Comparison of Long-term Survival After Open vs Endovascular Repair of Intact Abdominal Aortic Aneurysm Among Medicare Beneficiaries

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Endovascular repair of abdominal aortic aneurysm (AAA), initially introduced as an option for high-risk patients,\(^1\) has surpassed open surgery as the most common technique for elective management of AAA among Medicare beneficiaries in the United States.\(^2\) In randomized clinical trials (RCTs), endovascular AAA repair has been shown to decrease 30-day and in-hospital mortality,\(^3,4\) blood transfusion requirements, duration of mechanical ventilation, and intensive care unit and hospital length of stay after repair.\(^8\) However, RCTs have failed to demonstrate a long-term survival advantage of endovascular compared with open repair.\(^1,3\) Furthermore, compared with open repair, endovascular repair incurs higher costs\(^2\) and a need for long-term surveillance because of a 25% to 40% late complication rate,\(^6,7\) leading to ongoing controversy over the elective use of endovascular repair, especially in healthy patients with anticipated long-term survival.

Although clinical trials have failed to demonstrate a long-term mortality difference between open and endovascular repair, certain characteristics of RCTs limit the applicability of their results in clinical practice. In RCTs, repair of AAA is usually performed at high-volume centers by vascular surgeons experienced in endovascular technique. Participants in RCTs comparing endovascular with open AAA repair have, on average, fewer and less severe comorbidities and are more likely to be male than patients encountered in clinical practice.\(^8\) Most impor-
tantly, with rapidly evolving technology such as endovascular surgery, outcomes may change over time, rendering results of some previous RCTs obsolete.\(^8\) Well-designed retrospective cohort studies of open repair yield results that are both valid\(^9\) and more broadly generalizable than the results of RCTs. The objective of this study was to compare overall and AAA-specific mortality, readmission, and reintervention after endovascular vs open repair of intact AAA in a cohort of Medicare beneficiaries.

**METHODS**

The Johns Hopkins Medicine institutional review board, Centers for Medicare & Medicaid Services, and National Death Index approved this study. The Johns Hopkins Medicine institutional review board waived the requirement for patient consent.

**Databases and Patient Selection**

The study cohort was composed of eligible patients from the Medicare Standard Analytic Files (SAF), from January 1, 2003, through December 31, 2007. The Medicare SAF contain data from a 5% sample of Medicare inpatient discharges. The 5% sample is created based on selecting records that report a 05, 20, 45, 70, or 95 in positions 8 and 9 of the Health Insurance Claim number.\(^10\) Patient records contain longitudinal data from the index admission and subsequent hospital admissions, vital status, and date of death for deceased beneficiaries. Date of death in the Medicare SAF database is a Social Security Administration–validated date of death and is considered highly reliable. Therefore, follow-up for the primary study outcome, mortality, was considered complete. Longitudinal inpatient records were available through December 31, 2007, and vital status was ascertained through September 11, 2008.

Patients 65 years or older with an International Classification of Diseases, Ninth Revision (ICD-9) diagnosis code corresponding to intact AAA (441.4) and ICD-9 procedure codes corresponding to open (38.34, 38.44, 38.64, 39.52) or endovascular (39.71) AAA repair were included. Exclusion criteria were patient younger than 65 years; ICD-9 diagnosis codes for syphilitic (093.0), traumatic (901.0, 902.0), thoracoabdominal (441.6, 441.7), ruptured (441.3), or unspecified site aortic aneurysms (441.9); or ICD-9 procedure code for endovascular repair of thoracic aortic aneurysm (39.73). Patients with procedure codes for both open and endovascular repair recorded on the same date were also excluded, because it was not possible to determine procedure sequence in these patients.

Medicare SAF data were provided in deidentified form. For known decedents, patient identifiers (social security number, date of birth) were obtained to allow for linkage with the National Death Index (NDI). The NDI is a central computerized index of states’ death record information that exists to facilitate epidemiologic and health services research.\(^11\) For patients who died during the study period, the cause of death was determined from the NDI.

**Covariates**

Demographic variables (age, sex, and race) were obtained from the Medicare SAF. Age was categorized in 5-year increments. Race in the Medicare SAF is obtained from the Social Security Administration’s master beneficiary record. Race was classified as black or not black, because the cohort included very few nonblack minorities, compared with other racial groups. Calendar date of repair was treated as a continuous variable.

