Differences in Mortality, Risk Factors, and Complications After Open and Endovascular Repair of Ruptured Abdominal Aortic Aneurysms

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WHAT THIS PAPER ADDS

In this study peri-operative variables that affected outcome after ruptured abdominal aneurysm repair were analysed. The added value of this study is the comparison of independently significant variables between endovascular and open surgery, demonstrating that preoperative risk factors influence outcome differently, depending on the type of repair. This information could promote a treatment selection process, based on risk estimates that are repair-dependent.

Objective/background: Endovascular aneurysm repair (EVAR) for ruptured abdominal aortic aneurysm (rAAA) has faced resistance owing to the marginal evidence of benefit over open surgical repair (OSR). This study aims to determine the impact of treatment modality on early mortality after rAAA, and to assess differences in postoperative complications and long-term survival.
Methods: Patients treated between January 2000 and June 2013 were identified. The primary endpoint was early mortality. Secondary endpoints were postoperative complications and long-term survival. Independent risk factors for early mortality were calculated using multivariate logistic regression. Survival estimates were obtained by means of Kaplan—Meier curves.
Results: Two hundred and twenty-one patients were treated (age 72 ± 8 years, 90% male), 83 (38%) by EVAR and 138 (62%) by OSR. There were no differences between groups at the time of admission. Early mortality was significantly lower for EVAR compared with OSR (odds ratio [OR]: 0.45, 95% confidence interval [CI]: 0.21—0.97). Similarly, EVAR was associated with a threefold risk reduction in major complications (OR: 0.33, 95%CI: 0.15—0.71). Hemoglobin level <11 mg/dL was predictive of early death for patients in both groups. Age greater than 75 years and the presence of shock were significant risk factors for early death after OSR, but not after EVAR. The early survival benefit of EVAR over OSR persisted for up to 3 years.
Conclusion: This study shows an early mortality benefit after EVAR, which persists over the mid-term. It also suggests different prognostic significance for preoperative variables according to the type of repair. Age and the presence of shock were risk factors for early death after OSR, while hemoglobin level on admission was a risk factor for both groups. This information may contribute to repair-specific risk prediction and improved patient selection.

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INTRODUCTION

Since the introduction of endovascular aneurysm repair (EVAR) in 1991 by Volodos et al.[1] and Parodi et al.,[2] the use of this less invasive treatment for infra-renal aortic aneurysms has expanded significantly. Nowadays, >60—70% of all elective abdominal aortic aneurysm (AAA) repairs are performed with EVAR.[3,4] This is not the case for ruptured AAA (rAAA), for which the use of EVAR has not yet achieved generalized acceptance.[5,6] In general, rAAA are frequently fatal with a mortality of up to 80%,[7] but patients surviving until they receive hospital care, might expect to benefit from a minimally invasive technique.

For elective surgery, randomized trials have demonstrated a nearly uniform threefold reduction in perioperative mortality and prolonged survival benefit for EVAR over open surgical repair (OSR), which is maintained for at least 2 years.[8,9] These results, also confirmed by large registries and national audits,[10] have justified a shift

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towards a preferential use of EVAR. For rupture, however, evidence of a similar advantage is still lacking.

The aim of this study was to determine the impact of treatment modality on early mortality after rAAA repair, and to evaluate the differences in the prognostic capacity of preoperative variables in determining early survival for EVAR and OSR. Additionally, we investigated the differences in major postoperative complications and assessed any survival advantage related to treatment modality during follow-up.

METHODS

The study complied with the Declaration of Helsinki. According to our institutional guidelines, no formal ethical approval was required.

Patients

The study population consisted of all consecutive patients who underwent AAA repair between January 2000 and June 2013 at a single, tertiary institution. For this study, only patients with confirmed rAAA were included. Some of these patients have previously been included in a published 20-year overview of institutional trends in the management of rAAA.[7] Patients with infected aneurysms and those having had prior aneurysm repair were excluded from the analysis.

