Intra-abdominal Hypertension and Abdominal Compartment Syndrome after Endovascular Repair of Ruptured Abdominal Aortic Aneurysm

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KEYWORDS
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Abdominal compartment syndrome;
Abdominal aortic aneurysm;
Rupture;
Endovascular repair

Abstract  Objectives: To investigate the frequency of intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS) after endovascular repair (EVAR) of ruptured abdominal aortic aneurysm (rAAA).
Methods: This was a prospective clinical study. Patients with endovascular repair of rAAA between April 2004 and May 2010 were included. Intra-abdominal pressure (IAP) was measured in the bladder every 4 h. IAH and ACS were defined according to the World Society of the Abdominal Compartment Syndrome consensus document. Early conservative treatments (diuretics, colloids and neuromuscular blockade) were given to patients with IAP > 12 mmHg.
Results: Twenty-nine patients, who underwent endovascular repair of a rAAA, had their IAP monitored. Postoperatively, 10/29 (34%) patients had an IAP > 15 mmHg and six (21%) had an IAP > 20 mmHg. Three (3/29, 10%) patients developed ACS that necessitated abdominal decompression in two. Five out of six patients with IAP > 20 mmHg presented with preoperative shock. All patients except one with preoperative shock developed some degree of IAH.
Conclusion: IAH and ACS are common and potential serious complications after EVAR for rAAA. Successful outcome depends on early recognition, early conservative treatment to reduce IAH and decompression laparotomy if ACS develops.

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Intra-abdominal Hypertension after Endovascular Repair of rAAA

Patients and Methods

All patients treated with EVAR for rAAA at Gävle county hospital and Uppsala University Hospital between August 2004 and May 2010 were included, being in total 32 patients. Rupture was defined as extravasations of blood outside the aortic wall confirmed by computed tomography (CT). Patients with symptomatic AAA without evidence of rupture were excluded. The decision to perform EVAR or OR was based on the judgement of the vascular surgeon on call. All patients with rAAA were considered for EVAR except when: (1) preoperative CT indicated unsuitable morphology for endovascular treatment, (2) the surgeon on call was not comfortable performing EVAR in an emergent setting or (3) preoperative CT was not feasible in severely haemodynamically unstable patients. A policy of restricted fluid resuscitation and permissive preoperative hypotension, to minimise ongoing haemorrhage, was adopted in all patients.

IAP was measured in the bladder with the FoleyManometer device (Holtech Medical, Charlottenlund, Denmark), every 4 h during at least the first 48 post-operative hours. The FoleyManometer method is a new method, having the advantage of being simple and feasible not only at the intensive care unit (ICU), but also in a normal ward. This method does not require any filling of the bladder, reducing the risk of contamination. ACS is defined as an IAP of at least 20 mmHg with a new organ dysfunction (cardiac, respiratory or renal). IAH is defined by sustained or repeated pathological elevation of IAP > 12 mmHg and is graded as follows:

- Grade I: IAP 12–15 mmHg, grade II: IAP 16–20 mmHg, grade III: IAP 21–25 mmHg and grade IV: IAP > 25 mmHg. The abdominal perfusion pressure (APP) is the mean arterial pressure (MAP) minus the IAP (MAP – IAP), and a combination of an APP < 60 mmHg and new organ dysfunction is also defined as an ACS. Early conservative treatments (pain relief, diuretics, colloids and neuromuscular blockade) were given to patients with IAP > 12 mmHg, as described in the treatment guidelines from the Consensus Conference of the World Society of the Abdominal Compartment Syndrome (WSACS). Decompression laparotomy was performed when ACS developed (IAP > 20 mmHg and new organ dysfunction) by a standard midline incision (laparotomy) from the xyphoid process to the pubic bone. As temporary abdominal closure (TAC), a combination of vacuum-assisted wound closure and mesh-mediated traction was used. Demographic details and risk factors were recorded prospectively.

The study was approved by the Research Ethics Committee of the Uppsala/Örebro region.

Statistics

Group differences in ordinal variables were tested with the chi² test, differences between proportions with 95% confidence intervals and time trends with linear-by-linear associations-test. A p-value < 0.05 was considered statistically significant.

