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Adjusted Hospital Outcomes of Abdominal Aortic Aneurysm Surgery Reported in the Dutch Surgical Aneurysm Audit

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WHAT THIS PAPER ADDS

The Dutch Surgical Aneurysm Audit (DSAA) is a mandatory registry for risk adjusted hospital outcome measurement and comparison. Thirty day or in hospital mortality for elective abdominal aortic aneurysms (EAAA) and acute AAA (symptomatic [SAAA] and ruptured [RAAA]) was similar to other national registries. Mortality risk prediction by V-POSSUM (physiological and operative variables) showed a significant miscalibration with an overestimation of mortality in EAAA surgery and underprediction in the low risk groups and overprediction in the high risk groups of SAAA and RAAA surgery. EAAA patients with endovascular aneurysm repair had a significantly lower observed than predicted mortality, whereas observed mortality was significantly higher than predicted mortality for RAAA patients receiving open repair. Adjusting hospital mortality for V(p)-POSSUM (physiological variables only) re-estimated on the DSAA population decreased hospital variation in EAAA patients, but mortality between hospitals was not discriminative for hospital comparison. Adjusting hospital mortality by means of V(p)-POSSUM and setting for acute AAA re-estimated on the DSAA was effective and justifies the modified V(p)-POSSUM as a casemix adjustment model for acute AAA surgery.

Objective/Background: The Dutch Surgical Aneurysm Audit (DSAA) is mandatory for all patients with primary abdominal aortic aneurysms (AAAs) in the Netherlands. The aims are to present the observed outcomes of AAA surgery against the predicted outcomes by means of V-POSSUM (Vascular–Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity). Adjusted mortality was calculated by the original and re-estimated V(physiology)-POSSUM for hospital comparisons.

Methods: All patients operated on from January 2013 to December 2014 were included for analysis. Calibration and discrimination of V-POSSUM and V(p)-POSSUM was analysed. Mortality was benchmarked by means of the original V(p)-POSSUM formula and risk-adjusted by the re-estimated V(p)-POSSUM on the DSAA.

Results: In total, 5898 patients were included for analysis: 4579 with elective AAA (EAAA) and 1319 with acute abdominal aortic aneurysm (AAAA), acute symptomatic (SAAA; $n = 371$) or ruptured (RAAA; $n = 948$). The percentage of endovascular aneurysm repair (EVAR) varied between hospitals but showed no relation to hospital volume (EAAA: $p = .12$; AAAA: $p = .07$). EAAA, SAAA, and RAAA mortality was, respectively, 1.9%, 7.5%, and 28.7%. Elective mortality was 0.9% after EVAR and 5.0% after open surgical repair versus 15.6% and 27.4%, respectively, after AAAA. V-POSSUM overestimated mortality in most EAAA risk groups ($p < .01$). The discriminative ability of V-POSSUM in EAAA was moderate (C-statistic: .719) and poor for V(p)-POSSUM (C-statistic: .665). V-POSSUM in AAAA repair overestimated in high risk groups, and underestimated in low risk groups ($p < .01$). The discriminative ability in AAAA of V-POSSUM was moderate (.713) and of V(p)-POSSUM poor (.688). Risk adjustment by the re-estimated V(p)-POSSUM did not have any effect on hospital variation in EAAA but did in AAAA.

Conclusion: Mortality in the DSAA was in line with the literature but is not discriminative for hospital comparisons in EAAA. Adjusting for V(p)-POSSUM, revealed no association between hospital volume and treatment or outcome. Risk adjustment for case mix by V(p)-POSSUM in patients with AAAA has been shown to be important.

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INTRODUCTION

Auditing hospital outcomes after surgery is a powerful tool with which to monitor healthcare quality.[1] In the Netherlands several audits for surgical outcomes have been developed in cooperation with the Dutch Institute for Clinical Auditing. These audits, meant to improve healthcare, are developed in agreement with several stakeholders, such as insurance companies and the health inspectorate of the ministry of healthcare. Complete registration of data with a minimum of missing values and a motivated administrative culture are essential for robust and accurate conclusions for healthcare quality.[2] Therefore, a reduced set of preoperative patient -or disease related variables, easy to register, is desirable, especially as not every variable registered and of influence on mortality, needs to be included for casemix adjustment.[3,4]

The web based Dutch Surgical Aneurysm Audit (DSAA), introduced in 2012 and mandatory since 2013, registers all primary abdominal aortic aneurysm (AAA) operations in the Netherlands.

Because baseline characteristics of populations may differ between hospitals, with concomitant differences in outcome, risk adjustment by patient and disease specific characteristics for outcome measurement is necessary.[5] This can be achieved by using pre-operative variables of influence on the outcome.[6] Numerous models predicting mortality by pre- or peri-operative variables have been developed for aneurysm surgery. Only a few of them have been validated multiple times and are therefore considered as accurate, such as the Glasgow Aneurysm Score (GAS) or the Vascular Biochemistry and Haematology Outcome Model (VBHOM).[7,8]

The Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity (V-POSSUM) is a well known peri-operative mortality risk prediction model.[9,10] However, the operative variables included in the model are not suitable for adjustment to compare hospitals because they are, to a large extent, dependent on surgical care, such as, for example, blood loss. The "physiology-only" score of V-POSSUM (V(p)-POSSUM) only contains patient and disease specific characteristics, which can be suitable as casemix information for hospital comparisons.

Since the introduction of endovascular aneurysm repair (EVAR) mortality has decreased in elective AAA surgery (EAAA); however, the advantage of EVAR over open surgical repair (OSR) in ruptured abdominal aortic aneurysm (RAAA) suggested in observational studies has not been confirmed in randomised trials.[11–18] An explanation for differences between observational research and randomised trials could be selection bias.[16,19] Large registries, of consecutive patients undergoing surgery for acute aneurysms, might add insight to this issue. However, the results from national registries can be difficult to compare owing to differences in prevalence of RAAA in countries with screening programs, the percentage that refrains from operative repair of RAAA, and the variation in percentage of EVAR implemented.[20–22]

The aim of this study was to report the first results of auditing AAA surgery in the Netherlands. Post-operative mortality was the primary outcome parameter. As a secondary outcome parameter, variations in the implementation of EVAR and the possible association with volume were investigated. The performance of V-POSSUM, as prediction model, was assessed. For casemix correction hospital outcomes were compared and adjusted with the original V(p)-POSSUM and the re-estimated V(p)-POSSUM on the DSAA population.

MATERIAL AND METHODS

Clinical data

The DSAA is a mandatory, nationwide, population and web based database with detailed patient, diagnostic, procedural, and outcome data of all patients with a primary infra- or juxtarenal AAA operation in the Netherlands. Under Dutch law, no ethical approval or informed consent was required. In 2017 a project will be initiated to validate the existing data set. Patients prospectively registered in the DSAA, operated on for an AAA between 1 January 2013 and 31 December 2014 were included for analysis. Excluded were patients with secondary or revision surgery, surgery of highly complex aneurysm (suprarenal and thoraco-abdominal), and mycotic or infected aneurysms.[23] Furthermore, patients with incomplete data concerning date of birth, date of surgery, survival state, setting, or type of procedure (EVAR/OSR) were excluded (see "Results", subsection "Baseline characteristics"). Patient and treatment characteristics were described. Procedure for analysis, other than baseline, was calculated following "intention to treat" analysis and the percentage of EVAR (EVAR/(EVAR + OSR)) was tested for the association with hospital volume. For hospital comparisons two groups of patients were analysed: EAAA and AAAA.