Data collection

All possible operation codes and surgical reports were retrospectively retrieved, and hospital charts and computed tomography angiographies (CTAs) were checked for the presence of rupture. If confirmed, patient demographics, clinical baseline characteristics, intraoperative details, and clinical and laboratory outcome were obtained. Baseline characteristics on admission included age, gender, state of consciousness, blood pressure, and pulse rate. Duration from the emergency room (ER) to the operating theatre, operation duration, body temperature, blood pressure and pulse rate during operation, type of anesthesia, blood loss, and usage of blood products and fluids were derived from operative and anesthesia reports. Laboratory results on admission were also obtained. Postoperative complications and events were retrieved from hospital registries. Survival status and the exact date of death of treated patients were obtained via the national civil registry.

Missing data

Baseline data that were not retrievable were analyzed for differences between the OSR and EVAR groups. There were no significant differences in the number of missing data in either group, except for blood loss and the volume of intraoperative transfusion, owing to a lack of documentation about minimal blood loss and transfusions needed with an EVAR procedure. Only variables with <3% missing data were included in multivariate models.

Institutional management of rAAA

The Erasmus University Medical Center is a tertiary teaching institution with full capacity for endovascular and open vascular surgery (24 hours a day/7 days a week), serving about 1.5 million people living in the Rotterdam and surrounding area. Owing to the characteristics of the institution, a relatively high proportion of AAA repairs are done for rupture. Although the logistics involved in EVAR have been adapted and improved over time, the capacity to offer both treatment options was present throughout the entire study period. This made EVAR available for any anatomically suitable patient on any day and at any time. The choice of treatment is individualized, but preference is generally given to EVAR in older patients.

If a patient presents at the ER with a suspected rAAA, the on-call surgical team is informed. On arrival of the patient in the ER, an ultrasound of the abdominal aorta is done to confirm the presence of an aortic aneurysm if the patient is not known to have an AAA. Otherwise, a CTA can be performed immediately. Patients are managed by permissive hypotension in the ER, and resuscitation is started only if the patient becomes unconscious.

According to protocol, a multi-slice CT scanner is used for rAAA CTA. The patient is scanned from nipple to pubic symphysis with a collimation of 118*0.6, and plain and contrast series are acquired after administering 120 mL of Visipaque 320 contrast. Anatomical suitability for EVAR is determined by the surgeon's expectations and experience. In anatomically complex cases, or whenever time allows, a dedicated post-processing workstation (3Mensio Vascular 4.2 software; 3Mensio Medical Imaging, Bilthoven, the Netherlands) is available for sizing and planning. After diagnosis, informed consent is obtained whenever possible.

Aneurysm repair is performed either by consultant vascular surgeons or by residents during their vascular subspecialization under the direct supervision of a consultant vascular surgeon. For EVAR, repair is performed in the operating theatre using a mobile C-arm. Preference is given to local anesthesia for EVAR, although the decision depends on the individual case.

For OSR, a midline transperitoneal approach is preferred, and aorto-aortic or aorto-bi-iliac reconstruction is performed depending on the presence of concomitant iliac aneurysms. Postoperatively, intra-abdominal pressure using a vesical pressure probe is only checked when there is clinical suspicion of abdominal compartment syndrome.

Definitions

Rupture was defined by either direct visualization of fresh blood in the retroperitoneal or peritoneal compartments during OSR, or visualization of peri-aortic hematoma on the immediate preoperative CTA.[11] Early mortality was defined by in-hospital mortality or death within 30 days of surgery. Major complications were defined as one of the following: respiratory; cardiac; cerebrovascular; renal failure (estimated glomerular filtration rate [eGFR] < 30); abdominal; wound; bleeding-related; lower limb ischemia; graft-related.

Table 1. Preoperative baseline characteristics on admission.