In the data set provided, comorbidities were assigned using the Clinical Classifications Software (CCS) developed by the Healthcare Cost and Utilization Project of the Agency for Healthcare Research and Quality.\(^12\) The CCS is a categorization scheme that consolidates more than 14,000 ICD-9 diagnosis codes into a smaller number of CCS categories. Each patient had up to 25 CCS diagnostic categories assigned based on corresponding ICD-9 diagnosis codes from his or her patient, outpatient, skilled nursing facility, and home health agency Medicare files from the year preceding the index AAA repair. For patients in the 2003 Medicare SAF file, CCS diagnostic categories were assigned based on ICD-9 diagnosis codes from the year of the procedure, because files from the preceding year were not available.

The number of CCS diagnostic categories assigned to each patient was also recorded. Sixty-one diagnostic categories (corresponding to cardiovascular disease and risk factors, pulmonary disease, malignancy, and renal disease) known to be risk factors for poor outcomes after AAA repair\(^13-18\) were selected as adjustment variables for the propensity scores (eTable, available at http://www.jama.com). The selected diagnostic categories were treated as binary variables, with each patient classified as having or not having each of the 61 diagnoses.

**Primary Outcome**

The primary outcome was overall mortality following AAA repair, comparing open vs endovascular repair. Patients without recorded death dates were censored on September 11, 2008, because this was the last date at which death was ascertained in the Medicare SAF file used for analysis. Thirty-day mortality was used to compare perioperative mortality between repair types, because this has been shown to be more accurate than comparison of in-hospital mortality.\(^19\) Mortality within 30 days of repair was examined by censoring living patients at 30 days; mortality among patients who survived at least 30 days after repair was determined by excluding patients who died within 30 days after repair.

**Secondary Outcomes**

Secondary outcomes included AAA-related mortality, hospital length of stay, readmission (for any cause) within 1 year, repeat AAA repair, lower extremity amputation, and incisional hernia repair.

AAA-related mortality was defined by an ICD-9 diagnosis of intact or ruptured AAA denoting the underlying...
cause of death in the NDI record. AAA-related mortality occurring within 30 days of AAA repair and at more than 30 days after repair was examined using the method described for all-cause mortality. Repeat AAA repair was defined as open or endovascular repair after the index repair. Patients with both a diagnosis of iliac artery aneurysm (ICD-9 code 44.22) and an ICD-9 procedure code for aneurysm repair not specific to the aorta (39.52) were excluded from the analysis of repeat AAA repair, because these could represent primary repair of iliac artery aneurysm rather than repeat AAA repair. Indications for repeat AAA repair were categorized based on ICD-9 diagnosis codes as mechanical complication of vascular graft (996.1, 996.59), graft infection (996.60, 996.62), AAA rupture (441.3, 441.5), aortic (440.0) or graft (996.74) atherosclerosis, or embolization from the graft (444.2, 444.22, 444.81).

Lower extremity amputation was defined using ICD-9 procedure codes for lower extremity amputation at any level (84.10-84.18). Incisional hernia repair was defined using ICD-9 procedure codes specific to incisional hernia repair (53.51, 53.61, 53.62) or a combination of a procedure code for abdominal wall hernia repair (53.59, 53.63, 53.69) with a diagnosis code for incisional hernia (551.21, 552.21, 553.21, 998.31).

For readmission, event-free patients were censored 1 year after their index AAA repair or on December 31, 2007 (because this was the last date for which data on inpatient admissions were available), whichever was first. For the other secondary outcomes, event-free patients were censored on December 31, 2007.

Statistical Analysis
Baseline Characteristics and Event Rates. Baseline patient characteristics were compared between the open and endovascular AAA repair groups using the t-test for continuous variables and the \( \chi^2 \) statistic for binary and categorical variables. Incidence rates per person-time were calculated using Kaplan-Meier methods, and log-rank tests were used to compare survival functions between the open and endovascular repair groups. The t-test was used to compare mean hospital length of stay between repair groups. The \( \chi^2 \) statistic was used to examine the diagnosis codes related to repeat repair, comparing the initial open repair and initial endovascular repair groups.

Propensity Scores. Logistic regression was used to calculate a propensity score for each patient. Propensity scores were equal to the adjusted odds of a patient undergoing open AAA repair (vs endovascular repair), based on emergency presentation, age, calendar year of repair, sex, race, number of CCS diagnostic categories, and the 61 selected CCS diagnostic categories. To assess for treatment group balance, box plots of propensity scores by AAA repair type were examined, and median propensity score and interquartile range were compared between the open and endovascular repair groups.

