Improved Survival After Abdominal Aortic Aneurysm Rupture by Offering Both Open and Endovascular Repair

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Background: In the treatment of ruptured abdominal aortic aneurysm (rAAA), the results of open graft replacement (OGR) have remained constant but discouraging for the last 4 decades. Provided suitable anatomy, elective endovascular abdominal aortic aneurysm repair (EVAR) is less invasive and leads to improved perioperative mortality. Thus, it is reasonable to assume that endovascular treatment should improve the results of rAAA therapy.

Objectives: To determine whether the use of both endovascular and open repair of rAAA leads to improved results.

Design: A single-center, retrospective analysis of 89 patients suffering from rAAA treated either by EVAR or OGR.

Patients: From October 1999 until July 2006, a consecutive series of patients with rAAA were analyzed. Time was divided into 2 periods of 41 months. During the first period, 42 patients were treated by OGR exclusively. Period 2 started with the availability of an EVAR protocol to treat rAAA; 31 patients received open repair while 16 patients underwent EVAR.

Main Outcome Measures: Kaplan-Meier survival estimates were calculated and compared.

Results: Survival estimates showed a statistically significant reduction in overall postoperative mortality following the introduction of EVAR (P < .03). The 90-day overall mortality rate was reduced from 54.8% to 27.7% during the second period (P < .01). Survival of patients older than 75.5 years was especially improved (75% vs 28.6%; P < .01). There was a parallel pattern of significant reduction of the mortality rate after OGR to 29% (P < .03).

Conclusion: Offering both EVAR and OGR to patients with rAAA leads to significant improvements in postoperative survival.

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Most patients developing abdominal aortic aneurysms remain asymptomatic; the diagnosis is often established coincidentally during an evaluation for other abdominal nonvascular disorders. Otherwise, the devastating event of rupture followed by exsanguinating hemorrhage will be the first indexing symptom.

Several population-based studies demonstrated that the majority of patients (70%-80%) with ruptured abdominal aortic aneurysm (rAAA) do not reach a hospital alive. For those who receive open graft replacement (OGR), mortality rates as high as 40% to 50% are reported, leading to an overall mortality rate of 80% to 90%. The results of rAAA repair did not change substantially for more than 40 years, although essential improvements in perioperative intensive care have been achieved. In the elective treatment of rAAA, the availability of endovascular aneurysm repair (EVAR) has led to a decrease in hospital mortality, as shown by our own observational as well as prospective studies. Older patients and those who suffer from severe comorbidities in particular benefit from this new treatment option.

See Invited Critique at end of article

Because patients with rAAA are usually geriatric, with limited physiologic reserve, EVAR seems to be a reasonable alternative to standard OGR. The aim of this study was to test whether the use of EVAR has a beneficial effect on the survival rates of patients treated for rAAA.
In March 2003, we established an EVAR protocol for the treatment of rAAA at the Medical University of Vienna in Vienna, Austria. For 41 months after introduction of this protocol (ie, until July 2006), a consecutive series of patients with rAAA were treated preferentially by EVAR, provided they were hemodynamically stable and a proper stent graft device with respect to the individual anatomic preconditions was available. The intention of this protocol was to offer EVAR mainly to geriatric patients, even if their vascular anatomy did not seem optimally suitable for stent graft implantation. The remaining patients were treated by OGR. The results during this period were compared with the results of consecutive patients undergoing OGR exclusively during the preceding 41 months.

Patients who suffered from rAAA due to congenital connective tissue diseases and those who sustained a secondary rupture (ie, rupture after preceding elective aneurysm repair) were excluded from the analysis. One patient who had already received EVAR for rAAA in November 2000, since he had already undergone evaluation for elective EVAR several days prior to rupture and a proper stent graft was readily available for prompt use. This patient was excluded from the study because an intention-to-treat by EVAR protocol did not exist at that time. He survived for more than 11 months.