AAAA was defined as either acute non-ruptured without extravasation needing surgery within 24h after presentation (SAAA), or ruptured with extravasation requiring immediate surgery (RAAA).

Clinical outcomes

The primary outcome measure was 30 day or in hospital mortality. A sub-analysis was performed, when appropriate, by year of registration. Other outcome measurements were peri- and post-operative complications, any re-interventions, and length of hospital stay. Peri-operative complications were cardiopulmonary resuscitation, unplanned closure of a hypogastric artery, and visceral and renal injury. Post-operative complications concerned bleeding defined as blood loss needing surgery or blood transfusion; colonic ischaemia; arterial occlusion; paralysis; prosthesis associated

Table 1. Formula for the calculation of the POSSUM scores.

	Model	Scoring algorithm + formula
Risk prediction	V-POSSUM	(ln(R/1 − R)) = −8.0616 + (0.1552 * physiological score) + (0.1238*operative score)
		R = 1/(1 + e^−(−8.0616 + (0.1552 * physiological score) + (0.1238*operative score)))
Risk adjustment	V(p)-POSSUM	(ln(R/1 − R)) = −6.0386 + (0.1539 * physiological score)
		R = 1/(1 + e^−(−6.0386 + (0.1539 * physiological score)))

issues (migration, infection, any endovascular leakage); abscess, defined as an abscess of the inguinal wound; abdominal wound or intra-abdominal wounds; visceral complications (colonic or splenic); wound dehiscence; ileus; colostomy; major amputation; or profound wound infections and cardiopulmonary complications; renal insufficiency; neurological or thromboembolic complications; and infections other than surgical site or pulmonary infections not directly related to the surgical procedure. Because readmission could only be registered as an optional choice of the DSAA survey it was analysed when registered.

Prediction by V-POSSUM and adjustment by V(p)-POSSUM

The V-POSSUM (operative and physiological score) and V(p)-POSSUM (only physiological score) were calculated using the following variables: (i) physiological (age, cardiac comorbidity, pulmonary comorbidity, electrocardiogram status, systolic blood pressure, pulse rate, haemoglobin, leukocytes, urea (calculated from creatinine), sodium, potassium, Glasgow Coma Scale); (ii) operative (operation severity [severity of procedure was calculated as "major" for every procedure—EVAR and OSR—in accordance with the available literature], number of procedures, peri-operative blood loss, peritoneal contamination, malignancy status and setting [EAAA, SAAA, or RAAA]). Calculations for the V-POSSUM and V(p)-POSSUM were performed using the formulas shown in Table 1.[9,10,24,25] Predicted mortality was calculated using the exponent of the V-POSSUM in the following formula:[9]

Mortality = 1/1 + exp−(V-POSSUM or V(p)-POSSUM)

Mortality risk prediction

The observed mortality was compared with the expected (or predicted) mortality by V-POSSUM using the Hosmer and Lemeshow test,[9,10] which indicates a good calibration when not significant.[9,26] This goodness of fit statistic is computed as the Pearson chi-square from the contingency table of observed and expected (predicted) frequencies after having grouped the observations into deciles based on the predicted probabilities. The null hypothesis states that there are no systematic differences between observed and expected counts in different severity classes. The main idea behind this test statistic is the more closely the predicted and the observed frequencies match, the better the fit. Differences between observed and expected were shown in a bar plot in terms of percentages. The expected mortality was also calculated for the different procedures and compared with the observed mortality, tested according to the Fisher's combined probability test. As described earlier, two groups of patients were analysed: EAAA and AAAA. Combining the two patient groups having acute surgery was necessary in order to have an adequate sample size for the acute setting. When appropriate SAAA and RAAA were analysed separately.

Performance comparison

To compare the mortality between centres, an unadjusted funnel plot was constructed. Next, the adjusted mortality, based on the V(p)-POSSUM as casemix adjustment, was computed in a funnel plot to compare the performance of hospitals in the DSAA with the original British population (benchmark) on which V(p)-POSSUM was constructed. Note that V(p)-POSSUM was used rather than V-POSSUM, because the former is based on pre-operative patient characteristics (physiology parameters) only. Finally, V(p)-POSSUM was used as a casemix variable by fitting a logistic regression model on the DSAA data. This allowed a risk adjusted comparison to be made between the centres in the DSAA. All results are shown in funnel plots as the (effective) hospital volume versus the standardised mortality rate (i.e., the ratio of observed to expected events), together with 95% confidence intervals (CIs).

In the funnel plots two 95% CIs are reported. The orange narrow one represents a 95% CI that can be used to test the performance of any particular hospital. A hospital that actually performs exactly according the national average will still have 5% probability of falling outside this funnel (i.e., false positive). The wider, red 95% CI is corrected for multiple comparisons by using the Bonferroni correction. This means that if, for example, all hospitals perform exactly according to the national average, then there is a 5% probability that at least one of them will fall outside the red, wider funnel.

Missing data presented as "missing values" in the baseline tables were allocated to the normal category in V-POSSUM.[27] Normality for continuous variables was tested by the Kolmogorov—Smirnov test and rejected when $p < .05$. Medians are presented with an interquartile range; means are presented with a SD. Analysis was performed in SPSS version 23.0 (IBM, Armonk, NY, USA).

RESULTS

Baseline characteristics

A total of 5979 patients had primary AAA surgery and were registered in the DSAA during the study period in 65 hospitals. Patients with specific missing data, as is specified above under "Clinical data" ($n = 81$; 1.4%), were excluded. Of the remaining 5898 patients, 4579 patients had EAAA surgery (77.6%) and 1319 patients had AAAA surgery (RAAA surgery [$n = 948$; 16.1%] and SAAA surgery [$n = 371$; 6.3%]). Almost three quarters of the EAAA patients (74.8%)

were treated primarily by EVAR (74.5% were completed by EVAR [0.3% converted to OSR]). The majority of AAAA patients received OSR (60.7%). In the subgroup of patients with SAAA, 53.6% had EVAR (0.8% converted to OSR) versus 33.8% in patients with RAAA (1.4% converted to OSR). The converted EVAR were analysed as EVAR according the "intention to treat" principle. General baseline characteristics used for V-POSSUM are shown in Tables 2, 3 and 4.

Clinical outcomes

Procedure. The variation in percentage of EVAR performed was wide. In the majority of hospitals >50% of EVAR were performed in patients with EAAA (range 13—100%) There was no association between hospital volume and the percentage of EVAR performed ($p = .12$). High AAAA volume hospitals had a greater preference for EVAR compared with low volume hospitals, but this was not significant (range 0—100%; $p = .07$).

Mortality. The overall 30 day or in hospital mortality after EAAA surgery was 1.9% versus 7.5% after SAAA and 28.7% after RAAA surgery. EAAA mortality in 2013 and 2014 was comparable (1.9% and 2.0%, respectively). Mortality for AAAA was higher in 2013 than in 2014 in both settings (8.6% vs. 6.8% after SAAA and 34.8% vs. 23.8% after RAAA). The overall mortality after AAAA surgery was 22.7% (15.6% after EVAR vs. 27.4% after OSR). EVAR in EAAA showed a mortality rate of 0.9% and OSR a mortality rate of 5.0%. Mortality by procedure and setting is presented in Table 5.

