Improved Long-Term Survival After Abdominal Aortic Aneurysm Repair

Kevin Mani, MD; Martin Björck, MD, PhD; Jonas Lundkvist, RPh, PhD; Anders Wanhainen, MD, PhD

Background—Treatment of abdominal aortic aneurysm (AAA) has changed significantly over the past 2 decades. In this perspective, time trends in long-term survival were studied.

Methods and Results—We identified 8663 primary intact and 4171 ruptured AAA repairs in the Swedish Vascular Registry from 1987 to 2005. Mortality was obtained from the national population registry. Crude survival was analyzed, including all mortality. To analyze the long-term outcome among those surviving the AAA repair, relative survival, which denotes the survival rate of patients compared with that of the general population adjusted for age, sex, and calendar year, was calculated, excluding 90-day mortality. In a comparison of AAA repairs from 1987 to 1999 and 2000 to 2005, age (71.4 versus 72.5 years; \textit{P}<0.001), patients with comorbidities (65.0% versus 68.5%; \textit{P}<0.001), and endovascular repair (1.6% versus 17.0%; \textit{P}<0.001) increased. After intact AAA repair, crude 5-year survival was 69.0% (99% confidence interval [CI], 67.7 to 70.4), and relative 5-year survival excluding 90-day mortality was 90.3% (99% CI, 88.6 to 92.0). Relative 5-year survival was better for those operated on from 2000 to 2005 compared with 1987 to 1999 (difference, 4.7%; 99% CI, 1.3 to 8.1), for men versus women (4.6%; 99% CI, 0.4 to 8.8), and for octogenarians versus patients \textless 80 years of age (10.2%; 99% CI, 1.5 to 18.8); no difference was observed between open and endovascular repair (6.0%; 99% CI, –1.5 to 13.4). After ruptured AAA repair, crude 5-year survival was 41.7% (99% CI, 39.6 to 43.7) and relative 5-year survival was 87.1% (99% CI, 83.9 to 90.3). No significant differences in relative 5-year survival were observed between time periods, sex, or age groups.

Conclusions—Long-term survival improved over time after intact AAA repair despite a change in case mix toward older patients with more comorbidities. Long-term survival was stable after ruptured AAA repair. (Circulation. 2009;120:201-211.)

Key Words: aneurysm | aorta | surgery | survival

The observed changes in patient demography may, however, affect long-term survival after AAA repair. An increased age among patients undergoing AAA repair and improved short-term outcome could potentially result in a reduction of long-term survival. Long-term survival is fundamental for surgical decision making and has important health economic implications when the cost-effectiveness of a new treatment (eg, EVAR) or health intervention (eg, screening for AAA) is evaluated. Crude survival denotes the actual survival rate of patients treated for AAA; relative survival reports the survival of the patient group compared with the survival of a general population adjusted for age, sex, and calendar year. The concept of relative survival thereby corrects for changes in background mortality. The aim of this study was to analyze the long-term crude and relative survival after AAA repair in Sweden over an 18-year period (1987 to 2005).

Methods

All primary AAA repairs registered in the Swedvasc from 1987 to 2005 were identified. Operations on patients \textless 50 years of age, surgeries on nonresidents of Sweden without a personal identification number, and ruptured AAA repairs were excluded from the analysis. Mortality was obtained from the national population registry. Crude survival was analyzed, including all mortality. To analyze the long-term outcome among those surviving the AAA repair, relative survival, which denotes the survival rate of patients compared with that of the general population adjusted for age, sex, and calendar year, was calculated, excluding 90-day mortality. In a comparison of AAA repairs from 1987 to 1999 and 2000 to 2005, age (71.4 versus 72.5 years; \textit{P}<0.001), patients with comorbidities (65.0% versus 68.5%; \textit{P}<0.001), and endovascular repair (1.6% versus 17.0%; \textit{P}<0.001) increased. After intact AAA repair, crude 5-year survival was 69.0% (99% confidence interval [CI], 67.7 to 70.4), and relative 5-year survival excluding 90-day mortality was 90.3% (99% CI, 88.6 to 92.0). Relative 5-year survival was better for those operated on from 2000 to 2005 compared with 1987 to 1999 (difference, 4.7%; 99% CI, 1.3 to 8.1), for men versus women (4.6%; 99% CI, 0.4 to 8.8), and for octogenarians versus patients \textless 80 years of age (10.2%; 99% CI, 1.5 to 18.8); no difference was observed between open and endovascular repair (6.0%; 99% CI, –1.5 to 13.4). After ruptured AAA repair, crude 5-year survival was 41.7% (99% CI, 39.6 to 43.7) and relative 5-year survival was 87.1% (99% CI, 83.9 to 90.3). No significant differences in relative 5-year survival were observed between time periods, sex, or age groups.