Variable	OSR $n = 138$	EVAR $n = 83$	*p*
Age			
Mean ± SD	71.9 ± 7.8	72.1 ± 8.2	.89
>75 y, *n* (%)	46 (33)	29 (35)	.81
Male gender, *n* (%)	123 (89)	68 (93)	.37
Unconsciousness, *n* (%)	4 (3)	1 (1)	.65
Cardiopulmonary resuscitation before OR, *n* (%)	1 (1)	0 (0)	1
Hemodynamic status[a]			
Systolic blood pressure, mean ± SD	114 ± 37	115 ± 37	.81
Diastolic blood pressure, mean ± SD	69 ± 26	67 ± 21	.55
Heart rate (bpm), mean ± SD	85 ± 22	88 ± 25	.37
Shock index > 1[b]	31 (24)	29 (36)	.05
Hemoglobin (g/dL)			
Median (IQR)	11.1 (9.4–12.6)	11.8 (9.6–13.3)	.10
<11, *n* (%)	60 (46)	31 (42)	.59
Coagulation			
INR ≥ 1.5, *n* (%)[c]	33 (28)	24 (33)	.52
Platelet count (×10³/μL), median (IQR)[a]	177 (135–235)	196 (154–256)	.008
eGFR			
Median (IQR)	61 (45–77)	63 (46–75)	.96
< 60, *n* (%)	68 (53)	37 (51)	.86
Leukocytes (×10³/μL), median (IQR)[c]	12.0 (9.0–16.3)	12.5 (8.5–16.3)	.69
CRP (mg/dL), median (IQR)[c]	11 (5–47)	14 (4–70)	.58
Time from ER to OR (mins)[d]	50	36	.023

Note. OSR = open surgical repair; EVAR = endovascular aneurysm repair; OR = operating room; BPM = beats per minute; IQR = interquartile range; INR = international normalized ratio; eGFR = estimated glomerular filtration rate; CRP = C reactive protein; ER = emergency room.
[a] Missing 1–3% of baseline data.
[b] Heart rate/systolic blood pressure.
[c] Missing 3–15% of baseline data.
[d] Missing >15% of baseline data.

Endovascular complications and EVAR-related adverse events were classified according to the reporting standards for EVAR by Chaikof et al.[12] The shock index was calculated by dividing the heart rate by systolic blood pressure, and was calculated from the first heart rate and blood pressure recorded on arrival in the ER.[13]

Endpoints

The primary study endpoint was early mortality. Secondary endpoints were early major complications and overall survival during follow-up.

Statistical analysis

Categorical variables are presented as counts and percentages, and compared with chi-square tests. Continuous variables are presented as means ± standard deviation and compared with Student *t* tests; or as median and interquartile range, and compared with Mann–Whitney *U* tests if the distribution was non-parametric. The influence of missing data on results was tested by comparing the outcome of patients with missing data to those with complete data sets. A logistic regression model was used to assess the proportional outcome risk associated with EVAR. Variables associated with 30-day in-hospital mortality were tested in univariate analysis by type of repair, and significant variables were introduced in a multivariate logistic regression model to determine independent significance. From the beginning of the study period the implementation of EVAR evolved and the number of patients undergoing the procedure increased. As a result, the year of operation was used as a co-variable to adjust for the growth in patients treated with EVAR every year. A graph of the proportion of the groups per year and the mortality rates per year of both groups is shown to illustrate the changes in both groups during the study period. Overall survival during follow-up was estimated using Kaplan–Meier tables, and survival after EVAR versus open repair was compared using the log-rank (Mantel–Cox) statistical test.

RESULTS

From January 2000 to June 2013, 878 patients underwent AAA repair at our institution. The study sample of rAAA included 221 patients with a mean age of 72 ± 8 years (90% of whom were men). Of these 221 patients, 138 were treated with OSR and 83 with EVAR. The demographics and clinical characteristics of patients on admission did not differ significantly between groups (Table 1).

