Secondary Procedures and Long-Term Morbidity and Mortality Following Endovascular and Open Repair of Abdominal Aortic Aneurysm

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ABSTRACT: Purpose: To evaluate the durability, need for secondary procedures, and associated long-term morbidity of endovascular aneurysm repair (EVAR) compared to open repair procedures in patients with abdominal aortic aneurysm (AAA). Method: A retrospective study was performed in 1,005 patients who underwent EVAR and in 903 patients who underwent open repair between 1985 and 2009. Health system charts and medical correspondences were reviewed to obtain information related to durability, secondary procedures, and comorbidities. Secondary interventions included vascular (aortic graft or remote) and nonvascular (incisional or gastrointestinal) procedures. Results: Patients (n=1,908) had a mean age of 70 years, 16% were women, and 10% were nonwhite. During over 12 years of total follow-up, secondary procedures occurred in 23% (230 of 1,005) patients after EVAR and 22% (194 of 903) patients after open repair (odds ratio [OR], when EVAR was compared with open repair, 1.08; 95% confidence interval [CI], 0.87–1.34; P=.495). Secondary vascular procedures occurred in 22% (221 of 1,005) patients after EVAR and 13% (114 of 903) patients after open repair (OR, 1.95; 95% CI, 1.52–2.50; P<.001). Secondary nonvascular procedures occurred among 0.9% (9 of 1,005) patients after EVAR and 9% (80 of 903) patients after open repair (OR, 0.09; 95% CI, 0.05–0.19; P<.001). Conclusions: EVAR is associated with higher risk of secondary vascular procedures whereas open AAA repair is associated with higher risk of late secondary nonvascular procedures. Further prospective multicenter long-term studies may be required to reproduce these associations as well as identify factors that may help reduce secondary procedures.

Key words: abdominal aortic aneurysm, aneurysm repair, endovascular therapy

The US Preventive Services Task Force recommendation of screening for abdominal aortic aneurysm (AAA) in high-risk populations as well as the rapid increase of less-invasive endovascular aneurysm repair (EVAR) methods over the last 10 years has created a greater need for understanding long-term outcomes after AAA repair. Although prospective randomized trials have demonstrated lower perioperative complications, shorter recovery, and better short-term survival after EVAR compared to open AAA repair, the durability, higher reintervention rates, and increased cost of EVAR have been frequent concerns. Data regarding long-term secondary vascular and nonvascular procedures after EVAR and open repair are also limited. In this retrospective study, we evaluated the durability, need for secondary procedures, and associated long-term morbidity of EVAR compared to open repair procedures of AAA patients in a university setting that is independent of other confounders.

METHOD
The University of Alabama at Birmingham (UAB) Section of Vascular Surgery maintains a prospective vascular registry database since 1994 that
includes demographics, medical history, and surgical records for patients treated with vascular diseases. The data are continually updated throughout a patient’s follow-up and subsequent hospitalizations to capture subsequent events and annotate any prior vascular interventions. Of more than 30,000 various vascular operative procedures conducted at UAB to date; we queried and identified 1,908 unique patients who underwent primary infrarenal AAA repair procedures between 1985 and 2009. Thoracic aortic aneurysm and thoracoabdominal aortic aneurysm repairs were excluded.

Of the 1,908 patients, 1,005 (53%) received EVAR (the first case in 1999) and 903 (47%) received open repair. Patient demographics, operative characteristics, and clinical outcomes were reviewed using source medical records, medical correspondences, and national death indexes. The Institutional Review Board of the University of Alabama at Birmingham approved the use of the data for this research.

Secondary interventions were categorized as vascular or nonvascular procedures. Vascular procedures were subdivided into aortic and nonaortic procedures. Aortic vascular procedures were defined as any secondary intervention in the entire length of aorta usually from complications directly related to graft placement.

Nonaortic procedures were defined as vascular procedures involving lower extremity, carotid artery, or access complications that were performed beyond 30 days after the primary operation. Nonvascular interventions were classified as gastrointestinal (either requiring rehospitalization or re-

Table 1. Patient characteristics by type of aneurysm repair (n=1908).