Results

From April 2004 to May 2010, 32 patients with rAAA underwent EVAR and 108 patients with rAAA were treated with OR at the two hospitals. The majority of EVAR for rAAA (28 of the 32 operations) were performed in Uppsala university hospital. In Gävle county hospital, surgeons were still more comfortable with OR. Although it would seem that an increasing proportion was treated endovascular over time (Fig. 1), that trend was not significant (p = 0.227).

The overall 30-day mortality among the 108 patients was 35% (38/108). The 30-day mortality after EVAR for rAAA was 13% (4/32).

Exposure and access were obtained by bilateral femoral cut-downs (n = 3), percutaneously with a commercially available closure device (n = 15), or with a fascia suture (n = 14). The operation was performed under local anaesthesia and sedation in most cases (n = 29); three patients were operated on in general anaesthesia. Bifurcated endografts were used in all cases; Gore Excluder (n = 13, W.L. Gore & Associates, Flagstaff, AZ, USA) Talent/Endurant (n = 2/9, Medtronic Inc., Minneapolis, MN, USA) and Zenith (n = 8, Cook Inc., Bloomington, IN, USA).

Three of 32 patients were not monitored for IAP, they were all ≥80 years of age. In two patients a decision was taken to withhold further treatment; both had advanced cardiac failure and one of them also had renal failure. These two patients died on the first postoperative day. The short postoperative period precluded any meaningful postoperative monitoring. The third patient underwent successful EVAR and was shortly thereafter transferred back to the county hospital (not participating in this study), which had referred the patient, due to a temporary lack of ICU resources at the University Hospital.

Among the remaining 29 monitored patients, six had an IAP > 20 mmHg (21%) of whom three were successfully treated conservatively and three (3/29 10%) developed ACS (Table 1): A 84-year-old woman, tied to a wheelchair because of spinal stenosis and with a history of cardiac disease, had a 20-h diagnostic delay prior to the treatment of rAAA. An IAP of 46 mmHg was recorded postoperatively.
during the first 6 h in the ICU, but the relatives had a strong opinion that laparotomy should be avoided; further treatment was withheld, and the patient died.

The second patient, who developed an ACS, was a 79-year-old male with a history of previous EVAR despite a hostile anatomy because of obesity and serious chronic obstructive pulmonary disease (COPD). He developed a distal type-I endoleak, which resulted in a late rupture. He underwent re-intervention; a stent-graft extension was placed into the left external iliac artery. IAP was 23 mmHg 8 h postoperatively with poor urinary output. He was first treated with diuretics, and IAP was monitored more frequently. He developed ACS, however, and was treated with decompression laparotomy 12 h post EVAR and survived. The third patient, a 62-year-old male, had severe preoperative shock with a systolic blood pressure of only 50 mmHg at arrival. An occlusion balloon was used. Postoperatively, IAP was 24 mmHg after 12 h, and he developed clinical signs of ACS. He was treated with open abdomen and survived. Both these latter patients were transferred to Uppsala university hospital from distant county hospitals and received massive transfusions to survive the transport.

Ten (35%) patients had an IAH grade II, five (17%) grade III and one (3%) grade IV (Table 1). An occlusion balloon was used in two cases, both of whom were in shock; and one of them had heart arrest (asystole) at arrival to the hospital. She developed cerebral ischaemia and died because of her stroke; her maximum IAP was only 8 mmHg.

**Table 1** Different levels of intra-abdominal pressure (IAP) and clinical variables among 29 patients operated on with EVAR for rAAA and monitored consistently with IAP.

<table>
<thead>
<tr>
<th>IAP &lt; 12 mmHg</th>
<th>IAP 12–15, mmHg</th>
<th>IAP 16–20, mmHg</th>
<th>IAP 21–25, mmHg</th>
<th>IAP &gt; 25, mmHg</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of patients (%)</td>
<td>6 (21)</td>
<td>7 (24)</td>
<td>10 (35)</td>
<td>5 (17)</td>
</tr>
<tr>
<td>Age</td>
<td>74 (65–82)</td>
<td>71 (61–81)</td>
<td>76 (62–92)</td>
<td>68 (61–79)</td>
</tr>
<tr>
<td>Male/Female (%)</td>
<td>5/1 (83/17)</td>
<td>5/2 (71/29)</td>
<td>9/1 (90/10)</td>
<td>3/2 (60/40)</td>
</tr>
<tr>
<td>Preoperative shock (%)</td>
<td>1 (17)</td>
<td>—</td>
<td>3 (30)</td>
<td>4 (80)</td>
</tr>
<tr>
<td>Occlusion balloon (%)</td>
<td>1 (17)</td>
<td>—</td>
<td>—</td>
<td>1 (20)</td>
</tr>
</tbody>
</table>

