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## NATIONAL REGISTRY

# Treatment Outcome Trends for Non-Ruptured Abdominal Aortic Aneurysms: A Nationwide Prospective Cohort Study

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## WHAT THIS PAPER ADDS

This paper provides an overview of trends in peri-operative outcomes of patients who underwent standard endovascular aneurysm repair (EVAR) or open surgical repair (OSR) for an intact abdominal aortic aneurysm between 2014 and 2019 and who were registered in a mandatory nationwide registry. This study shows that all peri-operative outcomes (mortality, major complications, and textbook outcome) of EVAR and OSR for intact abdominal aortic aneurysms have improved since 2014, except for peri-operative mortality following EVAR which remained unchanged.

**Objective:** The Dutch Surgical Aneurysm Audit (DSAA) initiative was established in 2013 to monitor and improve nationwide outcomes of aortic aneurysm surgery. The objective of this study was to examine whether outcomes of surgery for intact abdominal aortic aneurysms (iAAA) have improved over time.

**Methods:** Patients who underwent primary repair of an iAAA by standard endovascular (EVAR) or open surgical repair (OSR) between 2014 and 2019 were selected from the DSAA for inclusion. The primary outcome was peri-operative mortality trend per year, stratified by OSR and EVAR. Secondary outcomes were trends per year in major complications, textbook outcome (TbO), and characteristics of treated patients. The trends per year were evaluated and reported in odds ratios per year.

**Results:** In this study, 11 624 patients (74.8%) underwent EVAR and 3 908 patients (25.2%) underwent OSR. For EVAR, after adjustment for confounding factors, there was no improvement in peri-operative mortality (aOR [adjusted odds ratio] 1.06, 95% CI 0.94 – 1.20), while major complications decreased (2014: 10.1%, 2019: 7.0%; aOR 0.91, 95% CI 0.88 – 0.95) and the TbO rate increased (2014: 68.1%, 2019: 80.9%; aOR 1.13, 95% CI 1.10 – 1.16). For OSR, the peri-operative mortality decreased (2014: 6.1%, 2019: 4.6%; aOR 0.89, 95% CI 0.82 – 0.98), as well as major complications (2014: 28.6%, 2019: 23.3%; aOR 0.95, 95% CI 0.91 – 0.99). Furthermore, the proportion of TbO increased (2014: 49.1%, 2019: 58.3%; aOR 1.05, 95% CI 1.01 – 1.10). In both the EVAR and OSR group, the proportion of patients with cardiac comorbidity increased.

**Conclusion:** Since the establishment of this nationwide quality improvement initiative (DSAA), all outcomes of iAAA repair following EVAR and OSR have improved, except for peri-operative mortality following EVAR which remained unchanged.

**Keywords:** Abdominal aortic aneurysm, Endovascular procedure, Operative procedure, Quality of care, Treatment outcome, Trends

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## INTRODUCTION

As a result of endovascular aneurysm repair (EVAR), the management of intact abdominal aortic aneurysms (iAAA) has changed dramatically in the last decades resulting in improved peri-operative outcomes.<sup>1</sup> Since the first EVAR was performed in the 1990s, many patients with suitable anatomy have received EVAR rather than open surgical repair (OSR) because of the lower peri-operative risks of EVAR,<sup>2</sup> with a subsequent decrease in the number of patients treated by OSR.<sup>2–5</sup> Furthermore, frail patients can receive EVAR rather than conservative treatment.<sup>6</sup> These changes in treatment strategy probably have resulted in fewer OSRs per hospital, which may have negatively influenced the outcomes of OSR.<sup>7</sup>

Previous studies have reported trends in the management and outcomes of iAAA repair. A study of an international cohort of vascular registries that described trends in the management and outcomes of iAAA repair from 2005 up to 2013 reported an overall decrease of peri-operative mortality from 3.0% to 2.4% while the peri-operative mortality after OSR increased from 3.9% to 4.4%.<sup>8</sup> Although this international study reported numerous patient outcomes, many of the registries included patients on a voluntary basis.<sup>9</sup> Furthermore, Swedvasc, the Swedish national vascular registry, reported a decrease in 30 day mortality rates following OSR (3.1% in 2006 – 2011, 2.5% in 2012 – 2016).<sup>2</sup> To date however, no studies have examined the most recent trends in the management and outcomes of iAAA repair, reflecting real world nationwide data.

The Dutch Surgical Aneurysm Audit (DSAA) is a mandatory quality registry for all aortic aneurysm repairs performed by vascular surgeons in The Netherlands, established in 2013, to monitor and improve the outcomes of the treatment of abdominal aortic aneurysms (AAAs). In the DSAA, all hospitals that perform AAA repair have insight into their results, using quality indicators, with other hospitals presented anonymously with a 95% confidence interval around the national average for comparison. In this way, internal feedback on the performance of hospitals is provided.<sup>10,11</sup> Although audit and feedback generally lead to small but potentially important improvements in professional practice,<sup>12</sup> it is not known yet whether the outcomes of iAAA repair have improved in The Netherlands since the establishment of the DSAA.

