Treatment of ruptured abdominal aortic aneurysms in the Amsterdam area

Reimerink, J.J.

Publication date
2014

7

CHAPTER 7

OUTCOMES AFTER OPEN REPAIR FOR RUPTURED ABDOMINAL AORTIC ANEURYSMS IN PATIENTS WITH FRIENDLY VERSUS HOSTILE AORTOILIAC ANATOMY

Sytse C van Beek
Jorik J Reimerink
Anco Vahl
Willem Wisselink
Jim Reekers
Dink A Legemate
Ron Balm
On behalf of the Amsterdam Acute Aneurysm Trial Collaborators

European Journal of Vascular and Endovascular Surgery - 2014

ABSTRACT

Objectives – In patients with a ruptured abdominal aortic aneurysm (rAAA), anatomic suitability for endovascular aneurysm repair (EVAR) depends on aortic neck and iliac artery characteristics. If the aortoiliac anatomy is unsuitable for EVAR ('hostile anatomy'), open repair (OR) is the next option. We hypothesized that the death rate for OR is higher in patients with hostile anatomy than in patients with friendly anatomy.

Methods – We conducted an observational cohort study in 280 consecutive patients with an rAAA treated with OR between 2004 and 2011. Primary endpoint was 30-day or in-hospital death. Aortoiliac anatomy (friendly vs. hostile) was determined prospectively by the vascular surgeon and the interventional radiologist treating the patient. A multivariable logistic regression analysis was done to assess the risk of dying in patients with hostile anatomy after adjustment for age, sex, comorbidity and hemodynamic stability.

Results – Aortoiliac anatomy was friendly in 71 patients and hostile in 208 patients. Death rate was 38% (95% confidence interval (CI) 28 – 50%) in patients with friendly anatomy and 30% (CI 24 – 37%) in patients with hostile anatomy (P=0.23). After multivariable adjustment, the risk of dying was not higher in patients with hostile anatomy (adjusted odds ratio 0.744, CI 0.394 – 1.404).

Conclusion – The death rate after open repair for an rAAA is comparable in patients with friendly and hostile aortoiliac anatomy.

INTRODUCTION

Anatomical suitability for endovascular aneurysm repair (EVAR) depends on aortic neck and iliac artery characteristics. The aortoiliac anatomy of patients with a ruptured abdominal aortic aneurysm (rAAA) has been shown to be suitable ('friendly anatomy') for EVAR, in approximately 40% of cases.[1, 2] If the anatomy is unsuitable for EVAR ('hostile anatomy'), open repair (OR) is the next option. Hostile anatomy comprises shorter, wider or more angulated aortic necks and calcified or tortuous iliac arteries. As the number of patients treated with EVAR is increasing[1], fewer patients with friendly anatomy are being treated with OR. This leaves the more challenging patients for OR. Previous studies have shown that outcomes are worse after OR in patients with hostile anatomy than in patients with friendly anatomy.[3-5] For this reason, aortoiliac anatomy might be an important confounder in observational and randomized studies comparing OR and EVAR.

In the present study, we hypothesized that after OR for an rAAA, outcomes are worse in patients with hostile anatomy for EVAR than in patients with friendly anatomy for EVAR. The objective was to test this hypothesis with regard to the outcomes of in-hospital death rate, in-hospital complication rate and long-term survival.

METHODS

We conducted an observational cohort study in all consecutive patients with an rAAA treated with OR in the Amsterdam ambulance region between May 2004 and February 2011. Patients who had previously undergone aortic reconstruction, or had an rAAA with an aortoenteric fistula or whose anatomy was not classified, were excluded. Details of the cohort of patients in the Amsterdam ambulance region have been published previously.[6, cohort study] All patients with an rAAA in the region, comprising 10 hospitals and 1.24 million inhabitants, were registered prospectively. All patients were to be evaluated with computed-tomographic angiography (CTA) on arrival at the hospitals. Patients regarded as too hemodynamically unstable to undergo CTA, immediately underwent OR after confirmation of the diagnosis with duplex ultrasound. After CTA, aortoiliac anatomy (friendly vs. hostile) was classified by the vascular surgeon and the interventional radiologist treating the patient in the acute setting. Patients with friendly anatomy who were clinically suitable for both EVAR and OR, were randomized to the Amsterdam Acute Aneurysm Trial.[6] Patients with a hostile anatomy were not randomized and were treated with OR. By this treatment algorithm, a cohort of patients treated with OR with either friendly or hostile anatomy was created for the present study. The criteria of friendly and hostile anatomy were based on the instructions for use (IFU) of an aorto-uni-iliac endograft and are shown in *Table 1*. OR comprised midline laparotomy and exclusion of the aneurysm by either polyester tube or polyester bifurcated graft.

The study was conducted in accordance with the principles of the Declaration of Helsinki. Because of its observational design, written informed consent from patients was not necessary for the present study.

