8	101.2 ± 20.7	0.15	115.3 ± 40.1	162.8 ± 80.1	0.003
IAA diameter at time of repair	45.3 ± 11.5	50.4 ± 10.2	0.10	68.6 ± 21.5	70.4 ± 22.0	0.76

Continuous values are reported as mean ± standard deviation. Statistical significance was tested with the Fisher's exact test, Mann Whitney U test, or unpaired t-test.