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Failure to Rescue – a Closer Look at Mortality Rates Has No Added Value for Hospital Comparisons but Is Useful for Team Quality Assessment in Abdominal Aortic Aneurysm Surgery in The Netherlands

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WHAT THIS PAPER ADDS

Clinical audit in vascular surgery has introduced healthcare quality improvement by providing hospital performance feedback. Endovascular aneurysm repair (EVAR) has decreased mortality. However, low event rates cause difficulties in the interpretation of the observed hospital variation. Mortality focuses on hospital performance but is dependent on casemix. Alternatively, "failure to rescue" (FTR) seems to be merely related to hospital processes, less depending on casemix. FTR increased variation between hospitals but identified the same best practices as for mortality and did not identify hospitals with a significantly higher mortality. Therefore, FTR is of limited use for hospital comparisons in AAA treatment evaluation.

Objectives: Failure to rescue (FTR) is a composite quality indicator, defined as the proportion of deceased patients following major complications. The aims of this study were to compare FTR with mortality for hospital comparisons in abdominal aortic aneurysm (AAA) surgery in The Netherlands and investigate hospital volume and associated factors.
Methods: Patients prospectively registered between 2013 and 2015 in the Dutch Surgical Aneurysm Audit (DSAA) were analysed. FTR was analysed for AAA patients and subgroups elective (EAAA) and acute (AAAA; symptomatic or ruptured) aneurysms. Variables and hospital volume were analysed by uni- and multivariable regression analysis. Adjusted hospital comparisons for mortality, major complications, and FTR were presented in funnel plots. Isomortality lines were constructed when presenting FTR and major complication rates.
Results: A total of 9258 patients were analysed in 61 hospitals: 7149 EAAA patients (77.2%) and 2109 AAAA patients (22.8%). There were 2785 (30.1%) patients with complications (unadjusted range 5–65% per hospital): 2161 (77.6%) with major and 624 (28.4%) patients with minor complications. Overall mortality was 6.6% (adjusted range 0–16% per hospital) and FTR was 28.4% ($n = 613$) (adjusted range 0–60% per hospital). Glasgow Coma Scale, age, pulse, creatinine, electrocardiography, and operative setting were independently associated with FTR. Hospital volume was not associated with FTR. In AAAA patients hospital volume was significantly associated with a lower adjusted major complication and mortality rate (OR 0.62, 95% CI 0.49–0.78; and 0.64, 95% CI 0.48–0.87). Four hospitals had a significant lower adjusted FTR with different major complication rates on different isomortality lines.
Conclusions: There was more variation in FTR than in mortality between hospitals. FTR identified the same best performing hospitals as for mortality and therefore was of limited additional value in measuring quality of care for AAA surgery. FTR can be used for internal quality improvement with major complications in funnel plots and diagrams with isomortality lines.

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INTRODUCTION

Clinical audits have become increasingly appreciated as a tool for quality improvement in vascular surgical care.[1] Medical improvement can be achieved using feedback on the hospital's structure, processes and outcomes of care. Traditionally, outcome parameters such as post-operative mortality and complication rates are used for this purpose.[2] However, statistical uncertainties associated with low hospital volume or low event rates cause difficulties in the interpretation of the observed variation in outcome between hospitals.[3] In abdominal aortic aneurysm (AAA) surgery the introduction of endovascular aneurysm repair (EVAR) has resulted in a marked decrease in post-operative mortality and complications.[4,5] With a mean mortality of 0.9% in EVAR patients in registries such as the Dutch Surgical Aneurysm Audit (DSAA) or 0.6% in the Swedish vascular registry (SWEDVASC), post-operative mortality as a single quality indicator seems to be of limited discriminative value for hospital comparisons.[6,7] Moreover, mortality is dependent on both casemix and hospital performance.[8]

To focus on hospital processes, composite outcome measures have been developed that tend to be more related to hospital processes and are less sensitive to errors in risk adjustment.[8–12] Examples of composite outcome measures are "textbook outcome" (TO), a measure for the percentage of patients with full achievement of desired outcomes, and "failure to rescue" (FTR), which represents the ability to treat complications effectively and therefore prevent death.[10,13–15]

The primary objective of this study was to compare FTR between hospitals performing AAA surgery. The second aim was to investigate whether FTR is a more discriminative outcome parameter than mortality or major complications. Additionally, variables contributing to FTR and the consequent adjusted association between FTR and hospital volume were investigated with the aim of comparing quality of AAA surgery between hospitals.

METHODS

Dataset

Variables and outcomes were retrieved from the DSAA, a mandatory national vascular audit in which every vascular unit has registered all primary AAA repairs in the Netherlands since 2013. Registration is performed according to a protocol approved by the scientific board, a group of vascular surgeons representing the interests of Dutch hospitals. For the year 2015 data verification was performed by at random selection of 14 hospitals for review (Supplementary material A).

Patients

All patients undergoing primary, infra- or juxtarenal AAA surgery in 2013, 2014, and 2015 registered in the DSAA were evaluated. Analysis was performed on a patient level. The minimal complete dataset to consider a patient eligible for analysis included date of birth, date of surgery, operative setting/urgency (elective/acute symptomatic/ruptured aneurysm), type of procedure (EVAR or open surgical repair; OSR), and mortality. Patients undergoing surgery in hospitals that stopped performing AAA surgery during the study period and fewer than 15 patients in three years registered in the DSAA were excluded from analysis.