Outcomes

The primary endpoint was the combined 30-day or in-hospital death rate.The primary endpoint of included patients was checked for errors in the communal registry of all death certificates in the Netherlands. The secondary endpoints were severe complications, a composite endpoint of death or complication, long-term survival, length of hospital stay, length of intensive care unit (ICU) stay and peroperative blood loss.

Details of severe complications were collected retrospectively from the medical patient charts by the primary author. Severe complications were defined as cardiac (myocardial infarction including enzymatic changes or severe hemodynamic dysfunction necessitating resuscitation or with a fatal outcome), renal (requiring temporary or permanent dialysis), gastrointestinal (ischemia necessitating bowel resection, stoma or fatal bowel ischemia), neurological (stroke or spinal chord ischemia), graft related (graft occlusion or infection), major amputation or the need for acute reoperation in accordance with the reporting standards.[7] Long-term survival was also derived from the communal registry of death certificates (last search October 10, 2013).

Table 1. Criteria for friendly and hostile aortoiliac anatomy based on the instructions for use of an aorto-uni-iliac endograft.

suitable infrarenal anchoring segment
a minimum length of the infrarenal segment of at least 10-15mm
an infrarenal diameter of 20-32mm
no obstructing calcifications, tortuosity or thrombus
suitable iliac anchoring segment
an ipsilateral iliac diameter of 8-18mm
a contralateral iliac diameter of 10-20mm
at least one iliac artery should be able to accommodate an endograft
no obstructing calcifications, tortuosity or thrombus

Data collection

Data collection and statistical analysis were done with IBM SPSS Statistics 19.0 (SPSS Inc., Armonk, New York, USA). Patient variables collected from the patient charts were age, sex, comorbidity categorised as cardiac disease (previous history of arrhythmia, cardiac surgery or myocardial infarction), pulmonary disease (chronic obstructive pulmonary disorder (COPD)), renal disease (previous history of chronic kidney failure or dialysis), cerebrovascular disease (previous history of transient ischemic attack or stroke), serum hemoglobin (in mmol/L, 1 mmol/L corresponds with 1.61 g/dL), serum creatinine (in µmol/L, 1 µmol/L corresponds with

88.4 mg/dL) and incidence of suprarenal aortic cross clamping. The preoperative lowest in-hospital systolic blood pressure (SBP) and incidence of cardiopulmonary resuscitation (CPR) were used as markers for hemodynamic stability. The preoperative Glasgow aneurysm score (GAS)[8], a validated score used for case-mix comparison, was calculated. Double data entry was done for the patient variables and data were checked for inconsistencies. Inconsistencies were resolved by consulting the original patient charts. To validate the decision of friendly or hostile anatomy, aneurysm characteristics were measured by the primary author in the sagittal, coronal and axial planes of the pre-operative CTA. The measurements were done blinded for type of anatomy and outcome.

In order to include all patients in the regression analyses, an imputation procedure was done using logistic and linear regression models whereby ten datasets were created.[9] The most critically ill patients needed the most urgent decisions and the fewest notes were made. To correct for bias of most missing data in the most critically ill patients, we included 'death' as a predictor in the imputation model. Other predictors were the baseline characteristics, level of consciousness and Glasgow coma scale. The statistical analysis was done in the ten separate imputed datasets and the outcomes were pooled.

