IMPORTANCE  The Society for Vascular Surgery recommends annual surveillance with computed tomography (CT) or ultrasonography after endovascular aortic aneurysm repair (EVAR) for abdominal aortic aneurysms. However, such lifelong surveillance may be unnecessary for most patients, thereby contributing to overuse of imaging services.

OBJECTIVE To investigate whether nonadherence to Society for Vascular Surgery–recommended surveillance guidelines worsens long-term outcomes after EVAR among Medicare beneficiaries.

DESIGN, SETTING, AND PARTICIPANTS We collected data from Medicare claims from January 1, 2002, through December 31, 2011. A total of 9503 patients covered by fee-for-service Medicare who underwent EVAR from January 1, 2002, through December 31, 2005, were categorized as receiving complete or incomplete surveillance. We performed logistic regressions controlling for patient demographic and hospital characteristics. Patients were then matched by propensity score with adjusting for all demographic variables, including age, sex, race, Medicaid eligibility, residential status, hospital volume, ruptured abdominal aortic aneurysms, and all preexisting comorbidities. We then calculated differences in long-term outcomes after EVAR between adjusted groups. Data analysis was performed from January 1, 2002, through December 31, 2011.

MAIN OUTCOMES AND MEASURES Post-EVAR imaging modality, aneurysm-related mortality, late rupture, and complications.

RESULTS Median follow-up duration was 6.1 years. Incomplete surveillance was observed in 5526 of 9695 patients (57.0%) who survived the initial hospital stay at a mean (SD) of 5.2 (2.9) years after EVAR. After propensity matching, our cohort consisted of 7888 patients, among whom 3944 (50.0%) had incomplete surveillance. For those in the matched cohort, patients with incomplete surveillance had a lower incidence of late ruptures (26 of 3944 [0.7%] vs 57 of 3944 [1.4%]; P = .001) and major or minor reinterventions (46 of 3944 [1.2%] vs 246 of 3944 [6.2%]; P < .001) in unadjusted analysis. Aneurysm-related mortality was not statistically different between groups (13 of 3944 [0.3%] vs 24 of 3944 [0.6%]; P = .07). In adjusted analysis of postoperative outcomes controlling for all patient and hospital factors by the tenth postoperative year, patients in the incomplete surveillance group experienced lower rates of total complications (2.1% vs 14.0%; P < .001), late rupture (1.1% vs 5.3%; P < .001), major or minor reinterventions (1.4% vs 10.0%; P < .001), aneurysm-related mortality (0.4% vs 1.3%; P < .001), and all-cause mortality (30.9% vs 68.8%, P < .001).

CONCLUSIONS AND RELEVANCE Nonadherence to the Society for Vascular Surgery guidelines for post-EVAR imaging was not associated with poor outcomes, suggesting that, in many patients, less frequent surveillance is not associated with worse outcomes. Improved criteria for defining optimal surveillance will achieve higher value in aneurysm care.
During the past decade, the repair of abdominal aortic aneurysms (AAAs) has transitioned from open surgical repair to endovascular aortic aneurysm repair (EVAR). Because of significant concerns regarding the long-term durability of EVAR, the Society of Vascular Surgery (SVS) advises surveillance with computed tomographic (CT) scanning at 1 and 12 months during the first postoperative year, followed by CT scanning every 12 months thereafter, with the alternative option of ultrasonography if no abnormality was detected during the first year. However, recent observations have begun to challenge these guidelines for lifelong surveillance as too conservative. Single-center studies have been unable to show that patients with incomplete surveillance have poorer outcomes compared with those with complete surveillance. Other publications argue that less frequent surveillance is sufficient for most patients and that the first postoperative CT scan should be used to stratify patients by risk and adjust surveillance guidelines accordingly. Although noteworthy, these studies were fundamentally limited in that they could not distinguish whether participants were lost to or unavailable for follow-up or whether they received care elsewhere. We sought to use 10 years of Medicare claims data to corroborate that nonadherence to SVS surveillance guidelines does not lead to worse long-term aneurysm-related outcomes after EVAR.

