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Endovascular Treatment and Open Repair of Ruptured Abdominal Aortic Aneurysms: Mortality Related to Abdominal Compartiment Syndrome

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Abstract

Ruptured Abdominal Aortic Aneurysm (RAAA) carries a high mortality rate of 32% to 80% in patients who survive surgery. Abdominal Compartment Syndrome (ACS) is an independent predictor of mortality in RAAA. The aim of the present study was to analyse 30-day survival in patients undergoing RAAA repair and the benefit of abdominal decompression in patients with ACS.

This retrospective observational study included all patients undergoing Open Surgery (OS) or Endovascular Repair (REVAR) for RAAA between 2005 and 2015 in our centre. Demographic variables, type of surgery, delayed abdominal closure, pre-, intra- and postoperative ACS risk factors and 30-day survival were collected.

A total of 61 patients were included: 39 open and 22 endovascular surgeries. Overall intra- and postoperative mortality was 54%. Mortality was higher in the OS group compared with REVAR.

The postoperative results of the 43 patients who survived surgery were analysed. No differences were detected in postoperative mortality of RAAA according to the type of surgery. ACS did not appear to increase mortality in the OS group, but did increase it in the REVAR group. Differences were observed in 30-day survival depending on the type of abdominal closure (primary or delayed). The open abdomen showed better survival with OS than with REVAR.

Consequently, in REVAR patients with ACS that require decompressive laparotomy, surgeons should consider evacuation of a space-occupying haematoma and opening the sac to ligate bleeding vessels within the aneurysm sac.

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Introduction

Ruptured Abdominal Aortic Aneurysm (RAAA) carries a high mortality rate of 32% to 80% in patients who survive surgery. Multi-organ failure is a very common cause of death in these patients [1-4].

Intra-Abdominal Pressure (IAP) and Abdominal Compartment Syndrome (ACS) are independent predictors of mortality and represent a frequent cause of multi-organ failure. ACS was first mentioned by Baggot in 1951, but it was not until 1984 that the pathophysiology of ACS in RAAA was described [5,6]. Subsequently, in 1989, Fietsam et al., [7] exposed the benefit of abdominal decompression with open abdomen in patients undergoing RAAA.

The aim of the present study was to analyse 30-day survival of patients undergoing RAAA repair, and the benefit of abdominal decompression in patients with ACS.

Material and Methods

A retrospective observational study was performed, with the inclusion of patients undergoing RAAA treatment in our Department of Vascular Surgery between 2005 and 2015.

Diagnosis of RAAA was based on the International Classifications of Diseases (ICD) and rupture was defined as the extravasation of blood or haematoma outside the wall of the Abdominal Aortic Aneurysm (AAA) in Computed Tomography (CT), angiography and/or evidence of haematoma

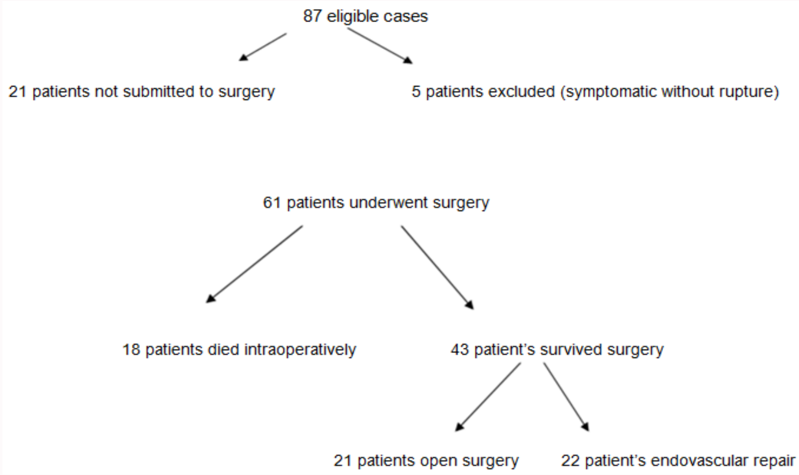

Figure 1:

outside the AAA during the surgery.