**Postoperative complications**

| Pulmonary failure (%) | — | 1 (14) | 2 (20) | 2 (40) | 1 (100) |
| Cardiac failure (%) | 1 (17) | 1 (14) | 3 (30) | 4 (80) | 1 (100) |
| Renal failure (%) | — | — | — | 2 (40) | 1 (100) |
| Reoperation for bleeding (%) | 1 (17) | 2 (28) | 2 (20) | 1 (20) | — |
| Femoral trombectomy (%) | 2 (33) | 2 (28) | 1 (10) | — | — |

**Outcomes and interventions:**

| ACS (%) | — | — | — | 2 (40) | 1 (100) |
| Diuretics* | — | 3 (42) | 6 (60) | 5 (100) | 1 (100) |
| Neuromuscular blockade (%) | — | — | — | — | — |
| DL (%) | — | — | — | 2 (40) | — |
| Mortality 30 days (%) | 1 (17) | — | — | — | 1 (100) |

ACS = Abdominal compartment syndrome; DL = Decompression laparotomy.
* Diuretics means intense treatment with diuretics and colloids.
Two of the patients who died were not monitored with IAP, but there were no clinical signs of ACS. In the remaining two patients, who died after EVAR of rAAA, IAP was measured (described above). There were no signs of colonic ischaemia among the patients treated with EVAR for rAAA.

One-quarter of patients treated with EVAR were in shock versus 48% of patients treated with OR ($p = 0.020$). Five out of six patients with IAH grade III or IV presented with shock. All patients except one with preoperative shock developed some degree of IAH.

Discussion

EVAR of rAAA is feasible and offers the potential for decreased morbidity and mortality, but there is an increased recognition of complications, such as ACS. In a report of 30 patients with rAAA treated with EVAR by Mehta et al., 20% developed ACS. However, a more strict definition of ACS (clinical criteria and IAP > 25 mm Hg) was used, it is unclear in how many patients IAP was monitored and no results of IAP measurements were reported. Four risk factors for ACS were identified: (1) use of an aortic occlusion balloon, (2) massive transfusion, (3) coagulopathy and (4) conversion from aortobiiliac to aorto-uni-iliac device. The mortality among those who developed ACS was significantly higher than among those who did not (67% vs. 13%, $p = 0.01$). In the present study, the aortic occlusion balloon was used in only two cases; ACS and decompression laparotomy was later performed in one of them, and no patient underwent conversion from an aortobiiliac to an aorto-uni-iliac device. In an extension of their case series, Mehta et al. later reported on 40 patients treated with EVAR for rAAA, and the frequency of ACS was 17%. Two other studies reported only sporadic cases of ACS and did not detect any survival advantage of EVAR over OR.

Makar et al. reported that EVAR of rAAA is associated with less IAH and inflammatory response compared with OR.

Thirty patients with rAAA were prospectively recruited; 14 underwent EVAR and 16 had OR. IAP was measured at 2 and 6 h and then daily for 5 days. One patient in the EVAR group, and one in the OR group developed ACS; both were treated with decompression laparotomy. There was no report on conservative treatment of IAH before ACS development, nor on how many patients developed IAH. In our experience, this low frequency of measuring IAP does not permit a proactive management of the patients, nor a scientific evaluation of the frequency of IAH. In particular, in the early postoperative period, the development of IAH/ACS is dynamic, with quick changes.