Methods

Data Set
We used claims from a 20% sample of Medicare fee-for-service beneficiaries from January 1, 2002, through December 31, 2011. Diagnoses and hospital procedures were identified from the Medical Provider and Analysis Review (MedPAR, part A) using the codes from the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM), reported for each inpatient admission. Physician procedures were identified from the physician Carrier files (part B) using Current Procedural Terminology (CPT) codes reported on each physician claim. Demographic data, Medicare enrollment information, and mortality were collected from the Medicare denominator and beneficiary summary files. Our investigation received approval by the institutional review board of Stanford School of Medicine, which granted a waiver of consent. Patient data were deidentified.

Patient Cohort
We identified patients who underwent AAA-related EVAR from January 1, 2002, through December 31, 2005. Patients were identified using an ICD-9-CM diagnosis code for intact AAA (441.4 or 441.9) or ruptured AAA (441.3 or 441.5) and an ICD-9-CM procedure code for AAA repair (38.34, 38.44, 38.64, 38.92, or 39.71). Patients were excluded if they had perioperative mortality—defined as death at discharge or within 3 days of surgery—or if they were younger than 65 years on the date of AAA repair. In addition, we excluded patients enrolled in a health maintenance organization (Medicare part C) or with incomplete Medicare part A or part B coverage during the year in which the EVAR was performed. Follow-up was defined as the duration from the date of AAA repair to the date of censoring, health maintenance organization enrollment, incomplete Medicare part A or part B coverage, or death at any time during the follow-up. All patients still in the sample on December 31, 2011, were censored at that date.

All postoperative imaging data during follow-up were collected using CPT codes for ultrasonography (76770, 76775, 93975, 93976, 93978, and 93979) and CT (72191, 72192, 72193, 72194, 74150, 74151, 74152, 74153, 74154, 74155, 74156, 74157, 74158, 74159, 74160, 74161, 74162, 74163, 74164, 74165, 74166, 74167, 74168, 74169, 74170, 74171, 74172, 74173, 74174, 74175, 74176, 74177, 74178, 74261, 74262, 74263, and 75635) of the abdomen. If multiple codes of the same imaging modality appeared on the same date, they were collectively counted as 1 postoperative examination.

Variable Definition
Our long-term outcomes of interest selected a priori included aneurysm-related in-hospital mortality, all-cause mortality, and late complications, defined as late rupture or AAA-related reinterventions. Late ruptures were identified by ICD-9-CM codes 441.3 and 441.5. Reinterventions related to AAA were identified using CPT codes and were categorized as a major or a minor reintervention. Major reinterventions included rupture repair (35082, 35092, and 35103), conversion to open repair from EVAR (34830, 34831, and 34832), repair of an infected graft or graft-enteric fistula (35907 and 35870), open AAA repair (35081, 35102, and 35646), and axillofemoral or axillofemoral bypass (35654 and 35621, respectively). Minor reinterventions included repeated EVAR (34800, 34802, 34803, 34804, 34805, 00787, 00807, 00071, and 00027), extension cuff (34825 and 34826), iliac aneurysm repair (34900 and 75954), angioplasty (35472 and 35473), and embolization (37204).

As described previously, complete surveillance was defined as 1 imaging event within 15 months of repair and at least 1 imaging event every 15 months thereafter until the point at which they were censored. Incomplete surveillance was subcategorized as surveillance gaps if the interval between images was longer than 15 months and as loss to follow-up if the censor date was longer than 15 months from the date of the last imaging event. Patients with a secondary intervention or complication were categorized as having complete or incomplete surveillance based on the status of their surveillance at the time of the secondary intervention or complication.