Intraoperative details

Within the OSR group, 13 (9%) intraoperative deaths occurred, while in the EVAR group four (5%) deaths occurred ($p = .21$; Table 2). Most deaths occurred as a result of severe hemorrhagic shock. Intraoperative complications were observed in 15 (11%) and 10 (13%) patients after OSR and EVAR, respectively ($p = .48$). These complications differed significantly between groups. Thrombosis ($n = 7$) and iatrogenic arterial lesions or dissection ($n = 6$) were the most frequent intraoperative complications for the OSR group; in the EVAR group, the main intraoperative complications were type I/III endoleaks ($n = 6$). Large differences were observed between the two treatment groups regarding the duration of operation, estimated intraoperative blood loss, and the intraoperative consumption of blood products and fluids ($p < .001$; Table 2).

Early survival

Early death occurred in 55 patients (40%) and 20 patients (24%) for OSR and EVAR, respectively. After adjusting for

Table 2. Intraoperative characteristics.

Variable	OSR	EVAR	p
Duration of surgery (h), median (IQR)[a]	3.42 (3.07–4.46)	2.46 (2.20–3.57)	<.001
Blood loss (mL), median (IQR)[b]	4,500 (2,050–8,875)	200 (0–500)	<.001
Red blood cell concentrates, median (IQR)[b]	6 (3–11)	2 (0–4.5)	<.001
Plasma units, median (IQR)[b]	6 (2–10)	0 (0–2)	<.001
Platelet units, median (IQR)[b]	1 (0–5)	0 (0–0)	<.001
Crystalloids, median (IQR)[b]	4,000 (2,500–7,000)	1,500 (1,000–2,125)	<.001
Colloids, median (IQR)[b]	1,500 (1,000–2,000)	500 (0–1,000)	<.001
Body temperature at end of surgery, °C, median (IQR)[b]	35.9 (35.0–36.5)	36.00 (35.50–36.25)	.21
Intraoperative death, *n* (%)[a]	13 (9)	4 (5)	.21
Intraoperative complications, *n* (%)[a]	15 (11)	12 (14)	.48
Endoleaks (type I/III), *n* (%)	—	6 (7)	
Graft occlusion	2 (1)	1 (1)	
Peripheral embolization/thrombosis	7 (5)	0 (0)	
Iatrogenic dissection	3 (2)	0 (0)	
Arterial disruption with bleeding	3 (2)	2 (2)	
Unintentional renal artery occlusion	0 (0)	2 (2)	

Note. OSR = open surgical repair; EVAR = endovascular aneurysm repair; IQR = interquartile range.
[a] Missing 1–3% of baseline data.
[b] Missing 3–15% of baseline data.

age, gender, eGFR, hemoglobin (Hgb) and hemodynamic status, and year of operation, EVAR was associated with a twofold risk reduction of early death compared with OSR (odds ratio [OR]: 0.45; 95% confidence interval [CI]: 0.21–0.97; Table 3). In multivariate analysis of risk factors for early mortality (Fig. 1), significant differences were observed between groups. Only a low Hgb level was an independent risk factor for both types of repair. Being older than 75 years and the presence of shock were risk factors for OSR only and not for EVAR. Univariate analysis suggested coagulopathy on admission as a risk factor for EVAR (OR: 4.60, 95%CI: 1.49–14.18) instead of OSR (OR: 1.69, 95%CI: 0.79–3.66), but the high number of missing values (12%) did not allow for inclusion of this variable in the multivariate model. Type of anesthesia (local vs. general) had no effect on mortality for EVAR patients (OR: 1.19, 95% CI: 0.67–2.04). Fig. 2 shows the proportion per year of EVAR- or OSR-treated patients, as well as the 30-day mortality per year per treatment.

Table 3. Thirty-day/in-hospital outcome after ruptured abdominal aortic aneurysm repair.

Variable	OSR	EVAR	OR[a]	95%CI
Mortality	55 (40)	20 (24)	**0.45**	0.21–0.97
Major complications	95 (76)	46 (58)	**0.33**	0.15–0.71
Systemic complications	80 (64)	42 (53)	0.69	0.34–1.38
Local complications	38 (30)	15 (19)	**0.37**	0.16–0.83
Fatal complications	37 (30)	13 (16)	**0.39**	0.17–0.90
Multiple complications	52 (42)	21 (27)	0.53	0.26–1.08

Note. ORs are given for EVAR compared with OSR. Significant values are presented in bold. OSR = open surgical repair; EVAR = endovascular aneurysm repair; OR = odds ratio; CI = confidence interval.
[a] Logistic regression is performed for each outcome measure, adjusting for age, gender, estimated glomerular filtration rate, preoperative hemoglobin level, hemodynamic status (shock index), and year of operation.

