Research Article

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Surgical Research

The Importance of Emergency Open Surgery for Ruptured Abdominal Aortic Aneurysms in a Single Center Retrospective Study

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ABSTRACT

Background: *A ruptured abdominal aortic aneurysm (rAAA) is life-threatening. The mortality is high and emergency surgery is vital. Endovascular (ER) and open surgical repair (OR) are alternative approaches. Although ER is considered as first-line treatment, there are scenarios which still require OR. We report a single-centre experience for rAAA treated by OR.*

Methods: *Medical records from patients with rAAA from 1 January 2005 through 31 December 2016 were screened. We defined rAAA as retro- or intraperitoneal haemorrhage originating from the infra- or juxtarenal aorta. We analysed the surgical approaches and report patient short-term and follow-up outcomes. Statistical differences were examined by log rank and chi-square test.*

Results: *Thirty-five patients at the mean age of 73 ± 10 years (47–91) were included. Aneurysm location was infrarenal (n = 20), juxtarenal (n = 8), and involved the iliac arteries (n = 7). OR was performed by tube (n = 26) or bifurcation graft (n = 9) implantation. Additional vascular reconstructions were performed in 14 patients. We observed one intra-operative oesophageal leakage. Post-operative complications included haemodialysis (n = 17), tracheotomy (n = 15), multiple organ failure (n = 11), cardiopulmonary resuscitation (n = 5), intestinal ischaemia (n = 5), sepsis (n = 5), stroke (n = 3) and coronary stenting (n = 2). Nine patients required early revision surgery. There were twelve patients available for the follow-up. Thirty-day mortality was 37%, and overall mortality was 40% after 118 months. Mortality was associated with the direction of rupture, the shock index (SI) and the need for early revision surgery (p = <0.05).*

Conclusion: *OR for rAAA remains valuable. In cases for which OR is warranted, the direction of rupture, SI and need for early revision surgery were predictors for mortality.*

Keywords

Abdominal Aorta, Rupture, Emergency, Open surgery.

List of abbreviations

AAA: Abdominal Aortic Aneurysm; ASA: American Society of Anesthesiologists; CT: Computed Tomography; ECAR: Endovasculaire ou Chirurgie dans les Anévrysmes aorto-iliaques Rompus; ER: Endovascular Repair; iAAA: intact Abdominal Aortic Aneurysm; ICU: Intensive Care Unit; OR: Open Repair; rAAA: ruptured Abdominal Aortic Aneurysm; RCT: Randomized Clinical Trials; SI: Shock Index.

Introduction

A ruptured abdominal aortic aneurysm (rAAA) is a life-threatening event, with 32% of patients dying before admission and a total mortality rate of 81% [1]. The incidence of rAAA is 6.9 per 100,000 persons, with a decreasing trend over the last decades (2000-2020) [2]. Since treatments that support tobacco cessation and best medical treatment became broadly available, an increasing number of elective repairs for AAA has been observed. Additionally, ultrasound screening programmes were implemented for patients older than 65 years of age in various countries [1]. The risk for AAA rupture exponentially increases with AAA diameter [3]. Therefore, surgeons nowadays base their suggestion for Endovascular (ER) or open surgical repair (OR) for non-symptomatic AAA on the maximum diameter and/or the annual AAA growth rate [3]. Up to the stage of rupture, AAA is usually asymptomatic. Of note, although the phenotypical triad of acute abdominal or back pain, haemodynamic destabilisation and pulsatile abdominal mass may only be seen in up to 25–50% of rAAA, several uncommon clinical symptoms have been reported [4]. A computed tomography scan (CT scan) that proves active bleeding can reliably establish the diagnosis in most cases [5]. The most common contained retroperitoneal rupture vs the free intraperitoneal rupture differs significantly in mortality rates (52.8 vs 75%) [4]. Enteric ruptures or a rupture into the caval vein is rare [4]. In a German register, around 8.7% (n = 455) of all in-hospital patients with abdominal aortic aneurysms (n = 5223) reached the stageof rupture [6]. Once the diagnosis is established, emergency OR or ER is vital. ER has evolved as the first-line treatment over the past years, with considerably lower mortality rates when compared to OR [2,6]. For that reason, the current guideline of the European Society of Vascular and Endovascular Surgery for the Management of Abdominal Aorto-iliac Artery Aneurysms suggests ER for rAAA, although OR remains the treatment of choice for the majority of rAAA in Germany [7,8]. We report an 11-year single-centre experience with OR for rAAA in 35 patients.