All patients who underwent emergency interventions for RAAA were included for analysis of 30-day survival. Patients submitted to emergency interventions for symptomatic AAA without evidence of rupture were excluded.

To analyze the presence of ACS and the benefit of abdominal decompression, patients who died intraoperatively were excluded. The diagnosis of ACS was made when one of the following criteria was fulfilled: 1. IAP >20 mmHg (with or without Abdominal Perfusion Pressure (APP) <60 mmHg) associated with new organ dysfunction/failure; 2. Physical examination reveals a tense abdominal wall and inability to close the abdomen due to bowel oedema.

Open repair is the established method of treating RAAA. Over the last decade, endovascular techniques have been increasingly used to treat elective AAA and this procedure has been introduced in patients with RAAA in an endeavor to reduce mortality. Endovascular repair has been used in our service since 2011 to treat stable patients RAAA with anatomical suitability and is currently our first option.

The primary outcome was 30-day survival in both groups, Open Surgery (OS) *vs.* Endovascular Repair (REVAR), following the surgical interventions. The secondary outcome was survival at 30 days in both groups after abdominal decompression in patients with ACS as a cause of multi-organ failure following RAAA.

Study variables: Baseline characteristics: sex, age and cardiovascular risk factors: diabetes mellitus, arterial hypertension, dyslipidaemia, smoking, cardiopathy, cerebrovascular pathology and chronic renal insufficiency.

Preoperative variables: lower arterial pressure, haemoglobin (g/dL) and abdominal aortic diameter.

Intraoperative variables: surgical time (minutes), lowest intraoperative pH (considered acidosis when pH <7.2), volume of perfused fluids (litres, considered massive if >5 L/24 h), transfusion (number of units of packed Red Blood Cells (RBC), platelets and plasma), temperature, lowest arterial pressure during the intervention (mmHg), arterial pressure <70 mmHg for more than 20 min, type of intervention (open/endovascular), and abdominal wall closure (primary or delayed).

Postoperative variables: coagulopathy (platelet count <50,000, International Normalized Ratio (INR) >1.5), intensive care unit stay (days), Intra-Abdominal Pressure (IAP) measurements, and highest IAP recorded postoperatively.

Risk factors for ACS were considered: arterial pressure <70 mmHg for more than 20 min, haemoglobin <8 g/dL, metabolic acidosis, infusion >5 litres in 24 hrs, transfusion >6 units of RBC, temperature <35ºC, coagulopathy and significant intestinal oedema.

Analysis

Quantitative variables are shown as means +/-95% Confidence Intervals (CI) and categorical variables as proportions +/-95% CI. To compare differences among the groups, the Student-Fisher t-test and the U Mann-Whitney test were used for quantitative variables, and Pearson's Chi-squared test and Fisher exact test were used for categorical variables.

The relative risk among the groups and their 95% CI were calculated as measurements of association. To evaluate whether the association was statistically significant, the CI should not include the null hypothesis Relative Risk (RR) =1.

This project was approved by the Ethics and Clinical Research Committee of our Centre.

Results

A total of 87 eligible cases were reviewed, of which 21 patients were not submitted to surgery, 5 were excluded as they were symptomatic but without evidence of rupture. Sixty-one patients were included (N=61); 39 (63.9%) were treated with OS and 22 (36.1%) with REVAR.

Overall mortality at 30 days was 54.1% (33/61). In the OS group (n 39), 18 patients died intraoperatively and 8 within 30 days following surgery. In patients who underwent REVAR (22 cases), 7 deaths occurred in the postoperative period. Mortality was higher in the OS group (66.7%) compared with the REVAR group (31.8%) (p=0.009).

To analyze the presence of ACS risk factors and the benefits of abdominal decompression, patients who died intraoperatively were excluded.

Demographic variables and ACS risk factors were collected.

Table 1: Demographic variables of AAAR patients (n=43).