Morbidity. Twenty-three percent ($n = 1068$) of patients with EAAA had a peri-operative and/or post-operative complication. Patients receiving EVAR had fewer complications than those undergoing OSR (16.1% vs. 44.8%). Almost 39% ($n = 144$) of the patients with SAAA had one or more peri- and/or post-operative complications versus 69.2% ($n = 656$) of the RAAA patients. Patients undergoing OSR had a higher percentage of complications than those undergoing EVAR (Tables 5 and 6).

In general, after OSR, there were more complications than after EVAR. Cardiopulmonary complications accounted for the most post-operative problems, especially with OSR.

In OSR for EAAA 5.2% of the patients versus 0.2% in EVAR had renal failure; the majority of these patients (4.6% and 0.1%, respectively) were temporarily dialysed. In the AAAA group most patients had renal failure after RAAA and OSR (18.0%). Patients undergoing EVAR had the most unplanned occlusions of the hypogastric artery during RAAA surgery (3.2%).

Re-interventions occurred more frequently after OSR than after EVAR (EAAA 10.7% vs. 2.5%; SAAA 7.0% vs. 9.3%; RAAA

Table 2. Baseline clinical characteristics.

Setting	EAAA	SAAA	RAAA
Patients (*n*)	4579	371	948
Patient characteristics			
Male sex, % (95% CI)	86.8 (83.4—87.8)	81.9 (78.0—85.8)	85.6 (85.8—87.8)
Mean ± SD age (y)	73 ± 7.7	73 ± 8.8	74 ± 8.4
Median (IQR) diameter (mm)	58 (55—64)	66 (55—80)	78 (65—90)
Missing, *n* (%)	107 (2.3)	8 (2.2)	60 (6.3)
Median (IQR) heart rate median (bpm)	72 (63—81)	79 (69—87)	83 (70—100)
Missing, *n* (%)	359 (7.8)	49 (13.2)	131 (13.8)
Median (IQR) SBP median (mmHg)	140 (127—152)	144 (127—160)	107 (84—135)
Missing, *n* (%)	278 (6.1)	42 (11.3)	91 (9.6)
Comorbidity, % (95% CI)			
Cardiac comorbidity			
None	46.2 (44.8—47.6)	44.5 (39.4—49.6)	40.1 (37.0—43.2)
Peripheral oedema	8.1 (7.4—9.0)	5.9 (3.2—7.8)	6.4 (4.8—8.0)
Elevated CVP	1.4 (1.1—1.7)	2.2 (0.7—3.7)	1.2 (0.5—1.9)
Antihypertensive medication	38.6 (37.2—10.0)	39.4 (34.4—44.4)	28.8 (26.0—31.7)
Missing	5.7 (5.0—6.4)	8.1 (5.3—10.9)	23.5 (20.8—26.2)
Pulmonary comorbidity			
None	75.4 (74.2—76.6)	73.9 (69.4—78.4)	59.9 (56.8—63.0)
Dyspnea during exercise	19.3 (18.2—20.4)	14.8 (11.2—18.4)	15.3 (13.0—17.6)
Invalidating dyspnea	2.7 (2.2—3.2)	1.9 (0.5—3.3)	2.8 (1.8—3.9)
Dyspnea during rest/fibrosis	1.1 (0.8—1.4)	1.6 (0.3—2.9)	2.1 (1.2—3.0)
Missing	1.4 (1.1—1.7)	7.8 (5.1—10.5)	19.8 (17.3—22.4)
Malignancy			
None	80.4 (79.3—81.6)	88.9 (85.7—92.1)	87.1 (85.0—89.2)
Primary only	4.2 (3.6—4.8)	2.2 (0.7—3.7)	2.3 (1.4—3.3)
Lymph node metastasis	13.9 (12.9—14.9)	7 (4.4—9.6)	7.2 (5.6—8.9)
Distant metastasis	0.6 (0.4—0.8)	1.1 (0.0—2.2)	0.7 (0.2—1.2)
Missing	1 (0.7—1.3)	0.8 (−0.1 to 1.7)	2.6 (1.6—3.6)

Note. 95% CI: p ± (1.96*(SQRT(p*(1 − p))/*n*)), where p = proportion and n = sample size. EAAA = elective abdominal aortic aneurysm; SAAA = symptomatic abdominal aortic aneurysm; RAAA = ruptured abdominal aortic aneurysm; CI = confidence interval; IQR = interquartile range; bpm = beats per min; SBP = systolic blood pressure; CVP = central venous pressure.

Table 3. Baseline characteristics: diagnostics.

	EAAA	SAAA	RAAA
Patients (*n*)	4579	371	948
Diagnostics			
Laboratory results			
Hemoglobin (mmol/L)	8.8 (8.1–9.3)	8.4 (7.5–9.2)	7.4 (6.4–8.3)
Missing, *n* (%)	104 (2.3)	7 (1.9)	36 (4.0)
Leukocytes ($\times 10^9$/L)	7.9 (6.6–9.6)	9.0 (7.4–12.0)	12.8 (9.9–16.4)
Missing, *n* (%)	1727 (37.7)	40 (10.8)	90 (9.5)
Sodium (mmol/L)	140 (138–141)	138 (136–140)	138 (135–140)
Missing, *n* (%)	387 (8.4)	13 (3.5)	58 (6.1)
Potassium (mmol/L)	4.2 (4.0–4.5)	4.1 (3.8–4.5)	4.0 (3.7–4.4)
Missing, *n* (%)	288 (6.3)	12 (3.2)	60 (6.3)
Creatinine (μmol/L)	90 (77–108)	85 (70–110)	108 (86–133)
Missing, *n* (%)	121 (2.6)	14 (3.8)	56 (5.9)
GCS, % (95% CI)			
15	90.8 (90.0–91.7)	92.2 (89.0–94.5)	60.9 (57.7–63.9)
12–14	0	1.9 (0.5–3.3)	15.3 (13.1–17.7)
9–11	0	0	3.7 (2.5–4.9)
<9	0	0.5 (−0.2 to 1.2)	6.9 (5.3–8.5)
Missing	9.2 (8.4–10.0)	5.4 (3.5–8.2)	13.3 (11.3–15.6)
ECG, % (95% CI)			
Normal	60.7 (59.3–62.1)	50.1 (45.1–55.2)	32 (29.1–35.0)
Atrial fibrillation 60–90 bpm	7.1 (6.4–7.9)	6.5 (4.4–9.4)	5.2 (3.9–6.8)
Ischaemia	21.8 (20.6–23.0)	26.4 (22.2–31.1)	17.6 (15.3–20.2)
Missing	10.4 (9.6–11.3)	17 (13.5–21.1)	45.3 (42.1–48.3)

Note. 95% CI: p ± (1.96*(SQRT(p*(1 − p))/n)), where p = proportion, n = sample size, SQRT = square root. Data are median (IQR) unless otherwise indicated. EAAA = elective abdominal aortic aneurysm; SAAA = symptomatic abdominal aortic aneurysm; RAAA = ruptured abdominal aortic aneurysm; GCS = Glasgow Coma Scale; CI = confidence interval; ECG = electrocardiography; bpm = beats per min.

12.8% vs. 20.7%). A total of 88.5% of patients with EAAA, treated with EVAR, were discharged within 5 days, and 85.8% of patients undergoing OSR were discharged after >5 days; 19% of the patients undergoing OSR remained in hospital for >14 days. The majority of patients with RAAA and SAAA, treated by EVAR, were discharged within 14 days (12.3% remained in hospital), while 38% of the patients undergoing OSR remained in hospital for > 14 days.