Methods

All patients who were treated by emergency OR for rAAA (juxta- or infrarenal AAA) from 1 January 2005 through 31 December 2016 in the Department of Vascular and Endovascular Surgery at the University Hospital Dusseldorf, Germany, and were available for follow-up were included. We defined rAAA as a retro- or intraperitoneal haemorrhage from no other source on initial CT scans, with macroscopic confirmation during surgery. During the study period, 901 patients were treated for intact AAA (iAAA) and 87 patients for rAAA. Of the rAAA cases, 69 patients received OR and 18 ER. We excluded 27 patients with either infected AAA (n = 14), anastomotic aneurysm (n = 4), thoraco-abdominal aortic aneurysm (TAAA) with rupture in the abdominal segment (n = 3), dissecting aortic aneurysm following aortic type b dissection (n = 2), aortic stent graft infection or migration with rupture (n = 2), rupture after plate osteosynthesis of the spinal column (n = 1) or incidental rupture during elective OR (n = 1). Another seven patients died during emergency OR for rAAA. The remaining 35 patients were subject to analysis in this study. Shock index (SI) was defined as heart rate divided by systolic blood pressure. Data was retrieved from archived medical records. Statistical analysis was performed using IBM SPSS Statistics Version 24. The results are reported as the means ± standard deviation. Survival and mortality rates were estimated using the Kaplan–Meier method. The log rank test was applied to compare mortality rates. The level of significance was set to $p < 0.05$. The chi-square test was used to determine the association between comorbidities and/or post-operative complications and patient 30-day survival. The institutional ethical review board of the Heinrich-Heine University of Duesseldorf (study number 4634) approved the study. All patients provided written informed consent before participation.

Results

Patients

The mean age of the study population was 73 ± 10 years (47–91). Most patients were transported by ambulance (n = 18), were transferred from other hospitals (n = 12) or other departments of the University Hospital Düsseldorf (n = 3) or presented on a walk-in basis (n = 2). Patients presented in a reduced state of consciousness, in a haemodynamically unstable condition with intubation (n = 5 each) or arrived under cardiopulmonary resuscitation (n = 2). The majority of patients presented with abdominal pain (n = 28) and/or with isolated pain in the flanks, legs or back (n = 3). Four patients suffered an initial pain-associated syncope. Three patients reported an unintentional weight loss during the past weeks. Two patients presented with emesis. Clinical examination included a palpable or visible abdominal mass (n = 9) and hyperhidrosis (n = 7). Mean systolic and diastolic blood pressure levels were 121 ± 45 mmHg (35–230) and 75 ± 29 mmHg (12–150), respectively. Mean heart rate was 89 ± 28 (3–140). Eight patients had an SI > 1. Initial arterial blood gas analysis revealed a mean haemoglobin level of 9.4 ± 2.5 g/dl (4.8–15.5), mean serum lactate of 4 ± 4 mmol/l (0.3–17) and mean pH level of 7.29 ± 0.16 (6.9–7.50). The risk classification according to the American Society of Anesthesiologists was III in 3, IV in 22 and V in 6 patients (unknown = 4). AAA had already been diagnosed earlier in eight patients. Of these, invasive therapy was postponed for two patients, since the AAA diameter had not reached the minimum dimension for surgery. One patient suffered from a symptomatic basilar artery aneurysm with brain stem compression (n = 1), and one patient refused the suggested operative treatment (n = 1). Another patient had recently experienced a myocardial infarction with cardiopulmonary decompensation (n = 1). The reason for deferred AAA treatment was unknown for the other three patients. Benchmarks of the aortic disease and comorbidities are listed in Table 1.

Aortic Locations and Direction of Rupture

Retroperitoneal rupture occurred in 29 and intra-abdominal rupture in six patients (Table 1). AAA was mostly limited to the infrarenal (n = 20) or juxtarenal (n = 8; Figure 1) aorta. Seven patients had aorto-iliac aneurysms (Figure 2), whereof four extended from the infrarenal and three from the juxtarenal segment. One patient immediately developed an aorto-caval fistula following rupture.

