Emergency Endovascular Repair for Ruptured Abdominal Aortic Aneurysms: Feasibility and Comparison of Early Results with Conventional Open Repair

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Purpose. To assess the feasibility of endovascular aortic repair (EVAR) on patients presenting with a ruptured abdominal aortic aneurysm (AAA) in a teaching hospital, and to compare there post-operative outcomes with contemporaneous patients treated with open repair (OR).

Methods. A series of consecutive patients presenting ruptured AAA with retro/intraperitoneal haematoma were included in the study. EVAR was attempted whenever possible. In all other cases (severe haemodynamic instability, adverse anatomy, device unavailability), ruptured AAA were treated by OR.

Results. Thirty-seven patients were enrolled between January 2001 and July 2004. Seventeen (46%) patients were treated using adapted designed aortoiliac endografts (eight bifurcated, eight aorto-uniiliac, one iliac extension). Twenty (54%) patients unfit for EVAR because of severe haemodynamic instability (n=8), adverse anatomical configuration (n=7), or unavailability of an appropriate endograft (n=5) were treated by OR. Twenty-seven (73%) had a retrospective suitable anatomy for EVAR. Three early conversions from EVAR to OR were performed. Blood loss, operating time, and intensive care stay were significantly decreased in EVAR patients (respectively: 156 min ± 60, 1520 ml ± 1175, 3 days for EVAR; vs. 222 min ± 82, 3075 ml ± 1750, 13 days for OR; P < .01). The 30-day mortality rate was 23.5% for EVAR vs. 50% for OR (P = 0.09).

Conclusion. EVAR of ruptured AAA is feasible for selected patients based on haemodynamic and morphologic criteria, and should be associated with improved immediate outcomes as compared with OR. These results should be tempered by the fact that these patients have heavy comorbidities which explains the absence of difference in mid-term mortality rates between the two groups, but should also encourage surgical institutions that are managing such life-threatening emergencies to introduce EVAR as part of their therapeutic arsenal for ruptured AAA.

Keywords: Ruptured abdominal aortic aneurysm; Endovascular repair.

Introduction

Despite many advances in the management of ruptured abdominal aortic aneurysm (AAA), the mortality rate of the conventional open repair (OR) has not improved significantly during the last 50 years and remains around 48%.1 There is now evidence that elective endovascular repair (EVAR) is technically feasible and safe for AAA exclusion2–4 with a reduced physiological impact.5,6 The feasibility of EVAR for ruptured AAA was proven in a case report by Yusuf7 in 1994. Recently larger series8–10 and prospective studies11,12 have been reported with an average perioperative mortality rate of 24% (Table 1). These results should encourage the use of EVAR for all patients with ruptured AAA whenever possible. We report our initial experience with emergency EVAR of ruptured AAA, and our prospective analysis of this new treatment approach in an unselected population. Our first aim was to assess the proportion of patients with ruptured AAA that can be treated with EVAR. Our second aim was to compare the patients treated with EVAR to a contemporary group of patients treated with OR.

Methods

Patient selection, inclusion and exclusion criteria

All patients presenting with a ruptured AAA who reached the emergency-room alive were included in
the study. Baseline demographic data, risk factors as defined by the Society for Vascular Surgery/American Association for Vascular Surgery reporting standard,\(^{13}\) were obtained for all patients. Rupture of the aneurysm is defined as hemorrhage outside the aortic wall, documented by pre-operative computed tomography (CT), or in case of laparotomy by direct observation. The criteria of inclusion and exclusion of the study are summarized in Table 2.

**Triage of enrolled patients**

**Haemodynamic criteria**
The resuscitation of all consecutive enrolled patients with a ruptured AAA was performed with a multidisciplinary approach, involving emergency, radiology, anesthesiology, operating theatre and surgical staff. Patients in stable haemodynamic condition, or with moderate haemodynamic instability (systolic blood pressure $\geq 80$ mmHg and no severe cardiac arrhythmia) underwent CT-examination. Severely unstable patients in profound hypovolemic shock (systolic blood pressure $<80$ mmHg and/or cardiac arrest) were taken to the operating room for immediate OR.

**Anatomic criteria**
A contrast-enhanced spiral CT-scan of the thoraco-abdominal aorta was performed for all patients with acceptable haemodynamic conditions. The diagnosis of ruptured AAA was confirmed on CT-scan and the aneurysm morphology was assessed for suitability for EVAR. Morphological suitability guidelines for EVAR were: Proximal neck length $>15$ mm; neck diameter $<32$ mm; neck angulation $<90^\circ$. When the anatomy of the AAA was considered unfeasible for EVAR, the patients were immediately treated by OR. Patients presenting these haemodynamic and anatomic criteria were recorded to be eligible for EVAR.