The variable "readmission" was recorded in 3471 (75.8%) patients with EAAA and 994 (75.4%) patients with AAAA. Of those with EAAA, 6.5% were readmitted: 6.2% after EVAR and 7.1% after OSR. In the AAAA group the majority of

Table 4. Baseline characteristics (continued): operative.

	EAAA	SAAA	RAAA
Patients (*n*)	4579	371	948
Treatment			
Procedure			
EVAR completed	74.5 (73.2–75.8)	52.8 (47.7–57.9)	32.4 (29.4–35.4)
EVAR Converted	0.3 (0.1–0.5)	0.8 (−0.1 to 1.7)	1.4 (0.7–2.2)
Open	25.2 (23.9–26.5)	46.4 (41.3–51.5)	66.2 (63.2–69.2)
No. of procedures			
>2	1.4 (1.1–1.7)	0.5 (−0.2 to 1.2)	2.1 (1.2–3.0)
Peri-operative blood loss (mL)			
≤100	22.0 (20.8–23.2)	13.7 (10.6–17.6)	7.1 (5.6–8.0)
101–500	23.8 (22.6–25.0)	24.3 (19.9–28.7)	12.1 (10.0–14.2)
501–999	6.1 (5.4–6.8)	12.1 (8.8–15.4)	4 (2.8–5.2)
≥1000	12.5 (11.5–13.5)	21 (16.9–25.2)	40.8 (37.7–43.9)
Missing	35.6 (34.2–37.0)	28.8 (24.5–33.7)	36 (33.0–39.1)
Peritoneal contamination			
None	95.2 (94.6–95.8)	93 (90.4–95.6)	76.3 (73.6–79.0)
Fluid	0.5 (0.3–0.7)	3 (1.3–4.7)	5.3 (3.9–6.7)
Abscess	0	1.1 (0.0–2.2)	0.3 (−0.0 to 0.7)
Peritonitis	0.3 (0.1–0.5)	1.3 (0.2–2.5)	14.8 (12.5–17.1)
Missing	4 (3.4–4.6)	1.6 (0.3–2.9)	3.5 (2.3–4.7)

Note. 95% CI: p ± (1.96*(SQRT(p*(1 − p))/n)), where p = proportion, n = sample size, SQRT = square root. Data are % (95% CI). EAAA = elective abdominal aortic aneurysm; SAAA = symptomatic abdominal aortic aneurysm; RAAA = ruptured abdominal aortic aneurysm; CI = confidence interval; EVAR = endovascular aneurysm repair.

Table 5. Outcome after abdominal aortic aneurysm repair by procedure.

	EAAA		SAAA		RAAA	
	EVAR	OSR	EVAR	OSR	EVAR	OSR
Patients (*n*)	3426	1153	199	172	320	628
Outcome	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)
Mortality (in hospital or < 30 d)	0.9 (0.6–1.3)	5.0 (3.9–6.5)	5.0 (2.7–9.0)	10.5 (6.8–16.0)	22.2 (18.0–27.1)	32.0 (28.5–35.8)
Peri-operative complications	4.1 (3.4–4.8)	6.5 (5.2–8.1)	5.5 (3.1–9.6)	9.9 (6.3–14.3)	13.8 (10.4–18.0)	21.8 (18.8–25.2)
Post-operative complications	12.5 (11.4–13.6)	42.9 (40.1–45.8)	27.6 (21.9–34.2)	44.2 (37.0–51.7)	49.5 (44.1–55.0)	72.6 (69.0–75.9)
Re-interventions	2.5 (2.0–3.1)	10.7 (9.0–12.6)	7.0 (4.2–13.9)	9.3 (5.8–14.6)	12.8 (9.6–16.9)	20.7 (17.7–24.0)
Hospital stay > 14 d	2.5	19.0	6.0	26.2	16.3	41.2
Hospital stay > 10 d	3.6	33.3	10.1	43.0	25.9	55.1
Hospital stay > 5 d	11.5	85.8	34.2	93.6	54.4	73.1
Hospital readmission[a]	6.2	7.1	11.3	9.1	10.3	4.5

Note. 95% CI: p ± (1.96*(SQRT(p*(1 − p))/n)), where p = proportion, n = sample size, SQRT = square root. EAAA = elective abdominal aortic aneurysm; SAAA = symptomatic abdominal aortic aneurysm; RAAA = ruptured abdominal aortic aneurysm; EVAR = endovascular aneurysm repair; OSR = open surgical repair; CI = confidence interval.

[a] Missing values excluded because not in short survey.

patients were not readmitted to the hospital (92.5%). Readmissions occurred twice as often after EVAR as after OSR (10.7% vs. 5.5%).

Risk prediction V-POSSUM

Predicted or expected mortality for EAAA by V-POSSUM showed significant miscalibration with observed mortality (Hosmer–Lemeshow $p < .01$; as reported in Fig. 1A). The observed mean mortality for EVAR differed significantly from that predicted ($p < .01$): 0.9% (95% CI 0.6–1.3) and 3.5% (95% CI 2.9–4.1), respectively. Also, the mean predicted mortality for EVAR was lower than for OSR. Observed mortality after OSR was 5% and predicted by V-POSSUM to be 5.3% (95% CI 4.1–6.6; $p = .65$), as shown in Table 7. The overall p value calculated with the Fisher's combined probability test showed a significant difference in observed versus expected mortality ($p < .001$). The discriminative ability of V-POSSUM was moderate (C-statistic = .719).

The observed mortality for AAAA surgery by V-POSSUM showed significant miscalibration (Hosmer–Lemeshow $p < .01$) compared with the predicted mortality (Fig. 1B). The observed mortality for RAAA was 22.2% (EVAR) versus 32.0% (OSR) and for SAAA 5.0% (EVAR) versus 10.5% (OSR). As reported in Table 7, predicted mortality was 6.9% (95% CI 3.6–10.2) for EVAR and 9.1% (95% CI 5.0–13.1) for OSR in patients with SAAA, implying there were no significant differences between the observed and predicted percentages. However, the predicted mortality in RAAA was 21.4% (95% CI 17.4–25.3) for EVAR and 28.6% (95% CI 25.5–31.7) for OSR, which differed significantly from the observed mortality ($p = .03$). The overall p value by Fisher's combined probability test showed a non-significant difference in observed versus expected mortality ($p = .16$). The discriminative ability of V-POSSUM was moderate (C-statistic = .713).

Risk adjustment V(p)-POSSUM: hospital comparison

The V(p)-POSSUM showed a moderate discriminative ability of 0.665 in patients with EAAA and 0.688 in patients with AAAA. Unadjusted mortality is shown in Fig. 2A and B for patients with EAAA and AAAA, respectively.

In both EAAA and AAAA, mortality was low and there was no evidence of over or underperformance of certain centres. In Fig. 3A the EAAA DSAA population was compared with the reference population (i.e., UK) on which the V(p)-POSSUM was calibrated. A much lower mortality was seen in the DSAA population, especially in the EVAR group, as reported in Table 7. In Fig. 3B the AAAA DSAA population is compared with the reference population (i.e., UK) on which the V(p)-POSSUM was calibrated. There was a higher mortality in the DSAA population with respect to the reference population. Finally, in Fig. 4 (A, B) the risk adjusted comparison of all centres in the EAAA DSAA and AAAA DSAA is shown. While for patients with EAAA there is no under- or overperformance, in AAAA there is no evidence of underperformance for any centre either, except for one hospital, which showed a significantly better performance after multiple testing.