Major postoperative complications

Median stay in the intensive care unit (ICU) was 4 (1–11) days for OSR and 1 (1–5) days for EVAR ($p = .001$). Median hospital stay was 14 (6–33) days for OSR and 8.5 (4–21) days for EVAR ($p = .001$). More major complications occurred after OSR than after EVAR (76% vs. 58%, $p = .007$). Furthermore, OSR patients were more likely to suffer from more than one complication (42% vs. 24%, $p = .047$) and have more frequent fatal complications (30% vs. 16%, $p = .033$). The distribution of complications is shown in Table 4. More abdominal, wound, and bleeding complications occurred after OSR, and more graft-related problems occurred after EVAR. Compared with OSR, EVAR was associated with a threefold risk reduction for major complications (OR: 0.33, 95%CI: 0.15–0.71), after adjusting for age, gender, Hgb, eGFR, hemodynamic status on admission, and year of surgery (Table 3).

Late survival

The survival benefit after EVAR on early outcome was maintained during the mid-term follow-up. The estimated survival after 2 years was 52% for OSR versus 65% for EVAR ($p < .001$; Fig. 3). After 3 years, the survival benefit after treatment with EVAR was no longer present.

DISCUSSION

In this study, EVAR was associated with a twofold reduction in early mortality after rAAA, after correcting for possible confounders. This benefit persisted for up to 3 years after the index event. Moreover, risk factors for early mortality varied in type and importance according to which

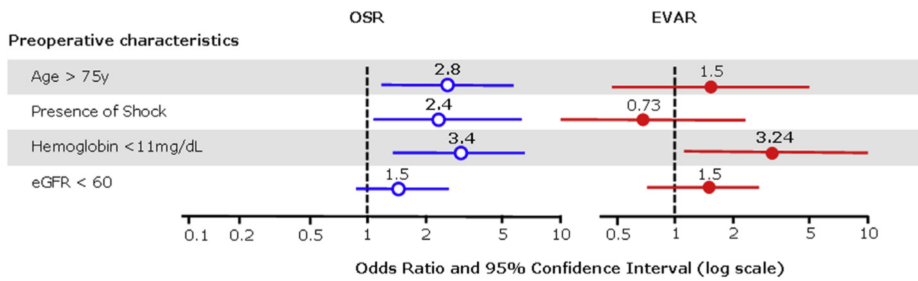


Figure 1. Multivariate logistic regression analysis of risk factors for early mortality, by type of repair (only including variables with <3% missing data). *Note*. eGFR = estimated glomerular filtration rate; OSR = open surgical repair; EVAR = endovascular aneurysm repair.

treatment modality was selected. These risk factors could have a potential impact on current clinical practice.

In contrast to elective EVAR, which is widely accepted, EVAR for rAAA is far from accepted owing to a significant lack of level A evidence.[5,6] To date, only two randomized controlled trials have been published on the subject. The Nottingham trial, which was only a pilot study, had difficulties with enrollment and was not able to show any differences in early mortality or complications. Recently, the results of the AJAX trial have been published.[14,15] In this study, no difference in 30-day mortality and severe complications between EVAR and OSR were found. This could be explained, in part, by the unexpectedly good results from OSR, arguably difficult to achieve in most settings. With regard to the secondary endpoints of the AJAX study, EVAR generally performed better: mean ICU stay, mean hospital stay, mean blood loss, and the need for mechanical ventilation all favored the EVAR group. Both of the aforementioned studies were limited by low inclusion rates, which may result in significant bias, and are both considered to be underpowered.