Procedures

Procedures were divided into EVAR or OSR and the setting into elective (EAAA) or acute (AAAA) surgery. The AAAA group was a composite group of ruptured (RAAA), a patient needing surgery within 2 hours, or as soon as possible if extravasation was seen on computed tomography angiography (CTA), and acute non-ruptured symptomatic aneurysms (SAAA), a patient needing surgery within 24 hours if no extravasation was present on CTA. EVAR procedures converted to OSR were categorised by intention to treat.

Outcome definitions

Mortality was defined as death within 30 days after surgery or within the same hospital admission (in hospital mortality). A *complication* was defined as death or any peri-operative- or post-operative complication.[11] A *major complication* was defined as post-operative death or a peri- or post-operative complication leading to a re-intervention or prolonged hospital stay. A *minor complication* was defined as a complication not resulting in a re-intervention, prolonged hospital stay, or mortality. A *prolonged hospital stay* was defined as the length of hospital stay (LOS) exceeding the 75th percentile of the LOS per subgroup of living patients registered in the DSAA between 2013 and 2015: EVAR or OSR stratified by EAAA, SAAA, or RAAA surgery.

Failure to rescue was defined as the number of patients that died within 30 days after surgery or in the same hospital admission, divided by the number of patients with major complications.

Statistical analysis

Baseline characteristics, surgical treatment and 30 day mortality were analysed for the overall group of AAA patients and for the subgroups of EAAA and AAAA patients when appropriate. Baseline analysis was performed for three outcomes on a patient level: no complications, only minor complications, or at least one major complication. Continuous variables were analysed to test normality and linearity. Missing values for continuous variables were imputed with the overall mean in the case of linearity and normality. When no linearity or normality was found for continuous variables, these were categorised. Categorical variables were dichotomised and missing values were analysed as the group unknown for further analysis. Univariable and multivariable logistic regression analysis were performed in order to identify independent casemix and operative setting variables associated with FTR. A p value $< .05$ was considered as statistically significant.

Adjusted mortality, major complication rates, and FTR were compared between hospital volume tertiles. To ensure casemix corrected comparison between hospitals, a multivariable logistic regression analysis was used to adjust outcomes for patient characteristics by variables measured on admission in part based on the re-estimated $V(p)$-POSSUM variables on the Dutch population,[6,16,17] including age, gender, systolic blood pressure, heart rate, pulmonary status, cardiac status, pre-operative electrocardiography (ECG), creatinine, Glasgow Coma Scale (GCS), haemoglobin, and operative setting: EAAA, SAAA or RAAA. Hospital comparisons were displayed in funnel plots with 95% confidence intervals: hospital volume versus mortality and major complications, as well as volume of major complications versus FTR. Finally, per hospital the percentage of adjusted FTR was shown in relation to the percentage of adjusted major complications represented by isomortality lines. Consequently, if mortality is considered a major complication, then the mortality rate equals the major complication rate multiplied by the FTR. If the major complication rate is plotted on the x-axis and the FTR on the y-axis, then all points lying on the line $y = c/x$ correspond to the same mortality rate c.

Adjusted outcome was calculated as the percentage observed events divided by the percentage expected events times the mean observed percentage of events, represented in funnel plots with 95% confidence intervals. Isomortality lines reflect the same mortality percentage across these lines for every hospital.

Additionally hospitals were divided into tertiles based on their procedural volume after three years of surgery: low, medium, and high volume hospitals. Mortality, major complications, and FTR were compared between these tertiles, both adjusted and unadjusted. Statistical analysis was performed in SPSS version 23.0.

RESULTS

Patients

A total of 9353 patients were registered by 63 hospitals and 9273 (99.1%) of these patients met the inclusion criteria of this study. After exclusion of two hospitals (registration of three and 12 patients), 9258 patients were included for analysis (Fig. 1). In Table 1 patient and treatment characteristics are shown as input for adjustment. The mean age was 73.2 years and 85.8% were male. Cardiac comorbidities and pulmonary comorbidities were most frequently seen, respectively 47.5% and 22.8%. There were 7149 EAAA patients (77.2%) and 2109 AAAA patients: 641 SAAA (6.9%) and 1468 RAAA (15.9%). The majority of patients were treated by EVAR ($n = 6{,}317$, 68.2%; and 0.5%, $n = 47$ EVAR converted to OSR). In the subgroup of EAAA patients 76.6% ($n = 5473$) were treated by EVAR compared with 58.0% ($n = 372$) of the SAAA and 35.4% ($n = 519$) of the RAAA patients.

Outcomes: complications and mortality

Overall, a total of 6473 (69.9%) patients had no complications. There were 2785 (30.1%) patients with one or more complications (range 5—65% per hospital). There were differences in baseline characteristics between patients with no, only minor, or at least one major complication. Patients with major complications had more comorbidities. Overall 6.7% ($n = 624$) of the patients had only minor complications. The overall percentage of major complications was 23.3% ($n = 2161$). The overall mortality was 6.6% ($n = 613$) with an adjusted range of 0—16% per hospital. In Table 2, more detailed information is shown for operative setting and technique performed.

The median length of hospital stay for EAAA, SAAA, and RAAA patients after EVAR was respectively 2 (IQR 2—4), 4 (IQR 2—6), and 7 (IQR 5—13) days. After OSR this was respectively 8 (IQR 7—12), 10 (IQR 7—15), and 15 (IQR 10—24) days.