**Material criteria**
In the patients eligible for EVAR, the endograft configuration and sizing was planned from the axial spiral CT-scan with a typically recommended oversizing of 20%. Only limited endograft designs and sizes were available on the shelf, therefore, patients eligible for EVAR, for whom no suitable endograft was available, were treated by OR.

**Emergent surgical procedures**

**Endovascular control of aortic rupture**
Transfemoral supraceliac aortic balloon occlusion (Reliant, Medtronic) was inflated if a patient became hemodynamically unstable during the procedure.

**Anesthetic management**
After establishing high-caliber peripheral venous accesses, inserting a urethral catheter, canulating the radial artery for continuous blood pressure monitoring, the patients were managed with permissive hypotension ($<110$ mmHg). OR for ruptured AAA necessitated a general anesthesia, but the choice between local or general anesthesia during EVAR was at the discretion of the anesthetic and surgical teams.

**Emergency EVAR**
All operations were performed in operating room by a surgeon and an interventional radiologist. Both femoral arteries were exposed and an introducer sheath and a guide wire were introduced in the aorta, under fluoroscopic control, followed by a pig tail angiography catheter. Angiography was performed to visualize the renal arteries, the proximal aortic neck, and the iliac arteries. A delivery system containing an appropriate proximal component of the stentgraft was placed in the infrarenal position. Bifurcated or aorto-uniiliac (AUI) stentgrafts could be deployed to exclude the AAA. The distal components were then deployed with their distal portion in a suitable segment of either the common or the external iliac artery. In case of an AUI device, a femoro-femoral bypass was performed, and an occluder was delivered into the contralateral common iliac artery.
Completion angiography confirmed adequate fixation at the proximal and distal landing zones and identified any endoleaks. Type I and III endoleaks were treated in the same session. Type II and IV endoleaks were accepted.

Emergency OR
In severely unstable patients or when a significant intraperitoneal haematoma was found, the descending thoracic aorta was first clamped through a left thoracotomy. Then a laparotomy was performed to expose the AAA and its proximal neck. Whenever possible, the clamp was moved down to the infrarenal position to limit visceral and renal ischemia. A midline laparotomy was performed in the other cases.

Post-operative follow-up
All patients were post-operatively treated in the intensive care unit. Clinical and imaging follow-up with a CT-scan was performed at 1, 3 and 6 months after the intervention. Adverse events and secondary procedures were prospectively recorded in a computed database.

Statistical analysis
All continuous data were expressed in mean ± standard deviation. Paired observations of continuous data were evaluated using an ANOVA analysis. The χ²-test was used to compare proportions of nominal data. Differences were deemed significant at $P < 0.01$.

Results
Thirty-seven patients presenting with a ruptured AAA were included between January 2001 and July 2004.

Table 3. Demographic data of included patients

<table>
<thead>
<tr>
<th></th>
<th>EVAR ($n=17$)</th>
<th>OR ($n=20$)</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>72.9 ± 9.8</td>
<td>72.8 ± 7.8</td>
<td>.96</td>
</tr>
<tr>
<td>Gender (male)</td>
<td>16 (94%)</td>
<td>20 (100%)</td>
<td>.27</td>
</tr>
<tr>
<td>Atherosclerosis risk factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smokers</td>
<td>13 (76%)</td>
<td>12 (60%)</td>
<td>.29</td>
</tr>
<tr>
<td>Hypertension</td>
<td>9 (53%)</td>
<td>12 (60%)</td>
<td>.67</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>5 (29%)</td>
<td>5 (20%)</td>
<td>.76</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1 (6%)</td>
<td>2 (10%)</td>
<td>.65</td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COPD</td>
<td>7 (41%)</td>
<td>4 (20%)</td>
<td>.16</td>
</tr>
<tr>
<td>CRF</td>
<td>3 (18%)</td>
<td>1 (5%)</td>
<td>.21</td>
</tr>
<tr>
<td>Angor</td>
<td>3 (18%)</td>
<td>4 (20%)</td>
<td>.86</td>
</tr>
</tbody>
</table>

COPD, chronic obstructive pulmonary disease; CRF, chronic renal failure.

EVAR was used to treat 17 patients, and the other 20 where treated with OR.

Demographic data
There were no significant differences in demographic data, atherosclerosis risk factors, and comorbidities between the EVAR and the OR patients (Table 3).