Because the relationship of propensity score to study outcomes was non-linear, it was preferable to use the propensity score as a categorical variable. Categorization of the propensity score also allowed the relationship between propensity score and outcome to vary between the different study outcomes. Propensity scores were divided into quintiles by repair type, and propensity score quintile was treated as a categorical variable in the multivariable models.

Univariable and Multivariable Analysis. In all multivariable analyses, models were adjusted for propensity score quintile. For 30-day mortality, univariable and multivariable logistic regression analysis were used. For hospital length of stay, univariable and multivariable linear regression were used.

For all other outcomes, univariable and multivariable analyses were performed using Cox proportional hazard models. Log-log plots and Schoenfeld residuals were checked for violations of Cox proportional hazard model assumptions.

Sensitivity Analyses. Two sensitivity analyses were performed to examine the effect of model assumptions on study results. The first sensitivity analysis examined the influence of possible misclassification of surgical complications as comorbidities in the portion of the cohort whose CCS categories were drawn from the same calendar years as the index AAA repair. The primary analysis adjusted for all CCS categories as comorbidities. A sensitivity analysis was performed in which for any patient in whom the CCS categories were assigned from the same calendar year as the index AAA repair, any CCS category that could have represented a postoperative complication was not adjusted for as a comorbid condition (eTable, available at http://www.jama.com). Propensity scores were recalculated based on these altered assumptions, and all multivariable analyses were performed as described above, adjusting for the recalculated propensity scores. These results were compared with the results of the primary analysis to assess whether uncertainty about comorbidities in this subset of patients confounded study results.

The second sensitivity analysis examined the influence of emergency presentation on study results. In the primary analysis, emergency presentation was adjusted for as a component of the propensity score. In the sensitivity analysis, patients with emergency presentation were excluded from the analysis and multivariable analysis was performed as described above, adjusting for propensity score quintile.

Two-sided tests for statistical significance were used, and statistical significance was defined as \( P \leq .05 \) for all outcomes. All analyses were performed using Stata 10.20.

RESULTS
Study Cohort
During the study period, 4561 patients 65 years or older underwent repair of an intact AAA. Of these, 702 underwent open repair alone, 3824 underwent endovascular repair alone, and 35 underwent both repair types at
SURVIVAL AFTER OPEN VS ENDOVASCULAR REPAIR OF AAA

Table 1. Baseline Patient Characteristics, by Repair Type

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Open Repair (n = 703)</th>
<th>Endovascular Repair (n = 3826)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>498 (70.8)</td>
<td>3057 (79.9)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Women</td>
<td>205 (29.2)</td>
<td>768 (20.1)</td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>660 (93.9)</td>
<td>3602 (94.2)</td>
<td>.06</td>
</tr>
<tr>
<td>Black</td>
<td>32 (4.6)</td>
<td>113 (3.0)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>11 (1.5)</td>
<td>111 (2.8)</td>
<td></td>
</tr>
<tr>
<td>Age, mean (SD)</td>
<td>75.2 (5.7)</td>
<td>76.4 (6.3)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Year of surgery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>143 (20.4)</td>
<td>558 (14.6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>2004</td>
<td>183 (26.0)</td>
<td>718 (18.8)</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>164 (23.3)</td>
<td>804 (21.0)</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>128 (18.2)</td>
<td>922 (24.1)</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>85 (12.1)</td>
<td>823 (21.5)</td>
<td></td>
</tr>
<tr>
<td>Emergency admission</td>
<td>64 (23.3)</td>
<td>562 (14.7)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>No. of CCS categories, mean (SD)</td>
<td>4.6 (4.01)</td>
<td>5.0 (3.78)</td>
<td>.003</td>
</tr>
<tr>
<td>Comorbidity*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>105 (14.9)</td>
<td>719 (18.8)</td>
<td>.02</td>
</tr>
<tr>
<td>Essential hypertension</td>
<td>370 (53.9)</td>
<td>2261 (59.1)</td>
<td>.01</td>
</tr>
<tr>
<td>Chronic renal failure</td>
<td>29 (4.1)</td>
<td>116 (3.0)</td>
<td>.13</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>93 (13.2)</td>
<td>472 (12.3)</td>
<td>.51</td>
</tr>
<tr>
<td>COPD</td>
<td>177 (25.2)</td>
<td>929 (24.3)</td>
<td>.61</td>
</tr>
</tbody>
</table>

Abbreviations: CCS, Clinical Classifications Software; COPD, chronic obstructive pulmonary disease. *Not all comorbidities are shown. Comorbidities differing by treatment group are discussed in the text.