Failure to rescue

In Table 3 the odds ratio (OR), unadjusted and adjusted, for FTR is shown after analysing the overall patient group, and for the subgroups of EAAA and AAAA patients. In 613

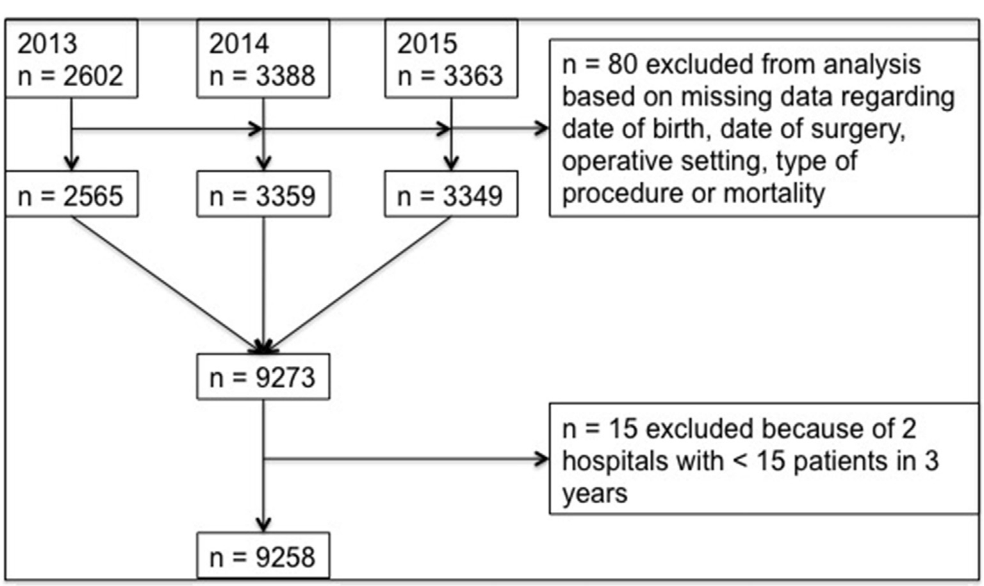

Figure 1. Flowchart of patient selection.

Table 1. Patient characteristics: casemix variables, including operative technique and setting, and outcome variables in patients with and without complications.

Variables	Total patient group		Patients without complications		Patients with only minor complications		Patients with major complications	
	No. patients	Percentage	No. patients	Percentage	No. patients	Percentage	No. patients	Percentage
Total no. of patients	9258	100%	6473	69.9%	624	6.7%	2161	23.3%
Age, mean ± SD	73.22 ± 7.85		72.87 ± 7.84		73.57 ± 7.97		74.19 ± 7.75	
Sex, male	7939	85.8%	5627	87.0%	553	88.8%	1759	81.4%
Procedure								
EVAR	6317	68.2%	5142	79.4%	487	78.0%	688	31.8%
EVAR converted	47	0.5%	16	0.2%	2	0.3%	29	1.3%
OSR	2894	31.3%	1315	20.3%	135	21.6%	1444	66.8%
Total	100%	100%	100%	100%				
Setting								
RAAA	1468	15.9%	459	7.1%	193	30.9%	816	37.8%
SAAA	641	6.9%	420	6.5%	35	5.6%	186	8.6%
EAAA	7149	77.2%	5594	86.4%	396	63.5%	1159	53.6%
Total	100%	100%	100%	100%				
Heart								
No cardiac problems	4229	45.7%	3043	47.0%	302	48.4%	884	40.9%
Peripheral oedema	708	7.6%	492	7.6%	42	6.7%	174	8.1%
Elevated CVP	129	1.4%	91	1.4%	6	1.0%	32	1.5%
Medication*	3566	38.5%	2522	39.0%	224	35.9%	820	37.9%
Unknown	626	6.8%	325	5.0%	50	8.0%	251	11.6%
Total	100%	100%	100%	100%				
Lungs								
No dyspnoea	6712	72.5%	4920	76.0%	448	71.8%	1344	62.2%
Dyspnoea exercise	1741	18.8%	1155	17.8%	120	19.2%	466	21.6%
Dyspnoea	263	2.8%	166	2.6%	21	3.4%	76	3.5%
Dyspnoea in rest	107	1.2%	60	0.9%	6	1.0%	41	1.9%
Unknown	435	4.7%	172	2.7%	29	4.6%	234	10.8%
Total	100%	100%	100%	100%				
Malignancy								
None	7576	81.8%	5231	80.8%	528	84.6%	1817	84.1%
Current or history	1596	17.2%	1188	18.4%	93	14.9%	315	14.6%
Unknown	86	0.9%	54	0.8%	3	0.5%	29	1.3%
Total	100%	100%	100%	100%				
GCS								
15	8175	88.3%	5931	91.6%	546	87.5%	1698	78.6%
12–14	219	2.4%	56	0.9%	23	3.7%	140	6.5%
9–11	58	0.6%	7	0.1%	4	0.6%	47	2.2%
<9	93	1.0%	8	0.1%	4	0.6%	81	3.7%
Unknown	713	7.7%	471	7.3%	47	7.5%	195	9.0%
Total	100%	100%	100%	100%				
ECG								
No abnormalities	4836	52.2%	3634	56.1%	297	47.6%	905	41.9%
Atrial fibrillation	589	6.4%	406	6.3%	42	6.7%	141	6.5%
MI or other	2350	25.4%	1604	24.8%	161	25.8%	585	27.1%
Unknown	1483	16.0%	829	12.8%	124	19.9%	530	24.5%
Total	100%	100%	100%	100%				
Sodium								
Normal (135–145)	7754	83.8%	5470	84.5%	532	85.3%	1752	81.1%
Divergent (<135 or >145)	761	8.2%	445	6.9%	55	8.8%	261	12.1%
Unknown	743	8.0%	558	8.6%	37	5.9%	148	6.8%
Total	100%	100%	100%	100%				
Potassium								
Normal (3.5–5.0)	7915	85.5%	5612	86.7%	539	86.4%	1764	81.6%
Divergent (<3.5 of >5.0)	769	8.3%	440	6.8%	54	8.7%	275	12.7%
Unknown	574	6.2%	421	6.5%	31	5.0%	122	5.6%
Total	100%	100%	100%	100%				