Patients n=43	Number of cases (%)
Men	41 (95.3%)
Diabetes mellitus	11 (25.6%)
Hypertension	33 (76.7%)
Dyslipidaemia	28 (65.1%)
Active smokers	23 (53.5%)
Ex-smokers	11 (25.6%)
Ischemic cardiopathy	15 (34.9%)
Carotid disease	4 (9.3%)
Chronic renal failure	6 (14%)

The demographic variables are reflected in Table 1. The mean age of patients was 72.8 years (+/-8.7).

Regarding the variables collected pre-, intra- and postoperatively, Table 2 shows that the most frequent risk factors of ACS are massive perfusion of fluids (51.2%), coagulopathy (45.2%), transfusion of more than 6 units of packed red blood cells and metabolic acidosis 41.86%). These factors were more frequent in OS than in REVAR (Table 3).

A total of 43 patients were analysed (Figure 1): 21 with OS and 22 with REVAR. Of the patients who underwent OS, the abdomen was left open in 9 cases, and primary abdominal closure was performed in 12. Of the patients who underwent REVAR, abdominal decompression was performed immediately after the procedure in 6 cases. The overall survival at 30 days (N=43) was 65.1%. According to the type of surgery, 13 OS patients (61.9%) and 15 REVAR (68.2%) survived (p=0.666).

Differences were observed in 30-day survival depending on the type of abdominal closure (primary or delayed). In the OS group, survival was 41.7% in the primary closed abdomen group and 89% in the delayed closure group (p=0.027).

In the REVAR group, survival was 81.2% in the closed abdomen group and 33.3% in the decompressive laparotomy group (p=0.032).

No differences in 30-day mortality were observed in the OS group according to the presence of ACS. In the OS group (21 cases), 12 patients were diagnosed with ACS (33%) and 4 died, compared to 4 deaths in the 9 non-ACS patients (44%) (p=0.604). In the REVAR group (22 cases), 6 patients were diagnosed with ACS and 4 died (66.7%), compared to 3 deaths in the 16 non-ACS REVAR patients (18.8%) (p=0.032).

Discussion

The mortality rate associated with RAAA treatment reaches 85%. Sixty-six per cent of these deaths occur before reaching the hospital or without undergoing surgery. The mortality rate of patients who undergo repair procedures is still 37% to 74% [8].

Laine et al., [9] reported data on all patients who received surgical treatment for RAAA and those deemed moribund and were turned down for operative treatment between 2003 and 2013. A total of 712 patients with RAAA were included in this study: 382 (53.7%) died before reaching the hospital; 330 reached the hospital alive and 34 were turned down for surgery (10.3%). Of the 296 patients treated surgically, 199 were alive at 30 days. The overall 30-day mortality rate for RAAA was 72.1%. In our study, overall 30-day mortality rate was 65.8%, 25.6% of which reached the hospital alive but were turned down for surgery and 40.2% who underwent surgery.

Table 2: Pre-, intra- and postoperative variables of patients who survived AAAR surgery.

Pre-, intra- and postoperative variables	
Aortic abdominal aneurysm diameter (mm)	8.52 (+/-1.77)
Lowest systolic blood pressure	87.68 (+/-22.36)
Preoperative haemoglobin	11.52 (+/-2.88)
Duration of intervention (minutes)	212.05 (+/-76.15)
Lowest intraoperative Ph	7.23 (+/-0.16)
Litres/24 hours	4.76 (+/-2.75)
Packed red blood (RBC) transfusion (number)	6.35 (+/-5.01)
Platelet transfusion (number)	0.67 (+/-1.64)
Plasma transfusion (number)	2.07 (+/-3.48)
Lowest intraoperative temperature (ºC)	35.47 (+/-1.13)
Lowest intraoperative systolic blood pressure	77.25 (+/-22.27)
Length of stay in intensive care unit (days)	18.68 (+/-23.93)
ACS	18 (41.86%)
Secondary abdominal decompression	1 (2.3%)
Ph <7.2	18 (41.86%)
>5 litres perfused fluids/24 h	22 (51.2%)
Transfusion >10 units of RBC	10 (23.26%)
Transfusion >6 units of RBC	19 (44.19%)
Arterial pressure <70 mmHg for more than 20 min	8 (18.6%)
Temperature <35ºC	2 (4.17%)
Coagulopathy	19 (45.2%)

Note: Values are expressed as n(%) for categorical variables and mean (+/-deviation) for non-categorical variables.