Figure 1. Numbers of Open and Endovascular Repairs of Abdominal Aortic Aneurysm in Study Cohort, by Calendar Year

The overall mortality rate was higher after open AAA repair, compared with endovascular repair (173 vs 752; 89 vs 76 deaths/1000 person-years, P=.04) (FIGURE 2). The number needed to treat to save 1 person-year of life was 77 patients.

Event Rates for Primary and Secondary Outcomes

In the analysis of survival, the mean follow-up time was 2.6 years (SD, 1.5 years) and the median follow-up time was 2.5 years (interquartile range, 2.4 years), with a maximum follow-up time of 5.7 years.

The overall mortality rate was substantially higher after open AAA repair than after endovascular repair (22 vs 28; 11.3 vs 2.8 deaths/1000 person-years, P < .001). The majority of deaths within 30 days after surgery were recorded as related to aortic aneurysm, and when patients who died within 30 days after surgery were ex-
cluded, there was no difference in the unadjusted risk of AAA-specific mortality after open vs endovascular repair (6 vs 22; 3.1 vs 2.2/1000 person-years, \( P = .36 \)). Hospital length of stay was significantly longer after open AAA repair (mean, 10.43 days [95% CI, 9.60-11.26 days]) vs endovascular repair (mean, 3.58 days [95% CI, 3.42-3.75 days]) \( (P < .001) \). The rate of incidental hernia repair was higher after open vs endovascular AAA repair (19 vs 23; 12 vs 3/1000 person-years, \( P < .001 \)). However, the incidence of 1-year readmission (188 vs 1070; 274 vs 376/1000 person-years, \( P < .001 \)) was similar to that of patients who underwent endovascular repair. Among patients who survived longer than 1 month, however, the risk of all-cause mortality did not differ by repair type (HR, 1.01 [95% CI, 0.84-1.22]; \( P = .91 \)).

**Secondary Outcomes.** The adjusted risk of AAA-related mortality was higher among patients who underwent open AAA repair, compared with those who underwent endovascular repair (HR, 4.37 [95% CI, 2.51-7.66]; \( P < .001 \)) (Table 3). Within the first month after repair, patients in the open repair group had a higher risk of AAA-related mortality (HR, 16.99 [95% CI, 4.62-62.54]; \( P < .001 \)), compared with patients who underwent endovascular repair. Among patients who survived longer than 1 month, however, the risk of AAA-related mortality did not differ by repair type (HR, 1.35 [95% CI, 0.44-4.11]; \( P = .60 \)).

The adjusted length of hospital stay was 6.5 days (95% CI, 6.0-7.0 days) lon-

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**Table 2.** Overall and Cause-Specific Mortality Rate per 1000 Person-Years of Follow-up

<table>
<thead>
<tr>
<th>Mortality</th>
<th>No. (Unadjusted No. of Deaths)</th>
<th>Overall Mortality ( ^a )</th>
<th>Overall Mortality Excluding 30-d Mortalities ( ^b )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Endovascular Repair ( n = 3825 )</td>
<td>Open Repair ( n = 703 )</td>
<td>( P ) Value</td>
</tr>
<tr>
<td>Overall</td>
<td>76 (752)</td>
<td>89 (173)</td>
<td>.04</td>
</tr>
<tr>
<td>Aneurysm-related</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abdominal aortic aneurysm</td>
<td>2.8 (28)</td>
<td>11.3 (22)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Thoracic/thoracoabdominal aortic aneurysm</td>
<td>0.5 (5)</td>
<td>0</td>
<td>.52</td>
</tr>
<tr>
<td>Aortic aneurysm, unspecified</td>
<td>1.4 (14)</td>
<td>2.6 (5)</td>
<td>.19</td>
</tr>
<tr>
<td>Aneurysm, other</td>
<td>0.2 (2)</td>
<td>0.2 (2)</td>
<td>.52</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>15.1 (149)</td>
<td>13.3 (26)</td>
<td>.67</td>
</tr>
<tr>
<td>Heart failure</td>
<td>2.2 (22)</td>
<td>4.6 (9)</td>
<td>.04</td>
</tr>
<tr>
<td>Other cardiovascular disease</td>
<td>8.7 (86)</td>
<td>5.6 (28)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Cancer</td>
<td>18.4 (182)</td>
<td>15.9 (31)</td>
<td>.47</td>
</tr>
<tr>
<td>COPD</td>
<td>6.1 (60)</td>
<td>5.1 (10)</td>
<td>.66</td>
</tr>
<tr>
<td>Other</td>
<td>19.4 (192)</td>
<td>20.0 (39)</td>
<td>.75</td>
</tr>
</tbody>
</table>

Abbreviation: COPD, chronic obstructive pulmonary disease.