Continued

Table 1-*continued*

Variables	Total patient group		Patients without complications		Patients with only minor complications		Patients with major complications	
	No. patients	Percentage	No. patients	Percentage	No. patients	Percentage	No. patients	Percentage
Creatinine, mean ± SD	101.52 ± 45.11		98.66 ± 42.72		106.24 ± 51.49		108.74 ± 49.05	
WBC, mean ± SD	9.01 ± 2.73		8.63 ± 2.36		9.56 ± 3.20		9.97 ± 3.29	
Haemoglobin, mean ± SD	8.43 ± 1.18		8.60 ± 1.05		8.26 ± 1.20		7.96 ± 1.38	
SBP, mean ± SD	135.87 ± 25.92		138.78 ± 22.43		133.85 ± 27.44		127.71 ± 32.58	
Heart rate, mean ± SD	75.50 ± 15.72		73.97 ± 14.15		77.55 ± 17.65		79.48 ± 18.59	
Aneurysm size, mean ± SD	63.31 ± 14.17		61.39 ± 12.62		64.64 ± 15.67		68.69 ± 16.50	

*Hypertension, angina pectoris, diuretics or digoxin. SD = standard deviation; CVP = central venous pressure; heart = cardiac comorbidity; lungs = pulmonary comorbidity; GCS = Glasgow Coma Scale; ECG = electrocardiography; MI = myocardial Infarction; IQR = interquartile range; WBC = white blood count; SBP = systolic blood pressure; LOS = length of stay.

Table 2. Summary of mortality, minor and major complications by procedure and setting.

	Overall		EAAA		AAAA		SAAA		RAAA	
	No. patients	%	No. patients	%	No. patients	%	No. patients	%	No. patients	%
Mortality										
EVAR	175	2.7	42	0.8	133	14.9	18	4.8	115	22.2
OSR	438	15.1	93	5.5	345	28.3	28	10.4	317	33.4
All patients	613	6.6	135	1.9	478	22.7	46	7.2	432	29.4
Minor complications										
EVAR	489	7.7	378	6.9	111	12.5	32	8.6	79	15.2
OSR	135	4.7	18	1.1	117	9.6	3	1.1	114	12.0
All patients	624	6.7	396	5.5	228	10.8	35	5.5	193	13.1
Major complications										
EVAR	717	11.3	456	8.3	261	29.3	64	17.2	197	38.0
OSR	1444	49.9	703	41.9	741	60.8	122	45.4	619	65.2
All patients	2161	23.3	1159	16.2	1002	47.5	186	29.0	816	55.6

Table 3. Uni- and multivariable analysis of variables associated with FTR for the whole group and subgroups of EAAA and AAAA patients.

	Univariable analysis			Multivariable analysis		
	Overall Odds ratio (95% CI)	EAAA Odds ratio (95% CI)	AAAA Odds ratio (95% CI)	Overall Odds ratio (95% CI)	EAAA Odds ratio (95% CI)	AAAA Odds ratio (95% CI)
Age (year)	**1.06 (1.05–1.08)**	**1.03 (1.00–1.06)**	**1.06 (1.04–1.08)**	**1.05 (1.03–1.07)**	1.02 (0.99–1.04)	**1.06 (1.04–1.08)**
Female gender	1.05 (0.82–1.33)	1.14 (0.74–1.77)	1.13 (0.82–1.57)	–	–	–
Cardiac comorbidity	1.23 (1.00–1.51)	1.28 (0.88–1.86)	**1.42 (1.07–1.88)**	–	–	1.06 (0.77–1.46)
Pulmonary comorbidity	**1.38 (1.11–1.72)**	**1.62 (1.11–2.35)**	**1.48 (1.09–2.02)**	1.34 (1.04–1.62)	**1.50 (1.03–2.20)**	1.26 (0.89–1.77)
Malignancies	0.99 (0.77–1.30)	1.30 (0.82–2.04)	1.14 (0.78–1.67)	–	–	–
GCS < 15	**6.89 (5.23–9.08)**	–	**3.04 (2.25–4.10)**	**2.22 (1.61–3.07)**	–	**2.21 (1.59–3.07)**
AAA size (mm)	**1.02 (1.02–1.03)**	1.00 (0.99–1.02)	1.00 (0.99–1.01)	1.00 (0.99–1.00)	–	–
RAAA	**8.53 (6.81–10.7)**	–	**3.24 (2.39–4.91)**	**3.91 (2.73–5.61)**	–	**1.89 (1.24–2.90)**
SAAA	**2.49 (1.71–3.64)**	–	–	**1.99 (1.32–2.99)**	–	–
ECG irregular	**1.86 (1.47–2.35)**	1.36 (0.94–1.99)	**1.97 (1.40–2.76)**	**1.52 (1.16–1.98)**	–	**1.84 (1.26–2.69)**
Creatinine level	**1.01 (1.01–1.01)**	**1.01 (1.00–1.01)**	**1.01 (1.00–1.01)**	**1.00 (1.00–1.01)**	1.00 (1.00–1.01)	**1.00 (1.00–1.01)**
Abnormal sodium	**2.02 (1.55–2.64)**	1.37 (0.70–2.68)	1.27 (0.92–1.75)	1.17 (0.85–1.60)	–	–
Abnormal potassium	**1.71 (1.31–2.23)**	1.34 (0.73–2.44)	1.16 (0.84–1.60)	1.01 (0.74–1.38)	–	–
WBC	**1.17 (1.13–1.20)**	1.03 (0.95–1.12)	1.02 (0.99–1.06)	1.01 (0.97–1.04)	–	–
SBP	**0.98 (0.98–0.98)**	1.00 (0.99–1.01)	**0.99 (0.99–0.99)**	1.00 (0.99–1.00)	–	**1.00 (0.99–1.01)**
Pulse rate	**1.02 (1.02–1.03)**	1.00 (0.99–1.02)	**1.01 (1.00–1.01)**	**1.01 (1.00–1.01)**	–	1.01 (1.00–1.01)
Haemoglobin	**0.64 (0.60–0.69)**	**0.75 (0.63–0.88)**	**0.83 (0.76–0.90)**	0.97 (0.89–1.06)	**0.80 (0.67–0.95)**	1.02 (0.92–1.13)
OSR	**1.35 (1.10–1.65)**	**1.50 (1.02–2.21)**	0.84 (0.63–1.11)	–	–	–