The aim of this study was to evaluate whether national outcomes of iAAA repair have improved since the establishment of the DSAA. Furthermore, changes in patient selection, hospital volumes, and preferred operative technique since 2014 were investigated.

## METHODS

This was a retrospective nationwide study of patients who underwent repair of an iAAA in The Netherlands. The study followed the STROBE statement.<sup>13</sup>

### Data source

The dataset was retrieved from the DSAA, a prospective registered compulsory quality registry for all aortic

aneurysm repairs performed by vascular surgeons in The Netherlands. The DSAA was established in 2013 and started by registering all Dutch patients undergoing infrarenal and juxtarenal AAA repair without previous aortic surgery. Since 2016, complex endovascular aneurysm repair, thoracic aortic aneurysm repair, and revision surgery have been registered. Data verification took place over 2015 through a random sample of hospitals showing a case ascertainment of 98.4% and no discrepancies in deaths or re-interventions.<sup>14,15</sup> Data verification will be repeated in the near future.

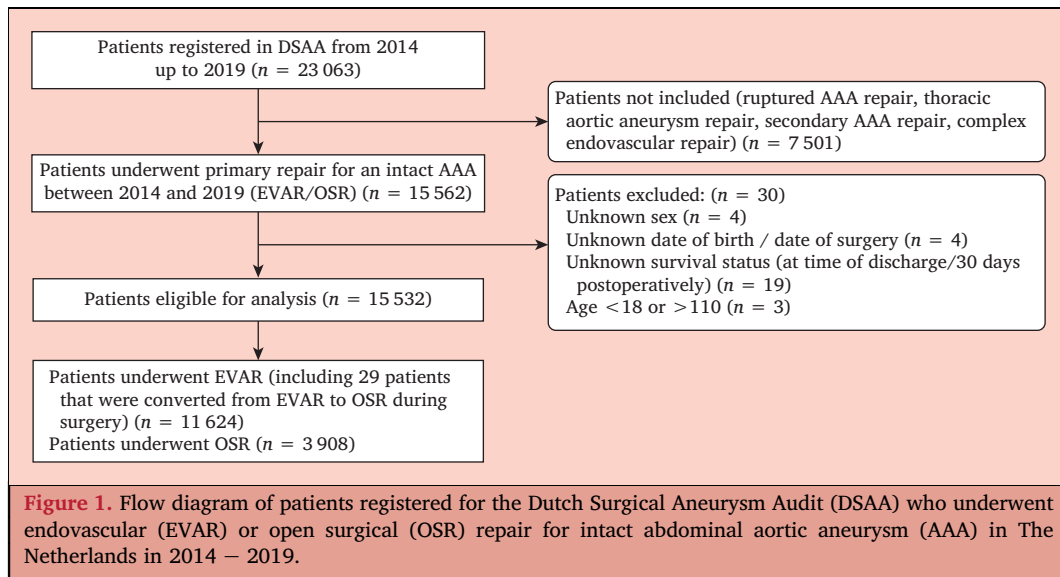
### Participants

All consecutive participants that were registered in the DSAA and underwent primary iAAA repair using either standard EVAR or OSR, between January 2014 and December 2019 were included. Patients with missing data on variables date of birth, date of surgery, sex, and survival status at the time of discharge or 30 days post-operatively, as well as patients aged < 18 or > 110 years were excluded. No ethical approval or informed consent was required for this study according to Dutch law. No distinction exists between private and public healthcare in The Netherlands.

### Definitions

Intact AAA repairs included both electively treated aneurysms and aneurysms that caused symptoms. Aneurysm treatments were categorised by intention to treat; attempts at endovascular treatment for aneurysms that were converted from EVAR to OSR during surgery were categorised as EVAR. The variables “pulmonary comorbidity” and “cardiac comorbidity” were dichotomised per patient into categories “present” or “absent”. From 2014 to 2018, the variables regarding pulmonary and cardiac comorbidities were based on parameters from the V-POSSUM,<sup>16</sup> while from 2019, “pulmonary comorbidity” and “cardiac comorbidity” were based on ICD-10 codes (Supplementary Table S1). During the study period, some hospitals have been merged. When hospitals have been merged during the study, the hospitals were classified as one hospital in the years before the merger.

**Outcomes.** The primary outcome was the peri-operative mortality trend per year (30 day mortality and in hospital mortality). Secondary outcomes were trends per year in the outcomes major complications and textbook outcome (TbO), and trends per year in patient characteristics, hospital volume, and applied surgical technique (OSR or EVAR). As described before,<sup>17,18</sup> major complications were defined as either intra-operative complications or peri-operative complications within 30 days that caused a prolonged stay (length of hospital stay above the 75th percentile of living patients registered in the DSAA, stratified by OSR, EVAR, elective, or symptomatic [thresholds: EVAR, elective > 3 days; EVAR, symptomatic > 7 days; OSR, elective > 12 days; OSR, symptomatic > 14 days]), intra-operative complications or peri-operative complications that caused a re-



intervention or death. The specific complications included in the categories of peri-operative complications that were included in the DSAA are shown in the [Supplementary Table S3](#). TbO is a desirable composite outcome measure that provides information on the overall quality of care that can be used for internal quality improvement,<sup>19–22</sup> and could be valuable in shared decision making processes. As described by Karthaus *et al.*,<sup>21</sup> TbO is achieved in the elective setting if no intra-operative or post-operative surgical complications, no re-interventions, no prolonged stay ( $\leq 4$  days for EVAR,  $\leq 10$  days for OSR), no re-admissions and no peri-operative mortality occur within 30 days.