Other measures included in the analysis were comorbidity, estimated as described by Elixhauser et al., and the annual AAA repair volume of the hospital at which the initial EVAR was performed, categorized into quintiles. Hospitals in the lowest quintile were defined as low-volume hospitals, and those in the highest quintile were defined as high-volume hospitals. Using the Medicare denominator and beneficiary summary files, patients’ age, sex, race, and Medicaid eligibility status were recorded. The US Department of Agriculture census-based Rural Urban Commuting Area codes were used to categorize patients’ residence as urban or rural as described previously.
Propensity Matching
Matched cohorts of patients with complete and incomplete surveillance were created to control for nonrandom assignment of patients into either treatment group. All demographic variables, including geographic variables, hospital volume, and co-morbidities at the time of AAA repair, were used to create the propensity-matched cohorts. Factors used in propensity matching included age, sex, race, Medicaid eligibility, residential status, hospital volume, valvular disease, congestive heart failure, peripheral vascular disease, hypertension, diabetes mellitus, pulmonary disease, renal failure, lymphoma, metastatic cancer, and solid tumor.

Statistical Analysis
Data analysis was performed from January 1, 2002, through December 31, 2011. We performed unadjusted comparisons of the outcomes of interest between patients with and without complete surveillance in unmatched and matched cohorts. We used a 2-tailed t test to analyze normally distributed continuous variables and a Wilcoxon signed rank test for nonparametric data. We analyzed categorical variables using a χ² test. Kaplan-Meier survival curves were computed to assess the time to event and compared using log-rank analysis. Multivariable logistic regression modeling was performed on the unmatched cohort controlling for all demographic variables, including age, sex, race, Medicaid eligibility, residential status, hospital volume, ruptured AAA, and all preexisting comorbidities (ie, valvular disease, congestive heart failure, peripheral vascular disease, hypertension, diabetes mellitus, pulmonary disease, renal failure, lymphoma, metastatic cancer, and solid tumor). Goodness of fit of logistic models was evaluated using the McFadden pseudo- R² value.

All statistical analyses with P values of less than .05 were considered significant. We used 2 commercially available statistical software programs for data extraction and management (SAS, version 9.1.3; SAS Institute Inc) and for data analysis (STATA, version 13.0; StataCorp).

Results
A total of 23 964 patients underwent AAA repair from January 1, 2002, through December 31, 2005, among whom 23 165 (96.7%) were 65 years or older during the year of repair. Among these, 22 399 (96.7%) had complete fee-for-service Medicare parts A and B coverage during the year of repair. From this subpopulation, 9975 patients (44.5%) underwent EVAR, and 9695 patients undergoing EVAR (97.2%) survived the initial hospital stay to define our unmatched cohort (Figure 1).

Mean (SD) duration of follow-up was 5.2 (2.9) years with a median follow-up duration of 6.1 years and interquartile range of 2.6 to 7.4 years. Of our cohort, we observed complete surveillance in 4169 patients (43.0%) and incomplete surveillance in the remaining 5526 patients (57.0%), including 497 (5.1%) who received no documented follow-up imaging. Among patients with incomplete surveillance, 2349 (42.5%) had gaps in surveillance, 1989 (36.0%) were lost to or unavailable for follow-up, and 1188 (21.5%) had both. After propensity matching, a total of 7888 patients constituted the matched cohort, with 3944 (50.0%) in the complete surveillance group and 3944 (50.0%) in the incomplete surveillance group. Table 1 describes the characteristics of these patients stratified by surveillance status before and after propensity matching.

In the unmatched cohort, the AAA-related complications were observed in 393 patients (4.1%), including late rupture in 99 (1.0%), major reinterventions in 15 (0.2%), and minor reinterventions in 314 (3.2%). For patients in the matched cohort, patients with incomplete surveillance experienced lower rates of total complications (1.6% vs 7.3%, P < .001), late rupture (0.7% vs 1.4%, P = .001), and major or minor reinterventions (1.2% vs 6.2%; P < .001) (Table 2). All-cause mortality was observed in 44.2% of the entire matched cohort and was lower among those with incomplete surveillance (28.7% vs 59.7%; P < .001). Aneurysm-related mortality was observed in 0.5% of the entire cohort and was not significantly different between those with complete and incomplete surveillance (0.3% vs 0.6%; P = .07). Consistent results were found in the unmatched cohort; patients with incomplete surveillance experienced lower rates of total complications (89 [1.6%] vs 304 [7.3%]; P < .001), late rupture (40 [0.7%] vs 59 [1.4%]; P = .001), major or minor reinterventions (59 [1.1%] vs 261 [6.3%]; P < .001), all-cause mortality (1571 [28.4%] vs 2539 [60.9%]; P < .001), and aneurysm-related mortality (23 [0.4%] vs 24 [0.6%]; P = .28).