DISCUSSION

The 30 day or in hospital mortality of 1.9% for elective AAA surgery in the Dutch Surgical Aneurysm Audit is comparable with other European registries. For example, the Swedish and UK elective populations reported mortality percentages of 1.5% and 2.4%, respectively.[21,23,28] With the Dutch mandatory minimum volume of 20 AAA operations per year per centre set by the Dutch Healthcare Inspectorate, mortality was not a discriminative outcome parameter between hospitals in the DSAA, as almost all unadjusted and adjusted observations were within the 95% CI. Patients with SAAA appear to be very different from those with EAAA, indicated by the mortality rate of 7.5%. The international reported mortality rate for acute symptomatic, non-ruptured aneurysms ranges between 11% and 18%.[29] Mortality after RAAA surgery in the DSAA was also comparable with mortality after RAAA in the Swedvasc (18% after EVAR, 32% after OSR in 2013).[30] The mortality after EAAA EVAR was

Table 6. Peri- and post-operative complications after abdominal aortic aneurysm repair by procedure.

	EAAA				SAAA				RAAA			
	EVAR $n = 3426$ % (95% CI)		OSR $n = 1153$ % (95% CI)		EVAR $n = 199$ % (95% CI)		OSR $n = 172$ % (95% CI)		EVAR $n = 320$ % (95% CI)		OSR $n = 628$ % (95% CI)	
One or more complications (peri- and post-operative)	16.1		44.8		30.7		48.3		52.5		77.7	
CPR	0.1	(0.02–0.02)	0.4	(0.2–1.0)	0.5	(0.09–2.8)	0.6	(0.1–3.2)	5.0	(3.1–8.0)	8.0	(6.1–10.3)
Unplanned closure of hypogastric artery	1.2	(0.9–1.6)	0.4	(0.2–1.0)	1.5	(0.5–4.3)	0.6	(0.1–3.2)	3.2	(1.7–5.7)	0.9	(0.4–2.0)
Visceral injury peri-operative	0	–	0.5	(0.2–1.1)	0	–	1.2	(0.3–4.1)	0.3	(0.06–1.8)	2.1	(1.2–3.5)
Urethral damage	0	–	0.4	(0.2–1.0)	0	–	0.6	(0.1–3.2)	0	–	0.3	(0.09–1.2)
Other peri-operative	2.7	(2.2–3.3)	4.7	(3.6–6.1)	3.5	(1.7–7.1)	7.0	(4.0–11.8)	5.3	(3.3–8.3)	10.6	(8.4–13.2)
Bleeding	1.0	(0.7–1.4)	2.7	(1.9–3.8)	2.5	(0.1–5.7)	1.2	(0.3–4.2)	2.5	(1.3–4.9)	4.9	(3.5–6.9)
Colonic ischaemia	0.2	(0.1–0.4)	3.7	(2.8–5.0)	1.0	(0.3–3.6)	2.9	(1.2–6.6)	5.3	(3.0–8.3)	9.4	(7.4–11.9)
Arterial occlusion	1.7	(1.3–2.2)	4.0	(3.0–5.3)	1.0	(0.3–3.6)	5.8	(3.2–10.4)	4.4	(2.6–7.2)	5.4	(3.9–7.5)
Paralysis	0	–	0	–	0	–	0	–	0	–	0	–
Any prosthetic complications[a]	1.3	(1.0–1.7)	0.3	(0.1–0.8)	4.0	(2.0–7.7)	0.6	(0.01–3.3)	3.7	(2.1–6.4)	0.3	(0.08–1.1)
Abscess	0	–	0.4	(0.2–1.0)	0.5	(0.09–2.8)	0.6	(0.01–3.3)	0	–	0.8	(0.3–1.9)
Visceral injury post-operative	0	–	0.2	(0.06–0.7)	0	–	0.6	(0.01–3.3)	0.6	(0.2–2.2)	1.5	(0.7–2.5)
Wound dehiscence	0	–	1.6	(1.0–2.5)	0	–	0.6	(0.01–3.3)	0	–	2.1	(1.2–3.6)
Ileus	0.1	(0.04–0.3)	2.7	(1.9–3.8)	0	–	1.7	(0.6–4.9)	0.9	(0.3–2.7)	1.1	(0.5–2.3)
Colostomy	0.1	(0.04–0.3)	3.0	(2.1–4.2)	0	–	1.7	(0.6–4.9)	3.1	(1.7–5.6)	9.2	(7.2–11.7)
Major amputation	0	–	1.0	(0.5–1.8)	0.5	(0.09–2.8)	0.6	(0.01–3.3)	0.3	(0.05–1.7)	1.1	(0.5–2.3)
Profound wound infection	0.8	(0.6–1.2)	0.7	(0.4–1.4)	0	–	0	–	0.6	(0.2–2.2)	0.2	(0.04–1.0)
Other surgical	4.5	(3.9–5.3)	14.6	(12.7–16.8)	11.1	(7.5–16.2)	16.3	(11.5–22.6)	13.4	(10.1–17.6)	23.1	(20.0–26.6)
Cardiac	1.3	(1.0–1.7)	10.1	(8.5–12.0)	6.5	(3.8–10.8)	14.5	(10.0–20.5)	12.5	(9.3–16.6)	19.7	(16.8–23.0)
Pulmonary	1.8	(1.4–2.3)	17.4	(15.3–19.7)	4.5	(2.4–8.4)	19.2	(14.0–25.7)	18.1	(14.3–22.7)	27.2	(23.9–30.8)
Neurological	0.6	(0.4–0.9)	3.6	(2.7–4.9)	1.5	(0.5–4.3)	3.5	(1.6–7.4)	3.4	(1.9–6.0)	7.3	(5.5–9.6)
Thromboembolic	1.4	(1.1–1.9)	4.7	(3.6–6.1)	2.5	(0.1–5.7)	5.2	(2.8–9.6)	4.4	(2.6–7.2)	8.0	(6.1–10.4)
Infections[b]	2.7	(2.2–3.3)	9.5	(7.9–11.3)	5.5	(3.2–9.6)	11.0	(7.2–16.6)	10.0	(7.2–13.8)	18.3	(15.5–21.5)
Renal insufficiency	0.2	–	5.2	(4.1–6.6)	1.0	(2.8–3.6)	8.7	(5.4–13.9)	6.9	(4.6–10.2)	18.0	(15.2–26.9)

Note. 95% CI: p ± (1.96*(SQRT(p*(1 − p))/n)), where p = proportion, n = sample size, SQRT = square root. EAAA = elective abdominal aortic aneurysm; SAAA = symptomatic abdominal aortic aneurysm; RAAA = ruptured abdominal aortic aneurysm; EVAR = endovascular aneurysm repair; OSR = open surgical repair; CI = confidence interval; CPR = cardiopulmonary resuscitation.

[a] Migration, infection, any leakage.

[b] Other than surgical or pulmonary.