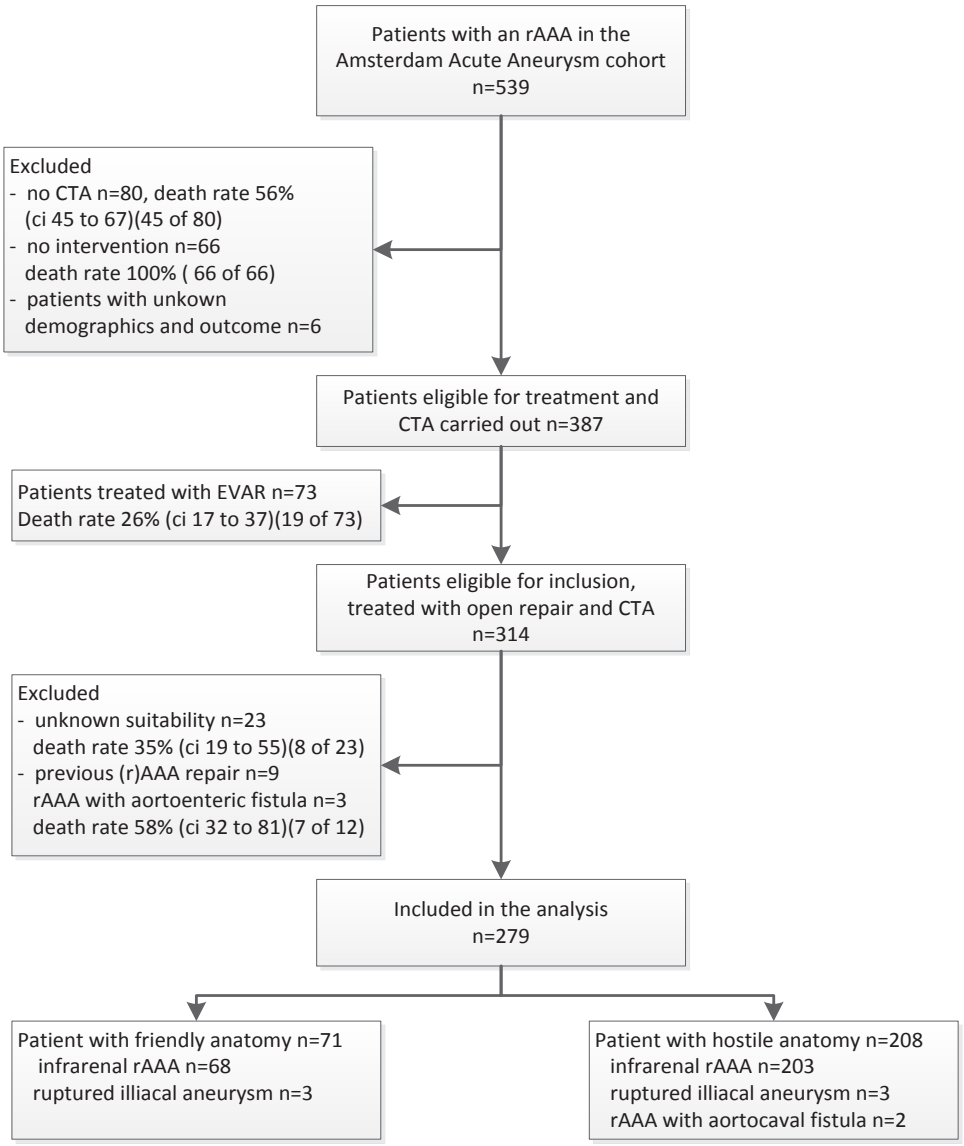
Statistical analysis

Continuous data were described by the mean with corresponding standard deviation (SD) for data normally distributed, and by the median with corresponding inter-quartile range (IQR) for data with skewed distribution. Baseline characteristics and outcomes were compared with the students t-test, the chi-squared test, the Kruskal-Wallis test and the Mann-Whitney U test (two-sided; α =.05). A $P<0.05$ was considered statistically significant. The ranges of outcomes of the statistical tests in the ten imputed datasets were reported. Long-term survival was assessed by Kaplan-Meier survival analysis and compared using the log rank test.

Two logistic regression models were made to assess the risk of the outcomes in friendly and hostile anatomy after adjustment for possible confounding baseline characteristics. The first model was of the endpoint death and the second model of the composite endpoint of death or severe complication. If a continuous variable was not linear on the logit scale, it was categorized. The chi-square statistic, the Hosmer and Lemeshow test and the area under the receiver operating characteristics curve were reported to represent model performance. The ranges of the performance outcomes in the ten imputed datasets were reported.

A sensitivity analysis was done to examine the impact of not including patients without a CTA and treatment with EVAR in our analysis. First, we compared the baseline characteristics of included vs. not included patients. Second, patients not included because no CTA was carried out were considered as hostile anatomy and EVAR treated patients were considered as friendly anatomy. Subsequently, a multivariable regression model was made to assess the risk of dying in friendly and hostile anatomy after adjustment for age, sex, comorbidity, SBP, CPR and type of intervention.

Figure 1 Flow chart



Flow chart of inclusion of 279 patients with friendly and hostile aortoiliac anatomy for EVAR. CTA = computed-tomographic angiography; EVAR = endovascular aneurysm repair; rAAA = ruptured abdominal aortic aneurysm

RESULTS

During the inclusion period, 539 consecutive patients with an rAAA were admitted to the hospitals in the Amsterdam ambulance region (*Figure 1).* Of these patients, 259 were not included in the present study because no CTA was carried out (80), they were treated with EVAR (73), no intervention was done (66) or demographics and outcome were unknown (6). Of 314 patients eligible for inclusion, 35 patients were excluded due to unknown aortoiliac anatomy classification (23), previous aortic reconstruction (9) or an rAAA with aortoenteric fistula (3). In total, 279 patients were included in the analysis of which 71 had friendly and 208 had hostile anatomy. The infrarenal aortic segment was hostile for EVAR in 156 cases, the iliac arteries were hostile in 39 cases and in 13 patients there were other or unknown reasons for hostile anatomy classification.

The baseline characteristics are shown in *Table 2* and were comparable between patients with friendly and hostile anatomy (p>0.05). Suprarenal aortic cross clamping was necessary in 27% of patients with friendly anatomy (19 of 70, 1 unknown), and in 43% of patients with hostile anatomy (87 of 201, 8 unknown) (p=0.02).