Note. Bold indicates statistically significant.

patients (28.4%) FTR was observed. The adjusted variation in FTR between hospitals ranged from 0 to 60%. The number of patients with a major complication in EAAA patients was 1159 with a mean percentage of FTR of 11.6% ($n = 135$): 9.2% after EVAR and 13.2% after OSR. In AAAA patients the number of patients with a major complication was 1002 with a percentage FTR of 47.7% ($n = 478$): 51.0% after EVAR and 46.6% after OSR. Pre-operative variables independently associated with FTR were GCS, age, pulse rate, creatinine, ECG, and operative setting (acute operation). Furthermore, for the subgroup of EAAA patients, pulmonary comorbidity and pre-operative haemoglobin were significantly associated with FTR; for AAAA pre-operative systolic blood pressure was also independently associated with FTR.

FTR and hospital volume

Total hospital volume, as for the subgroups of EAAA and AAAA patients, were split into tertiles. Low overall volume was defined as up to 149 patients in three years of AAA surgery and high volume at 198 patients or more. For subgroup analysis the EAAA volume was split into the following groups: < 110, 110—156, and > 156 patients per hospital. AAAA volume was split in groups of <36, 36—49, >49 patients per hospital. Nine of 12 high volume EAAA hospitals were also high volume AAAA hospitals. For unadjusted only, there was an association between lower FTR and medium or high volume hospitals rather than with low volume hospitals (OR for high volume 0.79; 95% CI 0.63—0.99, and for medium volume 0.79; 95% CI 0.63—0.98). There was a statistically significant independent adjusted association between high hospital volume and mortality (OR 0.79; 95% CI 0.62—1.00), but not for the percentage of major complications and FTR (Table 4). The subgroup of high volume AAAA hospitals treating 50 patients or more in three years performed significantly better regarding mortality (OR 0.64; 95% CI 0.48—0.87) and major complications (OR 0.62; 95% CI 0.49—0.78) than low volume hospitals. However, the adjusted OR for FTR was not significant.

Hospital comparisons

For hospital comparisons, the first step was the overall adjusted mortality rate per hospital volume (Fig. 2). There were four hospitals (green) with a statistically significant lower adjusted mortality than the national mean. There was only one low volume hospital with a significantly higher mortality (red). The second step was the percentage of patients with one or more major complications per hospital volume (Fig. 3). There was a wide variation in the number of complications and the (adjusted) complication rate including several hospitals performing significantly better or worse than the national average. However, the four green hospitals (low mortality) and one red (high mortality) performed within the confidence limits of the national average of major complication rates. However, in the third step (Fig. 4) it can be concluded that these four green hospitals, next to a lower mortality, also have significant lower FTR. In contrast, those hospitals with more complications than the national average scored within the confidence limits for FTR and for mortality, including the one hospital performing significantly worse for mortality than the national average.

In the final step (Fig. 5) adjusted FTR is plotted against the adjusted complication rate. By adding the isomortality lines, hospitals can get insight into their performance, compared with other hospitals, for three parameters together in one plot: mortality, complication rate, and FTR.

Table 4. Three year hospital volume tertiles for EAAA and AAAA surgery and the association with mortality, major complications, and FTR.

	Overall Low volume <149 Reference	Medium volume 149—197 Odds ratio (95% CI)	High volume >197 Odds ratio (95% CI)	EAAA Low volume <110 Reference	Medium volume 110—156 Odds ratio (95% CI)	High volume >156 Odds ratio (95% CI)	AAAA Low volume <36 Reference	Medium volume 36—49 Odds ratio (95% CI)	High volume >49 Odds ratio (95% CI)
No. of hospitals	30	19	12	31	18	12	33	17	11
Mortality (unadjusted)	Ref.	**0.82 (0.67—0.99)**	**0.78 (0.64—0.95)**	Ref.	0.95 (0.63—1.45)	1.08 (0.72—1.64)	Ref.	1.09 (0.86—1.39)	**0.75 (0.58—0.97)**
Mortality (adjusted)	Ref.	0.90 (0.71—1.13)	**0.79 (0.62—1.00)**	Ref.	0.96 (0.62—1.47)	1.08 (0.70—1.66)	Ref.	1.14 (0.86—1.51)	**0.64 (0.48—0.87)**
Major complications (unadjusted)	Ref.	0.97 (0.87—1.10)	0.92 (0.81—1.03)	Ref.	1.01 (0.87—1.18)	1.03 (0.89—1.21)	Ref.	0.93 (0.76—1.15)	**0.72 (0.58—0.89)**
Major complications (adjusted)	Ref.	1.04 (0.92—1.18)	0.91 (0.79—1.04)	Ref.	1.01 (0.86—1.18)	1.01 (0.86—1.18)	Ref.	0.92 (0.73—1.15)	**0.62 (0.49—0.78)**
FTR (unadjusted)	Ref.	**0.79 (0.63—0.98)**	**0.79 (0.63—0.99)**	Ref.	0.94 (0.60—1.46)	1.06 (0.69—1.64)	Ref.	1.22 (0.91—1.64)	0.90 (0.66—1.23)
FTR (adjusted)	Ref.	0.88 (0.67—1.14)	0.91 (0.69—1.20)	Ref.	0.97 (0.62—1.53)	1.11 (0.70—1.76)	Ref.	1.30 (0.93—1.82)	0.82 (0.58—1.17)