Disease / comorbidity	Patients
contained retroperitoneal rupture	6 (17%)
• Infrarenal • Juxtarenal • Aorto-iliac	2/6 (33%) 3/6 (50%) 1/6 (17%)
free intraperitoneal rupture	29 (83%)
• Infrarenal • Aorto-iliac • Juxtarenal	18/29 (62%) 6/29 (21%) 5/29 (17%)
arterial hypertension	29 (83%)
nicotine abuse	17 (49%)
cardiac comorbidities	17 (49%)
• Coronary heart disease • Former coronary bypass procedures / angioplasty • Myocardial infarction • Low- to intermediate-grade cardiac vitium • Tachyarrhythmia absoluta	15 (43%) 5 (14%) 4 (11%) 4 (11%) 4 (11%)
pulmonary comorbidities	14 (40%)
• Chronic obstructive pulmonary disease • Former pulmonary embolism • Obstructive sleep apnea	12 (34%) 1 (3%) 1 (3%)
renal comorbidities	10 (29%)
• Renal insufficiency without dialysis • Nephrectomy + contralateral RAS • Former renal transplantation • Unilateral nephrectomy	8 (23%) 1 (3%) 1 (3%) 1 (3%)
vascular comorbidities	7 (20%)
• Peripheral artery occlusive disease • Bilateral CAS + symptomatic BAS • Bilateral vertebral artery stenosis + symptomatic high-grade BAS • Former bilateral carotid eversion endarterectomy	5 (14%) 1 (3%) 1 (3%) 1 (3%)
dyslipidemia	5 (24%)
diabetes mellitus type II	4 (11%)
embolic stroke	3 (6%)
adiposity per magna	1 (3%)
alcohol abuse	1 (3%)

Table 1: Disease and comorbidities

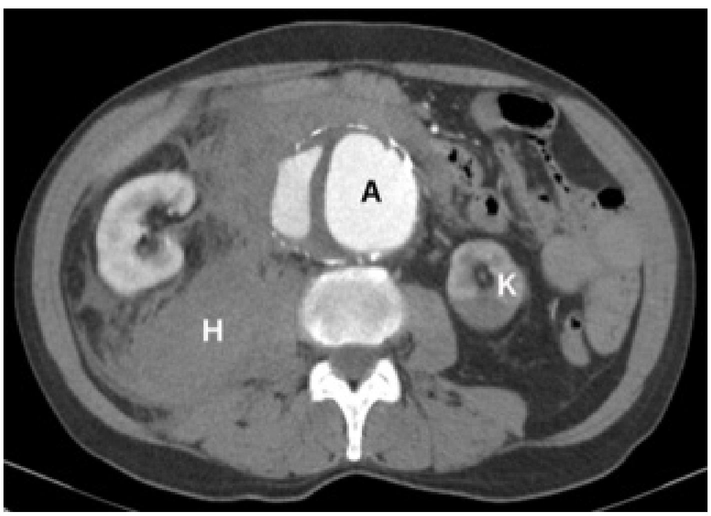

Figure 1: CT-scan demonstrating a juxtarenal abdominal aortic aneurysm (A) with right-sided retroperitoneal hematoma (H) and perfused mural thrombus. Left kidney (K) is not perfused as the renal artery is occluded (not shown). Tube graft interposition and left renal artery desobliteration was performed.

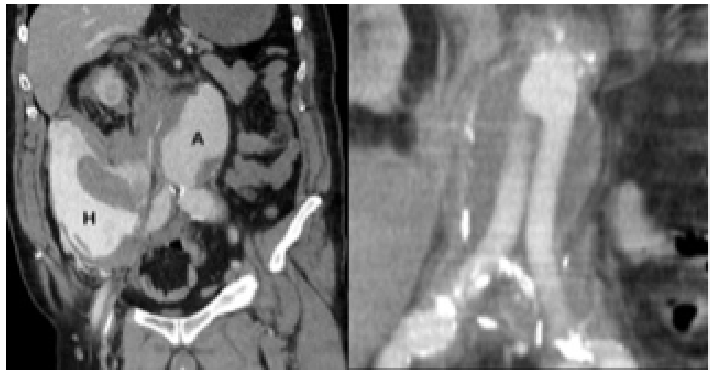

Figure 2: CT-scan of an infrarenal-biiliac aortic aneurysm (A) with large right-sided retroperitoneal hematoma (H). Bifurcation graft was performed.