Figure 2 depicts survival curves for the outcomes of interest adjusted for patient and hospital factors in the matched cohort, stratified by complete vs incomplete surveillance. The mean (SD) interval from repair to any complication (late rupture or any reintervention) was longer for patients with incomplete surveillance (4.0 [1.7] vs 2.0 [1.7] years [P < .001]; mean difference, 2.1 [0.2; 95% CI, 1.6-2.5] years), as was time to late rupture (5.2 [1.49] vs 3.6 [2.3] years [P < .001]; mean difference, 1.6 [0.5; 95% CI, 0.6-2.6] years), time to major or minor reintervention (3.4 [1.3] vs 1.6 [1.3] years [P < .001]; mean difference, 1.7 [0.2; 95% CI, 1.3-2.2] years), and time to death (4.2 [1.4] vs 2.3 [1.7] years [P < .001]; mean difference, 1.9 [0.1; 95% CI, 1.8-2.1] years). Similar results were found in the unmatched cohort. Table 3 shows adjusted comparisons of postoperative complications per year stratified by surveillance status. By postoperative year 10, patients in the incomplete surveillance group experienced lower rates of total complications (2.1% vs 14.0%; P < .001), late rupture (1.1% vs 5.3%; P < .001), major or minor reinterventions (1.4% vs 10.0%; P < .001), aneurysm-related mortality (0.4% vs 1.3%; P < .001), and all-cause mortality (30.9% vs 68.8%; P < .001).

In the unmatched cohort, the first postoperative CT scan was obtained within 30 days in 3085 patients (31.8%) and within 60 days in 5896 patients (60.8%). In a multivariable logistic regression, incidence of any complication (late rupture or any reintervention) was independently associated with receiving a postoperative CT scan within 30 days (odds ratio, 1.25 [95% CI, 1.02-1.55]; P = .03).

Discussion
To our knowledge, this study is the first US population-based investigation of the relationship between adherence to
Figure 1. Flow Diagram for Cohort Construction

23,964 Patients underwent AAA repair from 2002-2005

799 Aged <65 y

23,165 Aged ≥65 y

766 With HMO or incomplete Medicare coverage during year of repair

22,399 Without HMO or incomplete Medicare coverage during year of repair

12,424 Open repair

9975 EVAR

280 With perioperative mortality

9695 With follow-up

7,888 Propensity matched

23,964 Patients underwent AAA repair from 2002-2005

799 Aged <65 y

23,165 Aged ≥65 y

766 With HMO or incomplete Medicare coverage during year of repair

22,399 Without HMO or incomplete Medicare coverage during year of repair

12,424 Open repair

9975 EVAR

280 With perioperative mortality

9695 With follow-up

7,888 Propensity matched

AAA indicates abdominal aortic aneurysm; EVAR, endovascular aortic aneurysm repair; and HMO, health maintenance organization.