Diagnosis of rAAA was, whenever possible, obtained by contrast-enhanced computed tomography. In patients for whom the time delay necessary for computed tomography might have been fatal, diagnosis was obtained solely by clinical examination and sonography. Hemodynamic instability on admission was defined as (1) a systolic blood pressure of less than 80 mm Hg or (2) loss of consciousness or cardiac arrest due to exsanguination. Two initially hemodynamically unstable patients could not be stabilized by adequate resuscitation measures and died before a detailed personal medical history could be obtained. Patients’ survival rates were estimated at 3 monthly intervals, correlating with postoperative follow-up. To detect possible differences in outcome in relation to age, we divided the patients into 3 equally sized groups: patients younger than 68 years (n=30), patients aged 68 to 75.5 years (n=29), and patients older than 75.5 years (n=30). Patients’ data were collected retrospectively. Cardiac risk was defined as signs of cardiomyopathy, coronary artery disease, or congestive heart failure; pulmonary risk as the presence of chronic pulmonary disease with significant reduction of lung-function parameters; and renal failure as a serum-creatinine level greater than 1.5 mg/dL or the need for hemodialysis. We also searched for diabetes, hypertension, malignancy, cerebrovascular disease, peripheral artery occlusive disease, and liver dysfunction (γ-glutamyltransferase level >30 IU/L). In 13 patients, 10 during the first period and 3 during the second period, a complete risk profile of all preoperative parameters was not available, because the patients were not accessible on admission and died before a detailed personal medical history could be obtained. Patients’ survival rates were estimated at 3 monthly intervals, correlating with postoperative follow-up. To detect possible differences in outcome in relation to age, we divided the patients into 3 equally sized groups: patients younger than 68 years (n=30), patients aged 68 to 75.5 years (n=29), and patients older than 75.5 years (n=30).

Table 1 presents a comparison of demographic data and preoperative risk factors of patients undergoing repair of rAAA during periods 1 and 2.

### Abbreviation
- rAAA: ruptured abdominal aortic aneurysm

### METHODS

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Statistical analysis was performed with SAS software version 9.1 (SAS Institute Inc, Cary, North Carolina). Continuous variables were described by medians and possible differences analyzed by the Wilcoxon test. Discrete variables were described by contingency tables and possible differences ana-
lyzed by Fisher exact test. The probability of 1-year survival was estimated according to the Kaplan-Meier method; possible differences were tested by the Wilcoxon test and the log-rank test. Any P values less than .05 were regarded as statistically significant.

RESULTS

Table 1 summarizes demographic data and risk profiles comparing period 1 with period 2. Median age, the number of hemodynamically unstable patients, and the prevalence of preoperative risk factors did not differ in a statistically significant manner between the 2 observation periods. Table 2 focuses on the second period solely and compares the demographic data and preoperative risk profiles of patients receiving OGR with those treated by EVAR. Because of preoperative patient selection, the number of initially hemodynamically unstable patients was significantly higher in the OGR group (P < .006). The median age of patients receiving OGR was significantly younger than those undergoing EVAR (P < .01). This led to a statistically significant decrease of the median age of patients receiving OGR from 73.4 years in the first period to 69.2 years in the second period (P < .04).

The 90-day mortality rate for patients undergoing rAAA repair in the first period was 54.8%, compared with 27.7% during the second period (P < .01). Hemodynamically stable patients benefited from the introduction of EVAR for rAAA (40% vs 10.7%; P < .02), but the risk of death did not change for hemodynamically unstable patients (68.2% vs 52.6%; P < .35). The 90-day mortality rate for patients receiving OGR during the second period was 29% vs 54.8% (overall mortality) during the first period (P < .03).

Table 3 presents postoperative complications and length of intensive care unit and in-hospital stays, comparing OGR with EVAR during the second period. The frequency of postoperative complications and the median length of hospital stays were similar, but patients treated by EVAR were discharged from the intensive care unit significantly earlier.

Deployment of the stent graft device was successful in all patients. Endoluminal blockade of the aorta was never employed, despite its availability in all operations. Three patients treated by EVAR (18.75%) suffered from abdominal compartment syndrome after the endovascular procedure and underwent laparotomy and decompression by evacuation of the retroperitoneal hematoma. Diagnosis of compartment syndrome was confirmed by measurement of intraluminal bladder pressure. Pressure values exceeding 30 mm Hg were considered an indication of operative decompression.
Conversion to OGR was not necessary during the initial procedure nor throughout the observation period. Three patients needed an early reintervention, 2 because of an endoleak and 1 owing to a kinking stenosis of the graft.

**Figure 2** compares the probability of survival estimated according to the Kaplan-Meier method for the 2 different observation periods. It shows that patients in the second period had a statistically significantly higher chance of surviving the early postoperative period and the first year after rupture (Wilcoxon test, \( P < .03 \); log-rank test, \( P < .04 \)).