Two other randomized trials are still in progress (IMPROVE[16] and ECAR[17]). While the results of the ECAR trial are awaited, the IMPROVE investigators recently presented preliminary data.[18] They were able to recruit 613 patients (about two-thirds of all eligible patients) with a clinical diagnosis of ruptured aneurysm. Based on intention-to-treat analysis, no significant difference was found between the EVAR and OSR groups for 30-day mortality (35.4% and 37.4%, respectively), but there was a significant number of protocol variations (11%). In the endovascular first strategy group, patients who were actually treated by EVAR ($n = 150$) had a 30-day mortality of 25% compared with 37% for those treated in the OSR first strategy group ($n = 220$), results similar to those obtained in our study (24% and 40%, respectively). Subgroup analysis revealed a survival benefit for women treated with EVAR. After EVAR, patients had a shorter stay in hospital than OSR patients, and the costs related to both groups of patients after 30 days was comparable. They also found that the lowest measured systolic blood pressure was an independent risk factor for 30-day mortality, and that the use of local anesthesia during EVAR reduced the 30-day mortality. In this study shock and use of local anesthesia had no effect on mortality after EVAR.

In contrast to published randomized trials, retrospective data are generally more favorable for EVAR. Inclusion of symptomatic non-ruptured aneurysms in retrospective series could contribute to this difference between trials and retrospective studies. To avoid such a bias in our study, we individually assessed the presence of true rupture in all cases. Veith[19] has published collected data from 49 institutions that routinely use EVAR for the treatment of rAAA. One thousand and thirty-seven patients treated by EVAR and 763 patients treated by OSR were included in the review. The study showed a significant reduction in early mortality favoring EVAR (21% vs. 36%, $p < .001$). The author concluded that EVAR is superior to OSR for patients with suitable anatomy, especially those who are more hemodynamically unstable, which is in line with the findings in this study. A population-based study by Mandawat et al.[20] showed that EVAR is superior to OSR in regard to short-term clinical outcomes (36% vs. 18%, $p < .01$). Nedeau et al.[21] published a retrospective study comparing EVAR with OSR. Although their patient sample was smaller than in this study (19 EVAR and 55 OSR patients), their conclusions were very similar, with EVAR conferring an early and mid-term survival benefit. A recent publication by Mehta et al.[22] also compared early mortality for EVAR versus OSR in rAAA patients.[22] In a sample of 283 patients, of whom 120 underwent EVAR, the authors reached a similar conclusion regarding an early mortality benefit for EVAR, which was maintained over time. However, the study by Mehta et al.[22] found a higher risk for EVAR in elderly patients, which was only present for OSR in this study. In addition to survival analysis, more insight is provided into the complications after rAAA, suggesting important differences on the number and type of complications found after OSR and EVAR.

A low Hgb level on admission was associated with adverse early prognosis after rAAA. This seems logical, as it suggests more extensive bleeding and a more prolonged evolution, increasing the chance of cardiac ischemia due to inadequate oxygen delivery. This is potentially aggravated by the fact that OSR is associated with greater blood loss. Age more than 75 years was associated with a higher risk of early death after OSR, but not after EVAR. This could be the result of reduced physiological reserve in elderly patients, which is insufficient to withstand the added insult of open surgery. Similarly, the presence of shock on admission was an independent