### Statistical methods

Firstly, descriptive statistics of outcomes per year were shown for both EVAR and OSR patients together, as well as separately. To examine the linear time trends per year for outcomes, univariable as well as multivariable logistic

regression analyses, using known confounders “sex”, “age”, “pulmonary comorbidity”, “cardiac comorbidity”, “haemoglobin”, “creatinine”, “urgency”, “aneurysm diameter”, and “aneurysm location” were performed. For these multivariable analyses, the missing values of categorical variables were included in the models as separate categories. Missing values of continuous variables were not included in the multivariable analyses as these were  $< 5\%$ . Because of the low missing value rate, it was decided not to impute these using multiple imputation. Secondly, linear time trends per year of patient characteristics were examined from 2014 to 2019 using univariable logistic and linear regression analyses for dichotomous variables and continuous variables, respectively. Trends per year regarding hospitals that treated fewer than 30 patients per year and number of hospitals were examined using univariable linear regression analyses. Additionally, the trends regarding hospital volume were shown using boxplots. For linear regression analyses,

**Table 1.** Univariable and multivariable logistic regression analyses to examine the trend in outcomes per year of all 15 532 patients who underwent endovascular (EVAR) or open surgical (OSR) repair for intact abdominal aortic aneurysm in The Netherlands

Outcome	2014 (n = 2 753)	2015 (n = 2 709)	2016 (n = 2 655)	2017 (n = 2 481)	2018 (n = 2 489)	2019 (n = 2 445)	OR per year (95% CI) (ref: 2014)
Peri-operative mortality <sup>†</sup>	62 (2.3)	61 (2.3)	52 (2.0)	50 (2.0)	42 (1.7)	55 (2.2)	
Univariable							0.98 (0.91–1.04)
Multivariable*							0.95 (0.89–1.02)
Major complications <sup>‡</sup>	405 (14.7)	350 (12.9)	332 (12.5)	318 (12.8)	296 (11.9)	288 (11.8)	
Univariable							0.95 (0.93–0.98)
Multivariable*							0.93 (0.90–0.96)

Data are presented as n (%), unless stated otherwise. Missing values of dichotomous variables were added as separate categories to the multivariable models (number of missing values for variable cardiac comorbidity: 400 patients [2.6%], number of missing values for the variable, pulmonary comorbidity: 275 patients [1.8%]).

\* Multivariable analysis: type of surgery, sex, age, pulmonary history, cardiac history, creatinine (per 10  $\mu\text{mol/L}$ ), haemoglobin, diameter of the aneurysm (per 10 mm), urgency, location of aneurysm (abdominal or aorto-iliac).

<sup>†</sup> Peri-operative mortality: 30 day mortality and in hospital mortality.

<sup>‡</sup> Major complication: post-operative death or an intra-operative or post-operative complication leading to a re-intervention or prolonged hospital stay. Prolonged hospital stay: EVAR, elective repair:  $> 3$  days, EVAR, repair for a symptomatic AAA:  $> 7$  days, OSR, elective repair:  $> 12$  days, OSR, repair for a symptomatic AAA:  $> 14$  days.

**Table 2.** Details of the peri-operative complications that are defined as a major complication, stratified per category of peri-operative complications of 15 532 patients who underwent endovascular (EVAR) or open surgical (OSR) repair for intact abdominal aortic aneurysm

	All patients (n = 15 532)	EVAR (n = 11 624)	OSR (n = 3 908)
Patients with major complication	1 989	1 030	959
Abdominal	448 (22.5)	117 (11.4)	331 (34.5)
Neurological	191 (9.6)	82 (8.0)	109 (11.4)
Pulmonary	491 (24.2)	163 (15.8)	328 (34.2)
Cardiac	340 (17.1)	125 (12.1)	215 (22.4)
Reconstruction	110 (5.5)	74 (7.2)	36 (3.8)
Re-bleeding	176 (8.8)	95 (9.2)	81 (8.4)
Renal	257 (12.9)	64 (6.2)	193 (20.1)
Wound	153 (7.7)	65 (6.3)	88 (9.2)
Arterial occlusion	310 (15.6)	170 (16.5)	140 (14.6)
Infection	252 (12.7)	112 (10.9)	140 (14.6)
Other	491 (24.7)	279 (27.1)	212 (22.1)

Data are presented as n (%). Patients can suffer from more than one complication. Specific complications included in the categories of peri-operative complications are detailed in the [Supplementary Table S3](#).

the beta coefficients, including 95% confidence intervals, were reported. For logistic regression analyses, the odds ratios, the exponent of the beta coefficient, including 95% confidence intervals, were reported. All analyses were performed using R version 4.0.1.

