CLINICAL RESEARCH STUDIES

From the Peripheral Vascular Surgery Society

Effect of gender on long-term survival after abdominal aortic aneurysm repair based on results from the Medicare national database

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Objectives: **Historically, women have higher procedurally related mortality rates than men for abdominal aortic aneurysm (AAA) repair. Although endovascular aneurysm repair (EVAR) has improved these rates for men and women, effects of gender on long-term survival with different types of AAA repair, such as EVAR vs open aneurysm repair (OAR), need further investigation. To address this issue, we analyzed survival in matched cohorts who received EVAR or OAR for both elective (eAAA) and ruptured AAA (rAAA).**

Methods: **Using the Medicare Beneficiary Database (1995-2006), we compiled a cohort of patients who underwent OAR or EVAR for eAAA (n = 322,892) or rAAA (n = 48,865). Men and women were matched by propensity scores, accounting for baseline demographics, comorbid conditions, treating institution, and surgeon experience. Frailty models were used to compare long-term survival of the matched groups.**

Results: **Perioperative mortality for eAAAs was significantly lower among EVAR vs OAR recipients for both men (1.84% vs 4.80%) and women (3.19% vs 6.37%, $P < .0001$). One difference, however, was that the survival benefit of EVAR was sustained for the 6 years of follow-up in women but disappeared in 2 years in men. Similarly, the survival benefit of men vs women after elective EVAR disappeared after 1.5 to 2 years. For rAAAs, 30-day mortality was significantly lower for EVAR recipients compared with OAR recipients, for both men (33.43% vs 43.70% $P < .0001$) and women (41.01% vs 48.28%, $P = .0201$). Six-year survival was significantly higher for men who received EVAR vs those who received OAR ($P = .001$). However, the survival benefit for women who received EVAR compared with OAR disappeared in 6 months. Survival was also substantially higher for men than women after emergent EVAR ($P = .0007$).**

Conclusions: **Gender disparity is evident from long-term outcomes after AAA repair. In the case for rAAA, where the long-term outcome for women was significantly worse than for men, the less invasive EVAR treatment did not appear to benefit women to the same extent that it did for men. Although the long-term outcome after open repair for elective AAA was also worse for women, EVAR benefit for women was sustained longer than for men. These associations require further study to isolate specific risk factors that would be potential targets for improving AAA management. (J Vasc Surg 2011;54:1-12.)**

Elective or urgent endovascular repair (EVAR) of abdominal aortic aneurysms (AAA) has been widely accepted as the treatment of choice for these lesions.[1] The Dutch Randomised Endovascular Aneurysm Management (DREAM), Comparison of Endovascular Aneurysm Repair with Open Repair in Patients with Abdominal Aortic Aneurysm (EVAR1), and Veterans Affairs Open versus Endovascular Repair (OVER) clinical trials,[2,3] as well as population-based observational studies,[4,5] have demonstrated improved 30-day mortality and morbidity with EVAR compared with open aneurysm repair (OAR). However, they failed to show sustained survival benefit after 2 to 3 years from the initial surgery.[2-4]

Historically, the natural history, as well as the management of AAA in women has been associated with worse overall outcomes.[6-11] EVAR has improved immediate outcomes in women compared with OAR; however, a gender disparity in mortality persists.[6,9,12,13] Whether this initial benefit is sustained in long-term follow-up for women and

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Table I. Demographics and comorbidities for patients who underwent elective endovascular (*EVAR*) or open (*OAR*) repair of abdominal aortic aneurysm

	Overall			*EVAR*[a]		
Variable	*Men (n = 250,438)*	*Women (n = 72,454)*	P	*Men (n = 63,712)*	*Women (n = 13,644)*	P
Age, years	74.97	75.86	<.0001	76.16	77.45	<.0001
Age groups, %						
65-69	22.8	18.5	<.0001	18.9	13.8	<.0001
70-74	29.8	28.1	<.0001	25.7	23.0	<.0001
75-79	27.1	28.7	<.0001	27.5	28.2	.0928
80-84	15.1	17.6	<.0001	19.4	22.5	<.0001
≥85	5.2	7.1	<.0001	8.5	12.5	<.0001
Race, %						
White	95.2	92.1	<.0001	95.2	90.8	<.0001
Black	2.4	5.4	<.0001	2.4	6.6	<.0001
Hispanic	0.6	0.5	.541	0.6	0.6	.4167
Other	1.9	2.0	<.0001	1.9	2.0	.223
Comorbidities, %						
Coronary	51.3	38.9	<.0001	57.0	42.3	<.0001
Valvular	8.7	9.9	<.0001	9.3	10.7	<.0001
Arrhythmia	27.8	22.5	<.0001	26.6	20.6	<.0001
CHF	15.8	17.6	<.0001	15.0	16.1	.0017
Pulmonary	36.3	41.6	<.0001	35.9	41.8	<.0001
Cerebrovascular	7.6	8.2	<.0001	7.3	6.8	.0518
Neurologic	4.2	4.0	.01	4.9	5.0	.6815
Renal failure	4.8	4.5	.0002	6.3	6.1	.3921
PAD	20.6	27.9	<.0001	21.6	27.9	<.0001
Diabetes	12.8	11.0	<.0001	16.9	14.9	<.0001
Liver disease	1.2	1.2	.3769	1.1	1.1	.8037
Cancer	7.4	4.1	<.0001	8.2	4.8	<.0001
Hypertension	63.4	70.1	<.0001	72.6	78.2	<.0001
Hyperlipidemia	28.0	27.6	.0385	42.5	41.3	.009
Procedure, %						
EVAR	25.4	18.8	<.0001	100.0	100.0	
Conversion				2.0	4.6	<.0001
OAR	74.6	81.2	<.0001			

CHF, Congestive heart failure; *PAD,* peripheral arterial disease.
[a]Reflecting the introduction of the EVAR International Classification of Disease, 9th edition, procedure code in 2000, EVAR procedures were only identified during the last 6 years of the data set.

whether the initial survival advantage associated with male gender after EVAR or OAR persists over time needs further investigation. This study addressed these issues from a population perspective and determined the effect of gender on long-term survival differences after OAR and EVAR under elective and urgent circumstances.

METHODS

Data sources and population selection. The data source for analysis was the Medicare Inpatient Standard Analytical and Denominator files for years 1995-2006. Patients were selected through a combination of diagnoses codes (International Classification of Disease, 9th Clinical Modification [ICD-9-CM] codes 441.4—AAA, without mention of rupture, or 441.3—ruptured AAA) and ICD-9 procedure codes (39.71 for EVAR and 38.44, 39.25, 39.52, 38.34, 38.64, 38.40, 38.60 for OAR) in the primary or any secondary position. The study excluded patients with thoracic or thoracoabdominal aneurysms.

The hospitalization with the first AAA procedure was identified as the index hospitalization. Preindex and index hospitalizations were used to assess baseline comorbidities. The comorbidities included all those identified in prior hospitalizations and the chronic conditions reported at the index hospitalization. The comorbidities that were analyzed are reported in Appendix Table O1 (online only).