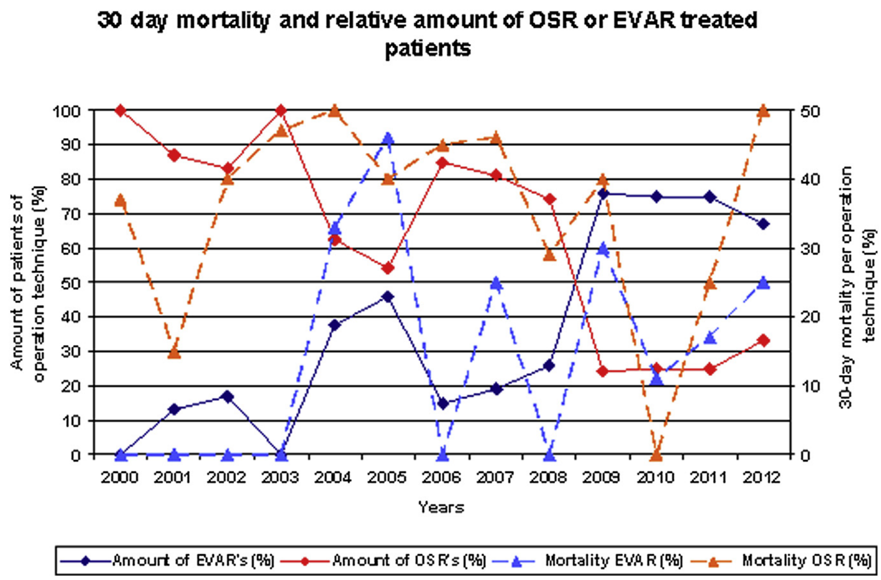


Figure 2. Thirty-day mortality and relative amount of open surgical repair (OSR)- or endovascular aneurysm repair (EVAR)-treated patients.

predictor for early outcome after OSR, but not after EVAR. This interesting observation may be explained by the less invasive nature of EVAR and the maintenance of higher peripheral resistance during endovascular operations. Another interesting observation is that coagulopathy on admission was associated with increased mortality after EVAR, but not after OSR. Although this could not be tested for confounders, it may be explained by persistent bleeding followed by abdominal compartment syndrome, and by a higher threshold for transfusion after EVAR.

The difference in early survival could also be explained by patient selection prior to the operation.[22] A common argument is that the most unstable patients would not undergo a CTA and, as a consequence, not be offered EVAR. In our population, however, admission hemodynamic status was similar for both groups, and the presence of shock was only found to influence outcome after OSR. It could be argued that the difference of admission time suggests that OSR patients are more unstable as theirs is shorter. We think that this difference is mainly due to the need for CTA in EVAR patients and not directly to patients' hemodynamic status. Furthermore, admission information was missing 16.7% of the data, which makes it less reliable than the shock index (<3%). These findings support the prior suggestion by Hinchliffe et al.[6] that the most unstable patients may be the ones to obtain the greatest benefit from EVAR. Also, it is possible that anatomically suitable patients for EVAR have a better outcome than those who are anatomically unsuitable, independent of the type of repair, as suggested by Ioannidis et al.[23] and Dick et al.[24] However, this effect was not observed in a study by Ten Bosch et al.,[25] in which anatomical suitability did not influence results in a cohort of patients who all underwent preoperative CTA irrespective of hemodynamic status. We could not confirm the hypothesis of anatomical suitability because some patients undergoing OSR did not undergo a preoperative CTA, and performing this analysis would inevitably incur bias. However, no supra-renal or type IV thoraco-abdominal aneurysm patients were included in our series.

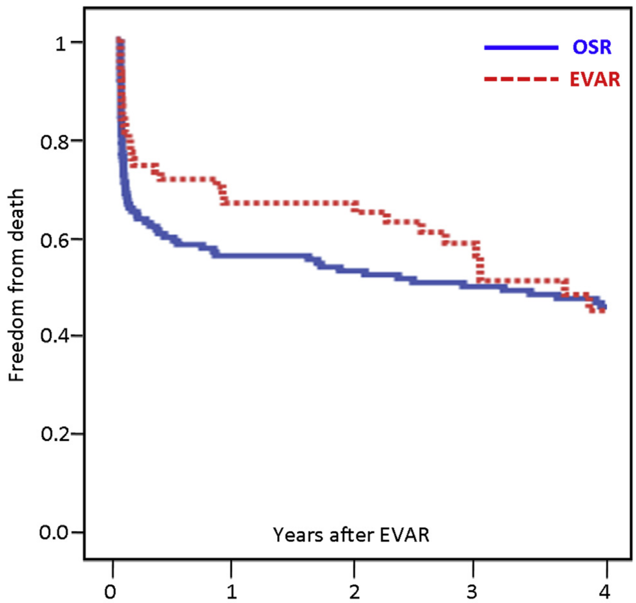
Postoperatively, the total admission period and ICU period for patients treated with EVAR was significantly lower than that of OSR-treated patients. This suggests a quicker recovery and less severe postoperative complications for EVAR. In parallel with mortality, EVAR was associated with a threefold reduction in the risk of major complications, and the occurrence of multiple and fatal complications were more frequent after OSR, contributing to better early survival rates for EVAR.