Conclusions—Long-term survival improved over time after intact AAA repair despite a change in case mix toward older patients with more comorbidities. Long-term survival was stable after ruptured AAA repair. (Circulation. 2009;120:201-211.)

Key Words: aneurysm | aorta | surgery | survival

The observed changes in patient demography may, however, affect long-term survival after AAA repair. An increased age among patients undergoing AAA repair and improved short-term outcome could potentially result in a reduction of long-term survival. Long-term survival is fundamental for surgical decision making and has important health economic implications when the cost-effectiveness of a new treatment (eg, EVAR) or health intervention (eg, screening for AAA) is evaluated. Crude survival denotes the actual survival rate of patients treated for AAA; relative survival reports the survival of the patient group compared with the survival of a general population adjusted for age, sex, and calendar year. The concept of relative survival thereby corrects for changes in background mortality. The aim of this study was to analyze the long-term crude and relative survival after AAA repair in Sweden over an 18-year period (1987 to 2005).

Methods

All primary AAA repairs registered in the Swedvasc from 1987 to 2005 were identified. Operations on patients \textless 50 years of age, surgeries on nonresidents of Sweden without a personal identifica-
tion number, redo procedures, and duplicate entries were excluded. Survival data were obtained through cross-checking of the unique personal identification number of each patient with the national population registry in October 2007. The fact that every Swedish citizen has a unique personal identification number makes it possible to obtain 100% accurate survival data of those registered. The Swedvasc registry is based on prospectively collected data and has nationwide coverage since 1994. The registry has been extensively validated both internally and externally, showing that core surgery (including AAA repair) is reported in >90% with great validity of data.7–13

Crude survival and relative survival were analyzed separately for patients operated on for iAAA and rAAA. Crude survival was calculated including all deaths. Relative survival was analyzed excluding AAA repair–related mortality,14 defined as death within 90 days after surgery.15 This was done to analyze the long-term outcome among those surviving the AAA repair, ie, to exclude the direct influence of differences and time trends in operative mortality7 on long-term survival. The definition of AAA repair–related mortality as death within 90 days after surgery was based on a visual inspection of the Kaplan–Meier plots for the first year after AAA repair to identify the approximate postoperative time period after which the survival curves stabilized (Figure 1). The observation that the operation-related mortality after AAA repair extends beyond 30 days has been reported by several previous investigators.15,16 In this analysis, crude survival at 30 and 90 days is reported to facilitate interpretation of the results and comparison of survival data in the present cohort with previous reports.

Relative survival17 was calculated by comparing the observed survival (excluding operation-related mortality) after AAA repair with the expected survival of the Swedish population adjusted for sex, age, and calendar year. The expected survival was calculated by using life tables attained from the Human Mortality Database.18 Subgroup analyses were based on age, sex, comorbidities, time period (1987 to 1999 versus 2000 to 2005), operative technique (open repair [OR] versus EVAR), and operative volume. Prospectively registered comorbidities were diabetes mellitus (treated with diet, oral medication, or insulin), heart disease (history of myocardial infarction, angina pectoris, atrial fibrillation, heart failure, coronary bypass, or heart valve surgery), pulmonary disease (any diagnosed pulmonary disease), renal impairment (serum creatinine ≥150 mmol/L), and cerebrovascular event (stroke or transient ischemic attack).