<table>
<thead>
<tr>
<th>N (%)</th>
<th>EVAR (n=1,005)</th>
<th>Open Repair (n=903)</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographics</td>
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<tr>
<td>Age 71 ±9</td>
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<tr>
<td>Male sex 848</td>
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<tr>
<td>Whites 901</td>
<td>712</td>
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<tr>
<td>Risk Factors</td>
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<td>Hypertension 695</td>
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<tr>
<td>Dyslipidemia 458</td>
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<td>Chronic obstructive pulmonary disease 242</td>
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<tr>
<td>Diabetes mellitus 148</td>
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<tr>
<td>Stroke 112</td>
<td>100</td>
<td>.355</td>
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</tr>
<tr>
<td>Dialysis 35</td>
<td>23</td>
<td>.121</td>
<td></td>
</tr>
</tbody>
</table>

ANOVA used for continuous variables and chi-square test used for categorical variables.
* Statistical significance at alpha of .05

Figure 1. Secondary procedures after endovascular repair (n=1,005).
GI, gastrointestinal; LE, lower extremity; SBO, small bowel obstruction; SBR, small bowel resection; TAA, thoracic aortic aneurysm
operation) or incisional hernia.

For descriptive analyses, we used the Pearson χ² and Wilcoxon rank sum tests, as appropriate. Associations of treatment and long-term outcomes were evaluated using multivariable logistic regression analysis. All statistical tests were two-tailed and 95% confidence intervals were constructed. All data analyses were performed using SPSS for Windows version 20.

RESULTS

Patients (n=1,908) had a mean (SD) age of 70 (9) years, 83% were men, and 89% were white. EVAR patients were older, more likely to be smokers, and had higher prevalence of comorbidities such as hypertension, dyslipidemia, coronary artery disease, and diabetes mellitus. There was no difference by race and gender between the two treatment groups.

Twenty-three percent of EVAR patients (230 of 1,005) and 22% of open repair patients (194 of 903) had secondary procedures during the 12 years of follow-up (odds ratio [OR], when EVAR was compared with open repair, 1.08; 95% confidence interval [CI], 0.87–1.34; P=.495; Table 2). Twenty-two percent (221 of 1,005) of patients who had an EVAR and 13% (114 of 903) of patients who had an open repair had secondary vascular procedures during follow-up (OR, 1.95; 95% CI, 1.52–2.50; P<.001; Table 2). Of the total 335 secondary vascular procedures in the EVAR and open repair groups, 175 (52% of

![Figure 2. Secondary procedures after open repair (n=903). GI, gastrointestinal; LE, lower extremity; TAA, thoracic aortic aneurysm](image)

| Table 2. Secondary interventions after endovascular and open abdominal aortic aneurysm repair. |
|----------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| N (%)                           | EVAR (n=1,005) | Open Repair (n=903) | Odds Ratio (95% CI) | P value |
| All secondary procedures        | 230            | 22.9%           | 194            | 21.5%           | 1.08 (0.87–1.34) | .495             |
| Secondary vascular procedures: aortic or nonaortic | 221            | 22.0%           | 114            | 12.6%           | 1.95 (1.52–2.50) | <.001            |
| Secondary vascular procedures: aortic* | 141            | 14.1%           | 69             | 7.6%            | 1.97 (1.46–2.67) | <.001            |
| Secondary vascular procedures: non-aortic** | 80            | 8.0%            | 45             | 5.0%            | 1.65 (1.13–2.40) | .004             |
| Secondary nonvascular procedures† | 9              | 0.9%            | 80             | 8.9%            | 0.09 (0.05–0.19) | <.001            |

*Aortic procedures include any secondary intervention in the entire length of aorta (thoracic aorta repair, explant, reline, proximal cuff, iliac extender, iliac complications, embolization, secondary aneurysm, hypogastric stent, graft excision/infection, graft limb occlusion).

**Nonaortic procedures include vascular procedures involving lower extremity, carotid artery, or access complications.

†Nonvascular procedures include gastrointestinal bleed, small bowel obstruction, abscess, hernia repair, or other bowel surgery.