Increasing evidence from observational studies shows that REVAR confers an early survival benefit over OS. The results, however, have been questioned; it is argued that a greater number of stable patients and those with less risky anatomy might have been treated with REVAR rather than with OS. Moreover, a multicentre randomized trial (IMPROVE) failed to favour the conclusion drawn from the previous observational studies [10]. The mortality rate in our patients was higher in the OS group (66.7%) than in the REVAR group (31.8%) (p=0.009). These results are thought to be subject to a major confounding bias. Patients treated with REVAR were stable and anatomically suitable. However, since 2015, we consider REVAR as the first treatment option in anatomically suitable patients (favourable neck and available femoral arteries for access), independently from haemodynamic instability. The optimal treatment for RAAA remains controversial in the absence of convincing high-level evidence from randomized trials. The perceived benefits of REVAR are supported by several observational studies that reveal a trend towards improved outcomes with this approach compared with OS [11]. It seems that the benefit is greater in patients with favourable anatomy for EVAR but not in complex anatomies [12]. In 2015, Badger et al., [13] published a Cochrane systematic review comparing endovascular repair *vs.* OS for RAAA. The three studies included were randomized controlled trials that analyzed 30-day mortality (Hinchliffe Study, AJAX Study and IMPROVE), with a total of 761 participants [10,14,15]. The fixed effects model found no clear evidence to support a difference in mortality between groups (OR 0.93; 95% CI: 0.69 to 1.25; p=0.63): 132

Table 3: Risk factors of ACS: OR vs. REVAR.

ACS risk factors		Type of surgery (n)		p value
		Open surgery (n=21)	Endovascular (n=22)	
Arterial pressure <70 mmHg for more than 20 min	no	15 (46.9%)	17 (53.1%)	p=0.874
	yes	4 (50%)	4 (50%)	
Haemoglobin <10 g/dL	no	15 (51.7%)	14 (48.3%)	p=0.426
	yes	5 (38.5%)	8 (61.5%)	
pH <=7.2	no	6 (33.3%)	12 (66.7%)	p=0.18
	yes	11 (55%)	9 (45%)	
>5 litres perfused fluids/24 h	no	6 (28.6%)	15 (71.4%)	p=0.009
	yes	15 (68.2%)	7 (31.8%)	
Transfusion >10 units of RBC	no	13 (39.4%)	20 (60.6%)	p=0.024
	yes	8 (80%)	2 (20%)	
Transfusion >6 units of RBC	no	9 (36%)	16 (64%)	p=0.047
	yes	12 (66.7%)	6 (33.3%)	
Temperature <33ªC	no	16 (44.4%)	20 (55.6%)	p=0.218
	yes	2 (100%)	0 (0%)	
Coagulopathy	no	8 (34.8%)	15 (65.2%)	p=0.03
	yes	13 (68.4%)	6 (31.6%)	

deaths (33.8%) in the REVAR group (388 patients) and 135 deaths (36.2%) in the OS group (373 patients). Our patients treated with REVAR had suitable anatomy compared with those in the OS group. Complex anatomies were not included in the REVAR group. Patients treated with OS were also more unstable, especially those who died during OS.