## RESULTS

A total of 23 063 patients (2 587 - 4 176 patients per year) were registered in the DSAA between January 2014 and December 2019. Of these, 15 562 patients treated in 61 hospitals underwent EVAR or OSR for a primary iAAA, of whom 15 532 (99.8%) were eligible (2 445 - 2 753 patients per year) and 30 (0.2%) were excluded ([Fig. 1](#)). The 7 501 patients who were not included in this study underwent ruptured AAA repair, thoracic aortic aneurysm repair, secondary AAA repair, or complex endovascular repair.

### Time trends in peri-operative outcomes

**All patients.** [Table 1](#) shows that the peri-operative mortality of all patients included in this study remained stable (aOR 0.95; 95% CI 0.89 - 1.02). In 2019, the crude peri-operative mortality of all patients was 2.2%. The crude percentage of major complications decreased after correction for confounders, from 14.7% in 2014 up to 11.8% in 2019. Details of the peri-operative complications that are defined as a major complication are shown in [Table 2](#).

**Open surgical repair patients and endovascular aneurysm repair patients.** In [Table 3](#), time trends in peri-operative outcomes per year of EVAR patients and OSR patients are shown. In EVAR patients, no linear mortality time trend was found (1.0% in 2014; 1.3% in 2019). Major complications decreased from 10.1% in 2014 to 7.0% in 2019. TbO

increased from 68.1% in 2014 to 80.9% in 2019. For OSR patients, mortality decreased from 6.1% in 2014 to 4.6% in 2019. The percentage of major complications decreased after adjustment for confounders, from 28.6% in 2014 to 23.3% in 2019. The TbO rate increased from 49.1% in 2014 to 58.3% in 2019.

### Time trends in patient characteristics

**All patients.** Patient characteristic time trends of all patients, EVAR patients, and OSR patients are shown in [Table 4](#) and [Supplementary Table S2](#). In the group that describes all EVAR and OSR patients, the proportion of patients with cardiac comorbidity increased from 2014 to 2019.

**Open surgical repair patients and endovascular aneurysm repair patients.** [Table 4](#) and [Supplementary Table S2](#) show that the mean age of EVAR patients increased from 2014, whereas it did not in OSR patients. Moreover, both in EVAR patients and OSR patients, the proportion of patients with cardiac comorbidity increased (EVAR: 50.6% in 2014 to 77.4% in 2019; OSR: 47.0% in 2014 to 75.9% in 2019), while the proportion of patients with pulmonary comorbidity remained stable (EVAR: 22.4% in 2014 and 24.8% in 2019; OSR: 22.4% in 2014 and 26.0% in 2019), and the mean aneurysm diameter decreased since 2014 (EVAR: 60.4 mm in 2014 to 59.0 mm in 2019; OSR: 63.8 mm in 2014 to 61.6 mm in 2019). The proportion of patients treated for an AAA below the ESVS guideline diameter threshold of 55 mm for men, 50 mm for women<sup>23</sup> was stable (EVAR: 16.0% in 2014 and 13.5% in 2019, OR 1.00, 95% CI 0.99 - 1.00; OSR: 13.2% in 2014 and 12.1% in 2019, OR 1.00, 95% CI 0.99 - 1.00). In EVAR patients, aneurysms were increasingly treated in symptomatic settings (5.9% in 2014 to 8.0% in 2019), while in OSR patients, the reverse applied (14.3% in 2014 to 12.9% in 2019). In both EVAR and OSR patients, the mortality of patients treated in elective settings was lower compared with patients treated in symptomatic settings (EVAR: 0.7% vs. 4.1%,  $p < .001$ , OSR: 4.9% vs. 8.7%,  $p < .001$ ). Additional analysis regarding the proximal clamp location was performed in OSR patients. OSR did not seem to be more complex over the years, as the proximal clamp location (suprarenal vs. infrarenal, only registered from 2016) did not change over time (suprarenal clamp 30.9% in 2016, 31.4% in 2019; OR 1.02, 95% CI 0.95 - 1.10; not shown in [Table 4](#)).

### Time trends in the application of surgical techniques

[Table 3](#) and [Figure 2](#) show the number of patients that received standard EVAR and OSR. Complex EVAR (fenestrated EVAR, chimney EVAR, and iliac branched devices [IBD]), which was registered in the DSAA from 2016, was shown to provide a complete overview of trends in the application of surgical techniques. In 2014 and 2015, the numbers of patients that underwent OSR were 683 (24.8%) and 585 (21.6%) per year, respectively. From 2016, the percentage of patients that underwent OSR increased from 23.2% in 2016 to 26.8% in 2019 (OR 1.07, 95% CI 1.03 -

**Table 3.** Univariable and multivariable logistic regression analyses to examine the trend in outcomes per year, stratified for endovascular (EVAR) and open surgical (OSR) aneurysm repair of intact abdominal aortic aneurysm in a total of 15 532 patients