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Secondary vascular nonaortic procedures were more common after EVAR (5% vs 8% after EVAR; OR associated with EVAR, 1.65; 95% CI, 1.13-2.40; P=.004).

One percent (9 of 1,005) EVAR patients and 9% (80 of 903) open AAA repair patients had secondary nonvascular procedures (OR associated with EVAR, 0.09; 95% CI, 0.05-0.19; P<.001; Table 2). Among all secondary procedures, overall lower extremity vascular procedures were most common after EVAR (Figure 1) while gastrointestinal events requiring hospitalizations were most common after open AAA repair (Figure 2). The frequency of various types of secondary procedures after EVAR and open AAA repair are displayed in Figures 1 & 2.

FINDINGS

Findings from our study demonstrate that compared to open AAA repair, EVAR was associated with a higher rate of secondary aortic and nonaortic vascular procedures. However, secondary interventions related to nonvascular procedures (predominantly gastrointestinal) were significantly higher after open repair procedures.

These findings are important as they suggest that EVAR may be a safe and effective method of treating AAA repair because not only do the EVAR findings demonstrate better survival (as published before), but also the open repair group demonstrated an increased risk of nonvascular secondary interventions unrelated to the AAA, thus negating the increased risk of secondary vascular procedures (predominantly aortic procedures) associated with EVAR.

Case 1: Patient having a secondary endograft repair 9 years after primary EVAR

An 81-year-old male presented with slow and steady increase in the size of his aortic aneurysm over 9 years since his primary repair of AAA using an Ancure endograft (Guidant Corporation). He denied any back or abdominal pain...
suspicious for aortic pathology. Upon examination, his abdomen was found to be soft and nontender. No pulsatile mass could be appreciated. Femoral pulses were satisfactory, while his pedal pulses were diminished.

Review of the CT angiogram showed an increase in the size of the aneurysm to 5.5 cm (Figure 3). There were no definite endoleaks, nor could any migration be noted. An aortogram demonstrated a small type II endoleak from an ascending branch of the left hypogastric artery (Figure 3). The endograft was treated by relining it with an additional Excluder AAA endograft (W.L. Gore) and also covering a stenotic origin of the left hypogastric artery.

The patient was discharged on the third postoperative day without event. He was seen in follow-up 1 year later and was functioning well with no abdominal symptoms and with good peripheral pulses after his secondary EVAR.

**DISCUSSION**

The two times increased risk of secondary vascular procedures associated with EVAR in our study was comparable with 2-3 times higher early risk of secondary interventions associated with EVAR in the randomized controlled EVAR 1 and Dutch Randomized Endovascular Aneurysm Management (DREAM) trials. However, in contrast to those studies, EVAR had a more robust increased risk of secondary vascular procedures while open repair had an increased risk of nonvascular procedures (major gastrointestinal procedures, in particular) in our study. Nonvascular secondary interventions were not tabulated as additional endpoints of the EVAR 1 and DREAM studies, but they were considered in the Standard Open Surgery Versus Endovascular Repair of Abdominal Aortic Aneurysm (AAA) OVER trial. Moreover, EVAR-associated secondary vascular procedures were predominantly transfemoral. Finally, when the secondary procedures were combined together, the overall long-term risk of any secondary procedures associated with EVAR as compared to open repair groups became equivalent. Findings from our recent publication included EVAR in the randomized controlled EVAR 1 and DREAM trials. However, that limitation is de novo to any observational study and these findings need to be replicated in other prospective studies.

**CONCLUSION**

EVAR is independently associated with two times higher risk of secondary vascular procedures, while open repair is associated with more than 10 times higher risk of late secondary nonvascular procedures. Further prospective studies are required to identify factors that may help reduce these complications in each treatment modality.

**Editor’s Note:** Disclosure: The authors have completed and returned the ICMJE Form for Disclosure of Potential Conflicts of Interest.
of Interest. The authors report that the University of Alabama received compensation for clinical trials in which some patients studied for this manuscript are enrolled. Dr. Jordan reports consultancy to W.L. Gore, Aptus Endosystems, Abbott Vascular, Medtronic, and Volcano Corporation. The remaining authors report no disclosures related to the content of this manuscript.

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REFERENCES