Center-specific operative volume was analyzed for the periods of 1994 to 1999 and 2000 to 2005. The period before 1994 was omitted in this analysis to focus on the time period during which the registry had full national coverage. Centers were divided into 3 categories based on number of AAA repairs performed during each 6-year period (low volume, <60 AAA repairs; medium volume, 60 to 149 AAA repairs; high volume, ≥150 AAA repairs).

Statistics
Independent-samples t test was used to compare normally distributed data. For comparison of 2 proportions, uncorrected χ² test was used. Crude survival was calculated with Kaplan–Meier analysis at 30 days, 90 days, 1 year, 5 years, and 10 years with 99% confidence intervals (CIs), and comparisons were made with the log-rank test. Relative survival (excluding 90-day mortality) was calculated at 1, 5, and 10 years with 99% CI. Differences were analyzed by calculating the differences in relative survival between groups with 99% CI. Adjustments for multiple comparisons were made, and a value of P<0.01 was considered significant. All proportions are described as percentage with 99% CI. Relative survival analysis was performed with R Statistical Software Package (R Foundation for Statistical Computing, Vienna, Austria), and other statistical analyses were performed with SPSS PC version 16.0 software (SPSS, Chicago, Ill).

The study ethics were approved by the registry review board, which, according to Swedish law, has the authority concerning registry data. According to the rules of the Swedvasc registry, informed consent is required from each patient before registration, except for fatal cases, which are exempted according to Swedish law.

Results
Of 12 834 primary AAA repairs identified in the Swedvasc registry over the study period (18 complete calendar years), 67.5% (n=8663) were performed for iAAA and 32.5% (n=4171) for rAAA. Mean follow-up was 9.1 years (SD, 4.6 years; range, 1.8 to 20.8 years). Patient characteristics are given in Table 1. The age of those operated on for both iAAA and rAAA increased over time (Table 1). Women were older...
than men, and those treated with EVAR were older than those treated with OR (Table 1). The proportion of iAAA repairs performed at high-volume centers increased from 61% in 1994 to 1999 to 73% in 2000 to 2005 (*P*<0.001), and the use of EVAR for iAAA repair increased from 2.3% to 22.6% over the same time period. No EVAR for rAAA was performed before 2000. After 2000, 5.1% of all ruptures were treated with EVAR. The proportion of patients with comorbidities increased between the 2 time periods for both the iAAA and rAAA groups (Table 1).

### Table 1. Patient Characteristics

<table>
<thead>
<tr>
<th>Overall</th>
<th>Sex</th>
<th>Age, y</th>
<th>Time Period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>IAAA, n</td>
<td>8663</td>
<td>7192</td>
<td>1471</td>
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<tr>
<td>Mean (SD) age, y</td>
<td>73.0 (7.7)</td>
<td>72.5 (7.7)</td>
<td>76.1 (7.1)</td>
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<tr>
<td>Age ≥80 y, %</td>
<td>22.4</td>
<td>20.5</td>
<td>33.9</td>
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<tr>
<td>Male %</td>
<td>85.7</td>
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<td>...</td>
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<tr>
<td>No comorbidities, %‡</td>
<td>36.2</td>
<td>36.1</td>
<td>37.1</td>
</tr>
<tr>
<td>Cardiac disease, %</td>
<td>52.4</td>
<td>52.9</td>
<td>49.5</td>
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<tr>
<td>Pulmonary disease, %</td>
<td>17.8</td>
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<td>19.6</td>
</tr>
<tr>
<td>Renal disease, %</td>
<td>10.7</td>
<td>10.8</td>
<td>9.9</td>
</tr>
</tbody>
</table>

‡Proportion of patients with no registered cardiac, pulmonary, renal, diabetic, or cerebrovascular disease.