\(^a\) The endovascular repair group included 9874 person-years of follow-up (84.5% of total); the open repair group included 1948 person-years (15.5% of total).

\(^b\) The endovascular repair group included 9873 person-years of follow-up (85.1% of total); the open repair group included 1946 person-years (14.9% of total).
ger after open AAA repair, compared with endovascular repair (P < .001). The adjusted hazard of incisional hernia repair was higher after open AAA repair, compared with endovascular repair (HR, 4.45 [95% CI, 2.37-8.34]; P < .001) (Table 3). There was no difference between the AAA repair types in the adjusted hazard of 1-year readmission (HR, 0.96 [95% CI, 0.85-1.09]; P = .52), repeat AAA repair (HR, 0.80 [95% CI, 0.46-1.38]; P = .42), or lower extremity amputation (HR, 0.55 [95% CI, 0.16-1.86]; P = .34). Statistical power to show a 20% reduction in the risk of 1-year readmission between the open and endovascular repair groups was 98%, but power was very low to detect a 20% reduction in risk of either repeat repair (13%) or lower extremity amputation (4%). Among patients who underwent repeat AAA repair, patients who initially underwent endovascular repair were more likely to have a diagnosis of mechanical graft complication than were patients who initially underwent open repair (38.7% vs 0%, P = .003) (Table 4). Other diagnoses associated with repeat repair did not differ between the open and endovascular repair groups.

For the Cox proportional hazard models, log-log plots and Schoenfeld residuals did not identify any violations of proportional hazards or other model assumptions.

### Sensitivity Analyses

In 27.2% of patients (36.2% undergoing open AAA repair vs 25.5% undergoing endovascular repair, P = .001) it was not possible to differentiate comorbidities from surgical complications, because their comorbidities were determined from the same calendar year as the index AAA repair. After removing from these patients’ comorbidities any CCS category that could have represented a postoperative complication (eTable), all multivariable outcomes remained similar to those reported in the primary analysis. The adjusted risk of overall mortality over the entire study period was higher for open repair, compared with endovascular repair (HR, 1.24 [95% CI, 1.05-1.48]; P = .01). This was related to a higher adjusted risk of all-cause 30-day mortality (HR, 4.61 [95% CI, 2.98-7.15]; P < .001), because the subsequent adjusted risk of all-cause mortality among patients who survived at least 30 days after the index repair did not differ by repair type (HR, 1.02 [95% CI, 0.84-1.23]; P = .86).

Similarly, both the overall (HR, 3.98 [95% CI, 1.99-7.96]; P < .001) and 30-day (HR, 16.99 [95% CI, 4.62-62.54]; P < .001) risk of AAA-related mortality were increased in patients who underwent open AAA repair, compared with endovascular repair. In patients who survived beyond 30 days after repair, there was no subsequent difference in the risk of AAA-related mortality between the open and endovascular repair groups (HR, 1.35 [95% CI, 0.44-4.11]; P = .60).

As in the primary analysis, the sensitivity analysis found that the length of hospital stay was, on average, 6.5 days (95% CI, 6.0-7.0 days) longer for patients who underwent open repair, compared with endovascular repair (P < .001). The adjusted risk of incisional hernia repair was increased after open AAA repair (HR, 4.41 [95% CI, 2.36-8.25]; P < .001), and the adjusted risk of 1-year readmission (HR, 0.96 [95% CI, 0.84-1.09]; P = .49), repeat AAA repair (HR, 0.77 [95% CI, 0.44-1.34]; P = .36), and lower extremity amputation (HR, 0.52 [95% CI, 0.16-1.78]; P = .30) were similar between repair groups.