Pre-operative data
Mortality risk factors
Eight patients (22%) presented with severe haemodynamic instability (three with cardiac arrest) and were taken immediately to the operating room for OR. Other risk factors were similar between the two groups (Table 4, Fig. 1).

Morphologic data
The average delay due to the CT-scan procedure was 43 ± 9 min. The anatomy of the ruptured AAA was suitable for EVAR in 22 of the 29 patients (76%) who underwent a CT-scan. The size of the AAA, the diameter and the angulation of the proximal neck were similar in both groups (Table 5). But the length of the proximal neck was significantly shorter in the OR group, and nine patients had a neck shorter than 15 mm.

Feasibility of EVAR
Of the 20 patients not undergoing EVAR, eight presented with severe haemodynamic instability, seven had an adverse anatomy, and the appropriate endograft was unavailable for the other five (Fig. 2). Twenty-seven patients had retrospectively a suitable anatomy for EVAR (73%). But only 22 of these patients full-filled haemodynamic criteria allowing a pre-operative CT-scan. The feasibility rate of EVAR on haemodynamic and morphologic criteria was 59%.

Table 4. Pre-operative risk factors of post-operative mortality

<table>
<thead>
<tr>
<th></th>
<th>EVAR ($n=17$)</th>
<th>OR ($n=20$)</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age&gt;76 years old</td>
<td>9 (53%)</td>
<td>6 (30%)</td>
<td>.16</td>
</tr>
<tr>
<td>Unconsciousness</td>
<td>2 (12%)</td>
<td>6 (30%)</td>
<td>.18</td>
</tr>
<tr>
<td>Electrocardiographic myocardial suffering</td>
<td>3 (18%)</td>
<td>4 (20%)</td>
<td>.86</td>
</tr>
<tr>
<td>Hemoglobinemia &lt;9 g/dl</td>
<td>6 (35%)</td>
<td>7 (35%)</td>
<td>.98</td>
</tr>
<tr>
<td>Creatininemia &gt;190 μmol/l</td>
<td>1 (6%)</td>
<td>1 (5%)</td>
<td>.91</td>
</tr>
</tbody>
</table>
Peri-operative data

EVAR procedures

Fifteen procedures were performed under general anesthesia (88%), one under local anesthesia, and one was converted from local to general anesthesia for comfort reasons. Only one intra-aortic occlusion balloon (5.9%) placed by femoral route was deployed in the first case to provide temporary haemostasis. Different endografts were used on the 17 EVAR patients: Eight bifurcated, eight AUI, and one iliac extension (Table 6). The mean proximal body diameter of the endografts was 28 mm ± 4.5 (Fig. 3). The operative time was similar for both type of endograft (157 min for bifurcated and 150 for AUI, P = .86).

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Table 5. Morphologic data of AAA, from CT-examinations and direct observations

<table>
<thead>
<tr>
<th></th>
<th>EVAR (N=17)</th>
<th>OR (N=20)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA diameter (mm)</td>
<td>85 ± 24.2</td>
<td>78.8 ± 21.5</td>
<td>.43</td>
</tr>
<tr>
<td>Length of the proximal neck (mm)</td>
<td>27.4 ± 20.1</td>
<td>13.5 ± 7.2</td>
<td>&lt;.02</td>
</tr>
<tr>
<td>Number of short necks &lt; 15 mm</td>
<td>0</td>
<td>9 (45%)</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Diameter of the aortic neck (mm)</td>
<td>22.1 ± 4</td>
<td>21.2 ± 2</td>
<td>.78</td>
</tr>
<tr>
<td>Number of large necks &gt; 32 mm</td>
<td>0</td>
<td>3 (15%)</td>
<td>.10</td>
</tr>
<tr>
<td>Angulation of the proximal neck</td>
<td>24.1 ± 22</td>
<td>35.7 ± 13</td>
<td>.17</td>
</tr>
<tr>
<td>Number of severe angled necks &gt; 90°</td>
<td>0</td>
<td>1</td>
<td>.35</td>
</tr>
<tr>
<td>Suitable anatomy for EVAR</td>
<td>17</td>
<td>10</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

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Fig. 1. Proportion of patients presenting the same pre-operative gravity level.

Fig. 2. Management of patients with ruptured AAA.

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Three conversions to OR were necessary leading to a 100% mortality rate in the first 24 h. In one patient with a 10 cm aneurysm without thrombus, we failed to catheterize the contralateral limb and the patient died of hemorrhage despite the conversion. Associated procedures were performed in four patients: Two access ilio-femoral bypasses, and two hypogastric embolisations. Five hypogastric arteries were occluded during these procedures.