### Survival After iAAA Repair

Long-term survival after iAAA repair is presented in Table 2 and Figure 2. Mean survival was 8.9 years (99% CI, 8.7 to 9.2). Short- and long-term crude survival improved over time (1987 to 1999: 90 days, 93.4% [99% CI, 92.5 to 94.3], and 5 years, 67.1% [99% CI, 65.4 to 68.9]; 2000 to 2005: 90 days, 96.9% [99% CI, 94.7 to 96.5], and 5 years, 72.2% [99% CI, 70.1 to 74.4]; log-rank *P*<0.001; Table 2 and Figure 3A). Crude long-term survival was lower for women at 10 years (women, 33.8% [99% CI, 29.5 to 38.1]; men, 40.4% [99% CI,

### Table 2. Crude and Relative* Survival After iAAA Repair in Different Subgroups

<table>
<thead>
<tr>
<th>Overall</th>
<th>Sex</th>
<th>Age, y</th>
<th>Time Period</th>
</tr>
</thead>
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<tr>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Crude survival</td>
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<td>(n=8663),</td>
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<tr>
<td>30 d</td>
<td>36.1</td>
<td>36.1</td>
<td>36.3</td>
</tr>
<tr>
<td>90 d</td>
<td>95.9 (95.3–96.4)</td>
<td>95.6 (95.3–96.4)</td>
<td>95.2 (95.3–96.4)</td>
</tr>
<tr>
<td>1 y</td>
<td>90.8 (90.0–91.8)</td>
<td>90.6 (90.6–91.6)</td>
<td>91.4 (89.8–92.4)</td>
</tr>
<tr>
<td>5 y</td>
<td>69.0 (67.7–70.4)</td>
<td>68.4 (67.7–70.4)</td>
<td>69.1 (68.4–70.4)</td>
</tr>
<tr>
<td>10 y</td>
<td>39.3 (37.5–41.0)</td>
<td>40.4 (38.5–42.3)</td>
<td>33.8 (29.5–38.1)</td>
</tr>
</tbody>
</table>

*Relative survival among those surviving AAA repair (ie, excluding operation-related mortality [90 days]).

†Only iAAA repairs performed from 2000 to 2005 are included.
38.5 to 42.3), but there was no significant difference at shorter follow-up (log-rank \( P=0.013 \); Table 2). Crude survival was lower for octogenarians (log-rank \( P<0.001 \); Table 2 and Figure 4A). There was no significant difference in crude 5-year survival between centers based on operation volume (low volume, 66.8% [99% CI, 61.1 to 72.5]; medium volume, 71.1% [99% CI, 68.3 to 73.9]; high volume, 69.4% [99% CI, 67.6 to 71.2]).

Relative long-term survival excluding 90-day mortality was better for those operated on from 2000 to 2005 compared with earlier (difference at 5 years, 4.7% [99% CI, 1.3 to 8.1]; Table 2 and Figure 3B) and for octogenarians compared with patients <80 years of age (difference at 5 years, 10.2% [99% CI, 1.5 to 18.8]; Table 2 and Figure 4B). No significant difference in relative survival was observed between other age groups (50 to 59, 60 to 69, and 70 to 79 years). The relative survival benefit for patients ≥80 years of age compared with younger patient groups did not change over time and was observed regardless of operative technique (OR or EVAR). Relative survival was lower for women compared with men (difference at 5 years, 4.6% [99% CI, 0.4 to 8.8]; at 10 years, 18.6% [99% CI, 11.1 to 26.1]; Table 2). Relative survival decreased with increasing number of comorbidities (at 5 years: no comorbidities, 93.6% [99% CI, 91.0 to 96.3]; 1 to 2
comorbidities, 83.2% [99% CI, 81.0 to 85.4]; and 3 to 5 comorbidities, 59.0% [99% CI, 49.7 to 68.3]).