In a second sensitivity analysis, 23.3% of patients who underwent open AAA repair (n = 64) and 14.7% of patients who underwent endovascular repair (n = 562) during emergency admission were excluded (Table 1). Results of this analy-

### Table 3. Numbers of Events for Open and Endovascular Repair of Abdominal Aortic Aneurysm and Adjusted Hazard Ratios for Open Repair, After Adjusting for Propensity Score

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Unadjusted</th>
<th>Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Endovascular Repair</td>
<td>Open Repair</td>
</tr>
<tr>
<td>All-cause mortality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>752</td>
<td>173</td>
</tr>
<tr>
<td>Within &lt;1 mo after surgery</td>
<td>47</td>
<td>41</td>
</tr>
<tr>
<td>≥1 mo after surgery</td>
<td>705</td>
<td>132</td>
</tr>
<tr>
<td>AAA-related mortality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>28</td>
<td>22</td>
</tr>
<tr>
<td>Within &lt;1 mo after surgery</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>≥1 mo after surgery</td>
<td>22</td>
<td>6</td>
</tr>
<tr>
<td>1-year readmission</td>
<td>1070</td>
<td>188</td>
</tr>
<tr>
<td>Repeat AAA repair</td>
<td>93</td>
<td>15</td>
</tr>
<tr>
<td>Incisional hermia repair</td>
<td>23</td>
<td>19</td>
</tr>
<tr>
<td>Lower extremity amputation</td>
<td>25</td>
<td>3</td>
</tr>
</tbody>
</table>

### Table 4. Diagnosis Associated With Repeat Repair of Abdominal Aortic Aneurysm, by Initial Repair Type

<table>
<thead>
<tr>
<th>Diagnosis (ICD-9 Codes)</th>
<th>Open Repair (n = 15)</th>
<th>Endovascular Repair (n = 93)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical complication of vascular graft (996.1, 996.59)</td>
<td>0</td>
<td>36 (38.7)</td>
<td>.003</td>
</tr>
<tr>
<td>Graft infection (996.60)</td>
<td>0</td>
<td>2 (2.2)</td>
<td>.57</td>
</tr>
<tr>
<td>Graft rupture (441.3, 441.5)</td>
<td>0</td>
<td>6 (6.5)</td>
<td>.31</td>
</tr>
<tr>
<td>Aortic atherosclerosis (440.0) or graft atherosclerosis (996.74)</td>
<td>0</td>
<td>11 (11.8)</td>
<td>.06</td>
</tr>
</tbody>
</table>

### Abbreviations: AAA, abdominal aortic aneurysm; HR, hazard ratio. aFrom χ² analysis.
sis were similar to those of the primary analysis. Open repair was associated with increased risk of overall (HR, 1.47 [95% CI, 1.06-2.03]; P = .02) and 30-day (HR, 4.70 [95% CI, 2.23-9.94]; P < .001) all-cause mortality, but there was no difference between repair types in the risk of all-cause mortality among patients who survived beyond 30 days (HR, 1.09 [95% CI, 0.74-1.60]; P = .66). Open AAA repair was also associated with increased risk of AAA-related mortality (HR, 4.85 [95% CI, 2.04-11.52]; P < .001) and repair of incisional hernia (HR, 20.75 [95% CI, 2.41-178.41]; P = .006), and hospital length of stay was longer after open AAA repair (6.1 days [95% CI, 4.5-7.6 days]; P < .001), compared with endovascular repair. There was no difference in the risk of 1-year readmission (HR, 1.18 [95% CI, 0.90-1.54]; P = .23), repeat AAA repair (HR, 1.39 [95% CI, 0.55-3.49]; P = .49), or lower extremity amputation (HR, 0.67 [95% CI, 0.14-3.21]; P = .62) between the 2 repair types.

**COMMENT**

This study of Medicare beneficiaries demonstrates a long-term overall and AAA-specific survival advantage associated with endovascular repair of intact AAA, compared with open repair, in patients 65 years or older. The long-term survival advantage associated with endovascular repair persisted in multivariable analysis, suggesting that this relationship was independent of patient demographics, emergency presentation, and comorbidities. Improved long-term survival was entirely associated with reduction in perioperative deaths after endovascular repair, compared with open repair. However, the survival advantage generated in the perioperative period persisted throughout the entire follow-up period, suggesting that, compared with open repair, endovascular repair was associated with similar protection against late AAA rupture.

Similar to our study, the EVAR 1 (Endovascular Aneurysm Repair 1) and OVERT (Open Versus Endovascular Repair) trials both reported a perioperative survival advantage of endovascular AAA repair over open repair. In these randomized trials, however, the survival advantage was not statistically significant at 2 years of follow-up. An earlier study of Medicare beneficiaries undergoing AAA repair between 2001 and 2004 showed an initial survival benefit for endovascular repair but equivalent survival beyond 3 years. The present study demonstrates an even longer survival advantage of endovascular over open repair, which was maintained throughout the entire 5.7 years of follow-up. Improved durability of endovascular repair over time, as well as the large sample size of the present study, may be important in explaining differences between the findings presented here and those of earlier studies.