Table 2. Baseline characteristics

	Friendly anatomy	**Hostile anatomy**	p
Number of patients	71	208	
Age in years, mean (SD)	74.6 (9.0)	74.3 (8.2)	0.80‡
Sex ratio m:f (% male)	59:12 (83)	161:47 (77)	0.40¶
Cardiac comorbidity	47 (33)	92 (44)	0.64 – 0.96†
Pulmonary comorbidity	14 (20)	45 (22)	0.73 – 0.94†
Renal comorbidity	9 (13)	28 (13)	0.71 – 0.95†
Cerebrovascular comorbidity	14 (20)	35 (17)	0.52 – 0.85†
Lowest in-hospital SBP, median (IQR)	90 (68 – 130)	100 (80 – 126)	0.17 – 0.37¶
Cardiopulmonary resuscitation	8 (11)	14 (7)	0.04 – 0.51†
Hemoglobin in mmol/L, median (IQR)	7.3 (5.9 – 8.1)	6.8 (5.9 – 8.0)	0.38 – 0.59¶
Creatinine in µmol/L, median (IQR)	108 (90 – 146)	108 (85 – 134)	0.26 – 0.49¶
GAS, median (IQR)	90 (80 – 99)	86 (74 – 97)	0.13 – 0.32¶
Suprarenal aortic cross clamping	19 (27) (1 unknown)	87 (43) (7 unknown)	0.02†

Values in parenthesis are percentages unless indicated otherwise. ‡ students t-test ¶ Mann-Whitney U test † chi-squared test EVAR = endovascular aneurysm repair, SD = standard deviation, SBP = systolic blood pressure, IQR = inter-quartile range, GAS = Glasgow aneurysm score The ranges of outcomes of the statistical tests in the ten imputed datasets were reported.

Outcomes

The outcomes are shown in *Table 3*. The death rate in patients with friendly anatomy was 38% (27 of 71, 95% confidence interval (CI) 28 – 50%) and in patients with hostile anatomy this was 30% (63 of 208, CI 24 – 37%) p=0.23). The composite death or severe complication rate in patients with friendly anatomy was 61% (43 of 71, CI 49 – 71%) vs. 60% in patients with hostile anatomy (125 of 208, CI 53 – 67%) (p=0.95). The proportion of any severe complication, length of hospital stay, length of ICU stay and peroperative blood loss did not differ between the groups (P>0.05). The survival analyses are shown in *Figure 2*. After two years, 49% (CI 38 – 61%) of patients with friendly anatomy were still alive vs. 58% of patients with hostile anatomy (CI 52 – 65%) (p=0.16).

Table 3. Outcomes

	Friendly anatomy		**Hostile anatomy**		
	% (patients)	CI	% (patients)	CI	p
Death rate	38 (27 of 71)	28 – 50	30 (63 of 208)	24 – 37	0.23†
Severe complication rate*	36 (16 of 44)	24 – 51	43 (62 of 145)	35 – 51	0.45†
Composite endpoint death or severe complication	61 (43 of 71)	49 – 71	60 (125 of 208)	53 – 67	0.95†
	median	IQR	median	IQR	
Length hospital stay in days*	16	9 - 30	16	10 - 30	0.39¶
Length ICU stay in days*	2	1 - 9	3	1 – 8	0.58¶
Estimated blood loss in L	3.5	1 - 5	3	1.4 - 6	0.47¶

*Death rate at 30 days or in-hospital. *rate in discharged patients† chi-squared test ¶ Mann-Whitney U test CI = 95% confidence interval, IQR = inter-quartile range, ICU = intensive care unit.*

Logistic Regression

After multivariable adjustment for possible confounders, the risk of dying was not higher in patients with hostile anatomy (adjusted odds ratio 0.744, CI 0.394 – 1.404). The risk of dying or developing severe complications was also not higher in patients with hostile anatomy (adjusted odds ratio 1.068, CI 0.591 – 1.930) (*Table 4*).

Aortoilliac anatomy

The CTA of 215 of 279 patients could be retrieved from the archives and details of the aortoiliac anatomy are shown in *Table 5*. In patients with friendly anatomy, the median infrarenal neck length was 23 mm (IQR 17 – 35) and diameter was 25 mm (22 – 27). In patients with hostile anatomy because of the infrarenal neck, the median infrarenal neck length was 10 mm (IQR 5 – 17) and diameter was 25 mm (IQR 23 – 32) (p<0.01 and p=0.01, respectively). In patients with friendly anatomy, the common iliac artery diameters were 16 mm (IQR 12 – 18) and 14 mm (IQR 12 – 18). In patients with hostile anatomy because of the iliac arteries, the common iliac artery diameters were 21 mm (IQR 15 - 31) and 18 mm (IQR 14 – 25) (p<0.01 and p=0.02, respectively).