The following perioperative outcomes were reviewed: cardiac, respiratory, and acute renal failure requiring dialysis, patient disposition, and 30-day mortality. Long-term adverse events included ruptured AAA, reoperation of AAA, arterial reinterventions (thrombectomy, embolectomy, catheter-based, and open reconstructive reinterventions for readmissions with a primary or secondary diagnosis of AAA) and interventions for incision- and laparotomy-related complications, including intestinal postoperative obstruction, postoperative adhesions and incisional, groin or abdominal wall hernia repairs (Appendix Table O1, online only).

Readmission rates were calculated per 1 year of survival. A discharge and readmission that occurred on the same day was considered one episode of care. Annual hospital and surgeon volume of AAA operations were defined as number

Table I. Continued

OAR			EVAR vs OAR	
Men (*n = 186,726*)	*Women* (*n = 58,810*)	P	*Women* P	*Men* P
74.56337	75.49	<.0001	<.0001	<.0001
24.2	19.5	<.0001	<.0001	<.0001
31.2	29.3	<.0001	<.0001	<.0001
26.9	28.8	<.0001	.1557	.0074
13.6	16.4	<.0001	<.0001	<.0001
4.0	5.9	<.0001	<.0001	<.0001
95.2	92.4	<.0001	<.0001	0.4911
2.4	5.1	<.0001	<.0001	0.5267
0.6	0.5	.2929	.1627	0.9368
1.9	2.0	.0217	.8891	0.675
49.4	38.1	<.0001	<.0001	<.0001
8.5	9.7	<.0001	.0006	<.0001
28.3	22.9	<.0001	<.0001	<.0001
16.0	17.9	<.0001	<.0001	<.0001
36.5	41.6	<.0001	.5936	.0106
7.7	8.6	<.0001	<.0001	<.0001
4.0	3.8	.0199	<.0001	<.0001
4.3	4.1	.0331	<.0001	<.0001
20.3	27.9	<.0001	.9015	<.0001
11.3	10.1	<.0001	<.0001	<.0001
1.3	1.2	.1701	.3094	<.0001
7.1	3.9	<.0001	<.0001	<.0001
60.3	68.2	<.0001	<.0001	<.0001
23.1	24.5	<.0001	<.0001	<.0001

of EVAR, OAR, or ruptured AAA (rAAA) repairs (EVAR and OAR) per year.[5] The analyses were stratified as follows: (1) women: OAR vs EVAR, (2) men: OAR vs EVAR, (3) EVAR: men vs women, and (4) OAR: men vs women.

Statistics. To control for life expectancies in the general population, we used relative survival. Relative survival was calculated using the life-table method[14] by comparing the observed survival after AAA repair (including and excluding operation-related mortality ≤90 days)[15,16] with the expected survival of the population[17] adjusted for background death based on age, sex, and calendar year.

Because each treatment group was vastly different, to control for baseline characteristics and assess solely the effect of procedure or gender on survival, we used a propensity-matching technique.[18-22] To increase the pool of data for matching, all 1995 to 2006 hospitalizations for OAR and hospitalizations from 2000 through 2006 for EVAR were included. To determine the propensity score, a logistic regression model was developed where the dependent variable was the type of procedure or gender. All baseline confounders, including gender, race, comorbidities (as cate-

Table II. Five-year relative survival estimates for men and women after open (*OAR*) and endovascular (*EVAR*) repair of abdominal aortic aneurysm (*AAA*)

Variable	*Men* % (95% CL)	*Women* % (95% CL)	P
Elective AAA			
OAR	86 (86, 87)	77 (76, 77)	<.0001
EVAR	87 (87, 88)	80 (78, 81)	<.0001
Excluding 90-day mortality			
OAR	93 (92, 93)	84 (84, 85)	<.0001
EVAR	91 (90, 91)	85 (83, 86)	<.0001
Ruptured AAA			
OAR	34 (33, 35)	19 (18, 21)	<.0001
EVAR	43 (39, 48)	32 (25, 39)	<.0001
Excluding 90-day mortality			
OAR	83 (82, 84)	72 (70, 74)	<.0001
EVAR	75 (67, 82)	65 (51, 78)	<.0001

CL, Confidence limit.

Table III. Perioperative and long-term complications for women and men after elective endovascular (*EVAR*) or open (*OAR*) repair of abdominal aortic aneurysm

	Women			*Men*		
Variable	*EVAR, %* *(n = 9080)*	*OAR, %* *(n = 9080)*	P	*EVAR, %* *(n = 33,240)*	*OAR, %* *(n = 33,240)*	P
Disposition						
Home/home care	82.7[a]	64.8	<.0001	92.3[a]	77.6	<.0001
SNF/rehabilitation	12.3	26.2[a]	<.0001	5.1	15.5[a]	<.0001
Perioperative complications						
Cardiac	4.45	8.96[a]	<.0001	3.13	8.67[a]	<.0001
Pulmonary	10.76	30.12[a]	<.0001	7.01	26.14[a]	<.0001
Renal failure w/dialysis	0.54	1.30[a]	<.0001	0.36	1.15[a]	<.0001
30-day mortality	3.19	6.37[a]	<.0001	1.84	4.80[a]	<.0001
Long-term adverse events/reinterventions						
Readmission rate	0.75[a]	0.69	<.0001	0.63[a]	0.57	<.0001
Ruptured AAA	0.29[a]	0.12	.0001	0.29[a]	0.10	<.0001
AAA revision	1.81[a]	0.53	<.0001	1.94[a]	0.71	<.0001
Open	0.64[a]	0.43	<.0001	0.79[a]	0.52	<.0001
Endovascular	1.09[a]	0.10	<.0001	1.11[a]	0.19	<.0001
Arterial reinterventions	1.77[a]	0.50	<.0001	1.72[a]	0.63	<.0001
Other reinterventions[b]	2.28	4.29[a]	<.0001	2.32	4.69[a]	<.0001

SNF, Skilled nursing facility.
[a]Represents a significantly higher rate.
[b]Reinterventions for incision or laparotomy-related complications, including intestinal postoperative obstruction, postoperative adhesions and incisional, groin or abdominal wall hernia repairs.

goric variables), age, year of surgery, hospital, and surgeon volume (as continuous variables) were included in the model as independent variables. The patients were matched by greedy algorithm using the 8- to 1-digit matching scheme without replacement.[18] Paired *t* tests were used for continuous variables and McNemar tests for categoric variables to ensure that there were no significant differences in demographics and comorbid characteristics between matched groups. The results of matching by propensity score are summarized in Appendix Tables O2 and O3 (online only). Perioperative complications and 30-day mortality were compared in matched groups using the McNemar test.

Survival curves were constructed with Cox models. Frailty models were used to control for matching (clustering). Hazard ratio (HR) of long-term survival was estimated using the SAS PROC PHREG procedure with the robust sandwich estimate option.[23,24] Propensity score and type of repair or gender were included in this regression analysis. We used the Martingale methods to check the proportional hazard assumption. Readmission rates were compared with Poisson regression analysis. Statistical significance was expressed as both *P* values and 95% confidence intervals. $P < .05$ was considered statistically significant. *P* values were reported without adjusting for multiple comparisons. SAS 9.13 software (SAS Institute Inc, Cary, NC) was used.