**OR procedures**
In seven cases the thoracic aorta was clamped for severe haemodynamic instability. No additional morbidity or prolonged stay in intensive care unit (ICU) could be related to thoracotomy in the OR group. Four out of seven died within the first day as they were very unstable patients. The mortality rate in this sub-group was 57%. Expose of the ruptured AAA was performed by a midline line abdominal incision in 18 cases and by a retroperitoneal approach in two cases. Ten tube and 10 bifurcated grafts were used for revascularization.

**Table 6. Inventory of endografts used in EVAR group**

<table>
<thead>
<tr>
<th>Endografts</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trifab Cook Bifurcated</td>
<td>7</td>
</tr>
<tr>
<td>TriFab Cook AUI</td>
<td>6</td>
</tr>
<tr>
<td>Excluder Gore AUI</td>
<td>1</td>
</tr>
<tr>
<td>AneuRx Medtronic AUI</td>
<td>1</td>
</tr>
<tr>
<td>Convector Cook AUI</td>
<td>1</td>
</tr>
<tr>
<td>Iliac extension Cook</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 6. Inventory of endografts used in EVAR group

The mean aortic diameter was 19 mm ± 3. The mean operating time was significantly longer for OR compared to EVAR (222 ± 82 vs. 156 ± 60 min, *P* < .01).

**Perioperative care**

The mean perioperative blood transfusion was significantly decreased in the EVAR group compared to the OR group (1520 ± 1175 vs. 3075 ± 1750 ml, *P* < .01). The median post-operative stay in ICU was also significantly decreased in the EVAR group compared to the OR group (3 vs. 13 days, *P* < .01). There was no statistically significant difference in hospital stay between the two groups (median 11.5 days for EVAR vs. 20 days for OR, *P* = .43).

**Post-operative data**

The mean follow-up was 6 months (range 1.1–26.3) in EVAR group and 4.4 months (range 1.5–13) in OR group. Five patients were lost to follow-up after discharge (three in EVAR and two in OR).

**30-Day mortality rate**

The 30-day mortality rate was 23.5% for EVAR vs. 50% for OR (*P* = .09). Time and causes of death are reported in Table 7.

**30-Day morbidity**

During the follow-up, nine complications were recorded in the EVAR group, and 18 in the OR group, leading to two secondary interventions in the EVAR group and to six in the OR group (*P* = .18) (Table 8).

**Mid-term follow-up**

The mortality increased to 35.2% in the EVAR during the follow-up period. The two additional deaths in the EVAR group were due to a major stroke in one patient,
and to a conversion to OR for endograft sepsis in another. Two type I endoleaks (11.8%) occurred at 5 and 6 months and could be treated with endovascular techniques. No other type of endoleak has been recorded. One proximal type I endoleak occurred after 6 months and was successfully treated by deploying a Palmaz stent over the proximal aortic neck. One second rupture occurred after 5 months in another patient and was treated by another endograft. This patient was first treated by an endograft providing good haemostasis and exclusion of the aneurysm. After 5 months the patient was readmitted as an emergency for a new rupture due to distal migration of the stent graft and a reperfusion of the aneurysm. This new rupture was successfully treated by deploying a new AUI endograft. None of the other 10 patients treated by EVAR had an increase in their aneurysm size during follow-up. In eight patients the aortic diameter decreased during follow-up (Figs. 3 and 4).

**Discussion**

**Patient selection**

Despite a slow recruitment to this study with an average of 10 patients per year, we decided not to include symptomatic but non-ruptured AAAs. Although these patients could have enlarged our series of patients treated by acute EVAR, their average post-operative mortality rate after OR of 10% does not compare with the 48% of true ruptured AAA.1 Currently, there is no consensus among surgeons on which patients with ruptured AAA should be offered an operation.15 Scoring systems exist which predict mortality.16,17 Whether these scoring systems are valid for patients undergoing EVAR is yet to be established. As EVAR has been performed successfully in patients turned down for open repair on the basis of medical co-morbidity and likelihood of survival,18 we decided to include every patient with ruptured AAA who reached hospital alive.

**Urgency of operation**

Most of the patients treated with OR were turned down for EVAR due to haemodynamic instability that required immediate hemorrhage control, and did not allow CT-examination.

Intra-operative calibration angiography (ICA) has been proposed to avoid pre-operative delay due to CT-scan, and evaluate directly in the OR the morphologic suitability of the AAA.19 Of course, this strategy could increase the feasibility of EVAR for ruptured AAA from 59 to 73% but the use of ICA alone has drawbacks. Use of ICA alone will not allow confirmation that the aneurysm has ruptured and does not reveal thrombus or atheroma lining the graft landing zones. In elective series, ICA is only able to predict the correct size of endograft in 60% of patients. For these reasons reliance on ICA alone was abandoned in our institution.