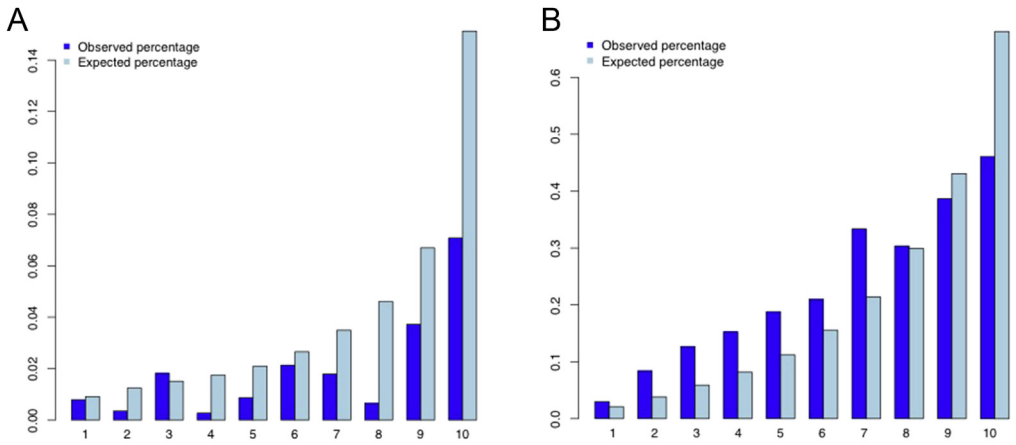

Figure 1. (A) The percentage observed mortality compared with the percentage expected mortality by V-POSSUM in deciles in elective AAA. (B) The percentage observed mortality compared with the percentage expected mortality by V-POSSUM in deciles in acute AAA patients (e.g., symptomatic abdominal aortic aneurysm and ruptured abdominal aortic aneurysm patients).

lower than after OSR in the DSAA and comparable with the UK data.[28] However, mortality after OSR in the DSAA (5%) compared less favourably with other registries, such as Swedvasc, which reported 3.2% mortality after OSR in their yearly report.[30] Patients undergoing OSR had a higher predicted mortality than those undergoing EVAR, which might be an indication of more comorbidities and also of more peri-operative blood loss.

The mortality after EVAR in patients with RAAA was lower compared to OSR, while most RAAA patients were treated with OSR. The mortality differences between OSR and EVAR, as in other observational studies, indicate that selection bias (i.e., different case mix) and a weighed choice of treatment could be responsible for this observation. The lower predicted mortality in patients undergoing EVAR compared with those undergoing OSR might indicate that

Table 7. Observed and predicted mortality (V-POSSUM) for abdominal aortic aneurysm patients.

Procedure	Setting	Observed	Predicted	Lower PI	Upper PI	*p*
EVAR	EAAA	0.88	3.52	2.91	4.12	<.01
OSR	EAAA	5.03	5.32	4.08	6.56	.65
EVAR	SAAA	5.03	6.88	3.55	10.21	.28
OSR	SAAA	10.47	9.06	5.00	13.13	.50
EVAR	RAAA	22.19	21.39	17.44	25.34	.70
OSR	RAAA	32.01	28.58	25.52	31.65	.03

PI = prediction interval; EVAR = endovascular aneurysm repair; EAAA = elective abdominal aortic aneurysm; OSR = open surgical repair; SAAA = symptomatic abdominal aortic aneurysm; RAAA = ruptured abdominal aortic aneurysm.

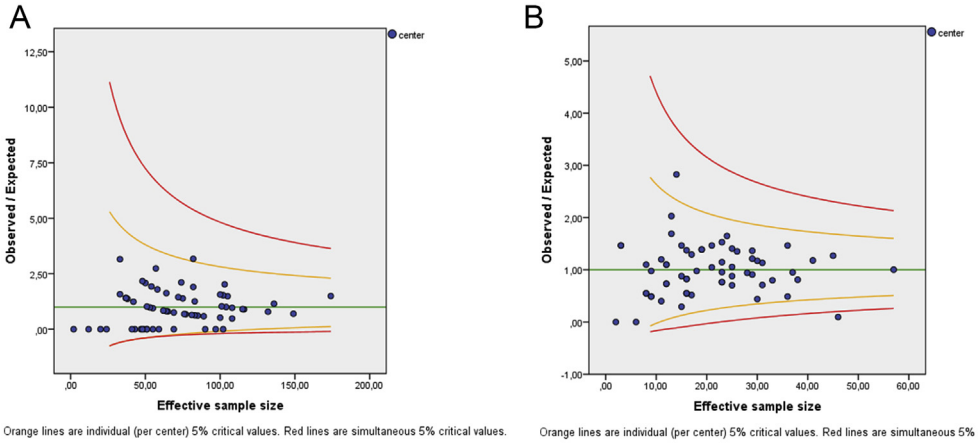

Figure 2. (A) The *unadjusted* standardised mortality ratio (SMR) (*y*-axis) of hospital mortality for elective abdominal aortic aneurysm patients. The *x*-axis describes the effective sample size, which takes into account the precision of the estimation of expected events, in this case the actual sample size. The expected number of events defined as the national average. The orange and red lines are 95% confidence intervals (CIs). The green line resembles 'SMR = 1' when observed divided by expected is the same. (B) The *unadjusted* SMR (*y*-axis) of hospital mortality for acute abdominal aortic aneurysm patients. The *x*-axis describes the effective sample size, which takes into account the precision of the estimation of expected events, in this case the actual sample size. The expected number of events defined as the national average. The orange and red lines are 95% CIs. The green line resembles 'SMR = 1' when observed divided by expected is the same.

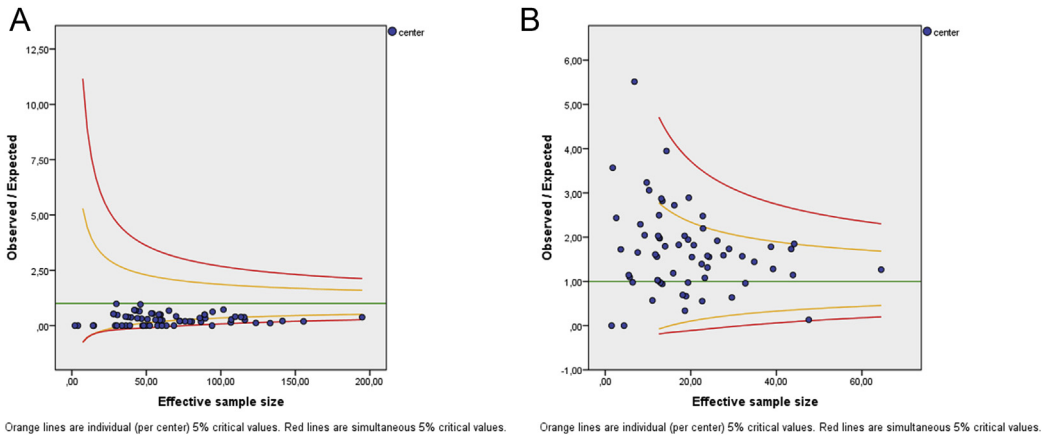

Figure 3. (A) The *adjusted* standardised mortality ratio (SMR) (*y*-axis) of hospital mortality for elective abdominal aortic aneurysm patients by V(p)-POSSUM benchmarked on the UK. The *x*-axis describes the effective sample size, which takes into account the precision of the estimation of expected events by V(p)-POSSUM. The expected numbers of patients are calculated by hospital based on the variables included in V(p)-POSSUM. The green line resembles 'SMR = 1' when observed divided by expected is the same. (B) The *adjusted* SMR (*y*-axis) of hospital mortality for acute abdominal aortic aneurysm patients by V(p)-POSSUM benchmarked on the UK. The *x*-axis describes the effective sample size, which takes into account the precision of the estimation of expected events by V(p)-POSSUM. The expected numbers of patients are calculated by hospital based on the variables included in V(p)-POSSUM. The orange and red lines are both 95% confidence intervals. The green line resembles 'SMR = 1' when observed divided by expected is the same.