Survival after OR and EVAR was compared for the period of 2000 to 2005 to compare contemporary results (Table 2 and Figure 5). Although EVAR patients were older (P<0.001; Table 1), crude 90-day survival did not differ significantly between the groups (Table 2). There was no significant difference in relative 5-year survival for patients alive at 90 days after iAAA repair for OR versus EVAR (difference at 5 years, 6.0% [99% CI, −1.5 to 13.4]; Table 2). No significant difference in relative 5-year survival between EVAR (85.7% [99% CI, 78.9 to 92.5]) and OR (90.3% [99% CI, 87.4 to 93.2]) was observed when all patients that were operated on were included in the relative survival analysis (ie, when including 90-day mortality). Among patients ≥80 years of age, crude 90-day survival was significantly higher after EVAR (97.2%; 99% CI, 94.3 to 100.1) compared with OR (89.8%; 99% CI, 85.5 to 94.0), but there was no significant difference in relative 5-year survival for patients alive at 90 days postoperatively (96.9% [99% CI, 74.5 to 119.4] for EVAR versus 104.7% [99% CI, 90.4 to 118.9] for OR).

Survival After rAAA Repair

Long-term survival after rAAA repair is presented in Table 3 and Figure 2. Mean survival was 5.4 years (99% CI, 5.1 to 5.7). Short-term crude survival after rAAA improved over time, but there was no significant difference in long-term survival (1987 to 1999: 90 days, 57.8% [99% CI, 55.2 to 60.4], and 5 years, 40.6% [99% CI, 37.4 to 42.5]; 2000 to 2005: 90 days, 63.9% [99% CI, 61.0 to 66.8], and 5 years, 43.7% [99% CI, 40.4 to 47.0]; log-rank P=0.001; Table 3). Crude survival was lower for women (log-rank P<0.001; Table 3), whereas no significant differences in crude 5-year survival based on center volume were observed (low volume, 38.7% [99% CI, 30.2 to 47.2]; medium volume, 43.1% [99% CI, 38.7 to 47.5]; high volume, 42.1% [99% CI, 39.3 to 44.9]).

Relative long-term survival among those surviving the operation for rAAA was not significantly lower after rAAA compared with iAAA repair; difference at 5 years, 3.2% (99% CI, −0.4 to 6.8; Table 3). Relative long-term survival (excluding 90-day mortality) after rAAA did not improve significantly over time (Table 3) and decreased with increasing number of comorbidities (at 5 years: no comorbidities, 89.6% [99% CI, 84.9 to 94.3]; 1 to 2 comorbidities, 79.3% [99% CI, 74.7 to 83.8]; 3 to 5 comorbidities, 56.6% [99% CI, 37.7 to 75.6]). Relative survival was lower for women at 10 years (difference at 10 years, 22.5%; 99% CI, 5.5 to 39.4), but the difference was not significant at 5 years (5.6%; 99% CI, −4.4 to 15.6; Table 3). There was no relative survival benefit for octogenarians compared with younger patients (Table 3).

Because only 2.2% of all rAAA repairs were performed with EVAR, this group was not analyzed further.

Discussion

The treatment of AAA has developed substantially over the past 2 decades, resulting in changes in treatment practice in terms of both patient selection and operative technique. Improvement over time in short-term outcome after AAA repair has been reported previously from the United Kingdom,19 the United States,20,21 and this cohort.7 The present analysis shows that in addition to improvements in short-term outcome,7 long-term outcome for those surviving iAAA repair has improved over time. Although short-term survival after rAAA repair increased over time,7 long-term outcome was unaffected. The improved survival after iAAA repair has implications for clinical decision making and health economic calculations, in particular those related to different screening programs for AAA.22,23
Although long-term survival after AAA repair has been studied previously, the effects of changes in clinical practice and patient selection on long-term survival have not. Data on long-term survival after EVAR and surgery among octogenarians are scarce and often are based on randomized trials with strict patient selection. The existence of a nationwide patient registry such as the Swedvasc offers a unique possibility to study the impact of recent changes in the management of AAA in a large, nonselected, population-based setting.