Some previous studies have raised concerns about the possible need for more reinterventions after endovascular AAA repair, compared with open repair. This analysis demonstrates substantially increased risk for incisional hernia repair among patients who underwent open AAA repair, compared with endovascular repair. Although this result makes intuitive sense, it deserves mention because comparisons of reintervention after open vs endovascular AAA repair have sometimes overlooked incisional hernia repair.

In our study, there was no evidence of a difference in hazard of 1-year readmission, repeat AAA repair, or lower extremity amputation between the 2 repair types. These results are comparable with those of the OVER trial, which demonstrated similar rates of procedure failure and secondary therapeutic procedures between the 2 repair types but higher rates of incisional hernia repair after open AAA repair. In contrast, the EVAR 1 trial group reported higher rates of reintervention for graft-related complications after endovascular AAA repair. The Medicare SAF uses ICD-9 (rather than Current Procedural Terminology) procedure codes, and it was therefore not possible to identify minor endovascular reinterventions, such as placement of an extension cuff, which may explain the difference between our findings and those of the EVAR 1 trial. However, the present study demonstrates that there was no increased risk of major AAA-related reintervention (repeat open or endovascular repair) between the repair types. Among patients undergoing repeat AAA repair, the present study did find a more frequent diagnosis of graft-related mechanical complications in patients who initially underwent endovascular repair, compared with those who initially underwent open repair. However, most repeat repairs after initial open repair did not have an associated explanatory diagnosis, suggesting that this difference may be attributable to reporting bias.

Although endovascular AAA repair was once considered an option for patients with significant comorbidities who were not good candidates for open repair, it is now accepted that patients who are unfit for open repair also have poor outcomes after endovascular repair. The criteria for endovascular repair are anatomical: candidates must have a length of at least 1.5 cm at both the infrarenal neck and the common iliac arteries for proximal and distal graft fixation as well as appropriate iliofemoral access without excessive tortuosity. Patients undergoing open and endovascular AAA repair had similar baseline characteristics and propensity score distributions, suggesting that surgeons selected patients for endovascular repair based on anatomy rather than age and comorbidity. Similarly, previous research among Medicare beneficiaries has shown no increase in overall AAA repair procedure volume, despite a more than 2-fold increase in endovascular repair procedure volume between 2001 and 2006. The finding of similar age and comorbidity distributions in patients undergoing open vs endovascular repair suggests an appropriate shift away from selection of repair type based on patient fitness toward selection based on patient anatomy.

Our study has some limitations related to the use of administrative data. First, our study was performed using Medicare data and only included patients 65 years or older. This is a minor limitation, because the prevalence of AAA is low in younger patients.
Second, our study was not a randomized trial, and patient comorbidities and age may have influenced the repair type chosen. However, if elderly patients or those with serious comorbidities were selectively chosen for endovascular repair, this would be expected to bias study results to show a survival disadvantage for endovascular repair. This limitation, therefore, cannot account for our finding of a mortality advantage for patients who underwent endovascular repair.

Third, the Medicare database does not contain information about aneurysm size or anatomical features, which influence mortality after AAA repair.\textsuperscript{25} Medicare data also do not allow adjustment for hospital or surgeon repair volume, which correlates positively with survival, particularly after open repair.\textsuperscript{26,27} However, previous research has shown that registry data andRCTs comparing endovascular and open repair yield similar results after controlling for comorbidity,\textsuperscript{20,27} suggesting that these limitations should not invalidate the findings of our study.

Fourth, the Medicare SAF database provides information only on inpatient procedures, and secondary interventions performed on an outpatient basis after the index AAA repair would not be captured by this study. However, although this strategy could overlook some repairs of incisonal hernia, it is unlikely to miss any repeat AAA repairs, because these procedures almost always necessitate inpatient admission.

CONCLUSIONS

We have demonstrated that, after adjusting for demographics and comorbidities, endovascular AAA repair was associated with a long-term survival advantage when compared with open repair in patients 65 years or older. This survival difference was related to higher mortality within the first month after open repair but persisted for the entire 5-year follow-up period. We demonstrated a longer average hospital stay after open AAA repair and a higher risk for repair of incisonal hernia after open AAA repair but did not find evidence of differences in the hazard of rehospi
tization within 1 year after AAA repair, repeat repair, or lower extremity amputation, comparing open vs endovascular repair.

Author Contributions: Dr Jackson had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study conception and design: Jackson, Chang, Freischlag.

Acquisition of data: Jackson, Chang.

Analysis and interpretation of data: Jackson, Chang, Freischlag.