Table 1. Characteristics of Patients With Complete and Incomplete Surveillance

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unmatched Cohort</th>
<th>Matched Cohort</th>
<th>P Value</th>
<th>Unmatched Cohort</th>
<th>Matched Cohort</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Complete Surveillance (n = 4169)</td>
<td>Incomplete Surveillance (n = 5526)</td>
<td></td>
<td>Complete Surveillance (n = 3944)</td>
<td>Incomplete Surveillance (n = 3944)</td>
<td></td>
</tr>
<tr>
<td>Age at repair, mean (SD), y</td>
<td>76.4 (6.32)</td>
<td>76.2 (6.25)</td>
<td>.10</td>
<td>76.4 (6.33)</td>
<td>76.2 (6.15)</td>
<td>.38</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>3469 (43.3)</td>
<td>4537 (56.7)</td>
<td>.16</td>
<td>3274 (49.6)</td>
<td>3324 (50.4)</td>
<td>.13</td>
</tr>
<tr>
<td>Female</td>
<td>700 (41.4)</td>
<td>989 (58.6)</td>
<td></td>
<td>670 (51.9)</td>
<td>620 (48.1)</td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>3896 (42.8)</td>
<td>5204 (57.2)</td>
<td>.09</td>
<td>3699 (49.9)</td>
<td>3710 (50.1)</td>
<td>.39</td>
</tr>
<tr>
<td>Black</td>
<td>162 (48.8)</td>
<td>170 (51.2)</td>
<td></td>
<td>147 (53.6)</td>
<td>127 (46.4)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>111 (42.2)</td>
<td>152 (57.8)</td>
<td></td>
<td>98 (47.8)</td>
<td>107 (52.2)</td>
<td></td>
</tr>
<tr>
<td>Medicaid eligible</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>385 (41.6)</td>
<td>540 (58.4)</td>
<td>.37</td>
<td>371 (53.0)</td>
<td>329 (47.0)</td>
<td>.10</td>
</tr>
<tr>
<td>No</td>
<td>3784 (43.1)</td>
<td>4986 (56.9)</td>
<td></td>
<td>3573 (49.7)</td>
<td>3615 (50.3)</td>
<td></td>
</tr>
<tr>
<td>Residence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>3043 (43.7)</td>
<td>3923 (56.3)</td>
<td>.05</td>
<td>2880 (49.8)</td>
<td>2903 (50.2)</td>
<td>.42</td>
</tr>
<tr>
<td>Small town</td>
<td>527 (40.3)</td>
<td>781 (59.7)</td>
<td></td>
<td>507 (49.2)</td>
<td>523 (50.8)</td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>587 (42.0)</td>
<td>811 (58.0)</td>
<td></td>
<td>557 (51.8)</td>
<td>518 (48.2)</td>
<td></td>
</tr>
<tr>
<td>Hospital volume</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>812 (46.3)</td>
<td>942 (53.7)</td>
<td>.04</td>
<td>1361 (50.7)</td>
<td>1326 (49.3)</td>
<td>.41</td>
</tr>
<tr>
<td>Medium</td>
<td>2489 (43.2)</td>
<td>3278 (56.8)</td>
<td>&lt;.001</td>
<td>2361 (49.5)</td>
<td>2411 (50.5)</td>
<td>.46</td>
</tr>
<tr>
<td>Low</td>
<td>868 (39.9)</td>
<td>1306 (60.1)</td>
<td>&lt;.001</td>
<td>748 (50.3)</td>
<td>738 (49.7)</td>
<td></td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valvular disease</td>
<td>275 (46.1)</td>
<td>322 (53.9)</td>
<td>.12</td>
<td>243 (50.5)</td>
<td>238 (49.5)</td>
<td>.81</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>461 (53.3)</td>
<td>404 (46.7)</td>
<td>&lt;.001</td>
<td>346 (50.2)</td>
<td>343 (49.8)</td>
<td>.91</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>1443 (44.5)</td>
<td>1801 (55.5)</td>
<td>.04</td>
<td>1361 (50.7)</td>
<td>1326 (49.3)</td>
<td>.41</td>
</tr>
<tr>
<td>Hypertension</td>
<td>2676 (42.6)</td>
<td>3610 (57.4)</td>
<td>.25</td>
<td>2548 (50.0)</td>
<td>2550 (50.0)</td>
<td>.96</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>583 (45.1)</td>
<td>711 (54.9)</td>
<td>.07</td>
<td>577 (51.4)</td>
<td>546 (48.6)</td>
<td>.32</td>
</tr>
<tr>
<td>Pulmonary disease</td>
<td>1434 (46.2)</td>
<td>1672 (53.8)</td>
<td>&lt;.001</td>
<td>1305 (49.5)</td>
<td>1330 (50.5)</td>
<td>.55</td>
</tr>
<tr>
<td>Renal failure</td>
<td>184 (52.1)</td>
<td>169 (47.9)</td>
<td>&lt;.001</td>
<td>151 (52.1)</td>
<td>139 (47.9)</td>
<td>.47</td>
</tr>
<tr>
<td>Lymphoma</td>
<td>31 (63.3)</td>
<td>18 (36.7)</td>
<td>.01</td>
<td>13 (46.4)</td>
<td>15 (53.6)</td>
<td>.71</td>
</tr>
<tr>
<td>Metastatic cancer</td>
<td>32 (76.2)</td>
<td>10 (23.8)</td>
<td>&lt;.001</td>
<td>3 (50.0)</td>
<td>3 (50.0)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Solid tumor</td>
<td>164 (53.6)</td>
<td>142 (46.4)</td>
<td>&lt;.001</td>
<td>125 (50.4)</td>
<td>123 (49.6)</td>
<td>.90</td>
</tr>
</tbody>
</table>