**COMMENT**

The surgical technique of OGR, as pioneered by Dubost et al\(^\text{14}\) and Bahnson,\(^\text{15}\) has remained nearly unchanged during the last 5 decades. With the introduction of EVAR in the elective treatment of abdominal aortic aneurysm, a minimally invasive technique for endoluminal repair became available. Superior early postoperative survival rates, especially in patients with considerable preoperative risk profiles, could be achieved. Thus, it is reasonable to assume that the use of EVAR in patients with rAAA may also ameliorate treatment results.

Yusuf et al\(^\text{16}\) in 1994 were some of the first to introduce EVAR as an alternative to standard OGR in the treatment of rAAA. Several subsequent reports\(^\text{17-38}\) suggested that this new method might be advantageous for select patients in need of emergency treatment of rAAA. The aforementioned reports about EVAR revealed similar outcomes regarding parameters like estimated blood loss, transfusion requirements, frequency of postoperative complications, and length of intensive care unit and in-hospital stays, and pointed toward the lower invasive-ness of the procedure, but differed widely with regard to the perioperative mortality rates (range, \( 0\%\text{-}19\%, 27\%-50\%\)\(^\text{18}\)). Some of the nonrandomized studies showed a statistically significant advantage to EVAR compared with OGR,\(^\text{23,33}\) while others were unable to confirm these findings.\(^\text{18,24,36}\) The different outcomes may be explained by the small number of recruited patients and by the varying number of hemodynamically unstable or hypotensive patients in these studies (range, \( 0\%\text{-}19\%, 27\%-50\%\)\(^\text{18}\)), because the patient’s hemodynamic status influences the early outcome.\(^\text{12,13}\) The usefulness of an aortic occlusive balloon for early proximal remote bleeding control has also been discussed.\(^\text{39,40}\) Despite the availability of such a device in our center, our strategy was to prefer the rapid deployment of the main aortic stent graft, thereby avoiding the possible risks of aortic balloon occlusion (eg, visceral or cerebral thromboembolic events, visceral ischemia, balloon dislocation, or rupture and possible time delay). Its usefulness in patients who cannot be hemodynamically stabilized by respective shock management remains to be evaluated, especially in combination with procedures circumventing further time delay of preoperative computed tomography examination. The application of balloon occlusion and intravascular ultrasound for determining AAA rupture and assessing the feasibility of stent graft implantation\(^\text{41,42}\) immediately within the operating theater may be a reasonable alternative to immediate open repair in hemodynamically unstable patients.

A study examining the results of EVAR in the 4 most populated states of the United States of America (\( n = 5798 \)) found a significantly better outcome in patients undergoing EVAR for rAAA. However, the mortality rate for EVAR was 39.3%,\(^\text{34}\) which closely resembles the mean mortality rate of 41% for OGR published in the year 2002.\(^\text{4}\)

At present, no randomized trial comparing OGR and EVAR in the treatment of rAAA has been completed; only a pilot study\(^\text{37}\) for such a trial has been recently published. The trial was terminated prematurely and did not show a statistically significant advantage of 1 option over the other. So the question of whether EVAR is the superior treatment option in rAAA repair is still to be answered.\(^\text{43}\)

Our findings strongly indicate that the implementation of EVAR is able to reduce the overall mortality in patients with rAAA. The issue of which subgroup of patients might benefit the most from this less-invasive technique still remains. Previous reports clearly showed that, in addition to hemodynamic stability, the age of the patient is inversely related to successful early outcome after exclusion of an rAAA.\(^\text{12,44,45}\) In our study, patients treated by EVAR were significantly older than those receiving OGR. As a consequence, patients treated by OGR in the second period were significantly younger than those in the first period. This might be an explanation for the statistically significant decrease in 90-day mortality rates for OGR by 25.8%. The similar duration of in-hospital stays after both treatment modalities may be explained by the significantly older age of patients treated by EVAR, compared with those undergoing OGR. Additionally, the effects of abdominal compartment syndrome with pro-

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**Table 3. Postoperative Outcome of Patients Undergoing Either Endovascular or Open Repair of rAAA in the Second Period**