	2014	2015	2016	2017	2018	2019	OR per year (95% CI) (ref: 2014)
<i>EVAR patients – n</i>	2 070	2 124	2 003	1 860	1 833	1 734	
<i>Peri-operative mortality</i> <sup>†</sup>	20 (1.0)	18 (0.8)	15 (0.7)	21 (1.1)	16 (0.9)	22 (1.3)	
Univariable							1.06 (0.95–1.18)
Multivariable <sup>*</sup>							1.06 (0.94–1.20)
<i>Major complications</i> <sup>‡</sup>	210 (10.1)	202 (9.5)	181 (9.0)	171 (7.2)	144 (7.9)	122 (7.0)	
Univariable							0.93 (0.89–0.97)
Multivariable <sup>*</sup>							0.91 (0.88–0.95)
<i>Textbook outcome, elective</i> <sup>§</sup>	1 326/1 948 (68.1)	1 498/1 962 (76.4)	1 380/1 813 (76.1)	1 330/1 689 (78.7)	1 333/1 682 (79.3)	1 291/1 596 (80.9)	
Univariable							1.13 (1.10–1.16)
Multivariable <sup>*</sup>							1.13 (1.10–1.16)
<i>OSR patients – n</i>	683	585	652	621	656	711	
<i>Peri-operative mortality</i> <sup>†</sup>	42 (6.1)	43 (7.4)	37 (5.7)	29 (4.7)	26 (4.0)	33 (4.6)	
Univariable							0.90 (0.83–0.98)
Multivariable <sup>*</sup>							0.89 (0.82–0.98)
<i>Major complications</i> <sup>‡</sup>	195 (28.6)	148 (25.3)	151 (23.2)	147 (23.7)	152 (23.2)	166 (23.3)	
Univariable							0.95 (0.91–0.99)
Multivariable <sup>*</sup>							0.95 (0.91–0.99)
<i>Textbook outcome, elective</i> <sup>§</sup>	287/585 (49.1)	291/499 (58.3)	318/550 (57.8)	291/532 (54.7)	337/593 (56.8)	361/619 (58.3)	
Univariable							1.05 (1.01–1.09)
Multivariable <sup>*</sup>							1.05 (1.01–1.10)

Data are presented as *n* (%), unless stated otherwise. OR = odds ratio. CI = confidence interval. Missing values of dichotomous variables were added as separate categories to the multivariable models (EVAR patients: number of missing values for variable cardiac comorbidity: 308 patients [2.6%], variable pulmonary comorbidity: 185 patients [1.6%], OSR patients: variable cardiac comorbidity: 92 patients [2.4%], variable pulmonary comorbidity: 90 patients [2.3%]).

\* Multivariable analysis: sex, age, pulmonary history, cardiac history, creatinine (per 10 mmol/L), haemoglobin, aneurysm diameter (per 10 mm), urgency, location of aneurysm.

<sup>†</sup> Peri-operative mortality: 30 day mortality and in hospital mortality.

<sup>‡</sup> Major complication: post-operative death or an intra-operative or post-operative complication leading to a re-intervention or prolonged hospital stay. Prolonged hospital stay: EVAR, elective repair: > 3 days, EVAR, repair for a symptomatic AAA: > 7 days, OSR, elective repair: > 12 days, OSR, repair for a symptomatic AAA: > 14 days.

<sup>§</sup> Textbook outcome: desirable composite outcome measure that could be achieved in the elective setting if no intra-operative or post-operative surgical complications, no re-interventions, no prolonged stay ( $\leq 4$  days for EVAR,  $\leq 10$  days for OSR), no re-admissions and no peri-operative mortality occurred within 30 days.

1.11, ref: 2016). Moreover, the percentage of patients that underwent standard EVAR decreased compared with the percentage of patients that underwent OSR and complex EVAR (standard EVAR: 71.1% in 2016, 65.3% in 2019, OR 0.91, 95% CI 0.88 – 0.95).

### Time trends in total volume, number of hospitals, and hospital volume

**Total volume per year and number of hospitals.** Table 5 shows the total number of patients per year, including patients that received complex EVAR from 2016. From 2016, the total number of patients per year appears to decline, from 2 814 patients in 2016 to 2 647 patients in 2019. Five hospitals stopped performing AAA surgery (from 61 to 56 hospitals), and another six hospitals merged into three hospitals during the study period (not shown in Table 4).

**Hospital volume.** The number of patients treated per hospital (hospital volume) did not change statistically over the years ( $\beta$  coefficient 0.59, 95% CI -0.75 – 1.94). As shown in Figure 3A, in 2014, the median hospital volume

was 40 (IQR 26, 58), while in 2019, the median hospital volume was 42 (IQR 34, 56.5). The number of hospitals that treated fewer than 30 patients per year decreased from 20 in 2014, to 10 in 2019 (Table 5). Figure 3B shows the median hospital volume and IQR, including complex EVAR stratified by OSR and EVAR. The median hospital volume per year of OSR was stable, around 11 patients per hospital per year.

### DISCUSSION

The present study aimed to evaluate whether iAAA repair outcomes have improved since the establishment of the DSAA, a mandatory registry of all AAAs operated on in The Netherlands. The study demonstrated that several important iAAA repair outcomes in The Netherlands improved from 2014 up to 2019, while patient characteristics showed that patients with similar or more comorbidities underwent surgery. The number of patients per hospital remained stable; however, the number of hospitals that treated fewer than 30 patients decreased, which is a sign of regionalisation of vascular services.