Rubenstein et al., [16] published a retrospective review of ACS associated with endovascular and OS of RAAA. They included 73 patients (44 OS and 29 REVAR); overall mortality was 42% (31/73), with 31% mortality in REVAR and 48% in OS. ACS developed in 21 patients (29%), more frequently in OS (15/44, 34%) than in REVAR (6/29, 21%). The diagnosis of ACS was made on the basis of a constellation of clinical findings including increased airway pressures, oliguria, tense abdominal wall and inability to close the abdomen due to bowel oedema. In our review, a total of 18 patients (41%) developed ACS, 57% in the OS group (12/21) and 27% in the REVAR group (6/22) (p=0.047). In the Rubenstein study, mortality was higher in patients who developed ACS compared with those who did not (13/21 (62%) *vs.* 17/52 (33%); p=0.022) [16]. This finding was especially pronounced in the REVAR group, in which mortality in patients with ACS was 83% (5/6) compared with 17% (4/23) without ACS (p=0.005). In patients who underwent OS, 9 deaths occurred among the 15 patients who developed ACS (60%), compared with 13 deaths in 29 patients (45%) who did not (p=NS). Our results are concordant with those obtained by Rubinstein et al., [16] without significant differences between groups in OS and a higher mortality in the REVAR group in patients with ACS.

An analysis of mortality in the OS group comparing open *vs.* closed abdomen, showed that mortality was higher in the closed abdomen group (5/12 cases) than in the open abdomen group (1/9 cases), p=0.027. Previous studies by Barker, Rasmussen, Ross and Wingren found better results in terms of multi-organ failure and mortality when comparing open vs. primary abdominal closure [2,17-19].

Mehta et al., [20] reported their findings of ACS in REVAR. They present 30 patients who underwent emergent EVAR of RAAA, and 6 (20%) developed ACS that required surgical decompressive laparotomy. The overall mortality was 23%. Patients with ACS had a higher mortality (67%) compared with those without ACS (13%), p=0.01. In 4 out of 6 patients, ACS was diagnosed immediately after completing the endovascular procedure, whereas in 2 patients it occurred 9 and 36 hrs postoperatively. In our series, 6 patients in the REVAR group were diagnosed with ACS; the mortality rate was 67% (4 patients). ACS developed at the completion of the procedure due to instability and intra-abdominal pressure more than 20 mmHg; decompression laparotomy was performed immediately. These patients required more intraoperative packed red blood cells, colloid and crystalloid. Despite early diagnosis and decompressive laparotomy, mortality was high. Although an endovascular graft is successfully placed, these patients can have a continued blood loss through a type II endoleak that is open to the abdominal cavity through the ruptured aneurysm sac as suggested by Mehta and Rubenstein [16,20]. Such a situation would require consideration for the evacuation of a space-occupying haematoma with a decompressive laparotomy and opening of the sac to ligate bleeding vessels within the aneurysm sac. Late development of ACS, with no evidence of ongoing blood loss is likely to be due to aggressive fluid resuscitations.

In the study by Li Yonghui, a total of 87 patients (9.2%) in the REVAR group suffered ACS and required abdominal exploration [21]. Two studies further investigated the role of ACS on perioperative mortality. Wallace found that patients undergoing decompressive laparotomy in addition to REVAR were less likely to survive than patients who underwent REVAR without decompression [22]. Mayed reported that only in patients without abdominal decompression by laparotomy could REVAR confer an early survival benefit over open repair [23].

In 2017, Adkar et al., [24] published the results of laparotomy during endovascular repair of RAAA and found that 91 of 1241 patients treated with REVAR (9.3%) required concomitant laparotomy. Patients who underwent concurrent laparotomy more frequently required preoperative transfusion of blood products (30% *vs.* 16%, p<0.005). The 30-day mortality was 60% in the laparotomy group and 21% in the standard REVAR group (p<0.001).

Rubenstein found that patients in the REVAR group with ACS required more packed red blood cells and Adkar detected persistent postoperative bleeding in more than 40% of patients in the REVAR group [16,24]. Both authors suggested a difference in ACS pathophysiology comparing REVAR versus open repair.

Study Limitations

The retrospective nature of the study can lead to data loss. The sample size was limited by the small number of RAAA cases that reached hospital alive and the high intraoperative mortality rate of patients who underwent surgery.

Conclusion

Ruptured abdominal aortic aneurysm carries high 30-day mortality. Open surgery with delayed abdominal closure has proved to reduce mortality, but abdominal compartment syndrome in endovascular repair produces high mortality rate despite the performance of decompression laparotomy.

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