Table 4. Multivariable logistic regression models with the endpoint death (30-day or in-hospital) and the composite endpoint death or severe complication.

Variable	Endpoint death model		Composite endpoint death or severe complication model	
	odds ratio	CI	odds ratio	CI
Age <69 (n=72)	reference category		reference category	
Age 69 – 75 (n=67)	1.520	0.631 – 3.658	1.173	0.564 – 2.442
Age > 75 (n=141)	2.049	0.948 – 4.427	1.442	0.754 – 2.759
Male	0.651	0.334 – 1.269	0.939	0.497 – 1.776
Cardiac comorbidity	1.255	0.704 – 2.238	1.161	0.682 – 1.976
Pulmonary comorbidity	2.329*	1.169 – 4.638	1.433	0.749 – 2.739
Renal comorbidity	1.394	0.597 – 3.254	0.794	0.354 – 1.782
Cerebrovascular comorbidity	1.288	0.599 – 2.771	1.783	0.853 – 3.730
Lowest in-hospital SBP per 10 mmHg	0.828*	0.759 – 0.902	-	
Lowest in-hospital SBP > 128 (n=71)	-		reference category	
Lowest in-hospital SBP 100 – 128 (n=72)	-		1.772	0.885 – 3.549
Lowest in-hospital SBP 76 – 100 (n=67)	-		4.496*	2.100 – 9.624
Lowest in-hospital SBP <76 (n=70)	-		2.766*	1.317 – 5.811
Cardiopulmonary resuscitation	2.099	0.696 – 6.331	2.886	0.828 – 10.061
Hostile anatomy	0.744	0.394 – 1.404	1.068	0.591 – 1.930

The death endpoint model included 279 patients and 90 events. Performance: Chi-squared statistic 51.9 – 57.8 (10 degrees of freedom), p < 0.001, Hosmer & Lemeshow test p = 0.09 – 0.88 area under the receiver operating characteristics curve 0.75 – 0.77. The composite endpoint model included 279 patients and 169 events: Chi-squared statistic (12) = 28.0 – 32.7, P = .001 - .005, Hosmer & Lemeshow test p = 0.43 – 0.96, area under the receiver operating characteristics curve = 0.69 – 0.70
** p <0.05 CI = 95% confidence interval, COPD = chronic obstructive pulmonary disorder, SBP = systolic blood pressure*

Sensitivity Analysis

Most baseline characteristics were comparable between included and not included patients (data not shown). The median pre-operative SBP of patients included in the analysis was 100 mmHg (IQR 75 – 128 mmHg) and 60 mmHg (IQR 18 – 95 mmHg) of patients not included because no CTA was carried out (p<0.01). CPR was needed in 8% (23 of 279) of patients included in the analysis and in 32% (25 of 80) of patients not included because no CTA was carried out.

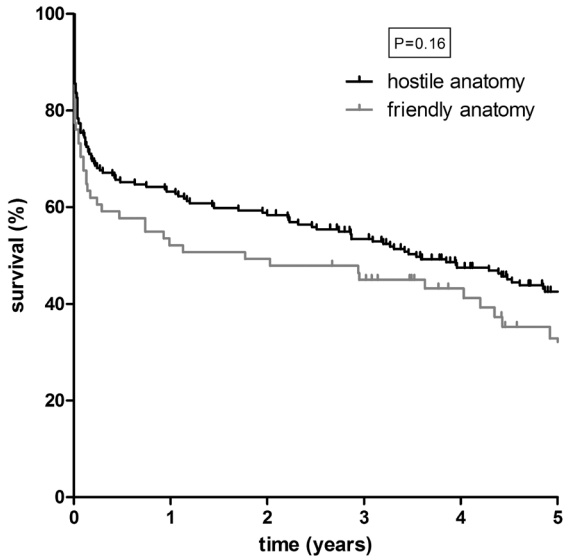
The logistic regression model considering patients in whom no CTA was carried out as hostile anatomy and EVAR treated patients as friendly anatomy included 432 surgically treated patients. Of these patients 144 had friendly and 288 had hostile anatomy. After multivariable adjustment for age, sex, comorbidity, SBP, CPR and type of intervention, the risk of dying was not higher in patients with hostile anatomy (adjusted odds ratio 1.090, CI 0.593 – 2.004) (data not shown).

Table 5. Retrospective measurement of aortoiliac anatomy.