<table>
<thead>
<tr>
<th>Outcome</th>
<th>OGR (n=31)</th>
<th>EVAR (n=16)</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraoperative mortality, No. (%)</td>
<td>4 (12.90)</td>
<td>0</td>
<td>.28</td>
</tr>
<tr>
<td>90-d mortality rate, No. (%)</td>
<td>9 (29.03)</td>
<td>4 (25.00)</td>
<td>1.00</td>
</tr>
<tr>
<td>Postoperative complications, No. (%)</td>
<td>5 (18.52)</td>
<td>4 (25.00)</td>
<td>.70</td>
</tr>
<tr>
<td>Cardiac</td>
<td>8 (29.63)</td>
<td>4 (25.00)</td>
<td>1.00</td>
</tr>
<tr>
<td>Pulmonary</td>
<td>6 (22.22)</td>
<td>3 (18.75)</td>
<td>1.00</td>
</tr>
<tr>
<td>Renal</td>
<td>2 (7.41)</td>
<td>1 (12.5)</td>
<td>.62</td>
</tr>
<tr>
<td>Bleeding</td>
<td>4 (14.81)</td>
<td>1 (6.25)</td>
<td>.60</td>
</tr>
<tr>
<td>Wound infection</td>
<td>168</td>
<td>24</td>
<td>.02</td>
</tr>
<tr>
<td>Median length of ICU stay, h</td>
<td>72-288</td>
<td>24-96</td>
<td></td>
</tr>
<tr>
<td>Interquartile range, h</td>
<td>19</td>
<td>17</td>
<td>.74</td>
</tr>
<tr>
<td>Median length of hospital stay, d</td>
<td>13-29</td>
<td>12-22</td>
<td></td>
</tr>
<tr>
<td>Range, d</td>
<td>7-107</td>
<td>6-64</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: EVAR, endovascular aneurysm repair; ICU, intensive care unit; OGR, open graft replacement; rAAA, ruptured abdominal aortic aneurysm.

\(^a\) Of those who survived the initial procedure.

\(^b\) Of those who survived the ICU stay.

\(^c\) Of those who survived the hospital stay.
longed organ dysfunction after EVAR may extend the hospital stay. The treatment modality in hemodynamically unstable patients, ie, OGR, remained unchanged during the 2 periods, as did its results. In contrast, hemodynamically stable patients were more likely to survive the first 3 months after rupture following the implementation of EVAR.

In 2003, Peppelenbosch et al published the outcomes of a prospective intention-to-treat by EVAR protocol for ruptured and symptomatic nonruptured abdominal aortic aneurysms. They compared an early period of time when OGR was the sole treatment option for rAAA with a later period, after the introduction of EVAR as a treatment alternative. Analogous to our findings, the authors observed a 23% reduction in overall mortality during the later period as well as a 14.3% decrease in mortality among patients receiving OGR. Another article, published in 2006, about an intention-to-treat by EVAR policy that also compared 2 time periods prior to and after the introduction of EVAR as a treatment option for rAAA showed a 20% reduction in overall perioperative mortality. In addition, the mortality rate for OGR was reduced by 12%, from 59% to 47%. When focusing solely on ruptured aneurysms, the mentioned reduction in perioperative mortality rates did not reach statistical significance in either of those studies.

The physical status of our patients with rAAA did not change during the 2 observation periods; median age, proportion of hemodynamically unstable patients, and prevalence of preexisting comorbidities remained constant. In the second period, the older and hemodynamically stable patients were preferably treated by EVAR, while younger patients and those who were hemodynamically unstable received OGR. As a result, the early mortality rates of older and hemodynamically stable patients improved after March 2003. Interestingly, the early outcome for OGR also improved. Because the mortality rate for unstable patients did not change, we think that assigning older patients to EVAR led to a decrease in early mortality for stable patients treated by OGR (those not suitable for EVAR). This might have caused the significant reduction in overall mortality, although the treatment regimen and the mortality rate for hemodynamically unstable patients did not change. It remains to be determined whether EVAR should be administered to hemodynamically unstable patients, but our data suggest the liberal use of endoluminal aneurysm exclusion in hemodynamically stable and older patients.

We have demonstrated a significant reduction in postoperative mortality that confirmed the observation that offering the combined approach of EVAR and OGR led to an improvement in early survival after rupture of an AAA. We showed a similar effect in the elective management of AAA. By offering both treatment options, it was possible to improve the immediate and midterm overall results by shifting high-risk patients from the OGR to the EVAR group, thereby improving the results of open surgery.

The availability and selective use of both options, EVAR and OGR, for rAAA repair leads to a decrease in early overall mortality. Hemodynamically stable and older patients seem to benefit the most from this new, less-invasive technique, thereby improving the overall results of emergency aneurysm treatment.

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