**Table 4.** Patient characteristics in 2019 and trends in patient characteristics since 2014 stratified by all patients, and patients undergoing endovascular (EVAR) or open surgical (OSR) repair for intact abdominal aortic aneurysm (AAA) in The Netherlands

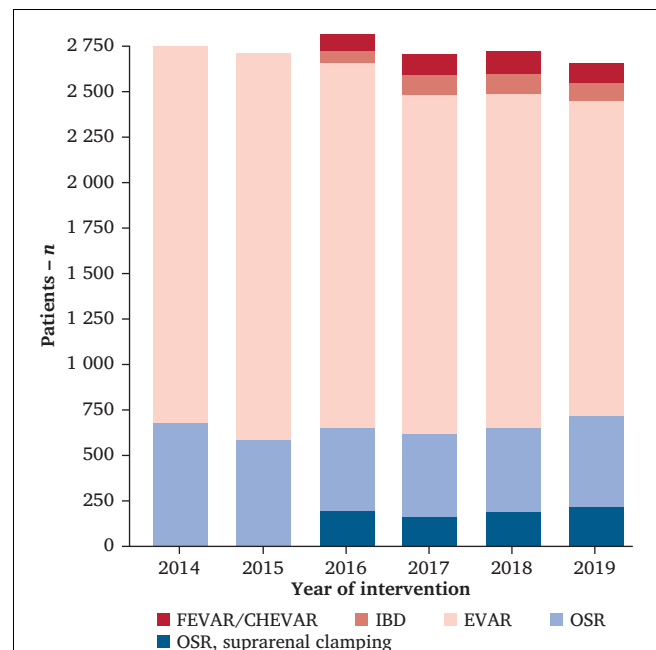
	Intact AAA – all patients			Intact AAA – EVAR			Intact AAA – OSR		
	2019 (n=2 445)	Unadjusted OR / $\beta$ coefficient per year (95% CI) (ref: 2014)	p	2019 (n=1 734)	Unadjusted OR / $\beta$ coefficient per year (95% CI) (ref: 2014)	p	2019 (n=711)	Unadjusted OR / $\beta$ coefficient per year (95% CI) (ref: 2014)	p
Women	385 (15.7)	1.02 (0.99–1.04)	.24	245 (14.1)	1.01 (0.98–1.05)	.37	140 (19.7)	1.00 (0.96–1.05)	.90
Age – y*	73.57 $\pm$ 7.69	0.08 (0.01–0.15)	.021	74.89 $\pm$ 7.41	0.19 (0.11–0.27)	<.001	70.35 $\pm$ 7.42	-0.08 (-0.22–0.06)	.26
Cardiac comorbidity	1 882 (77.0)	1.22 (1.20–1.24)	<.001	1 342 (77.4)	1.22 (1.19–1.25)	<.001	540 (75.9)	1.22 (1.17–1.27)	<.001
Pulmonary comorbidity	615 (25.2)	1.02 (0.995–1.04)	.13	430 (24.8)	1.02 (0.99–1.04)	.18	185 (26.0)	1.02 (0.98–1.06)	.41
Haemoglobin – mmol/L*	8.57 $\pm$ 1.05	-0.01 (-0.02 – -0.001)	.029	8.58 $\pm$ 1.03	-0.02 (-0.03 – -0.004)	.008	8.57 $\pm$ 1.10	0.003 (-0.02 – 0.02)	.75
Creatinine – $\mu$ mol/L*	89 (75.00, 107.00)	-0.25 (-0.64–0.13)	.20	90 (76)	-0.27 (-0.73–0.19)	.25	87 (73)	-0.10 (-0.79–0.59)	.78
Symptomatic AAA	230 (9.4)	1.02 (0.99–1.05)	.26	138 (8.0)	1.05 (1.01–1.09)	.014	92 (12.9)	0.95 (0.90–0.996)	.037
Aneurysm diameter – mm*	59.76 $\pm$ 12.47	-0.29 (-0.40 – -0.18)	<.001	59.01 $\pm$ 11.69	-0.30 (-0.42 – -0.18)	<.001	61.59 $\pm$ 14.03	-0.40 (-0.66 – -0.15)	.002
Aorto-iliac location	189 (7.7)	1.12 (1.08–1.16)	<.001	126 (7.3)	1.10 (1.06–1.15)	<.001	63 (8.9)	1.15 (1.07–1.23)	<.001

Data are presented as *n* (%) or mean  $\pm$  standard deviation or median (interquartile range) unless stated otherwise. OR = odds ratio; CI = confidence interval. Missing values of < 5% per variable are not shown (cardiac comorbidity: 400 patients [2.6% of all patients], pulmonary comorbidity: 275 patients [1.8% of all patients], haemoglobin: 394 patients [2.5% of all patients], creatinine: 387 patients [2.5% of all patients], aneurysm diameter: 108 [0.7% of all patients]).

\* For continuous variables, the beta coefficients per year are reported; for other variables, the odds ratios (OR) per year are reported.