	Friendly anatomy	Hostile infrarenal neck	Hostile iliac arteries	p
Number of patients	58	118	28	
Infrarenal neck length in mm	23 (17 – 35)	10 (5-17)	21 (17 – 28)	<0.01
Infrarenal neck diameter in mm	25 (22 – 27)	25 (23 – 32)	23 (19 – 27)	0.01
Infrarenal neck angulation in degrees	40 (25 – 55)	37 (19 – 50)	36 (18 – 62)	0.47
Aneurysm angulation in degrees	51 (30 – 66)	45 (27 – 62)	56 (31 – 74)	0.25
Aneurysm diameter in mm	72 (64 – 86)	80 (67 – 91)	70 (61 – 84)	0.03
Common right iliac artery diameter in mm	16 (12 – 18)	15 (12 – 19)	21 (15 – 31)	<0.01
Common left iliac artery diameter in mm	14 (12 – 18)	15 (12 – 18)	18 (14 – 25)	0.02

All measurements are median values, values in parentheses are IQR = inter-quartile range A Kruskal-Wallis test was performed for the corresponding p-values.

Figure 2 Survival analysis of patients with friendly and hostile anatomy.



friendly anatomy	patients at risk	71	37	35	31	22	14
	death	0	34	36	39	40	45
	censored	0	0	0	1	9	12
hostile anatomy	patients at risk	208	130	120	105	82	63
	death	0	76	86	96	107	115
	censored	0	2	2	7	19	30

DISCUSSION

In patients with a ruptured abdominal aortic aneurysm treated with open repair, the outcomes are comparable between patients with friendly and hostile aortoiliac anatomy for EVAR. We reject our hypothesis.

For us, the most plausible explanation for this surprising conclusion is optimisation of logistics in the Amsterdam ambulance region. In this region care has been centralised in three hospitals with 24-hr full emergency vascular service since 2003. In the Amsterdam Acute Aneurysm Trial, the precursor of the present study, the results after OR were better than anticipated.[6] Further analysis of the referral patterns showed that the lower death rates can be explained by the regional cooperation.[22] Thus, we consider logistic aspects of care to be more important contributors to the outcomes after an rAAA than aortoiliac anatomy. Examples of such logistic aspects are permissive hypotension during transport, the availability of a 24-hr full vascular service with specialised staff, a preoperative CTA immediately on arrival at the hospital, specialised anaesthetic care and a level III intensive care unit.

Confounding by aortic anatomy

Some observational studies have reported a higher death rate after OR than after EVAR in patients with an rAAA.[10, 11] However, two randomised trials showed no significant difference in death rates after OR and EVAR. [6, 12] To date, only patients with friendly anatomy for EVAR have been included in the randomised trials. It has been hypothesized that selection by aortoiliac anatomy explains the inconsistencies between observational and randomized studies.[3] Aortoiliac anatomy might also be an important confounder within observational studies comparing EVAR and OR. The results of the present study contradict these hypotheses. We suspect that other confounding factors explain the conflicting outcomes between observational and randomised studies. Examples of such factors are preoperative blood pressure[13] and resuscitation[14], intervention at a specialised vascular hospital with a high annual case-load[15, 16], hypothermia[17], after-hours surgery[18], and specialised anaesthetic[19] and intensive care.

Friendly anatomy rate

Of patients evaluated with CTA, the friendly anatomy rate for EVAR in the present study was 49% (174/356). The friendly anatomy rate of previous studies ranged between 54% and 99%[20 3, 21]. Compared to these studies, the friendly anatomy rate in the Amsterdam region was rather low. Caregivers adhered mostly to the IFU because little data or guidelines are available on the use of endografts outside the IFU in patients with an rAAA. One might consider the IFU criteria for friendly and hostile anatomy in our study as conservative. The anatomy of some patients graded as hostile by our observers, might be considered friendly by others. Possibly, this resulted in comparable aortoiliac anatomy between the two groups. However, the retrospective measurements of aortoiliac anatomy showed that in patients with hostile anatomy the infrarenal necks were shorter and wider indeed and the common iliac arteries wider.

Previous studies

The present study expands upon previous studies that considered the outcomes in patients with friendly or hostile anatomy for EVAR. [3-5, 21] First, aortoiliac anatomy was classified prospectively in the acute setting by the treating vascular surgeon and interventional radiologist. In this way, the classification is applicable to the previously described selection bias by type of intervention in observational studies. Second, the present study was conducted in several hospitals reflecting daily practice and increasing the external validity of our results.

Our results conflict with those of three previous studies.[3-5] The largest and most important study was conducted in 233 patients in Bern, Switzerland.[3] In the Bern study, the 30-day death rate after OR in patients with suitable aortoiliac anatomy was only 4% (CI 1 – 12%), in patients with borderline anatomy 16% (CI 9 – 27%) and in patients with unsuitable anatomy 24% (CI 17 – 33%). After multivariable adjustment for case-mix and hemodynamic stability, the risk of dying was higher in patients with unsuitable anatomy. It is hard to determine why our results are so conflicting with those of this similar study. Differences between the studies are numerous and listed in *Table 6* (appendix), but their importance is difficult to judge. The most striking difference was the method of anatomical classification (prospectively vs. retrospectively). Moreover, patients hemodynamically unstable to undergo CTA were considered as unsuitable for EVAR in the Bern study. Applying these criteria to our study would not change our conclusions, because the odds ratio for dying in hostile vs. friendly anatomy would then be 1.103 (CI 0.599 – 2.032) after adjustment for age, sex, comorbidity, SBP and CPR (data not shown).