In the largest study published on ACS after endovascular rAAA repair, Mayer et al. reported that treatment with open abdomen (OA) was necessary because of ACS in 20/102 rAAAs (20%) treated by EVAR, a higher proportion than in the present investigation, where only 3/29 patients (9.4%) developed ACS and two (6%) were treated with OA. No information was given in Mayer’s article regarding the IAP measurements, nor on how many patients developed IAH, or if they were treated conservatively before developing ACS and treatment with OA. There are multiple possible explanations for this difference in frequency of OA treatment. First, the Zürich group had a very proactive approach to OA treatment. They state that “...decompression laparotomy was done in all cases before organ failure occurred.” Adhering strictly to the WSACS definition of ACS, they consequently did not have any patients with ACS, as the definition of ACS is an IAP > 20 mmHg and new organ failure. Second, they do not describe any conservative treatment prior to decompression laparotomy, and it was not included in their management algorithm. We have implemented the WSACS guidelines, including aggressive conservative treatment of IAH to prevent ACS (Fig. 2). Finally, we still treated a large proportion of the patients with OR, and those treated with EVAR were less often in preoperative shock.

Patients in the present study were treated according to the recommendations of the WSACS. Cheatham and Safscak recently reported an interesting experience from the Surgical/Trauma Intensive Care Unit in Orlando, Florida. They implemented those recommendations, summarised as

| Table 2 | Risk factors and outcome after endovascular and open repair. |
|---|---|---|
| **EVAR (n = 32)** | **OR (n = 108)** | **p-value** |
| Age | 74 (61–92) | 74 (56–89) | 1.000 |
| Male/Female (%) | 26/6 (81/19) | 85/23 (79/21) | 0.755 |
| **Risk factors:** | | | |
| Diabetes mellitus (%) | 7 (22) | 27 (25) | 0.717 |
| Hypertension (%) | 28 (88) | 82 (76) | 0.161 |
| Cardiac disease (%) | 21 (66) | 62 (57) | 0.406 |
| Pulmonary disease (%) | 11 (34) | 23 (21) | 0.130 |
| Renal insufficiency (%) | 5 (16) | 11 (10) | 0.396 |
| Cerebrovascular disease (%) | — | 10 (9.3) | 0.074 |
| Preoperative shock (%) | 8 (25) | 52 (48) | 0.020 |
| IAP monitoring (%) | 29 (91) | 85 (79) | 0.128 |
| ACS (%) | 3 (9.4) | 20 (19) | 0.187 |
| Mortality 30 days (%) | 4 (13) | 38 (35) | 0.017 |

* Defined as S-creatinine >150 mmol/l; IAP = Intra-abdominal pressure; ACS = Abdominal compartment syndrome.
a proactive strategy initiating conservative treatment early with an IAP $> 12$ mmHg, and performing decompression laparotomy early before multiple organ failure develops. In a prospective 6-year study, 478 patients treated with open abdomen were investigated. Whereas disease severity remained unchanged, measured with APACHE II, Simplified Acute Physiology Score (SAPS) and ISS scores, mortality decreased (from 72% to 50%), the fascial closure increased (from 59% to 81%) and resource usage decreased.

A limitation of this study is the small number of patients. EVAR was mostly used in haemodynamically stable patients with favourable anatomy, which, to some extent, may explain the better survival in this group of patients. The patient groups are not comparable, and the aim of this investigation was not to compare results after OR and EVAR. As our experience increased, we used EVAR in haemodynamically unstable patients more often, yet most patients with rAAA were treated with OR. Five out of six patients with IAH grade III or IV after EVAR presented with shock, and all except one patient with preoperative shock developed some degree of IAH. A more liberal use of EVAR among patients in shock will probably result in a higher frequency of ACS. One of the patients who died had a major stroke secondary to cerebral hypoperfusion, which illustrates the potential danger of permissive hypotension prior to surgery. Although it is unlikely that the patient would have survived an OR, it cannot be ruled out. The issue of which primary strategy, EVAR or OR, results in best outcome after rAAA repair, is presently being investigated in three randomised trials, the AJAX, ECAR and Immediate Management of the Patient with Rupture: Open Versus Endovascular repair (IMPROVE) trials, and debated and commented.

Most patients with IAH were successfully treated conservatively, and only 6/16 developed an IAP $> 20$ mmHg (IAH grade III) of whom three developed ACS. This indicates that early recognition and timely treatment may prevent progression to a more severe state.

**Conclusion**

IAH and ACS are common and potential serious complications after EVAR for rAAA. Successful outcome depends on early recognition, early conservative treatment to reduce IAH and decompression laparotomy if ACS develops.

**Conflict of Interest**

None.

**Funding**

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