Note. Bold indicates statistically significant. Adjusted for variables: age, systolic blood pressure, heart rate, pulmonary status, cardiac status, pre-operative electrocardiogram and pre-operative creatinine, GCS, haemoglobin, gender, setting/urgency, and year of surgery, OR = odds ratio (95% confidence interval).

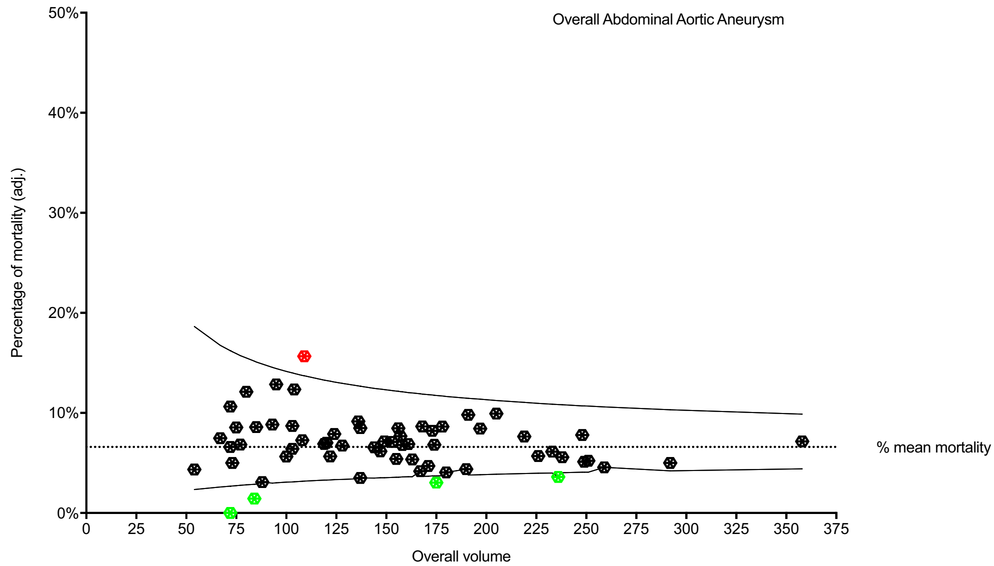

Figure 2. The adjusted mortality rate per hospital (volume) in patients after AAA surgery (95% CI).

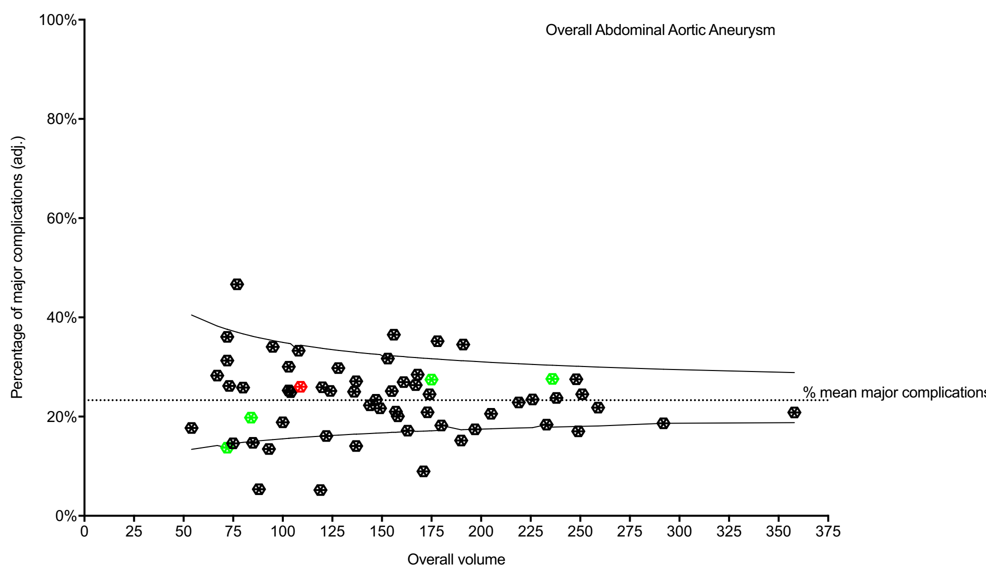

Figure 3. The adjusted major complication rate per hospital (volume) in patients after AAA surgery (95% CI).

Additional analysis for EAAA and AAAA can be found in the Supplementary material B and C.

DISCUSSION

This study has shown an increased variation between hospitals in The Netherlands performing AAA surgery for the composite outcome measure FTR compared with the single measure mortality. But FTR did not identify those hospitals with a significantly higher mortality following major complications. Besides, best performing hospitals regarding mortality were the same hospitals for FTR, independent of the low power in the denominator. Therefore, FTR can be used for internal quality purposes, but is of limited use for hospital comparisons in the AAA treatment evaluation next to mortality and complication rates. By combining FTR and complication rate in one plot together with isomortality lines, each hospital gets insight in these three parameters for quality assessment in one plot.