Mean AAA diameter was 7.8 ± 1.6 cm (4.5–11.2). The diagnosis was either established upon CT scan (n = 27) or sonography (n = 5). The diagnosis for the remaining three patients, all with an established AAA diagnosis, was based on their clinical presentation only.

Procedures

All operations were performed under general anaesthesia, and midline laparotomy was used for access. Suprarenal aortic cross-clamping was performed in 17 patients (infra-diaphragmatic = 5) to obtain haemodynamic stabilisation (n = 6) or for patients with supra- or juxtarenal AAAs (n = 11). Following haemodynamic stabilisation or completion of the proximal anastomosis (and renal artery reconstruction), the aortic clamps were changed to the infrarenal aortic segment or prosthesis. Mean suprarenal aortic cross-clamping time was 30 ± 41 min (4–146). Tube grafts (n = 26) for isolated infrarenal (n = 18) or juxtarenal (n = 8) AAAs or bifurcation grafts (n = 9) for aorto-iliac aneurysms (n = 7) or isolated infrarenal AAAs with persistent bleeding at the distal anastomosis or unilateral chronic external iliac artery occlusion were used for vascular reconstruction. Primary abdominal wound closure was performed in 34 patients, whilst abdominal zipper closure was used for one patient who required a second look laparotomy due to deranged coagulation and massive diffuse intraoperative bleeding.

Severe intraoperative complications included clamping-associated oesophageal leakage, which was treated by open suture repair and a large-bore stomach tube. Additional vascular reconstructions were required for 14 patients (Table 2). The mean usage of intraoperative transfusion products was as follows: 12 ± 11 (2–55) red blood cell transfusions, 15 ± 18 (3–100) fresh frozen plasmas transfusions and 4 ± 2 (2–11) platelet transfusions. The maximum number of red blood cell transfusions and fresh frozen plasmas was required for a patient with massively deranged coagulation, who died during the post-operative period. An autologous blood recovery system was used for 22 patients. The mean recovered blood volume was 2 ± 2.4 (0–11) l, whilst the mean loss of blood volume was 4.6 ± 5.4 (0.4–21.4) l. The mean operation time was 196 ± 97 (75–560) min. All patients left the operating room alive.

Surgical procedures	Patients
Tube graft	26 (74%)
Bifurcation graft	9 (26%)
Reconstruction of the renal arteries	7 (20%)
• Inclusion into proximal graft anastomosis • Desobliteration • Prothesio-renal 8 mm Dacron graft interposition (solitary kidney) • reimplantation	2 (6%) 1 (3%) 1 (3%) 3 (9%)
Reconstruction of the iliac arteries	4 (11%)
• Thrombectomy • Transaortic thromboendarterectomy	3 (9%) 1 (3%)
Reimplantation of the inferior mesenteric arteries*	4 (11%)
Unilateral femoral thromboendarterectomy + Dacron patch plasty	2 (6%)
Temporary external 16 mm PTFE axillo-femoral shunt (protection of kidney transplant)	1 (3%)
Caval vein suture (aorto caval fistula)	1 (3%)
Hemicolectomy (left colon ischemia)	1 (3%)
Abdominal zipper closure	1 (3%)
Esophageal suture repair	1 (3%)

Table 2: Surgical procedures
**= chronic occlusion in 4 patients, unknown in 1 patient.*

Complication	Patients
Pulmonary insufficiency	22 (63%)
• Tracheotomy	15 (43%)
Renal failure	20 (57%)
• Hemodialysis	17 (49%)
30-day mortality	13 (37%)
Cardiac arrhythmia	13 (37%)
MOF	11 (31%)
Operative revision <30 days	9 (26%)
Pneumonia	9 (26%)
Sepsis	7 (20%)
Delirium	7 (20%)
Abdominal compartment syndrome with Intestinal ischemia	5 (14%)
Myocardial infarction	5 (14%)
• Coronary angiography • Coronary intervention	3 (9%) 2 (6%)
Cardiac arrest	4 (11%)
Cerebral infarction	4 (11%)
Deranged coagulation	2 (6%)
Leg ischemia	2 (6%)
General convulsions	2 (6%)
Hemorrhagic shock	1 (3%)
Fascial dehiscence with later entero-cutaneous fistula	1 (3%)
Pulmonary embolism	1 (3%)
Acute respiratory distress syndrome	1 (3%)
Paralytic ileus with hemicolectomy (day 38)	1 (3%)
Pleural effusion with drainage	1 (3%)
Gastrointestinal bleeding	1 (3%)
Pancreatitis	1 (3%)

Table 3: Postoperative complications.