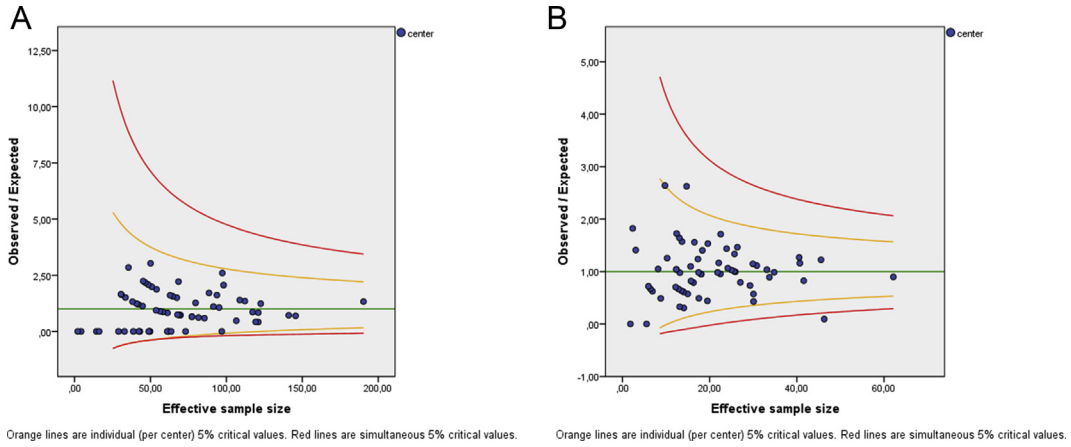

Figure 4. (A) The *adjusted* standardised mortality ratio (SMR) (*y*-axis) of hospital mortality for elective abdominal aortic aneurysm patients by V(p)-POSSUM re-estimated on the Dutch Surgical Aneurysm Audit (DSAA). The *x*-axis describes the effective sample size, which takes into account the precision of the estimation of expected events. The orange and red lines are both 95% confidence intervals (CIs). The green line resembles 'SMR = 1' when observed divided by expected is the same. (B) The *adjusted* standardised mortality ratio (SMR) (*y*-axis) of hospital mortality for acute abdominal aortic aneurysm patients by V(p)-POSSUM re-estimated on the DSAA. The *x*-axis describes the effective sample size, which takes into account the precision of the estimation of expected events. The orange and red lines are both 95% CIs. The green line resembles 'SMR = 1' when observed divided by expected is the same.

patients undergoing EVAR had fewer comorbidities, less peri-operative blood loss, or both. So, when comparing the results after EVAR and OSR there is at least some selection bias.[16] Conclusions about whether EVAR is a better operative technique cannot be made from this analysis.

The V-POSSUM is one of the most frequently validated mortality risk prediction models in the literature. Because all V-POSSUM variables were implemented in the DSAA, mortality risk adjustment by V(p)-POSSUM, containing only the pre-operative variables, could be performed easily. Risk adjustment of outcomes in the DSAA by, for example, V(p)-POSSUM, in order to compare hospital performances is not performed by other registries, such as Swedvasc. They do not risk adjust their yearly outcomes by case mix, which makes comparisons between registries difficult. Interestingly, in the DSAA, risk adjustment by V(p)-POSSUM for EAAA did not influence hospital variation, even after re-estimation on the Dutch population. This might be caused by the relatively low event rate of the outcome "mortality". Perhaps compound measurements can be the key when comparing hospital outcomes. Examples are "failure to rescue", the number of patients that die as a result of complications, and "textbook outcome", the ideal healthcare pathway for every patient.[31,32] Risk adjustment for AAAA did change the position on the

y-axis of every hospital, showing the effect of differences in case mix on mortality and the necessity for risk adjustment.

Missing data

Missing data are a well known and common problem in registries.[2] To maintain data quality, there are several ways of dealing with missing data. It is possible for instance, to exclude patients that miss relevant data, to choose imputation of the mean or use multiple imputation.[27,33] Although missing values are an unwanted outcome, the effect on hospital outliers is only relevant in low volume hospitals.[34] Missing data in the DSAA were scarce and exceeded the 20% for leukocytes in EAAA, which may be a non-routinely measured variable in patients who undergo AAA surgery. For peri-operative blood loss, data were missing in >25% in every setting. Therefore, the percentage of missing values could indicate poor administrative performance, and a decrease in the number of missing values might therefore be used as a quality indicator when comparing hospitals.

Clinical outcomes

It has been suggested that only specialised centres with appropriate expertise should perform EVAR. However, there is no significant variation in the outcome of EAAA between hospitals in the DSAA. Furthermore, there was no relationship between the percentage of EVAR performed and hospital volume in the DSAA, as well as no association between hospital volume (minimum volume of 20 patients per year) and outcome mortality in both EAAA and AAAA. In the DSAA almost three quarters of the patients with EAAA were treated by EVAR. There is no reason to concentrate on EVAR for EAAA in the Netherlands in the current setting.

However, the volume per centre for primary elective surgery in the Netherlands is 20 to more than 100 procedures per year, indicating a volume of five to more than 20 OSRs per hospital. This number could be challenging for many hospitals, as several studies have proposed a minimum of 3–12 elective OSRs per surgeon per year, or at least 7–30 elective OSRs per hospital per year.[35–41] Moreover, as hospital experience in one procedure does not translate into expertise in the other, it is necessary to retain experience in both.[38] Potential bias in the outcome of the DSAA can also be caused by the selection by indication for operation dependent on patient or disease characteristics (aneurysm diameter, restriction to patients with comorbidities), and the concomitant choice for a certain operative technique (OSR or EVAR preference, or even fenestrated EVAR or chimneys). The choice of operative procedure influences mortality and depends on patient characteristics as well as on surgeon's preference. Therefore, operative variables cannot be used for casemix adjustment, because a correction for surgical skills is undesirable. Unfortunately, correction for this kind of bias is not possible. However, the overall mortality rate of 5% for OSR for EAAA is a matter of concern. The differences in outcome between EVAR and OSR for AAAA in the DSAA can be biased by "selection by indication" for surgery. Because results are influenced by patient or disease characteristics (aneurysm diameter, restriction to patients with comorbidities), and the concomitant choice for a certain operative technique (liberal use of EVAR or conservative choice for OSR). Patients receiving EVAR in the DSAA seem to have less comorbidity. Identifying the best operative technique for the individual patient remains a challenge. Vascular units face the challenge of choosing the surgical technique while at the same time retaining experience in both open and endovascular techniques.[42]

Risk prediction V-POSSUM

Mortality risk prediction models like V-POSSUM aim to predict mortality for an individual patient. Ideally, a model is discriminative and calibrates well. Because discrimination and calibration are reversely dependent, this will never be the case.[26] The observed miscalibration of V-POSSUM can be a sign of overfitting, which can be explained by several factors: the presence of too many variables compared with the number of events, the statistical procedure used for selection of the variables (e.g., forward or backward selection, or high *p* value for inclusion), the number of categories used per variable, the handling of missing data, and the degree to which a population differs from the original population in severity.[26] The significant miscalibration between observed and expected mortality after EAAA EVAR can be explained, in part, by the fact that V-POSSUM was developed before the introduction of EVAR.[43] However, in patients with AAAA mortality was underestimated for those undergoing OSR, but still higher compared with EVAR.