RESULTS

Elective AAA repair. There were 322,892 patients with elective AAA repair from 1995 through 2006, and 245,536 underwent OAR (70.5% men, 29.5% women) and 77,356 underwent EVAR (82.4% men, 17.6% women). Baseline characteristics of men and women are reported in

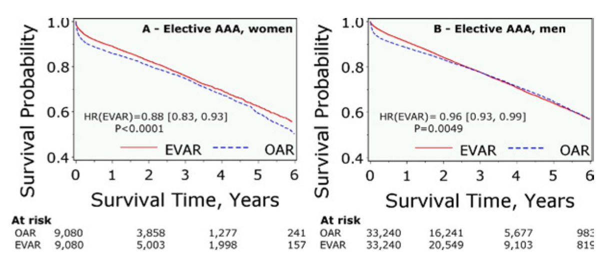

Fig 1. Long-term survival of **(A)** women and **(B)** men treated with elective endovascular (*EVAR*) and open (*OAR*) repair of aortic abdominal aneurysm (*AAA*). Cases were matched by propensity score. The hazard ratio (*HR*) is the quotient of the hazard rates of the EVAR and OAR comparison groups and is expressed as a point estimate with a 95% confidence interval.

Table I. The 30-day mortality rates for women were 6.43% after OAR and 2.96% after EVAR and for men were 4.64% and 1.63%, respectively. After adjusting for life expectancy and calendar year, the 5-year relative survival for both men and women was less than in the general population and was significantly lower for women than men after either procedure (Table II). The worst 5-year relative survival was observed in women undergoing OAR (84%).

Women: OAR vs EVAR. Women who underwent EVAR differed from those who underwent OAR: they were older, had a higher frequency of coronary artery disease (CAD) and diabetes, and a lower frequency of cardiac arrhythmias and cerebrovascular disease (Table I). Adjustment for these differences was accomplished by propensity score matching, which resulted in 9080 paired women who

Table IV. Disposition, perioperative, and long-term complications after elective endovascular (*EVAR*) or open repair (*OAR*) of abdominal aortic aneurysm by gender

Variable	*EVAR* Men, % (n = 13,710)	*EVAR* Women, % (n = 13,710)	*EVAR* P	*OAR* Men, % (n = 59,279)	*OAR* Women, % (n = 59,279)	*OAR* P
Disposition						
Home/home care	91.6[a]	83.7	<.0001	80.0[a]	70.5	<.0001
SNF/rehabilitation	6.1	12.0[a]	<.0001	11.1	17.7[a]	<.0001
Perioperative complications						
Cardiac	2.67	4.13[a]	<.0001	8.41	9.26[a]	<.0001
Pulmonary	6.23	9.85[a]	<.0001	24.47	26.78[a]	<.0001
Renal failure w/dialysis	0.39	0.50	.205	0.96	1.27[a]	<.0001
30-day mortality	1.77	2.96[a]	<.0001	4.98	6.43[a]	<.0001
Long-term adverse events/reinterventions[a]						
Readmission rate	0.66	0.77[a]	<.0001	0.57	0.66[a]	<.0001
Ruptured AAA	0.33	0.28	.99	0.57	0.66	.1616
AAA revision	2.04	1.91	.1168	0.63[a]	0.48	.0049
Open	0.79	0.63	.6306	0.52	0.43	.3077
Endovascular	1.20	1.21	.0444	0.11[a]	0.05	<.0001
Arterial reinterventions	2.01	1.81	.3489	0.60	0.49	.1766
Other reinterventions[b]	2.23	2.08	.1125	4.40[a]	3.96	.0325

SNF, Skilled nursing facility.
[a]Represents a significantly higher rate.
[b]Reintervention for incisional or laparotomy-related complications, including intestinal postoperative obstruction, postoperative adhesions and incisional, groin, or abdominal wall hernia repairs.

were balanced in baseline characteristics (Appendix Table O2, online only).

The 30-day mortality in these matched groups was 6.37% after OAR and 3.19% after EVAR ($P < .0001$). Higher rates of complications were observed in the OAR group (Table III). EVAR recipients had a significant survival benefit that was sustained for the 6 years of observation (Fig 1, *A*). The relative risk of dying was 12% less in the EVAR than in the OAR group (HR, 0.88; $P < .0001$). However, EVAR recipients had higher rates of AAA and arterial reinterventions, and OAR recipients had a higher rate of laparotomy or incision-related reinterventions (Table III).

Men: OAR vs EVAR. The balanced subgroups consisted of 33,240 pairs (mean age, 75.5). Comorbidities included CAD in 55%, congestive heart failure (CHF) in 16%, renal failure in 6%, and neurologic diseases in 4.6% (Appendix Table O2, online only).

Perioperative mortality in these balanced groups was 1.84% after EVAR and 4.80% after OAR ($P < .0001$; Table III). Similar to women, rates of perioperative complications were lower in the EVAR group.

Distinct from what was seen with women, the survival advantage for EVAR was greatest during the first 2 postoperative years, but then the curves converged (Fig 1, *B*). The relative risk of dying was about 4% lower for EVAR recipients (HR, 0.96; $P = .0049$). Like women, men undergoing EVAR had higher readmission, AAA, and arterial reintervention rates, whereas OAR recipients had higher laparotomy-related reinterventions (Table III).

Elective OAR: Men vs women. Demographics and comorbidities of the balanced subgroups (59,279 pairs) are available in Appendix Table O2 (online only). Mean age was 75.4; comorbidities were CAD in 38%, CHF in 18%, and renal failure in 4%.

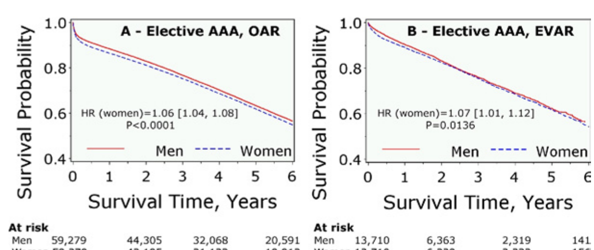

Fig 2. Long-term survival after elective **(A)** open (*OAR*) and **(B)** endovascular (*EVAR*) repair of men and women with aortic abdominal aneurysms (*AAAs*). Cases were matched by propensity score. The hazard ratio (*HR*) is the quotient of the hazard rates of the two comparison groups (men and women) and is expressed as a point estimate with 95% confidence interval.

The 30-day mortality rate in these matched groups was 6.43% for women and 4.98% for men ($P < .0001$). Women also had higher rates of postoperative complications (Table IV). Men experienced superior survival throughout the 6-year follow-up period (HR, 1.06; $P < .0001$; Fig 2, *A*). The survival curves remained parallel, indicating that the survivals for the comparison groups as a whole were different, conditional on the initial 2-year survival. Women experienced higher rates of readmission (0.66 vs 0.57 for men, $P < .0001$), and slightly lower AAA revision rates (Table IV).