Post-operative Course

All patients were transferred to the intensive care unit (ICU) after surgery. There, 13 patients (37%) died after a mean period of 21

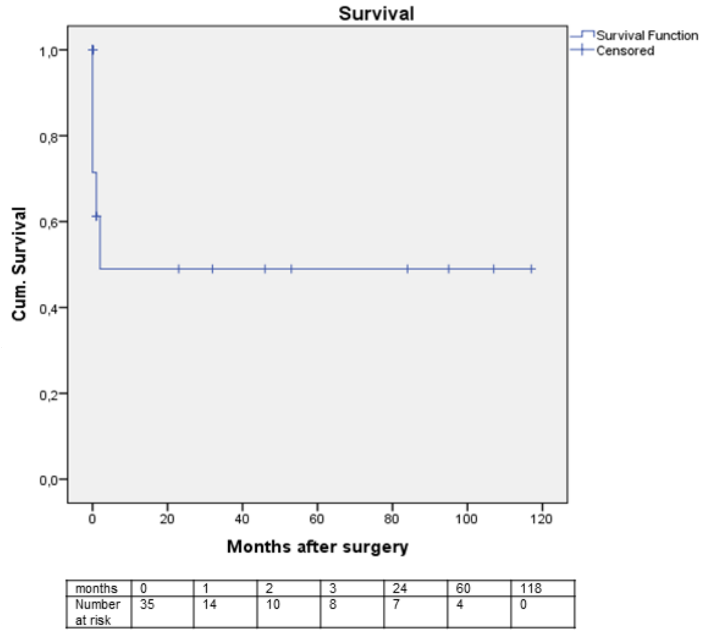

Figure 3: Cumulative survival after open repair of ruptured abdominal aortic aneurysms with a 30 day survival rate of 71.4% for 35 patients who survived the emergency procedure.

arrhythmia, including atrial fibrillation (n = 5; defibrillation = 3), ventricular (n = 5) or supraventricular (n = 1) tachycardia (n = 6, amiodarone = 3), other types of arrhythmia (n = 2) and ventricular fibrillation (n = 1). Five patients suffered from a myocardial infarction. Five patients received cardiopulmonary resuscitation for cardiac arrest (n = 4) and ventricular fibrillation (n = 1). Further complications are presented in Table 3. A perioperative antibiotics was administratedd to 31 patients for a mean period of 3.7 ± 2.2 (1–9; patients with early death were excluded) days. A prolonged administration of antibiotics was required in 18 patients for a mean period of 9 ± 6 (2–24) days. The mean time in ICU of the survivors was 17 ± 13 (2–55) days, and the mean time of in-hospital stay was 21 ± 12 (2–55) days. Patients were either transferred to external hospitals (n = 9) or to a rehabilitation centre (n = 6) or were discharged (n = 7).

Follow-up

Follow-up data was available for 12 of the 22 survivors (55%) after a mean of 53 ± 42 (1–118) months. The majority of our patients (11/12, 92%) were asymptomatic after recovery and could perform activities of daily living. One patient presented with a sudden onset of abdominal pain and a syncope, 2871 days after surgery. The clinical examination, blood test findings and diagnostic medical imaging revealed multiple hepatic abscess formations and periprosthetic contrast media enhancement. Hepatic aspirates further revealed microbiological activity, although periprosthetic aspirates were sterile. Following open surgical placement of an abscess drainage and antibiotic therapy, infection parameters normalised, and the patient was discharged in good clinical condition. No patient required primary-surgery-related re-do surgery at long term.

Statistics

Seven patients died during emergency procedure. These patients were not included in the analysis. The remaining 35 patients who survived the primary procedure were subject to analysis in this study. The 30-day and prior-to-discharge mortality rates were 29% (n = 10) and 37% (n = 13), respectively. After a follow-up of 118 months, the overall mortality rate was 40% (n = 14), with the latest death being seen 95 days after surgery. Cumulative one-month survival rate was 71 ± 7.6%, 2-months survival rate was 61 ± 9.4% and overall survival rate was 49 ± 10.8% (Figure 3). Patients' mean follow-up survival period was 58 months at a median of two months. Statistical analysis revealed that patient survival depends on the type of rupture, the SI and the need of early revision surgery ($p = <0.05$), whereas we did not find such association for the aneurysm localisation, ASA class, graft material or type or the location of aortic cross-clamping. Further, we did not find any association between patient comorbidities and short- or long-term survival.