The discriminative ability was moderate in the DSAA, still resulting in false predictions compared with the observed outcomes. This might imply that there are variables lacking in the model that could lead to better predictions.[26] Moreover, according to the instructions of V-POSSUM, EVAR was scored in the same operative severity category as OSR (major surgery, 4 points as exponential in the regression coefficient). It is questionable whether EVAR has to be marked as major vascular surgery.

Risk adjustment V(p)-POSSUM: hospital comparison

Risk adjusted hospital outcomes are a prerequisite for meaningful hospital comparisons. Adjusting mortality in the DSAA with V(p)-POSSUM provides the effect of risk adjustment by case mix according to the population (UK) in which V(p)-POSSUM was developed. Therefore, and because it was built on an overall aneurysm population and on top of that the continuous predominance of EVAR procedures, the V(p)-POSSUM was re-estimated for the Dutch population by logistic regression. The POSSUM physiology-only models can be a useful tool for comparative outcome audits.[9] However, it might have become necessary to include more EVAR and outcome specific variables or to re-estimate the variables included on a mixed (EVAR and OSR) population. The POSSUM physiology-only models contain a significant number of variables compared with other pre-operative mortality-risk prediction models such as the GAS and VBHOM.[7,8] These latter models might be more suitable and easier to use. Suitability for clinical practice not

only depends on the number of variables, but also on the administrative burden in clinical practice. An ideal model should contain clear and distinct variables, be suitable for both acute and elective surgery at a definite endpoint, and have well defined categories. Although, hospital mortality changed owing to the effect of casemix adjustment, it was still not possible to recognise underperforming hospitals. Most hospitals, except one, remained within the CIs.

Limitations

When registering data, coding and documentation errors (internal validity), or errors in the external validity of the data, occur. As the registry started in 2013 there were fewer patients than in 2014. This could have been the result of under-registration. However, a crude check of mortality between the two years revealed no differences in mortality in elective AAA or a registered lower mortality for acute AAA in 2014. As the data are not yet validated and hospitals were not audited for data verification, the results presented in the current overview should be interpreted with care. The presence of missing data does not necessarily indicate that a comparison between hospitals is unreliable providing the volume of AAA repair is large enough and comparable.[34] In the Netherlands external validation is difficult because all AAA operations, including revisions and suprarenal AAA surgery, are registered nationally in the national hospital statistics with the same code as primary AAA surgery. Visits to hospitals in order to validate the registered data will be the next best step in the verification process.

It was not possible to differentiate between referral centres and non-referral centres in the current DSAA, as there was no definition for referral centre for highly complex cases. The option of registering the referral of a patient was recently added to the updated dataset of the DSAA. Referral centres potentially have more complex aneurysm morphology with a greater risk of proximal aneurysm neck related complications and increased mortality.[44] Reported mortality for complex aneurysms is higher than average AAA, but published results for endovascular repair of difficult aortic necks look promising.[45]

Conclusions

Nearly all patients registered in the Dutch Surgical Aneurysm audit could be included for analysis. Operative mortality, adjusted and non-adjusted, after EAAA surgery was not a discriminative outcome parameter for hospital comparisons in the DSAA. The overall post-operative (EVAR and OSR) and, specifically, EVAR related mortality was low and there was no significant association between hospital volume and (risk adjusted) percentage of EVAR performed. Therefore, the Dutch minimum volume of 20 EAAA procedures appears to be sufficient for EVAR. However, the overall mortality after OSR was relatively high, resulting in concerns with regard to this low volume operation in the era of preference for EVAR. Also in patients with AAAA, the observed mortality of OSR for RAAA was significantly higher than the predicted mortality. Patients undergoing EVAR have a lower mortality, but this can be at least partly explained by the lower predicted mortality by V-POSSUM, indicating patient selection. In this study, risk adjusted mortality for elective AAA surgery has limited capability for hospital comparison quality assessment.

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CONFLICT OF INTEREST

None.

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COUP D'OEIL

Successful TEVAR with a Through and Through Guidewire in an Extremely Tortuous Aorta

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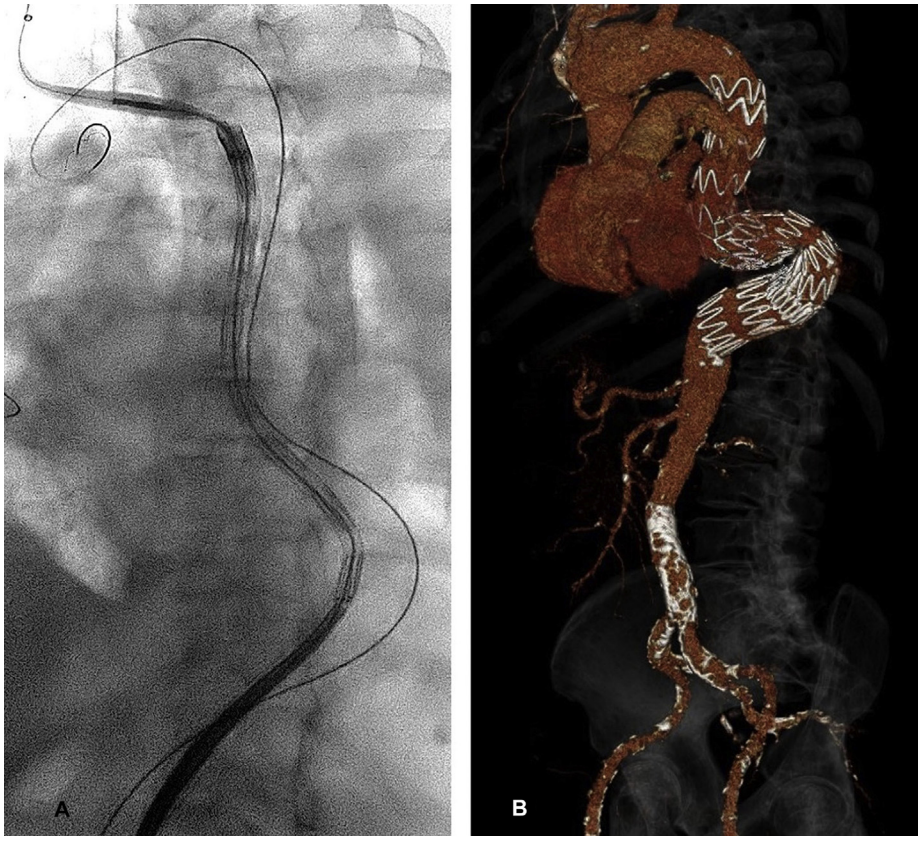

An 83 year old female patient presented acutely with flank pain. Computed tomography angiography (CTA) revealed a type B aortic dissection with a thoracic false lumen aneurysm of 58 mm in an extremely tortuous aorta. Thoracic endovascular aneurysm repair was performed following establishment of a brachio-femoral through and through guidewire (Glidewire, Terumo, Japan). Moderate tension was applied to the wire at both ends to straighten the anatomy and permit graft deployment (A). TX2 and Alpha endografts (Cook Aortic Intervention, Bloomington, IN, USA; 42-38-173 proximally, 38-34-154 distally) were successfully implanted. Post-operative CTA (B) showed good graft conformability, false lumen thrombosis and wall apposition without endoleak.

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