Elective EVAR: Men vs women. For this analysis we constructed subgroups of 13,710 patients with a matched

Table V. Baseline demographics and comorbidities for patients who had endovascular (*EVAR*) or open (*OAR*) repair of ruptured abdominal aortic aneurysm

	Overall			*EVAR*		
Variable	*Men* (*n* = *37,371*)	*Women* (*n* = *11,494*)	P	*Men* (*n* = *1497*)	*Women* (*n* = *510*)	P
Age, years	75.9	78.2	<.0001	77.5	78.8	.0003
Age groups, %						
65-69	20.9	13.1	<.0001	15.8	13.5	.2245
70-74	26.9	21.0	<.0001	23.2	17.1	.0037
75-79	25.5	25.8	.5083	24.1	23.5	.7891
80-84	16.9	23.0	<.0001	22.4	26.7	.0484
≥85	9.8	17.1	<.0001	14.6	19.2	.0127
Race, %						
White	94.5	90.5	<.0001	92.3	87.5	.0009
Black	3.1	6.9	<.0001	5.6	10.6	.0001
Hispanic	0.6	0.5	.525	0.7	0.6	.7312
Other race	1.9	2.1	.189	1.3	1.4	.9507
Comorbidities, %						
Coronary	28.6	24.7	<.0001	37.6	30.6	.0043
Valvular	5.2	6.8	<.0001	8.6	8.0	.7196
Arrhythmia	30.5	27.0	<.0001	33.7	33.3	.8903
CHF	20.9	24.5	<.0001	22.8	26.5	.0905
Pulmonary	35.0	37.3	<.0001	39.4	38.0	.5831
Cerebrovascular	5.4	6.4	<.0001	6.9	7.6	.5957
Neurologic	5.6	6.7	<.0001	6.2	6.9	.6037
Renal failure	6.3	6.7	.1409	11.8	11.8	.9962
PAD	11.3	11.8	.1342	13.7	15.7	.2656
Diabetes	8.5	9.6	.0001	10.8	11.8	.5576
Liver disease	1.3	1.2	.5139	1.2	1.6	.5276
Cancer	4.8	3.1	<.0001	7.4	6.5	.4755
Hypertension	44.8	53.4	<.0001	59.3	64.1	.0555
Hyperlipidemia	9.9	11.2	<.0001	19.8	22.5	.1797
Procedure, %						
EVAR	4.0	4.4	.0416	100.0	100.0	
Conversion				6.9	7.3	.7743
OAR	96.0	95.6	.0416	0.0	0.0	

CHF, Congestive heart failure; *PAD,* peripheral arterial disease.

mean age of 77.4 years and major comorbidities of CAD in 42%, CHF in 16%, diabetes in 15%, and renal failure in 6% (Appendix Table O2, online only).

The 30-day mortality rate was 2.96% for women and 1.77% for men ($P < .0001$), with women experiencing higher rates of perioperative complications (Table IV). Interestingly, although overall survival was superior for men (HR, 1.07; $P = .0136$), the initial survival advantage in men lessened over time, and the survival curves began to converge after 2 years (Fig 2, *B*).

Ruptured AAA. Among the 48,865 patients with rAAA repairs, 76.5% were men and 23.5% were women (Table V), and only 2007 underwent EVAR. The ratio of men to women by either approach was about 3:1 (OAR: 76.6% vs 23.4%; and EVAR: 74.6% vs 25.4%). Overall 30-day mortality 52.7% after OAR and 41.05% after EVAR for women was and 44.06% after OAR and 33.07% after EVAR for men. Regardless repair type, relative survival for women was inferior to survival for men, with the worst survival after EVAR (65%; Table II). Women were older, with a mean age of 78 vs 76 years ($P < .0001$) and had higher rates of valvular and pulmonary disease, CHF, renal failure, diabetes, hypertension, and hyperlipidemia. On the other hand, men had higher rates of CAD, cardiac arrhythmia, and cancer (Table V). Thus, we constructed four sets of matched subgroups to compare survival after aortic rupture for men and women undergoing EVAR and OAR. Details of patients' baseline characteristics are reported in Appendix Table O3 (online only).

Ruptured AAA women: OAR vs EVAR. Demographics and comorbidities of 495 matched pairs of women (EVAR vs OAR) are available in Appendix Table O3 (online only). The mean age was 78 years, and 18% were aged ≥85. CAD was present in approximately 30%, CHF in 25%, and renal failure in 12%.

Perioperative mortality was significantly lower after EVAR (41.01%) compared with OAR (48.28%, $P = .0201$) in these matched subgroups. Rates of postoperative cardiac, pulmonary complications, and renal failure requiring dialysis were higher in the OAR recipients (Table VI).

Analysis of early data from 2000 to 2004 showed equivalent survival for OAR and EVAR recipients even after 1, 6, and 12 months of repair. However, when we included more recent years (2005 and 2006), we discovered a survival benefit of EVAR over OAR that persisted 6 months after surgery (Fig 3, *A*). Overall survival rates were similar

Table V. Continued

OAR			EVAR vs OAR	
Men (n = 35,874)	*Women (n = 10,984)*	P	*Women* P	*Men* P
75.9	78.2	<.0001	.0564	<.0001
21.1	13.1	<.0001	.7839	<.0001
27.1	21.2	<.0001	.0239	.0008
25.5	25.9	.4551	.2331	.2162
16.7	22.8	<.0001	.0412	<.0001
9.6	17.0	<.0001	.1914	<.0001
94.6	90.6	<.0001	.0167	.0002
2.9	6.7	<.0001	.0008	<.0001
0.6	0.5	.5623	.8319	.396
1.9	2.1	.1796	.2525	.1101
28.2	24.5	<.0001	.0017	<.0001
5.1	6.8	<.0001	.2755	<.0001
30.4	26.7	<.0001	.001	.0073
20.8	24.4	<.0001	.2942	.0608
34.8	37.2	<.0001	.7169	.0003
5.3	6.3	<.0001	.223	.0057
5.6	6.6	<.0001	.8478	.3278
6.1	6.5	.1515	<.0001	<.0001
11.2	11.7	.215	.006	.0033
8.4	9.5	.0002	.0919	.0008
1.3	1.2	.4195	.4103	.8375
4.7	3.0	<.0001	<.0001	<.0001
44.2	52.9	<.0001	<.0001	<.0001
9.5	10.7	<.0001	<.0001	<.0001
0.0	0.0		<.0001	<.0001
0.0	0.0			
100.0	100.0		<.0001	<.0001

for EVAR and OAR recipients (HR, 0.94; P = .41). Readmission, AAA revision, and arterial reinterventions rates were significantly higher after EVAR (Table VI).

Ruptured AAA men: OAR vs EVAR. We compared OAR with EVAR outcomes in 1421 pairs of matched men with rAAA. The mean age was 77; 14% were aged ≥85. Pulmonary disease was present in almost 40%, CAD in about 38%, and renal failure in 11% (Appendix Table O3, online only). Similar to women, men in these matched groups had higher 30-day mortality after OAR than after EVAR (43.70% vs 33.43% $P < .0001$) and a higher rate of perioperative pulmonary complications (Table VI). Distinct from what was observed with women, overall survival was better for men with rAAA after EVAR than after OAR (Fig 3, *B*). The overall relative risk of dying was 15% higher in the OAR group (HR, 0.85; $P = .0008$), with lower readmission and AAA reintervention rates (Table VI).