Overall, one third of all AAA repairs during the study period were performed for rAAA. The ratio of rAAA repairs to iAAA repairs in Sweden was similar to that of the Netherlands but different from reports from North America, where 4 to 12 times more iAAs than rAAs were treated. Whereas the incidence of iAAA repair is higher in North America (41 to 94 per 100 000) compared with Sweden (27 to 29 per 100 000), the incidence of rAAA repair is similar (7 to 19 per 100 000 in the United States versus 14 per 100 000 in Sweden). This indicates a differ-
ence either in the selection of patients for iAAA repair or in diagnostic activity. The use of EVAR increased over time. The proportion of iAAA repairs performed with EVAR in Sweden was higher than that in Denmark and New Zealand, similar to that in Scotland, but lower than that in North American reports. The proportion of EVAR among iAAA repairs in 2003 was 23% in this study compared with 40% in the United States. Expanding use of EVAR in Sweden resulted in an increased total numbers of AAA repairs, indicating that new patient groups are offered treatment with this minimally invasive technique. In contrast, no increase in total AAA repairs was reported from the United States.

Perioperative mortality after EVAR for iAAA was 2.3% at 30 days, increasing to 3.5% at 90 days (Table 2). This can be compared with an in-hospital mortality rate of 1.9% after EVAR in the United States and 30-day mortality rates after EVAR in randomized controlled trials of 1.7% (EVAR trial) and 1.2% (Dutch Randomized Endovascular Aneurysm Management

Figure 4. A, Crude survival after iAAA repair for patients <80 and ≥80 years of age. B, Relative survival excluding 90-day mortality after iAAA repair for patients <80 and ≥80 years of age (ie, survival of patients who were alive at 90 days postoperatively vs survival of the matched general population, which is equal to 1.0). CIs are indicated at 90 days for crude survival and at 5 years for crude and relative survival.
The present report was based on a nationwide population-based practice in which patients often were selected to EVAR because of advanced age and high comorbidities. This affects survival negatively compared with the randomized trials, in which patients randomized had to be eligible to both EVAR and OR.

This study showed that crude and relative long-term survival after iAAA repair improved over time despite a change in patient mix toward older patients and higher proportion of patients with comorbidities during the latter time period. Thus, changes in patient selection and case mix resulting from the current developments in AAA repair have not had any negative effects on long-term outcome. An increasing proportion of AAA repairs was performed at high-volume centers over time. However, long-term survival was not dependent on center volume. The increased crude survival in the patient cohort could be explained partly by a reciprocal improvement in survival in the general population. The life expectancy for a 65-year-old man in Sweden increased by almost 3 years from 1987 to 2007. This was the
among diabetic patients. During the same time period, the proportion of the observed total increase in relative survival among patients after AAA repair. From 1995 to 2002, 1-year mortality data from the Medicare database were used to analyze crude 90-day survival. In combination, these findings support a preference toward EVAR among the elderly. However, a strong limitation of both the present analysis and the Medicare-based report is their retrospective nature with inherent differences in patient groups, making comparisons difficult. Despite a 6% increase in crude 90-day survival after rAAA repair over time, there was no significant change in long-term crude or relative survival over time in this group. The increased 90-day survival would be expected to have an adverse effect on relative long-term survival when perioperative mortality was excluded if patients with more comorbidities survived the operation during the later time period. However, long-term survival after rAAA was stable, suggesting that this effect may be balanced by a true long-term survival benefit. Although perioperative mortality is high after rAAA repair, relative long-term survival for patients surviving rupture was similar to survival after iAAA repair. There is, however, an important “selection of the fittest” rationale for performing the rather complex analysis of relative survival, in which every patient is compared with the entire cohort of Swedish citizens of the same age and sex at the time of the operation.