Discussion

Endovascular techniques have widened the therapeutic spectrum and indications for various vascular beds for modern vascular surgery. Over the past decade (2010-2020), the knowledge about endovascular approaches and their outcomes for rAAAs has expanded immensely since several randomised clinical trials (RCT) and meta-analyses which compared ER vs OR for rAAA have been published [9-13,15,18,19].

Those RCTs did not find differences in 30-day and/or 1-year mortality between ER and OR. Interestingly, Gunnarsson et al. demonstrated that these findings are independent of the primary therapeutic strategy of the surgical centre [9]. At first glance, this seems surprising since lower early mortality for ER vs OR has been reported in elective cases [10]. But a meta-analysis of outcomes of OR and ER of rAAA in patients with hostile or friendly aortic anatomy shows that a hostile aortic anatomy was associated with an increased mortality for the ER group [11]. In addition, a Dutch observational cohort study with 467 patients (ER = 73, OR = 394) stated higher re-intervention rates for ER vs OR at 5-year follow-up [12]. However, ER is associated with lower blood loss, fewer severe complications, reduced mechanical ventilation time, and shorter ICU stay and shorter in-hospital stay [13]. Patients who survived OR for rAAA for six months have a similar long-term survival and quality of life when compared to the general population [14]. Furthermore, ER has proven a poorer cost-effectiveness ratio when compared to OR; however, there is a current scientific dispute on whether the same is true in emergency settings [13]. Taking the aforementioned into consideration, it seems impossible to recommend one approach over the other in rAAA, due to the limited data available. That said, more RCTs which particularly focus on patient outcomes the long term are warranted. We are aware that some researchers might suggest ER as the primary approach in emergency patients with suitable anatomy. To this end, it should be mentioned that these recommendations are partially based on observational and register studies which, when compared to RCTs, have reported superior outcomes for ER in rAAA [15]. This discrepancy might occur because specialised centres with high volumes and experienced surgeons have better outcomes, suggesting a substantial publication bias [16].

Our early and late mortality rates are in line with previous findings (Table 4). Since in these studies the term 'major complications' has been unequally defined and is unclearly specified, a comparison to our results seems somewhat invalid. Moreover, other studies did include dissecting aortic aneurysms, which makes comparison even more difficult [17]. Nevertheless, we and others identified intestinal ischaemia as one of the most frequent complications that required revision surgery [13,18-21]. Similar to our findings, major bleeding due to deranged coagulation is another leading cause for revision surgery, whilst early prosthetic graft occlusion seems seldom to be [13,18-20]. Major amputations following revision surgery for lower limb ischaemia is reported for up to 4-5% of all cases [13,18,19]. In this regard, none of our patients required amputation, although limb ischaemia occurred in 5.7% of our study cohort. The abdominal compartment syndrome which is associated with an intestinal ischaemia is a major cause of death and occurred in 14% of our patients. Other authors have suggested that this complication occurs more frequently after ER, since a reversed flow over lumbar arteries and the inferior mesenteric artery is maintained, resulting in bleeding through the rAAA sac [21]. The incidences are suggested to be as high as 7% after OR and 8% after ER, with mortality rates being as high as 50% [22]. Furthermore, kidney failure rates are ranging from 18 to 57%, depending on the definition criteria that are being applied

Author	Year	Period	Patients [n] (ER/OR)	Mortality [%]			
				30 days		1 year	
				ER	OR	ER	OR
Hinchliffe et al. [25]	2006	2002-04	32 (15/17)	53	53		
Reimerink et al. [18]	2013	2004-11	116 (57/59)	21	25	-	-
IMPROVE [19]	2015	2009-13	616 (316/297)	35.4	37.4	41.1	45.1
ECAR [13]	2015	2008-13	107 (56/51)	18	24	30.3	35
Schmitz-Rixen et al. [6]	2017	2015	455 (197/258)	25.9*	38.0*	-	-
Gunnarsson et al. [9]	2016	2008-12	1304 (236/1068)	21.6	30	31.5	36.5