Ruptured AAA OAR: men vs women. We compared the outcomes of men and women after OAR in two matched subgroups, each with 10,911 individuals. They were a mean age of 78 years, and CAD was present in 24%, CHF in 24%, pulmonary disease in 37%, and renal failure in 6.5% (Appendix Table O3, online only). The mortality rate ≤30 days after OAR for rAAA in these balanced groups was 52.61% for women and 46.57% for men (Table VII). No differences in perioperative cardiac, pulmonary, or renal complications between men and women were recorded. Long-term survival was significantly higher for men (HR, 1.17; $P < .0001$; Fig 4. *A*), whereas women had higher readmission and rAAA rates (Table VII).

Ruptured AAA EVAR: men vs women. We compared the outcomes of matched pairs of men and women after EVAR with 499 individuals in each group. The distribution of demographic characteristics was similar between genders (Appendix Table O3, online only). Their mean age was 79 years, and 46% of men and women were aged ≥80. The rate of underlying pulmonary disease was 38%, CAD was about 32%, CHF was about 26%, and renal failure was about 10%.

The perioperative mortality rate was about 10% higher for women (41.08%) than for men (30.66%; $P < .0001$), and women had substantially lower long-term survival (Fig 4, *B*), with a 33% higher relative risk of dying (HR, 1.33; P = .0005) and higher readmission rates (Table VII).

Table VI. Perioperative and long-term complications for women and men after endovascular (*EVAR*) or open (*OAR*) repair of ruptured abdominal aortic aneurysm (*AAA*)

	Women			*Men*		
Variable	*EVAR, % (n = 495)*	*OAR, % (n = 495)*	P	*EVAR, % (n = 1421)*	*OAR, % (n = 1421)*	P
Disposition						
Home/home care	27.7[a]	20.0	.0061	38.6[a]	26.7	<.0001
SNF/rehabilitation	25.9	29.5	.2053	22.9	25.0	.1883
Perioperative complications						
Cardiac	16.16	21.41[a]	.0326	17.80	19.92	.1499
Pulmonary	44.65	54.55[a]	.0017	43.07	53.48[a]	<.0001
Renal failure w/dialysis	3.23	7.07[a]	.0078	3.66	5.00	.0739
30-day mortality	41.01	48.28[a]	.0201	33.43	43.70[a]	<.0001
Long-term complications/reinterventions						
Readmission rate	1.02[a]	0.79	.0002	0.92[a]	0.76	<.0001
Ruptured AAA	1.72	3.48	.1451	2.45	2.81	.8465
AAA revision	2.19[a]	0.61	.0226	2.35[a]	0.79	.0001
Open	0.94	0.61	.4089	0.82	0.72	.4488
Endovascular	1.25[a]	0.0	.0081	1.53[a]	0.07	.0013
Arterial reinterventions	2.19[a]	0.20	0.0134	1.79[a]	0.42	.0003
Other reinterventions[b]	2.97	2.46	.3350	2.81	3.67	.6273

SNF, Skilled nursing facility.
[a]Represents a significantly higher rate.
[b]Reintervention for incisional or laparotomy-related complications, including intestinal postoperative obstruction, postoperative adhesions and incisional, groin, or abdominal wall hernia repairs.

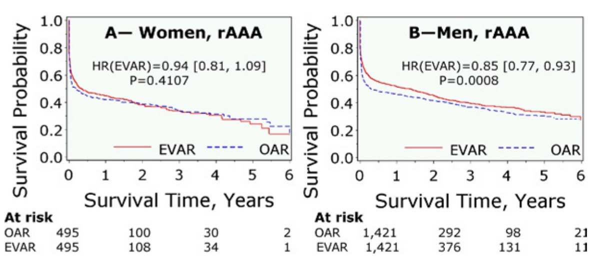

Fig 3. Long-term survival of **(A)** women and **(B)** men treated with endovascular (*EVAR*) and open (*OAR*) repair of ruptured aortic abdominal aneurysm. Cases were matched by propensity score. The hazard ratio (*HR*) is the quotient of the hazard rate of the EVAR and OAR comparison groups and is expressed as a point estimate and 95% confidence interval.

DISCUSSION

There are significant anatomic and biologic differences between men and women that challenge the management of aortic aneurysmal disease in women. The abdominal aorta and iliac arteries in women are, on average, smaller;[25-27] women tend to have a shorter infrarenal aortic neck,[28,29] and their aneurysm more frequently involves the juxtarenal and suprarenal aorta.[30] Moreover, women with AAA are older than men by at least 4 to 5 years[7] and have more cerebrovascular[31] and iliac occlusive disease.[7,12,13,28]

The natural history of AAA disease in women is not as well defined because of worse representation in clinical trials. However, there is an indication that AAA might be more dangerous in women. Data derived from United Kingdom Small Aneurysm Trial (UKSAT) indicate that the rupture rate is at least three times higher in women compared with men and that it occurs in smaller sized aneurysms.[32,33]

Another concern is that women have higher rates of undiagnosed comorbid conditions that increase operative risk, as has been documented for cardiovascular disease.[34] Even when diagnosed, treatment tends to be underutilized: women with CAD are less likely to receive statins and β-blockers,[35,36] and those with carotid stenosis are less likely to receive antiplatelet treatment.[37] Strong emerging evidence from clinical trials (Dutch Echographic Cardiac Risk Evaluation Applying Stress Echo II and IV [DECREASE II and IV]) suggests that lack of medical optimization before procedures has a major adverse effect on perioperative cardiovascular mortality and morbidity.[38,39]

The more challenging anatomy, higher chances of undiagnosed risk factors, and the higher likelihood of inadequate cardiovascular medical optimization, may partly explain why women with AAA have worse outcomes than men. Indeed, the perioperative mortality rates in women after elective repair was reported as high as 10.6% in 1980 through 1990 in the Michigan registry, 3.8% higher than men during the same period.[10] More recent reports, which reflect the introduction of EVAR and improved perioperative management, continue to demonstrate this gender disparity, with a mortality rate of 2.6% to 3.2% in men vs 4.8% to 5.45% in women.[9,40]

With rAAA, the differences in mortality are more pronounced.[40,41] In the Michigan registry, the mortality rate for women was 60.5%, 12% higher than for men. More recently, these rates have dropped in both groups, but a significant gender disparity persists (52.9% in women vs 43% in men).[9,40,41]

Table VII. Perioperative and long-term complications for women and men after endovascular (*EVAR*) or open (*OAR*) repair of ruptured abdominal aortic aneurysm (*AAA*)

Variable	*EVAR*			*OAR*		
	Men, % *(n = 499)*	*Women, %* *(n = 499)*	P	*Men, %* *(n = 10,911)*	*Women, %* *(n = 10,911)*	P
Disposition						
Home/home care	38.3[a]	27.9	.0005	28.2[a]	19.6	<.0001
SNF/rehabilitation	25.9	25.9	1	17.6	20.1[a]	<.0001
Perioperative complications						
Cardiac	18.44	16.23	.3576	19.78	19.79	.9864
Pulmonary	39.68	43.69	.2059	49.95	48.93	.1319
Renal failure w/dialysis	3.41	3.41	1	5.13	4.83	.3041
30-day mortality	30.66	41.08[a]	.0005	46.57	52.61[a]	<.0001
Long-term complications/reinterventions						
Readmission rate	0.88	1.04[a]	.0052	0.66	0.80[a]	<.0001
Ruptured AAA	2.70	1.76	.1721	2.34	2.43[a]	.0104
AAA revision	1.67	2.08	.6938	0.81[a]	0.45	.0023
Open	0.39	0.80	.3615	0.74[a]	0.41	.0051
Endovascular	1.29	1.28	.8779	0.07	0.02	.0688
Arterial reinterventions	1.71	2.13	.3808	0.47	0.32	.1989
Other reinterventions[b]	3.22	3.04	.6752	4.70	4.06	.7936

SNF, Skilled nursing facility.
[a]Represents a significantly higher rate.
[b]Reintervention for incisional or laparotomy-related complications, including intestinal postoperative obstruction, postoperative adhesions and incisional, groin, or abdominal wall hernia repairs.