Two important trends in patient demography and treatment were observed: increased rates of EVAR and operations on octogenarians over time. The introduction of EVAR was not related to an increase in long-term survival. Overall, relative survival (excluding AAA repair–related mortality) did not differ significantly between EVAR and OR. The increase in rate of octogenarians over time could explain only a small proportion of the observed total increase in relative survival after iAAA repair. Although patients ≥80 years of age had a higher relative survival rate than younger patients, octogenarians still constituted a small minority of all patients treated for rAAA after 2000 (Table 1). Cardiovascular disease is the major cause of death among AAA patients. An improvement in cardiovascular care could affect long-term outcome for patients after AAA repair. From 1995 to 2002, 1-year mortality after myocardial infarction in Sweden decreased from 17% to 12% among nondiabetic and from 30% to 20% among diabetic patients. During the same time period, the use of statins and angiotensin-converting enzyme inhibitors in Sweden increased significantly.

Despite a 6% increase in crude 90-day survival after rAAA repair over time, there was no significant change in long-term crude or relative survival over time in this group. The increased 90-day survival would be expected to have an adverse effect on relative long-term survival when perioperative mortality was excluded if patients with more comorbidities survived the operation during the later time period. However, long-term survival after rAAA was stable, suggesting that this effect may be balanced by a true long-term survival benefit. Although perioperative mortality is high after rAAA repair, relative long-term survival for patients surviving rupture was similar to survival after iAAA repair. There is, however, an important “selection of the fittest” effect in this group resulting from the high perioperative mortality.

The present study confirmed previous findings of higher long-term relative survival rates for men compared with women and for patients ≥80 years of age compared with younger patients. The observed improved long-term relative survival in aged patients could be a result of selection bias in which those ≥80 years of age offered surgery were relatively healthy. This was reflected in the comorbidity rates of octogenarians, which were similar to those of all patients <80 years of age, on average 12 years younger (Table 1). If an increased comorbidity rate with increasing age is assumed, this finding suggests that octogenarians selected for iAAA repair were relatively healthier than their age-matched controls.

A previous analysis of trends in AAA repair in Sweden indicated that elective EVAR is increasingly being used in elderly patients who previously were not offered OR. Such a change in patient selection could be inappropriate if the long-term survival of this patient group is not adequate. The present analysis shows, however, that the higher relative survival of octogenarians compared with younger patients also was valid among those treated with EVAR. Patients ≥80 years of age treated with EVAR had the same 5-year relative survival as those treated with OR and lived as long as their age- and sex-matched controls, indicating that these patients are still adequately selected for iAAA repair. In addition, octogenarians treated with EVAR had a lower perioperative mortality than those treated with OR. In combination, these findings are in line with a previous report on long-term outcome after EVAR based on Medicare data and may support a preference toward EVAR among the elderly. However, a strong limitation of both the present analysis and the Medicare-based report is their retrospective nature with inherent differences in patient groups, making comparisons between OR and EVAR hazardous. Neither of these 2 reports includes data on aneurysm morphology, a factor that can be