**AAA morphology**

We believe that contrast-enhanced spiral CT-scan from the thoracic aorta to the common femoral arteries is currently required in all cases. As well as making the positive diagnosis of AAA rupture, it is used to assess the suitability for EVAR and to predict graft size. Unsuitable access or inadequate graft landing zones may result in endoleak or mandate conversion to OR, associated with a high mortality in our study. Our patients presented with larger AAA with more adverse morphological features than their usual intact counterparts,20 which increased the technical difficulty and reduced the applicability of the endovascular technique.21 The overall anatomical suitability rate for EVAR was 73%. Other reports suggest that between 58 and 80% of ruptured AAAs are suitable for EVAR.8–12
In our study, EVAR was feasible on haemodynamic and morphologic criteria in 59% of the patients.

**Endovascular control of aortic rupture**

Our experience with intra-aortic balloons is limited. This method of hemorrhage control was used in the first case treated with EVAR via the femoral route. We currently prefer to fully exclude the aneurysm from the circulation as quickly as possible by deployment of the graft.

**Anesthetic considerations**

OR of ruptured AAA necessitates a general anesthesia. The ability to perform elective EVAR under local anesthesia is well established. Only two patients of our EVAR were performed under local anesthesia. We found the patients to be restless and in considerable pain from the rupture, which appeared to be exacerbated by endovascular instrumentation of the aorta and iliac arteries, and from lower limb ischemia. Inadequate analgesia may result in an adverse physiological response and movement artifacts on imaging. Furthermore, the use of AUI stentgraft necessitates a conversion to general anesthesia for placement of the femoro-femoral bypass graft. Thus, we advocate emergency EVAR under general anesthesia.

**Graft configuration**

Though the need for a femoro-femoral bypass graft may prevent the use of local anesthesia for the whole procedure, AUI devices have some advantages during EVAR of ruptured AAA. They can be used to exclude contralateral common iliac aneurysms, and are quick and easy to deploy. Although we did not show any difference in operative time between bifurcated and AUI endografts, the latter avoids the difficulty of catheterization the contralateral limb, particularly in big aneurysm without thrombus, and may produce faster hemorrhage control.

We began our experience with bifurcated models as they were the only available endoprothesis. We have now moved towards AUI devices, especially when the hemorrhage needs to be controlled quickly, and in case of complex anatomies (large AAA, without thrombus, with iliac tortuosity). We advocate the availability of three sizes of AUI endografts on the shelf (24, 28 and 32 mm) with their extensions and iliac occluders.

**Post-operative outcomes**

Although the cohort is rather small and differences in major outcome variables did not achieve statistical significance, the results suggest that EVAR may be of benefit in the reduction of perioperative morbidity and mortality as compared with OR, especially in the subset of stable patients. Furthermore, the reductions in blood loss, procedure time, and ICU length of stay in the setting of ruptured AAA seem to mirror the published results comparing elective repairs of intact AAA.

One of the limitations of this study, as most of the comparative series in the literature regarding EVAR for ruptured AAA, is that the two groups compared are not homogeneous. In the OR group 40% were operated on because of haemodynamic instability. It is well known that post-operative outcome is worse for such patients. In fact, the mortality rate in the subgroup of eight unstable patients was 75%. Mid-term mortality was 35% in the EVAR group, but none of the deaths could be related to a delay due to CT-scan during the management of their rupture, or to any technical difficulty during their acute endograft deployment.

During the follow-up period, we experienced a range of previously described EVAR complications for ruptured AAA. One case of severe compartment syndrome was treated by early surgical decompression. One case of colonic ischemia was related to the occlusion of a hypogastric artery. Two type I endoleaks were treated by endovascular techniques. One was due to the distal migration of an inappropriate AUI device, and led to a new rupture of the AAA. This latter complication reminds us that, even once excluded, the ruptured aneurysm is still a perforated sack in the retroperitoneum. Any defect of the endograft, such as a migration or type 1 endoleak, may lead directly to a new rupture. EVAR for ruptured AAA has to be as technically perfect as possible to avoid such late technical failures. This can be difficult to achieve in an emergency and may requires a secondary procedures before discharge.

**Conclusion**

This study confirms that EVAR of ruptured AAA is feasible for selected patients based on haemodynamic and morphologic criteria. We encourage surgical institutions that are managing such life-threatening emergencies to introduce EVAR as part of their therapeutic arsenal for ruptured AAA.

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Despite Many Advances in the Management of Ruptured AAA

References


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