Drafting of manuscript: Jackson.

Critical revision of manuscript: Chang, Freischlag.

Statistical analysis: Jackson, Chang.

Study supervision: Chang, Freischlag.

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REFERENCES

1. Parodi JC, Palmaz JC, Barone HD. Transfemoral intu-

2. Levin DC, Rao VM, Parker L, Frangos AJ, Sunshine JH. Endovascular repair vs open surgical repair of ab-
6(7):506-509.

3. EVAR Trial Participants. Endovascular aneurysm re-
pair versus open repair in patients with abdominal aor-

4. Lederle FA, Freischlag JA, Kyradakis TC, et al. Open Versus Endovascular Repair (OVER) Veterans Affairs Cooperative Study Group. Outcomes following en-
dovascular vs open repair of abdominal aortic aneu-
rysms: a randomized trial. JAMA. 2009;302(14):
1535-1542.

5. Blankenstein JD, de Jong SE, Prinssen M, et al; Dutch Randomised Endovascular Aneurysm Management (DREAM) Trial Group. Two-year outcomes after con-
2405.

6. Harris PL, Vallabhaneni SR, Desgranges P, Beccquelin JP, van Marrewijk C, Laheij RJ; European Collaborators on Stent-Graft Techniques for Aortic An-
eurysm Repair. Incidence and risk factors of late ruptu-
re, conversion, and death after endovascular repair of infrarenal aortic aneurysms: the EUROSTAR experi-

7. van Marrewijk CJ, Buth J, Harris PL, Norgren L, Nevelsteen A, Wyatt MG. Significance of endoleaks after endovascular repair of abdominal aortic aneur-
35(3):461-473.


9. Leurs LJ, Buth J, Harris PL, Blankenstein JD. Im-
 pact of study design on outcome after endovascular vs open abdominal aortic aneurysm repair: a comparison between the randomized controlled DREAM-trial and the observational EUROSTAR-registry. Eur J Vasc Endo-

10. Standard Analytical Files—ICD-9-CM. Centers for Medi-
cms.gov/LimitedDataSets/12_StandardAnalyticalFiles.

11. National Death Index. Centers for Disease Con-

12. Hausauer A, Steiner C, Pahl S. Clinical Classi-

13. Crawford ES, Saleh SA, Babb JW III, Claeser DH, Vaccaro PS, Silvers A. Infrarenal abdominal aortic aneu-

14. Hertzler NR. Fatal myocardial infarction follow-
 ing abdominal aortic aneurysm resection: three hun-

15. Hohler LH, Plate G, O’Brien PC, et al. Late sur-
vival after infrarenal aortic aneurysm repair: influ-


17. Giles KA, Schermerhorn ML, O’Malley AJ, et al. Risk prediction for perioperative mortality of endo-
vascular vs open repair of abdominal aortic aneu-

18. Kossas F, Kieffer E; Association for Academic Re-
search in Vascular Surgery (AURC). Long-term sur-
vival after elective repair of infrarenal abdominal aor-

19. Schermerhorn ML, Giles KA, Sachs T, et al. De-
ing perioperative mortality after open and endo-
vascular aortic aneurysm repair in the US Medicare pop-


21. Schermerhorn ML, O’Malley AJ, Jhaen A, Cotterell P, Pompeoseli F, Landon BE. Endovascular vs. open re-
pair of abdominal aortic aneurysms in the Medicare pop-

22. EVAR Trial Participants. Endovascular aneurysm repair and outcome in patients unfit for open repair of abdominal aortic aneurysms (EVAR trial 2): ran-
domised controlled trial. Lancet. 2005;365(9478):
2187-2192.

23. Townsend CM, ed. Sabiston Textbook of Sur-

24. Lederle FA, Johnson GR, Wilson SE, et al; Aneu-
rysms Detection and Management (ADAM) Veterans Affairs Cooperative Study Group. Prevalence and as-
sociations of abdominal aortic aneurysm detected through screening. Ann Intern Med. 1997;126
(6):461-469.

25. Sternbergh WC III, Money SR. Hospital cost of endo-
vascular versus open repair of abdominal aortic aneu-
31(2):237-244.

26. Holt PJ, Poloniwick JD, Khalid U, Hinchcliffe RJ, Loftus IM, Thompson MM. Effect of endovascular aneu-
rysm repair on the volume-outcome relationship in an-

27. Landon BE, O’Malley AJ, Giles K, Cotterell P, Schermerhorn ML. Volume-outcome associations and ab-
122(13):1290-1297.

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