### Table 3. Crude and Relative Survival After rAAA Repair in Different Subgroups

<table>
<thead>
<tr>
<th>Age, y</th>
<th>Overall (n=4171)</th>
<th>Male (n=3576)</th>
<th>Female (n=595)</th>
<th>&lt;80 (n=3235)</th>
<th>≥80 (n=936)</th>
<th>1987–1999 (n=2375)</th>
<th>2000–2005 (n=1796)</th>
<th>OR (n=1705)</th>
<th>EVAR (n=91)</th>
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<tr>
<td>30 d</td>
<td>64.2 (62.3–66.1)</td>
<td>65.5 (63.4–67.5)</td>
<td>56.6 (51.4–61.9)</td>
<td>68.6 (66.5–70.7)</td>
<td>49.0 (44.8–53.2)</td>
<td>61.7 (59.1–64.3)</td>
<td>67.5 (64.7–70.4)</td>
<td>66.8 (63.6–69.5)</td>
<td>85.7 (76.3–95.2)</td>
</tr>
<tr>
<td>90 d</td>
<td>60.4 (58.5–62.4)</td>
<td>61.8 (59.7–63.9)</td>
<td>52.1 (46.8–57.4)</td>
<td>65.0 (62.9–67.2)</td>
<td>44.6 (40.4–48.7)</td>
<td>57.8 (55.2–60.4)</td>
<td>63.9 (61.0–66.8)</td>
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<td>1 y</td>
<td>56.8 (54.9–58.8)</td>
<td>58.3 (56.2–60.4)</td>
<td>48.1 (42.6–53.3)</td>
<td>61.7 (59.5–63.9)</td>
<td>40.2 (36.0–44.3)</td>
<td>54.4 (51.8–57.0)</td>
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<td>5 y</td>
<td>41.7 (39.6–43.7)</td>
<td>43.0 (40.8–45.2)</td>
<td>33.8 (28.6–38.9)</td>
<td>47.0 (44.7–49.3)</td>
<td>23.0 (19.3–26.7)</td>
<td>40.0 (37.4–42.5)</td>
<td>43.7 (40.4–47.0)</td>
<td>42.9 (39.4–46.3)</td>
<td>53.6 (37.8–69.4)</td>
</tr>
<tr>
<td>10 y</td>
<td>23.3 (21.2–25.4)</td>
<td>24.9 (22.6–27.2)</td>
<td>13.2 (8.4–17.9)</td>
<td>28.1 (25.6–30.6)</td>
<td>5.5 (2.8–8.2)</td>
<td>22.3 (20.0–24.5)</td>
<td>. . .</td>
<td>. . .</td>
<td>. . .</td>
</tr>
</tbody>
</table>

*Relative survival among those surviving AAA repair (ie excluding operation-related mortality [90 days]).
†Only rAAA repairs performed from 2000 to 2005 are included. Because of the small number of EVAR cases for rAAA, relative survival was not analyzed.
decisive for the choice of operative technique. It is likely that elderly patients operated on with OR often were selected for open surgery as a result of a hostile aneurysm anatomy.

Conclusions
Over the last 2 decades, long-term survival improved after iAAA repair and was stable after RAAA repair. Changes in patient demographics and case mix toward older patients, a higher proportion of patients with comorbidities, and the increasing use of EVAR have thus not had any negative effects on long-term outcome after operation.

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Disclosures
None.

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CLINICAL PERSPECTIVE

Abdominal aortic aneurysm (AAA) is a common and potentially lethal disease if the AAA ruptures. The disease is preferably treated with prophylactic repair in selected patients. The treatment of AAA has developed substantially over the past 2 decades with the introduction of endovascular aneurysm repair, the timing of intervention established by randomized trials, and improved postoperative care. These developments have made it possible to treat AAA among older patients with more comorbidities while improving short-term outcome. The observed changes in patient demography may, however, affect long-term survival after AAA repair. Long-term survival is fundamental for surgical decision making and has important health economic implications when the cost-effectiveness of a new treatment (eg, endovascular aneurysm repair) or health intervention (eg, screening for AAA) is evaluated. In this population-based nationwide study, long-term survival after AAA repair in Sweden over an 18-year period was analyzed on the basis of 12,834 primary operations performed from 1987 to 2005. Both short- and long-term outcome after intact AAA repair improved over time. Long-term relative survival among those surviving the operation compared with a general population (adjusted for age, sex, and calendar year) was superior for octogenarians and male patients compared with younger patients and women. Although short-term survival after ruptured AAA repair increased over time, long-term outcome was unaffected. Changes in patient demography and case mix toward older patients, a higher proportion of patients with comorbidities, and the increasing use of endovascular aneurysm repair thus have not had any negative effects on long-term outcome after operation.

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Kevin Mani, Martin Björck, Jonas Lundkvist and Anders Wanhainen

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