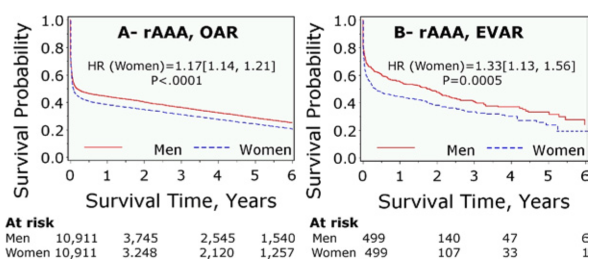

Fig 4. Long-term survival after **(A)** open (*OAR*) and **(B)** endovascular (*EVAR*) repair of ruptured aortic abdominal aneurysm in men and women. Cases were matched by propensity score. The hazard ratio (*HR*) is the quotient of the hazard rates of the two comparison groups (men and women) and is expressed as a point estimate and 95% confidence interval.

The introduction of EVAR has reduced the rate of early mortality with elective AAA repair.[6,7,9,40,41] EVAR has been frequently used for patients with multiple systemic diseases and decreased life expectancy who would not tolerate the major stress from OAR. Indeed, the 5-year relative survival for EVAR recipients compared with OAR recipients was uniformly worse. Even though women generally have longer life expectancy than men, the observed 5-year relative survival after AAA repair was lower for women than men (Table II), which was consistent with previous observations.[11] Women who received EVAR did the worst: 85% after elective and only 65% after rAAA EVAR reached the expected survival for their age group. This suggests that the EVAR group consists of patients with higher rates of systemic diseases, such as cancer, cardiac, and chronic pulmonary diseases than in the general population, and these factors are responsible for lower survival.

This speculation obviously needs further investigation; however, it led us to construct matching pairs adjusted for known comorbidities to evaluate the effect of gender in long-term outcomes. We observed a survival benefit for EVAR that persisted for the entire 6 years of follow-up for women who underwent elective repair (Fig 1). This pattern is distinct from what had been seen for EVAR use in a mixed cohort of men and women in clinical trials. It is possible that long-term survival benefit after EVAR for women was not seen in clinical trials due to the underrepresentation of women.

We also observed superior long-term survival with elective EVAR in men compared with women. However, the survival difference was greatest in the first 2 postoperative years and disappears afterward. This finding regarding the long-term equalization of survival curves after AAA repair is reported here for the first time. It may reflect anatomic differences between genders that favor women in the long-term. Women with AAA are less likely than men to have dilated iliac arteries.[13,28] Iliac artery dilation is often responsible for late reintervention and poor long-term outcome after primary intervention. The aortic wall in women has different compliance than in men[25,42] and probably responds differently to exclusion after insertion of a stent graft. In fact, Ouriel et al[12] have reported more rapid shrinkage of the aortic sac in women undergoing EVAR.

For open procedures, both eAAA and rAAA, and urgent EVAR, the survival benefit for men persisted. The recovery after OAR and rAAA repair appears to be more complicated for women. They experience higher rates of postoperative complications and are less likely to be discharged home. Such high rates were not seen for women after elective EVAR, reflecting that elective EVAR is less invasive and less disruptive to body function. The favorable anatomic factors for women may play a lesser role in the case of elective open and urgent repair of rAAA. Women with AAA are elderly and more likely than men to live alone, have sicker and older spouses incapable of caring for them, or have lower income. For all these reasons, women after OAR or rAAA repair are less likely to go home.[9] Institutionalization and poor functional status after intervention may have an effect on long-term survival. Further analysis of the causes of death and reasons for readmissions will be very important to understand these findings.

Analysis of the long-term effect of gender on survival after urgent repair alone uncovered additional findings of interest. Initial data analysis from 2000 to 2004 showed no benefit in survival of EVAR over OAR in women whose aneurysm had ruptured. However, when we expanded the analysis and included data from 2005 and 2006, we noticed a 6-month advantage in survival in women undergoing urgent EVAR. It is likely that this benefit will last longer in the future as smaller-profile devices are used and operators become more experienced in selecting the right devices for the female anatomy in the face of the urgent nature of aortic rupture.

One limitation of our study is that it is observational and carries all the potential biases inherent to such study designs. For instance, the subgroups of men and women differed substantially (Tables I and IV). We adjusted our comparisons for these differences by comparing propensity score-matched cohorts; however, there may still be some bias due to confounders that were not recognized. In addition, men and women were matched according to age and comorbidities and therefore some "healthier" men were excluded from comparisons. Thus, the men in the matched group may no longer be representative of all men undergoing aortic procedures. Nevertheless, we think that the matched comparisons are necessary to determine the effect of gender alone, without the distorting effects of other factors that could alter long-term survival.

Another limitation is that the data were originally collected for administrative purposes and are subject to coding errors. In addition, it is often difficult to distinguish whether a second intervention is related to the initial aneurysm repair. For instance, we assumed that all postoperative arterial reconstructions were related to the initial AAA repair, although they might have been performed for an entirely different condition.

Finally, the ICD9-CM codes used for EVAR have more general use than those used for OAR. Therefore, readmission and reintervention rates were probably overestimated, and it is quite possible our analysis carries a bias against EVAR. Given that these limitations affect men and women equally, the observed differences in reintervention and readmission rates should be accurate and the reported gender effect should be real. A distinct benefit of using Medicare data sets is that there is ample representation of women to address issues of gender and that data sets reflect "real world" medicine because they are derived from all types of medical centers.

CONCLUSIONS

Our study is unique in identifying gender-related differences not only postoperatively but long-term after different types of AAA repair. We observed sustained gender-associated disparities in mortality favoring men after all types of repairs in elective and urgent clinical settings. However, it is encouraging that EVAR has decreased long-term mortality in women after aortic aneurysm repair and that the women's survival begins to equal men's after 2 years. Moreover, EVAR has begun to have a positive effect in the urgent clinical setting of acute rupture with a prolonged benefit from this type of intervention. As experience with endovascular interventions grows and devices improve to better fit the female anatomy, we believe that the historic disparities in aortic outcomes between men and women may soon disappear.