FTR reflects the ability of a surgical team to recognise and treat complications adequately. However, hospitals with undesirably high complication rates can have a low FTR while a high FTR can be observed next to a low complication rate. Since FTR is merely dependent on the number of major complications related to overall hospital volume and death rate, it is important to report this outcome measure together with mortality and major complications by hospital volume. Mortality as a single indicator is highly dependent on the type of admission and operative setting and separate analyses are necessary for EAAA and AAAA surgery for hospital comparisons. The advantage of FTR as an indicator is that all AAA patients can be analysed together. The ability to recognise and treat major complications and avoid

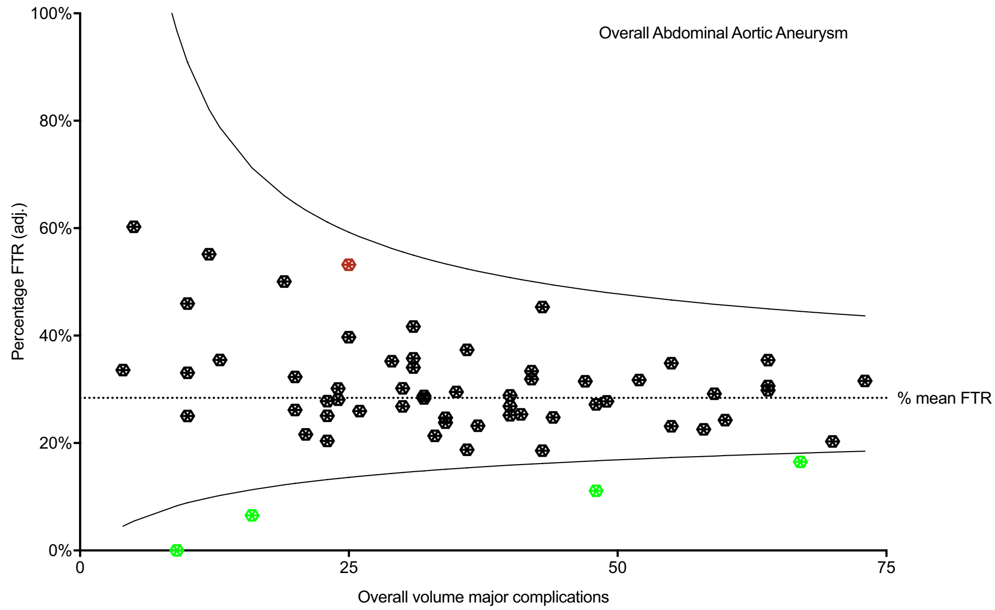

Figure 4. The adjusted failure to rescue per volume of complications by hospital after AAA surgery (95% CI).

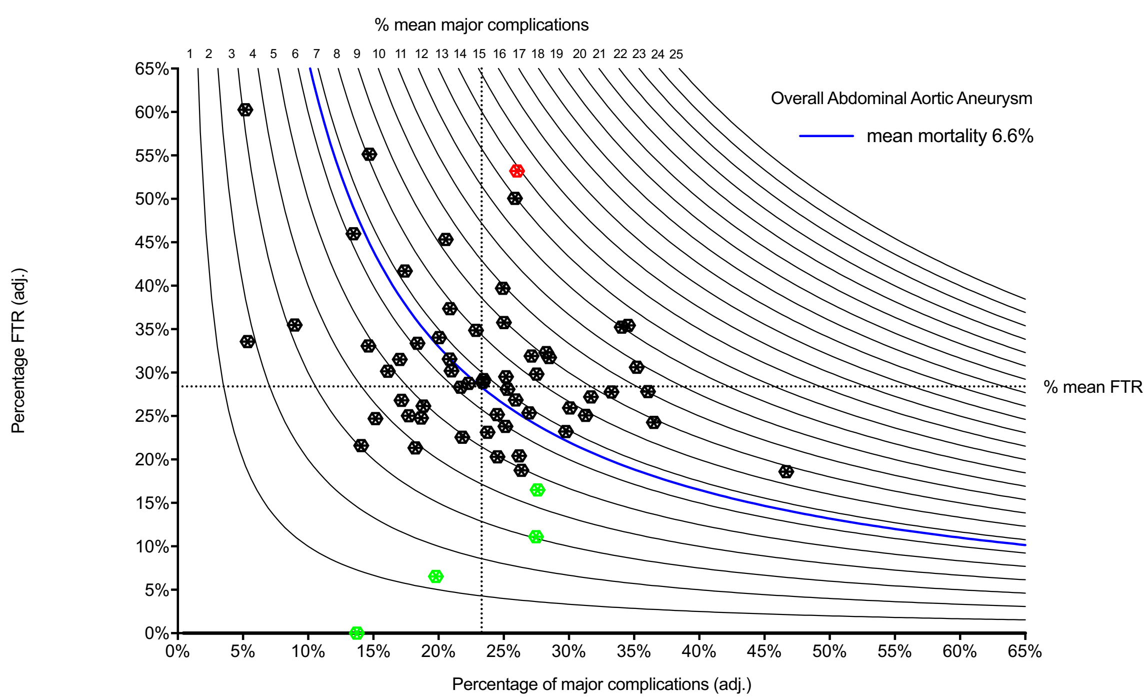

Figure 5. The adjusted percentages of failure to rescue and major complications after AAA surgery. The hyperbolic lines project the mortality in relation to the percentage major complications and the mortality after major complications. From left to right each line has a 1% higher mortality for every hospital crossing that line starting at 1%, with the overall mean percentage mortality of 6.6% projected with the blue line.

mortality is unrelated to the type of admission and operative setting. In other words, complications associated with acute surgery must be just as appropriately treated as complications in the elective setting.