The present study shows that during the study period, patients who received EVAR became slightly older, and more patients had cardiac comorbidities. In contrast to OSR, the peri-operative mortality rate following EVAR did not decrease and remained between 0.7% and 1.3%, consistent with rates described in contemporary literature.<sup>8</sup> Although mortality did not change, the major complications after EVAR declined, and the TbO rate increased remarkably. The decrease in major complications and the increase in TbO suggest that the peri-operative care quality for patients that underwent EVAR has increased. The exact cause of this improvement is hard to determine and is probably multifactorial, including better patient selection, increased experience, and further regionalisation of services. It is likely that the audit itself also plays an important role, as described previously.<sup>12</sup>

Furthermore, this study shows that all examined patient outcomes following OSR for iAAA repair improved over time, while more patients had cardiac comorbidities but were of similar age during the study period. An important finding from this study is that the peri-operative mortality following OSR improved, from 6.1% in 2014 to 4.7% in 2019, in line with rates described in international registries.<sup>8</sup> However, some of these registries might be biased by voluntary data contributions,<sup>24</sup> while the DSAA is a compulsory registry. Additionally, the percentage of major complications following OSR declined, and the percentage of TbO increased. Altogether, this suggests that the outcomes of patients who received OSR have improved. As for



**Figure 2.** The number of patients that received endovascular (EVAR) or open surgical (OSR) aneurysm repair for intact abdominal aortic aneurysm, or complex EVAR (fenestrated EVAR [FEVAR] / chimney EVAR [ChEVAR] / iliac branched device [IBD]) per year. Complex EVAR was not included in the study and is shown only to provide a complete overview. Complex EVAR was registered in the Dutch Surgical Aneurysm Audit (DSAA) since 2016.

**Table 5.** Univariable regression analyses to examine the trend in the number of hospitals that treat patients with abdominal aortic aneurysm and the trends in the number of hospitals that treat fewer than 30 patients per year in The Netherlands

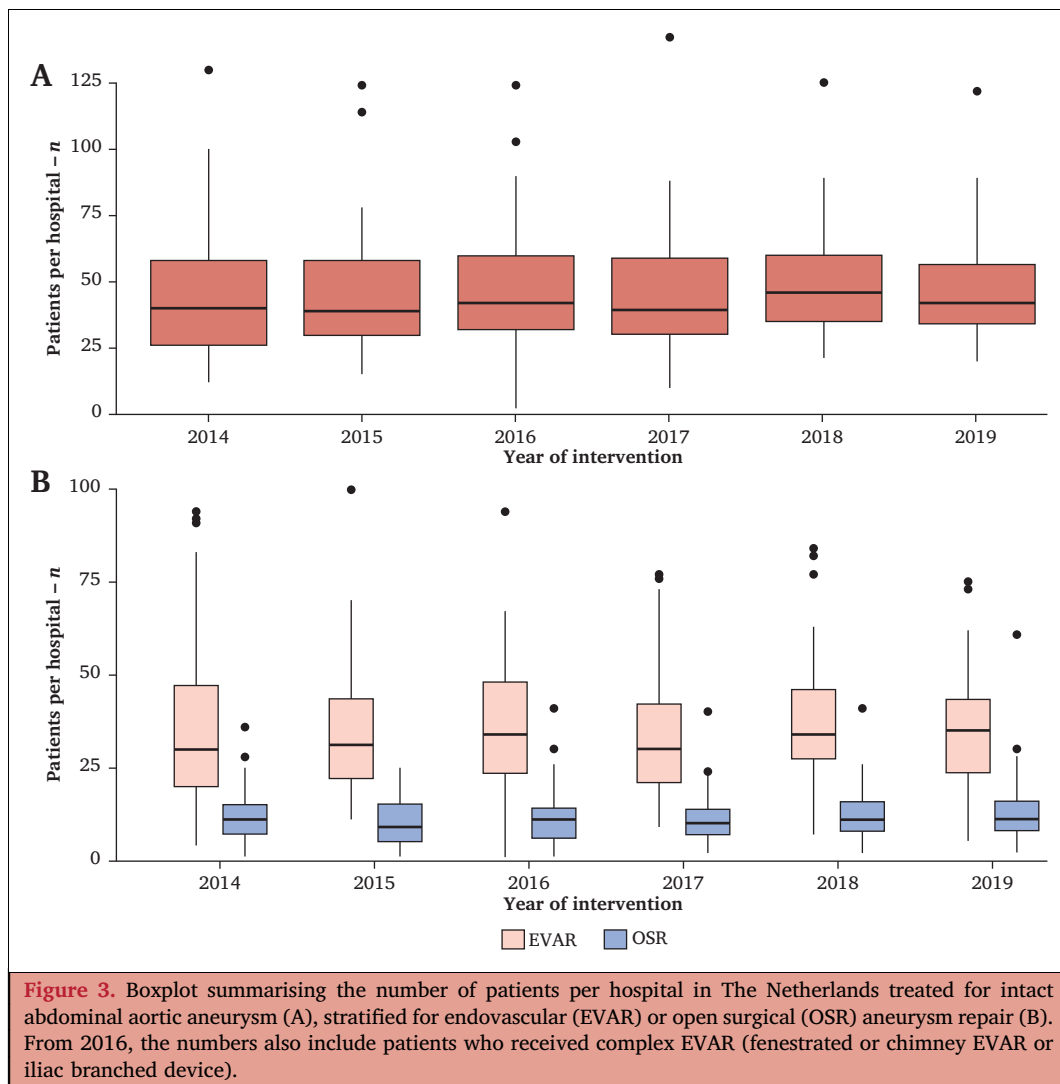
	2014	2015	2016	2017	2018	2019	Beta coefficient per year (95% CI) (ref: 2014)
Total number of patients including complex EVAR	2 753	2 709	2 815	2 704	2 723	2 654	
Numbers of hospitals	61	60	59	58	56	56	
Univariable							-1.09 (-1.36 – -0.81)
Number of hospitals that treated < 30 patients / year	20	15	12	13	9	10	
Univariable							-1.91 (-3.19 – -0.64)