Table 4: Mortality rates after open versus endovascular repair of ruptured abdominal aortic aneurysm.
*ER= endovascular aneurysm repair; OR= open repair; *=in-hospital mortality.*

[18,20,21]. Of this patient cohort, 3.9–21% require haemodialysis [13,21]. Myocardial infarction occurs in 3.0–15.9% and strokes in 2.0–11.0% of all cases of rAAA treated with ER [13,18,21]. Of note, we did not observe spinal cord ischaemia in our patient cohort, which is a common problem for endovascular approaches [23]. Comparable to other reports of multiple organ failure, sepsis and intestinal ischaemia were the most common causes of death [13,20].

Cardiac bleeding complications are also reported as major causes of death and are in line with our findings [13,20]. The ECAR (Endovasculaire ou Chirurgie dans les Anévrysmes aorto-iliaques Rompus) study further reported acute respiratory distress syndrome as another cause of death [13].

Several studies identified age, prolonged shock, syncope, cardiac disease, aorto-iliac aneurysms, implantation of a bifurcation graft, preoperative haemoglobin level and renal impairment as independent predictors for perioperative mortality [9,20]. In contrast, the type of rupture (intra- vs retroperitoneal), the SI and the need for early revision surgery contributed significantly to patient long-term survival in the present study. Those factors named in several studies have been used for different scoring systems. The most recent scoring system applies to endovascular treatment and is limited to three factors (age >76, creatinine level >1.5 mg/dl, systolic blood pressure <70 mmHg) with an accurate 30-day mortality prediction [24].

Our study has several limitations. Its retrospective nature and monocentric study design might have compromised results. The authors are aware that the limited sample size of the present study may have caused substantial confounding for subgroup analyses, thus a generalisation of our findings is not valid.

Conclusion

OR for rAAA remains a valuable therapeutic option in the era of endovascular treatment. The type of rupture (free vs contained), the SI (<1.5 vs >1.5) and the need for early revision surgery contribute to patient mortality.

References

1. Reimerink JJ, van der Laan MJ, Koelemay MJ. et al. Systematic review and meta-analysis of population-based mortality from ruptured abdominal aortic aneurysm. Br J Surg. John Wiley & Sons, Ltd. 2013; 100: 1405-1413.
2. Lilja F, Mani K, Wanhainen A. Trend-break in Abdominal Aortic Aneurysm Repair With Decreasing Surgical Workload. European Journal of Vascular & Endovascular Surgery. Elsevier Ltd. 2017; 53: 811-819.
3. Brewster DC, Cronenwett JL, Hallett JW. et al. Guidelines for the treatment of abdominal aortic aneurysms. Report of a subcommittee of the Joint Council of the American Association for Vascular Surgery and Society for Vascular Surgery. Journal of vascular surgery. 2003; 37: 1106-1117.
4. Assar AN, Zarins CK. Ruptured abdominal aortic aneurysm: a surgical emergency with many clinical presentations. Postgrad Med J. The Fellowship of Postgraduate Medicine. 2009; 85: 268-273.
5. Cerna M, Kocher M, Thomas RP. Acute aorta, overview of acute CT findings and endovascular treatment options. Biomed Pap Med Fac Univ Palacky Olomouc Czech Repub. 2017; 161: 14-23.
6. Schmitz-Rixen T, Steffen M, Grundmann RT. Treatment of abdominal aortic aneurysms (AAA) 2015. Gefässchirurgie. Springer Medizin; 2017; 24: 1-9.
7. Wanhainen A, Verzini F, Van Herzeele I. et al. Editor's Choice - European Society for Vascular Surgery (ESVS) 2019 Clinical Practice Guidelines on the Management of Abdominal Aorto-iliac Artery Aneurysms. European journal of vascular and endovascular surgery : the official journal of the European Society for Vascular Surgery. 2019; 57: 8-93.
8. Beckerath von O, Schrader S, Katoh M. et al. Mortality in endovascular and open abdominal aneurysm repair - trends in Germany. VASA. Hogrefe AG. 2018; 47: 43-48.
9. Gunnarsson K, Wanhainen A, Djavani Gidlund K. et al. Endovascular Versus Open Repair as Primary Strategy for Ruptured Abdominal Aortic Aneurysm: A National Population-based Study. Eur J Vasc Endovasc Surg. 2016; 51: 22-28.
10. Stather PW, Sidloff D, Dattani N. et al. Systematic review and meta-analysis of the early and late outcomes of open and endovascular repair of abdominal aortic aneurysm. Br J Surg. John Wiley & Sons, Ltd. 2013; 100: 863-872.
11. Kontopodis N, Galanakis N, Antoniou SA, Tsetis D, Ioannou CV, Veith FJ, Powell JT, Antoniou GA. Meta-Analysis and Meta-Regression Analysis of Outcomes of Endovascular and Open Repair for Ruptured Abdominal Aortic Aneurysm. Eur J Vasc Endovasc Surg. 2020; 59: 399-410.
12. van Beek SC, Vahl A, Wisselink W. et al. Midterm Re-interventions and Survival After Endovascular Versus Open Repair for Ruptured Abdominal Aortic Aneurysm. Eur J Vasc Endovasc Surg. 2015; 49: 661-668.
13. Desgranges P, Kobeiter H, Katsahian S. et al. Editor's Choice - ECAR (Endovasculaire ou Chirurgie dans les Anévrysmes aorto-iliaques Rompus): A French Randomized Controlled Trial of Endovascular Versus Open Surgical Repair of Ruptured Aorto-iliac Aneurysms. Eur J Vasc Endovasc Surg. 2015; 50: 303-310.
14. Hinterseher I, Saeger HD, Koch R. et al. Quality of life and long-term results after ruptured abdominal aortic aneurysm. European Journal of Vascular & Endovascular Surgery. 2004; 28: 262-269.
15. van Beek SC, Conijn AP, Koelemay MJ. et al. Editor's Choice - Endovascular aneurysm repair versus open repair for patients with a ruptured abdominal aortic aneurysm: a systematic review and meta-analysis of short-term survival. Eur J Vasc Endovasc Surg. 2014; 47: 593-602.
16. Dubois L, Mayer D, Rancic Z. et al. Debate: whether endovascular repair offers a survival advantage over open repair for ruptured abdominal aortic aneurysms. J Vasc Surg. 2015; 61: 546-555.