* Unless otherwise indicated, data are expressed as number (percentage) of patients.

† Percentages have been rounded and may not total 100. Data are missing for some categories and numbers may not sum totals.

‡ Calculated for continuous outcomes (age) using a Wilcoxon signed rank test; for categorical variables, a χ² test.
recommended postoperative surveillance guidelines and long-term outcomes after EVAR in actual practice. We found that incomplete surveillance after EVAR was not associated with adverse long-term outcomes. A major strength of our study is that it captures all surveillance images, long-term outcomes, and mortality after EVAR, irrespective of institution or location, and therefore more accurately evaluates nonadherence to SVS guidelines and its effect on long-term outcomes after EVAR.

Our findings are consistent with those of single-institution investigations reporting that infrequent follow-up after EVAR was not associated with adverse AAA-related outcomes, including incidence of endoleak, device migration, reintervention, or AAA-related mortality compared with patients who received frequent follow-up. These investigators also observed that patients with frequent follow-up paradoxically experienced a higher incidence of these adverse outcomes. Early or persistent endoleak after EVAR may have led to increased surveillance and increased interventions that did not improve AAA-related mortality.

Because the goal of postoperative surveillance is to prevent AAA-related mortality, our findings suggest that not all patients require yearly imaging after EVAR. Although the SVS recommends annual surveillance because of significant concerns regarding the long-term durability of EVAR, we found that only 7.2% of patients with complete surveillance experienced a complication (late rupture or any reintervention), and 6.2% required a reintervention. These findings are similar to those of Dias et al, who found that only 20 of 304 patients (6.6%) undergoing annual CT surveillance after EVAR required reintervention. Only a few patients may benefit from

**Table 2. Overall Unadjusted Incidence of Rupture, Reinterventions, and Mortality by Surveillance Status in Propensity-Matched Patients**

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Incidence, No. (%) of Patients</th>
<th>Complete Surveillance (n = 3944)</th>
<th>Incomplete Surveillance (n = 3944)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All ruptures and reinterventions</td>
<td>287 (7.3)</td>
<td>63 (1.6)</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Late rupture</td>
<td>57 (1.4)</td>
<td>26 (0.7)</td>
<td>.001</td>
<td></td>
</tr>
<tr>
<td>Any reintervention</td>
<td>246 (6.2)</td>
<td>46 (1.2)</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Major</td>
<td>9 (0.2)</td>
<td>5 (0.1)</td>
<td>.30</td>
<td></td>
</tr>
<tr>
<td>Minor</td>
<td>242 (6.1)</td>
<td>45 (1.2)</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Aneurysm-related mortality</td>
<td>24 (0.6)</td>
<td>13 (0.3)</td>
<td>.07</td>
<td></td>
</tr>
<tr>
<td>All-cause mortality</td>
<td>2355 (59.7)</td>
<td>1133 (28.7)</td>
<td>&lt;.001</td>
<td></td>
</tr>
</tbody>
</table>

![Figure 2. Adjusted Kaplan-Meier Curves for Outcomes of Interest in Propensity-Matched Patients](image)