AUTHOR CONTRIBUTIONS

Analysis and interpretation: NE, AV, AM, PF, AG, CK, GM
Data collection: NE
Writing the article: NE, AV
Critical revision of the article: NE, AV, AM, PF, AG, CK, GM
Final approval of the article: NE, AV, AM, PF, AG, CK, GM
Statistical analysis: NE
Obtained funding: AG, CK
Overall responsibility: AG

REFERENCES

1. Kent KC. Endovascular aneurysm repair--is it durable? N Engl J Med 2010;362:1930-1.
2. Greenhalgh RM, Brown LC, Powell JT, Thompson SG, Epstein D, Sculpher MJ. Endovascular versus open repair of abdominal aortic aneurysm. N Engl J Med 2010;362:1863-71.
3. De Bruin JL, Baas AF, Buth J, Prinssen M, Verhoeven EL, Cuypers PW, et al. Long-term outcome of open or endovascular repair of abdominal aortic aneurysm. N Engl J Med 2010;362:1881-9.
4. Schermerhorn ML, O'Malley AJ, Jhaveri A, Cotterill P, Pomposelli F, Landon BE. Endovascular vs. open repair of abdominal aortic aneurysms in the Medicare population. N Engl J Med 2008;358:464-74.
5. Egorova N, Giacovelli J, Greco G, Gelijns A, Kent CK, McKinsey JF. National outcomes for the treatment of ruptured abdominal aortic aneurysm: comparison of open versus endovascular repairs. J Vasc Surg 2008;48:1092-100:100:e1-2.
6. McPhee JT, Hill JS, Eslami MH. The impact of gender on presentation, therapy, and mortality of abdominal aortic aneurysm in the United States, 2001-2004. J Vasc Surg 2007;45:891-9.
7. Vouyouka AG, Kent KC. Arterial vascular disease in women. J Vasc Surg 2007;46:1295-302.
8. Johnston KW. Influence of sex on the results of abdominal aortic aneurysm repair. Canadian Society for Vascular Surgery Aneurysm Study Group. J Vasc Surg 1994;20:914-23; discussion: 923-6.
9. Dillavou ED, Muluk SC, Makaroun MS. A decade of change in abdominal aortic aneurysm repair in the United States: Have we improved outcomes equally between men and women? J Vasc Surg 2006;43: 230-8; discussion: 238.

10. Katz DJ, Stanley JC, Zelenock GB. Operative mortality rates for intact and ruptured abdominal aortic aneurysms in Michigan: an eleven-year statewide experience. J Vasc Surg 1994;19:804-15; discussion: 816-7.
11. Norman PE, Semmens JB, Lawrence-Brown MM. Long-term relative survival following surgery for abdominal aortic aneurysm: a review. Cardiovasc Surg 2001;9:219-24.
12. Ouriel K, Greenberg RK, Clair DG, O'Hara PJ, Srivastava SD, Lyden SP, et al. Endovascular aneurysm repair: gender-specific results. J Vasc Surg 2003;38:93-8.
13. Wolf YG, Arko FR, Hill BB, Olcott Ct, Harris EJ, Jr, Fogarty TJ, et al. Gender differences in endovascular abdominal aortic aneurysm repair with the AneuRx stent graft. J Vasc Surg 2002;35:882-6.
14. Ederer F, Axtell LM, Cutler SJ. The relative survival rate: a statistical methodology. Natl Cancer Inst Monogr 1961;6:101-21.
15. Laukontaus SJ, Pettila V, Kantonen I, Salo JA, Ohinmaa A, Lepantalo M. Utility of surgery for ruptured abdominal aortic aneurysm. An Vascul Sur 2006;20:42-8.
16. Mani K, Bjorck M, Lundkvist J, Wanhainen A. Improved long-term survival after abdominal aortic aneurysm repair. Circulation 2009;120: 201-11.
17. Centers for Disease Control and Prevention. Life tables. Available at: http://www.cdc.gov/nchs/products/life_tables.htm. Accessed October 20, 2010.
18. Parson L. Reducing bias in a propensity score matched-pair sample using greedy matching techniques. Proceedings of the 26th Annual SAS Users Group International Conference, p. 214-26; 2001.
19. Rubin DB. Estimating causal effects from large data sets using propensity scores. Ann Intern Med 1997;127:757-63.
20. Austin PC. Assessing balance in measured baseline covariates when using many-to-one matching on the propensity-score. Pharmacoepidemiol Drug Saf 2008;17:1218-25.
21. Austin PC. Goodness-of-fit diagnostics for the propensity score model when estimating treatment effects using covariate adjustment with the propensity score. Pharmacoepidemiol Drug Saf 2008;17:1202-17.
22. Austin PC. Primer on statistical interpretation or methods report card on propensity-score matching in the cardiology literature from 2004 to 2006: a systematic review. Circ Cardiovasc Qual Outcomes 2008;1: 62-7.
23. Ying G, Liu C. Statistical analysis of clustered data using SAS system. Portland, ME: NorthEast SAS Users Group; 2006. p. 1-13.
24. Gharibvand L, Liu L. Analysis of survival data with clustered events. SAS Glob Forum Proc Stat Data Anal 2009;48; paper 237.
25. Katz DJ, Stanley JC, Zelenock GB. Abdominal aortic aneurysms. Semin Vasc Surg 1995;8:289-98.
26. Pedersen OM, Aslaksen A, Vik-Mo H. Ultrasound measurement of the luminal diameter of the abdominal aorta and iliac arteries in patients without vascular disease. J Vasc Surg 1993;17:596-601.
27. Pleumeekers HJ, Hoes AW, van der Does E, van Urk H, Hofman A, de Jong PT, et al. Aneurysms of the abdominal aorta in older adults. The Rotterdam Study. Am J Epidemiol 1995;142:1291-9.
28. Velazquez OC, Larson RA, Baum RA, Carpenter JP, Golden MA, Mitchell ME, et al. Gender-related differences in infrarenal aortic aneurysm morphologic features: issues relevant to Ancure and Talent endografts. J Vasc Surg 2001;33:S77-84.
29. Biebl M, Hakaim AG, Hugl B, Oldenburg WA, Paz-Fumagalli R, McKinney JM, et al. Endovascular aortic aneurysm repair with the Zenith AAA Endovascular Graft: does gender affect procedural success, postoperative morbidity, or early survival? Am Surg 2005;71:1001-8.
30. Silane MF, Conte KM, Fantini GA, Kazam E. Aortic aneurysmal disease in women. Is there a greater incidence of suprarenal involvement? Ann N Y Acad Sci 1996;800:256-7.
31. Lederle FA, Johnson GR, Wilson SE. Abdominal aortic aneurysm in women. J Vasc Surg 2001;34:122-6.
32. Lederle FA, Wilson SE, Johnson GR, Reinke DB, Littooy FN, Acher CW, et al. Immediate repair compared with surveillance of small abdominal aortic aneurysms. N Engl J Med 2002;346:1437-44.
33. United Kingdom Small Aneurysm Trial Participants. Long-term outcomes of immediate repair compared with surveillance of small abdominal aortic aneurysms. N Engl J Med 2002;346:1445-52.
34. Mikhail GW. Coronary heart disease in women. BMJ 2005;331:467-8.
35. Miller M, Byington R, Hunninghake D, Pitt B, Furberg CD. Sex bias and underutilization of lipid-lowering therapy in patients with coronary artery disease at academic medical centers in the United States and Canada. Prospective Randomized Evaluation of the Vascular effects of Norvasc Trial (PREVENT) Investigators. Arch Intern Med 2000;160: 343-7.
36. Enriquez JR, Pratap P, Zbilut JP, Calvin JE, Volgman AS. Women tolerate drug therapy for coronary artery disease as well as men do, but are treated less frequently with aspirin, beta-blockers, or statins. Gend Med 2008;5:53-61.
37. Cheanvechai V, Harthun NL, Graham LM, Freischlag JA, Gahtan V. Incidence of peripheral vascular disease in women: is it different from that in men? J Thorac Cardiovasc Surg 2004;127:314-7.
38. Dunkelgrun M, Boersma E, Schouten O, Koopman-van Gemert AW, van Poorten F, Bax JJ, et al. Bisoprolol and fluvastatin for the reduction of perioperative cardiac mortality and myocardial infarction in intermediate-risk patients undergoing noncardiovascular surgery: a randomized controlled trial (DECREASE-IV). Ann Surg 2009;249: 921-6.
39. Schouten O, Boersma E, Hoeks SE, Benner R, van Urk H, van Sambeek MR, et al. Fluvastatin and perioperative events in patients undergoing vascular surgery. N Engl J Med 2009;361:980-9.
40. Mureebe L, Egorova N, Giacovelli JK, Gelijns A, Kent KC, McKinsey JF. National trends in the repair of ruptured abdominal aortic aneurysms. J Vasc Surg 2008;48:1101-7.
41. Mureebe L, Egorova N, McKinsey JF, Kent KC. Gender trends in the repair of ruptured abdominal aortic aneurysms and outcomes. J Vasc Surg 2010;51:9S-13S.
42. Ailawadi G, Eliason JL, Roelofs KJ, Sinha I, Hannawa KK, Kaldjian EP, et al. Gender differences in experimental aortic aneurysm formation. Arterioscler Thromb Vasc Biol 2004;24:2116-22.