17. Speicher PJ, Barbas AS, Mureebe L. Open versus endovascular repair of ruptured abdominal aortic aneurysms. Ann Vasc Surg. 2014; 28: 1249-1257.
18. Reimerink JJ, Hoornweg LL, Vahl AC. et al. Endovascular repair versus open repair of ruptured abdominal aortic aneurysms: a multicenter randomized controlled trial. Ann Surg. 2013; 258:248-256.
19. IMPROVE Trial Investigators. Endovascular strategy or open repair for ruptured abdominal aortic aneurysm: one-year outcomes from the IMPROVE randomized trial. European Heart Journal. The Oxford University Press. 2015; 36: 2061-2069.
20. Grotemeyer D, Strauß K, Weis-Müller BT. et al. [Ruptured abdominal aortic aneurysm : perioperative indicators for the clinical course following conventional open surgery]. 2008; 79: 745-752.
21. Rubenstein C, Bietz G, Davenport DL. et al. Abdominal compartment syndrome associated with endovascular and open repair of ruptured abdominal aortic aneurysms. J Vasc Surg. 2015; 61: 648-654.
22. Karkos CD, Menexes GC, Patelis N. et al. A systematic review and meta-analysis of abdominal compartment syndrome after endovascular repair of ruptured abdominal aortic aneurysms. J Vasc Surg. 2014; 59: 829-842.
23. Peppelenbosch AG, Vermeulen Windsant IC, Jacobs MJ. et al. Open repair for ruptured abdominal aortic aneurysm and the risk of spinal cord ischemia: review of the literature and risk-factor analysis. Eur J Vasc Endovasc Surg. 2010; 40: 589-595.
24. Healey CT, Neilson M, Clark D. et al. Predicting Mortality of Ruptured Abdominal Aortic Aneurysms in the Era of Endovascular Repair. Ann Vasc Surg. Elsevier Inc. 2017; 38: 59-63.
25. Hinchliffe RJ, Bruijstens L, MacSweeney STR. et al. A randomised trial of endovascular and open surgery for ruptured abdominal aortic aneurysm - results of a pilot study and lessons learned for future studies. European Journal of Vascular & Endovascular Surgery. 2006; 32: 506-513.