In accordance with our results, a retrospective study of 82 patients by Ten Bosch et al. reported a 30-day death rate in patients treated with OR but with anatomy suitable for EVAR of 46% (CI 28 – 64%) vs. 49% (CI 34 – 64%) in patients with anatomy unsuitable for EVAR (P=0.75).[21] It is noteworthy that in this study, the assessment of anatomy was retrospective as it was in the Bern study.

No definite conclusions can be drawn from these conflicting results and more studies are needed. A barrier to solving the controversy is that only observational studies can be used and these are always subject to bias. Adjustment to eliminate differences in hemodynamic stability, as was done in the Bern study and in our study, is of major importance in minimizing the risk of confounding within such a study.

Limitations

An important limitation of the present study was the inclusion of only 279 of all 467 surgically treated patients. We examined the impact of excluding three groups of patients separately. The first and most important group consisted of 80 patients in whom no CTA was carried out and 73 EVAR treated patients. The second group contained 23 patients in whom no prospective evaluation of aortoiliac anatomy was available. The third group harboured 12 patients who were excluded because of their diagnosis. For the first group, the sensitivity analysis was conducted. After multivariable adjustment for possible confounders, the risk of dying was not higher in patients with hostile anatomy Moreover, pre-operative SBP per 10 mmHg (adjusted odds ratio

0.858, CI 0.805 – 0.914) and CPR (adjusted odds ratio 2.740, 1.228 – 6.113) were significantly associated with dying in this model. This underlines the importance of hemodynamic stability in patients with an rAAA.

For the second group if we considered these patients as having friendly anatomy, the death rate in patients with friendly anatomy would be 37% (35 of 94, CI 28 – 47%) and in patients with hostile anatomy 31% (64 of 209, CI 25 – 37%). If we considered these patients as having hostile anatomy, the death rate in patients with friendly anatomy would be 38% (27 of 71, CI 28 – 50%) and in patients with hostile anatomy 31% (72 of 232, CI 25 – 37%). These crude death rates barely differ from the primary outcomes.

The third group of excluded patients was considered as 'extra difficult rAAA patients'. Risk profiles and outcomes of these patients were so unalike, that statistical methods could not eliminate differences in case-mix.

To summarise, the impact of not including 188 of 467 surgically treated patients appears to be little on our conclusions. However, we cannot rule out any residual confounding or selection bias. Moreover, the number of patients in the friendly and hostile anatomy group was disproportional and we might falsely reject our hypothesis.

Another limitation was that in 9% (26 of 280) of patients some data was missing. Most missing data concerned the variables SBP (5%, 15 of 280), and CPR (5%, 13 of 280). In these 26 patients, the death rate was high (58%, 15 of 26, CI 39 – 75%). We coped with the missing data by multiple imputation and included 'death' as a predictor in the imputation model to adjust for most missing data in the most critically ill patients.

While statistical methods were used to eliminate differences in observed confounders, another limitation of the present study was that we were unable to adjust for differences in unobserved intra-operative confounders such as blood loss and duration of intervention.

Conclusions

In patients with an rAAA treated with OR in the Amsterdam region, the death rate in patients with friendly and hostile aortoiliac anatomy was comparable. Moreover, severe complication rate, a composite endpoint of in-hospital death or severe complication, long-term survival, length of hospital stay, length of intensive care unit (ICU) stay and peroperative blood loss did not differ. Finally, after adjustment for possible confounders the risk of dying or a severe complication was not higher in patients with hostile anatomy than in patients with friendly anatomy. Based on these results, we conclude that outcomes after open repair for a ruptured abdominal aortoiliac aneurysm are comparable in patients with anatomy friendly and hostile to EVAR.

REFERENCE LIST

(1) Mani K, Lees T, Beiles B, Jensen LP, Venermo M, Simo G, et al. Treatment of abdominal aortic aneurysm in nine countries 2005-2009: a vascunet report. Eur J Vasc Endovasc Surg 2011 Nov;42(5):598-607.

(2) Reichart M, Geelkerken RH, Huisman AB, van Det RJ, de SP, Volker EP. Ruptured abdominal aortic aneurysm: endovascular repair is feasible in 40% of patients. Eur J Vasc Endovasc Surg 2003 Nov;26(5):479-86.

(3) Dick F, Diehm N, Opfermann P, von AR, Tevaearai H, Schmidli J. Endovascular suitability and outcome after open surgery for ruptured abdominal aortic aneurysm. Br J Surg 2012 Jul;99(7):940-7.

(4) Perrott S, Puckridge PJ, Foreman RK, Russell DA, Spark JI. Anatomical suitability for endovascular AAA repair may affect outcomes following rupture. Eur J Vasc Endovasc Surg 2010 Aug;40(2):186-90.