Patients are stratified by complete vs incomplete surveillance. A, All complications (including late rupture or reintervention). B, Late rupture. C, Major or minor reintervention. D, All-cause mortality. EVAR indicates endovascular aortic aneurysm repair.
routine yearly postoperative surveillance after EVAR, and these patients may instead undergo adequate follow-up with less frequent imaging to detect and prevent late complications.27,18

Although we found no difference in the incidence of aneurysm-related mortality between patients with complete and incomplete surveillance, we observed a lower incidence of all-cause mortality in patients with incomplete surveillance. Although these data may appear paradoxical, our findings are comparable with those of previous studies reporting that patients with complete surveillance had worse overall survival.6,7 Similar to previous authors,6 we hypothesize that patients with other considerable medical conditions that increase the risk for death may be more likely to have physician visits and undergo surveillance. In addition, patients who develop other serious illness subsequent to EVAR are more likely to receive additional imaging—not necessarily for surveillance purposes—and are subject to increased mortality unrelated to AAA or EVAR.

Our study supports the need for better defined post-EVAR surveillance guidelines that protect patients from adverse outcomes while appropriately using medical resources. Previous studies9-13 have proposed that long-term surveillance guidelines should be based on risk stratification using clinical indicators, especially because certain preoperative anatomic features, intraoperative findings, and postoperative abnormalities have been associated with adverse outcomes after EVAR. For example, Bastos Gonçalves et al9 found that a normal result on a postoperative CT scan within 17 days of EVAR significantly reduced the risk for aneurysm-related adverse events during a median follow-up of 4.1 years, thus resulting in a large number of unnecessary imaging events for these low-risk patients. The authors9 concluded that the first postoperative CT scan should be used to stratify patients based on risk and that the surveillance guidelines should be adjusted accordingly. Similarly, another study10 used data from the US Zenith Endovascular multicenter trial and found that freedom from endoleak at 1 month was highly predictive of reduced aneurysm-related mortality, thus leading the authors to conclude that a new EVAR surveillance regimen based on early outcomes is needed. In the present study, we found that most patients receive a postoperative CT scan within 6 months of EVAR; thus, using a risk-stratification protocol based on the first CT might be a viable solution to optimizing surveillance guidelines.

In addition to the frequency, the modality of long-term surveillance has also been questioned, especially because CT is associated with higher costs compared with ultrasonography.20-22 The study by Dias et al8 found that only 20 of 304 patients (<10%) undergoing annual CT surveillance had a reintervention, leading the authors to conclude that non-contrast-enhanced CT or ultrasonography might be an appropriate modality of surveillance. Similarly, Bastos Gonçalves et al9 and Sternbergh et al23 also concluded that ultrasonography might be an acceptable substitution for CT for long-term surveillance. Several studies comparing CT and ultrasonography24-26 have concluded that ultrasonography is a viable and highly sensitive substitution for CT in detecting endoleaks and that it does not affect the incidence of secondary interventions. Routine surveillance using an ultrasonography-first approach likely would have a substantially beneficial effect on the cumulative costs of postoperative surveillance without sacrificing quality of care. Further research is needed to quantify the amount of cost savings.

Our study is subject to limitations owing to the nature of administrative data. As with all studies using administrative data, we were unable to collect clinical information, such as the presence or absence of endoleak and other clinical conditions that may have prompted postoperative imaging. Such clinical information would have provided additional information for our analysis. Our intent was to investigate all postoperative imaging to capture all instances of potential post-EVAR surveillance. Furthermore, administrative data may be...
subject to errors or variability in coding that would skew our results.\textsuperscript{27} However, for hospitalizations involving serious medical conditions and/or major surgical procedures, such as EVAR, coding errors are unlikely.\textsuperscript{28,29} Finally, our data set only includes Medicare beneficiaries, and results could differ in other populations, although more than 70% of elective AAA repairs are among the Medicare population.\textsuperscript{30} We do not believe these limitations detract from our primary findings.

**Conclusions**

Nonadherence to the SVS guidelines for post-EVAR imaging was not associated with poor outcomes, suggesting that, in many patients, less frequent surveillance may be recommended. Improved criteria for defining optimal surveillance will achieve higher value in AAA care.

**REFERENCES**