One of the difficulties regarding FTR is the definition used in which every patient that dies following a major complication is graded as preventable death.[18] However, death may be an unwanted outcome but cannot always be prevented, which can be the case in emergency surgery, such as RAAA patients.[19,20] Another difficulty is that the definition used for FTR varies in the types of complications that are included in the denominator or whether or not to exclude those patients that die without a complication.[19] The authors support the view of the developers of FTR, that death is considered as a result of a complication and therefore all deaths should be included in FTR, in the numerator and in the denominator.[11] Although alternatives have been proposed, the inclusion of mortality in the denominator also overcomes the problem of under, or different, registration of complications and statistical uncertainties following low volume and wide confidence intervals.[9,18,20,21] These discrepancies make international comparisons difficult.

Primarily, FTR was investigated because of the low discriminative ability of the low mortality rates in elective AAA surgery.[6] Indeed, the mean FTR in this study is higher (9.2% EVAR and 13.2% OSR), with more variation, than the mean mortality as described for EAAA patients and was similar to a study in 2015: 9.6% FTR for EVAR and 11.1% FTR for OSR.[22] However hospital variation regarding outliers is disappointing. A study investigating FTR in EAAA surgery revealed percentages even lower than earlier described: 0.6% for EVAR and 2.7% for OSR.[23] This can be caused by the inclusion of different complications in the FTR denominator. The standardisation of definitions, assessment tools, clinically relevant endpoints, and adherence to national reporting guidelines would help improve the investigation of system factors that influence vascular outcomes.[24] In addition, combining FTR with other composite outcome measures, for example TO, could improve quality assessment and create awareness regarding the performance of individual hospitals.[15]

An advantage of FTR is that it reflects the ability of the surgical team to treat complications and avoid (consequential) death. It is therefore more dependent on hospital factors than on patient (casemix) factors.[10,25] However, the influence of age on outcomes like FTR cannot be underestimated.[26] In this study there were only a few baseline characteristics of influence on FTR with the majority for overall and acute AAA surgery indicating that in general, FTR is merely influenced by hospital characteristics instead of casemix. Hospital volume was not found to be associated with FTR. However several studies have underlined the importance and influence of hospital volume on FTR.[14,23,27,28] One study found a significant volume FTR association for OSR but not for EVAR.[25] Consequently, as expected, AAAA surgery resulted in a less favourable FTR than EAAA and OSR had a worse FTR than EVAR. Therefore, operative setting was included for adjustment as it is an important casemix variable. Owing to the minimum number of 20 EAAA operations in The Netherlands the volume differences between hospitals have become smaller and have probably reached the goal by improving Dutch AAA healthcare. However, in AAAA surgery a significant association was observed between the three year volume tertiles and the outcomes major complications and mortality.

Limitations

There are some limitations of this study. First, patients requiring more specialised care being referred to a tertiary referral centre, could not be extracted from the data. However, adjusting for casemix will in part solve this problem of treating more morbid patients in the case of a tertiary referral centre. Second, no other hospital characteristics than procedural volume were registered in this dataset. Therefore, the observed variation of FTR cannot be easily attributed to specific differences in (infra) structure or other processes that influence FTR. Third there is a risk of registration bias due to missing data, which is a common problem of observational data. It has been reported that complications are often underreported.[11] However, every hospital in The Netherlands participates in the mandatory DSAA and every compulsory variable needs to be filled before finalising a patient's registration. Therefore, missing or inaccurate data are kept as low as possible and exceeded 10% in only a few cases. Moreover, data verification of randomly selected patients of 14 hospitals revealed that only minor complications were missing in 7.1% of 298 patients (Supplementary material A). However, no re-interventions or mortality, included in the definition of a major complication, were missed. Still variation in the percentage of complications registered by hospitals was wide. Though FTR and complication rate were analysed over all AAA (EAAA, SAAA and RAAA) patients, with the assumption that the outcome severe complications, like bleeding or colonic ischaemia can be recognised and treated in every setting, and that adjustment for operative setting will correct for the difference in incidence of these outcomes between settings. Under this assumption complete surgical care can be analysed, which would be a great advantage when comparing hospitals. However, adequate adjustment remains important, but the difference between the percentages of EAAA and AAAA by hospital could result in bias. Additional figures are presented as Supplementary material to compare FTR versus major complication rates with isomortality lines for EAAA and AAAA surgery.

Last, patients turned down for surgery are not included in this registry. It is possible that this may cause selection bias, especially in the group of RAAA patients where turning down a patient for surgery is highly variable between countries.

CONCLUSIONS

FTR reflects the ability of the vascular team to recognise and treat complications after AAA surgery in order to prevent consequent mortality. Hospitals with a significant adjusted difference from the mean for mortality, major complications and FTR could be identified. However, there were only a few significant outliers that were all performing better than the national average regarding FTR, despite a wide variation of FTR rates between hospitals. These hospitals corresponded to the hospitals that also scored better on the single variable mortality on different isomortality lines without significant differences in major complication rates. This shows FTR alone to be of limited use when comparing hospitals. There was also no association between FTR and hospital volume. To get a useful interpretation of FTR for internal quality improvement it needs to be combined with the percentage of major complications related to mortality reflected in diagrams by isomortality lines.

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APPENDIX A. SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ejvs.2018.06.062.

CONFLICTS OF INTEREST

None.

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