(5) Slater BJ, Harris EJ, Lee JT. Anatomic suitability of ruptured abdominal aortic aneurysms for endovascular repair. Ann Vasc Surg 2008 Nov;22(6):716-22.

(6) Reimerink JJ, Hoornweg LL, Vahl AC, Wisselink W, van den Broek TA, Legemate DA, et al. Endovascular Repair Versus Open Repair of Ruptured Abdominal Aortic Aneurysms: A Multicenter Randomized Controlled Trial. Ann Surg 2013 Apr 1.

(7) Chaikof EL, Blankensteijn JD, Harris PL, White GH, Zarins CK, Bernhard VM, et al. Reporting standards for endovascular aortic aneurysm repair. J Vasc Surg 2002 May;35(5):1048-60.

(8) Samy AK, Murray G, MacBain G. Glasgow aneurysm score. Cardiovasc Surg 1994 Feb;2(1):41-4.

(9) Donders AR, van der Heijden GJ, Stijnen T, Moons KG. Review: a gentle introduction to imputation of missing values. J Clin Epidemiol 2006 Oct;59(10):1087-91.

(10) Veith FJ, Lachat M, Mayer D, Malina M, Holst J, Mehta M, et al. Collected world and single center experience with endovascular treatment of ruptured abdominal aortic aneurysms. Ann Surg 2009 Nov;250(5):818-24.

(11) Giles KA, Hamdan AD, Pomposelli FB, Wyers MC, Dahlberg SE, Schermerhorn ML. Population-based outcomes following endovascular and open repair of ruptured abdominal aortic aneurysms. J Endovasc Ther 2009 Oct;16(5):554-64.

(12) Hinchliffe RJ, Bruijstens L, MacSweeney ST, Braithwaite BD. A randomised trial of endovascular and open surgery for ruptured abdominal aortic aneurysm - results of a pilot study and lessons learned for future studies. Eur J Vasc Endovasc Surg 2006 Nov;32(5):506-13.

(13) Tambyraja A, Murie J, Chalmers R. Predictors of outcome after abdominal aortic aneurysm rupture: Edinburgh Ruptured Aneurysm Score. World J Surg 2007 Nov;31(11):2243-7.

(14) Chen JC, Hildebrand HD, Salvian AJ, Taylor DC, Strandberg S, Myckatyn TM, et al. Predictors of death in nonruptured and ruptured abdominal aortic aneurysms. J Vasc Surg 1996 Oct;24(4):614-20.

(15) Holt PJ, Poloniecki JD, Gerrard D, Loftus IM, Thompson MM. Meta-analysis and systematic review of the relationship between volume and outcome in abdominal aortic aneurysm surgery. Br J Surg 2007 Apr;94(4):395-403.

(16) McPhee J, Eslami MH, Arous EJ, Messina LM, Schanzer A. Endovascular treatment of ruptured abdominal aortic aneurysms in the United States (2001-2006): a significant survival benefit over open repair is independently associated with increased institutional volume. J Vasc Surg 2009 Apr;49(4):817-26.

(17) Quiroga E, Tran NT, Hatsukami T, Starnes BW. Hypothermia is associated with increased mortality in patients undergoing repair of ruptured abdominal aortic aneurysm. J Endovasc Ther 2010 Jun;17(3):434-8.

(18) Dueck AD, Kucey DS, Johnston KW, Alter D, Laupacis A. Survival after ruptured abdominal aortic aneurysm: effect of patient, surgeon, and hospital factors. J Vasc Surg 2004 Jun;39(6):1253-60.

(19) Walsh SR, Bhutta H, Tang TY, Nunn DL, Armon MP, Clarke JM, et al. Anaesthetic specialisation leads to improved early- and medium-term survival following major vascular surgery. Eur J Vasc Endovasc Surg 2010 Jun;39(6):719-25.

(20) Mayer D, Aeschbacher S, Pfammatter T, Veith FJ, Norgren L, Magnuson A, et al. Complete replacement of open repair for ruptured abdominal aortic aneurysms by endovascular

aneurysm repair: a two-center 14-year experience. Ann Surg 2012 Nov;256(5):688-96.

(21) Ten Bosch JA, Willigendael EM, van Sambeek MR, de Loos ER, Prins MH, Teijink JA. EVAR suitability is not a predictor for early and midterm mortality after open ruptured AAA repair. Eur J Vasc Endovasc Surg 2011 May;41(5):647-51.

(22) van Beek SC, Reimerink JJ, Vahl AC, Wisselink W, Reekers JA, van Geloven N, Legemate DA, Balm R; Amsterdam Acute Aneurysm Trial Collaborators. Effect of regional cooperation on outcomes from ruptured abdominal aortic aneurysm. Br J Surg. 2014 Jun;101(7):794-801