Over time, the prognosis of patients treated with EVAR gradually converged with that of OSR patients. In this series,

Table 4. Postoperative complications.

Variable	OSR	EVAR	*p*
Days in ICU, median (IQR)	4 (1–11)	1 (1–5)	.001
Total days of admission, median (IQR)	14 (6–33)	8.5 (4–21)	.001
Major complications	95 (76)	46 (58)	.007
Systemic complications	80 (64)	42 (53)	.124
Cardiac	20 (16)	8 (10)	
Cerebrovascular	6 (5)	3 (4)	
Renal	49 (39)	25 (32)	
Pulmonary	33 (26)	18 (23)	
Local complications	38 (30)	12 (19)	.070
Bowel ischemia	13 (10)	2 (3)	
Abdominal compartment syndrome	10 (8)	4 (5)	
Bleeding	7 (6)	1 (1)	
Distal embolization/ thrombosis	5 (4)	1 (1)	
Wound infection	9 (7)	1 (1)	
Graft-related	3 (2)	5 (6)	
Multiple complications	52 (42)	19 (24)	.047
Fatal complications	37 (30)	11 (16)	.033

Note. OSR = open surgical repair; EVAR = endovascular aneurysm repair; ICU = intensive care unit; IQR = interquartile range.



	0	1	2	3	4
OSR	134 - (-)	73 0.56 (0.042)	66 0.52 (0.43)	61 0.49 (0.043)	53 0.45 (0.043)
N at risk, proportion of survival, (SE)					
EVAR	74 - (-)	40 0.67 (0.054)	35 0.65 (0.055)	20 0.53 (0.066)	12 0.47 (0.072)

Figure 3. Kaplan–Meier curve of survival after ruptured abdominal aortic aneurysm repair, by type of repair (log rank $p = .52$). *Note.* OSR = open surgical repair; EVAR = endovascular aneurysm repair.

the benefit of EVAR was maintained up to 3 years; beyond this point, the survival of the two groups was similar. No clear explanation for this effect could be found, but it is hypothesized that it may reflect the less aggressive nature of EVAR, therefore minimizing the "second hit" after rupture. In patients with severe comorbidities, the additional surgical aggression of OSR could result in early death. Similarly, frail patients may survive the acute period after EVAR, but succumb to their comorbidities at mid-term. We found no evidence that EVAR-related complications could explain the observed pattern.

The results of this study are limited by the retrospective design and individualized treatment selection, which could result in bias. Also, the time span of the study may have influenced results, with inevitable management and referral modifications occurring over time. For the outcome analysis, year of operation was used as a co-variable, therefore adjusting for this potential confounder. Because of the relatively small sample, and because many patients died very early after the start of follow-up owing to the rupture, there was not sufficient statistical power to determine differences in long-term survival, and restricted the analysis to 4 years after repair. Finally, accurate turn-down rates for repair, which are known to significantly influence the overall survival after rAAA, could not be provided. This important limitation probably has less impact on direct comparison between treatment modalities than on the overall results of rAAA repair.

In conclusion, this study shows a twofold early mortality risk reduction for rAAA patients undergoing EVAR, which is maintained over the mid-term. Old age and the presence of shock were significant predictors of early mortality for OSR only, suggesting that EVAR may be particularly beneficial for patients presenting with these factors.[26] Also, OSR patients were at higher risk of major postoperative complications, required longer ICU and hospital stays, and appeared more likely to suffer from multiple and fatal complications after surgery. These results support the preferential use of EVAR for rAAA, and suggest a potential improvement in risk prediction by introducing the type of repair into the equation.

CONFLICT OF INTEREST

None.

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