Data are presented as *n*. CI = confidence interval.

after EVAR, the exact cause of this is likely to be multifactorial, for example a result of stricter case selection.

Several studies have suggested that lower hospital volume is associated with increased mortality.<sup>7,25</sup> The present study described the trends in hospital volume and the number of hospitals that performed iAAA repair. For OSR, the median hospital volume of 11 per year raises some concern,<sup>26</sup> and should be investigated in the near future. Although the hospital volume of all iAAA repairs per year

and the median hospital volume of OSR patients did not increase, the number of hospitals that treated patients decreased, and the number of hospitals that treated fewer than 30 patients per year decreased. This regionalisation of aneurysm care is probably a result of the European Society for Vascular Surgery (ESVS) guideline,<sup>23</sup> which suggests that a minimum of 30 AAA repairs should be performed per hospital per year or could be related to the clinical auditing process of the DSAA.<sup>10</sup> The DSAA monitors and



**Figure 3.** Boxplot summarising the number of patients per hospital in The Netherlands treated for intact abdominal aortic aneurysm (A), stratified for endovascular (EVAR) or open surgical (OSR) aneurysm repair (B). From 2016, the numbers also include patients who received complex EVAR (fenestrated or chimney EVAR or iliac branched device).



provides feedback about the number and outcomes of patients that underwent elective AAA repair per hospital, as well as the total number of aortic aneurysm repairs per hospital.

Finally, this study examined the proportion of OSR vs. EVAR per year, including the total number of patients. It was noted that the total number of patients per year has declined since 2016. Interestingly, the proportion of patients with an AAA diameter below the guideline threshold remained stable, while the mean diameter of iAAAs decreased; however, this decrease was small (0.3 mm per year). The National Vascular Registry reported a decrease in the number of elective infrarenal AAA repairs in the UK, and it was stated that this could indicate a more conservative approach in the management of sicker patients.<sup>27</sup> Furthermore, including patients that were treated by complex endovascular means for AAA, the applied surgical technique slightly changed with an increase of OSR and decrease of standard EVAR. The increase in OSR might be a result of the recent discussion regarding preferred treatment for specific patients<sup>23,28–30</sup> or published findings indicating inferior long term survival and more secondary interventions after EVAR.<sup>31,32</sup> A decrease in the number of standard EVAR was also reported in the UK in 2018.<sup>27</sup> In 2019, the percentage of patients that received standard EVAR in the present study was 65.3% of all patients, which was similar to the overall proportion of EVAR in international registries from 2010 to 2013 but far lower compared with the USA (79%), as reported by Vascunet.<sup>33</sup>

To the present authors' knowledge, this is the first study reporting treatment trends for iAAAs based on data from a compulsory national quality registry for all aortic aneurysm repairs and therefore represents real world data. One important limitation of this study is that the DSAA was initially designed for quality measurement and not for scientific purposes, which may result in some missing variables. The possible influence of these missing variables was considered in the present study and attempts were made to deal accurately with the missing values. Another limitation is that the DSAA does not contain anatomical morphological details, and only patients who underwent aneurysm repair were included in the DSAA. Therefore, selection and confounding bias cannot be excluded. Finally, the DSAA does not include information on surgeon volumes, and therefore, it was not possible to describe surgeon volume, in contrast to other countries.<sup>34,35</sup>

In conclusion, since the establishment of this nationwide quality improvement initiative (DSAA), all iAAA repair outcomes following standard EVAR and OSR have improved except for peri-operative mortality following standard EVAR which remained unchanged, although the proportion of patients with cardiac comorbidity increased over time in this group. The number of major complications after both OSR and EVAR decreased, and the proportion of TbO increased. The peri-operative survival after OSR increased, despite a higher proportion of patients with cardiac comorbidity. This nationwide audit provides real world data on

aneurysm care and can be seen as an important tool for further quality improvement initiatives.

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## CONFLICT OF INTEREST

JJW: Consultant for Cordis/Cardinal Health, former consultant for Baxter. HV: Consultant for Medtronic, WL Gore, Terumo, Endologix, and Arsenal AAA. Speakers bureau: Abbott

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## APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ejvs.2021.08.019>.

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