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Additional material for this article may be found online at www.jvascsurg.org.

DISCUSSION

Dr M. Schermerhorn (*Boston, Mass*): We've known that men and women are different for a while now. There is a lower prevalence of aneurysms in women, they tend to occur later in life, and they've got a higher rupture risk at any given diameter, and women typically live longer than men. Your analysis has discovered some important additional differences.

Why do you think there is this perioperative mortality difference between men and women? With many vascular surgical procedures we've assumed it's because of smaller arteries, but I'm not sure that holds true for an aortic tube graft.

Since women are supposed to live longer than men, why don't they after an aortic aneurysm repair?

As you showed, the EVAR-1, DREAM, and our prior Medicare analysis, showed the survival curves coming together after just a couple of years and we've heard many theories as to why this happens. Your analysis forces us to re-think these theories and I'd like to get your thoughts on why the curves come together in the men and why don't they come together in the women.

Finally, I'd like to thank you for highlighting that we all need to start thinking about the potential for gender disparities in other procedures as well.

Dr Egorova: As we all know, large data set analysis generates new hypotheses that can be verified in future clinical studies. The current analysis showed that women compared to men had higher perioperative mortality. The long-term survival was worse for women after elective open repair and emergent repair of ruptured AAA. The reasons for these gender disparities are not well understood but certain hypothesis can be made.

Answer to question 1. Similar to any kind of vascular reconstruction, immediate mortality after AAA was higher for women than for men. We think that vascular anatomy (smaller arteries) and devices not made to fit female anatomy play significant role. But we agree that there are other not well understood factors responsible for the higher mortality in women. One possible explanation is that women tend to have unrecognized cardiovascular disease and other, not well identified risk factors preoperatively and thus are not as well optimized as their male counterparts before the surgery. There is ample literature suggesting that cardiovascular disease in women is more likely to be under-diagnosed, and when recognized, women are less likely to be on aspirin, beta-blockers and statins. Lack of aggressive treatment of cardiovascular disease may contribute to higher mortality after procedures but, obviously, further research is needed to give all the answers.

Answer to question 2. We also observed a difference in long-term survival between men and women. It is well-known that women live 6-7 years longer and should be able to catch up to men in the long-term despite the initial perioperative disadvantage. And they do after elective EVAR when the survival curves of men and women coincide 2 years after surgery. The different pattern of survival was observed after elective open repair and repair of ruptured AAA. The survival curves remained parallel for the entire follow-up period with better survival for men. One speculation is that these procedures, as opposed to elective EVAR, cause significantly more stress to women. The recovery is more difficult and prolonged, and women are less likely than men to return to their preoperative level of function. In addition, women usually do not have the same level of socioeconomic support compared to men of the same advanced age. In fact, studies have shown that after any vascular procedure women are less likely than men to return home and are more likely to end up in an extended care facility. Level of function and long-term institutionalization influences significantly long-term survival. Again, we think that there are many other parameters that cause such sustained discrepancy between genders and would like to explore more of these findings in the future papers.

Answer to question 3. Finally, we observed small but sustained difference in survival for 6 years between women undergoing open repair and women undergoing EVAR, favoring EVAR. Differences in functionality after the two procedures probably play some role in this finding. However, we are very curious to see if other authors utilizing different databases will replicate our observations and we are eager to further investigate this finding by analyzing causes of death and diagnoses at readmissions after the two procedures.

Appendix Table O1. (online only). List of International Classification of Diseases, 9th Clinical Modification (*ICD-9-CM*) codes for comorbidities and complications

Variable	*ICD-9-CM code*
Comorbidities: Index hospitalization	
Congestive heart failure	398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.91, 404.13, 404.93, 425.4, 425.5, 425.7, 425.8, 425.9, 428.0, 428.1, 428.20, 428.22, 428.30, 428.32, 428.40, 428.42, 428.9
Cardiac arrhythmia	426.0, 426.10, 426.11, 426.12, 426.13, 426.7, 426.9, 427.0, 427.1, 427.2, 427.3, 427.9, V45.0, V53.3
Valvular disease	093.2, 394, 395, 396, 397, 424, V42.2, V43.3
Coronary disease	412, 413, 414, 429.2
Diabetes	250
Hypertension	401, 402, 403, 404, 405
Pulmonary diseases	416, 417.9, 490, 491, 492, 493, 494, 495.0, 495.1, 495.2, 495.3, 495.4, 495.5, 495.6, 495.8, 495.9, 496, 500, 501, 502, 503, 504, 505, 506.0, 506.2, 506.4, 506.9, 508.1, 508.8, 508.9
Clinically significant lower extremity vascular diseases	440.22, 440.23, 440.24, 440.3, 444.22, V43.4,
Renal atherosclerosis	440.1
Vascular intestine disease	557.1
Renal failure w dialysis	V45.1, V56.0, V56.1, V56.2, V56.3, V56.8, 585.6, 39.95 (w/o 586)
Renal failure without dialysis	403.01, 403.11, 403.91, 404.02, 404.03, 404.12, 404.13, 404.92, 404.93, 585 (w/o 585.6), 588.0
Other renal diseases	582, 583.0, 583.1, 583.2, 583.4
Kidney transplant	V420
Liver disease	070.22, 070.23, 070.32, 070.33, 070.44, 070.54, 070.9, 456.0, 456.1, 571, 572.1, 572.2, 572.3, 572.4, 572.8, 573.0, 573.1, 573.8, 573.9
Cerebrovascular diseases and paralysis	342, 344.1, 344.3, 344.4, 344.5, 344.9, 437.0, 438
Other neurological diseases	330, 331, 332, 333, 334.0, 334.1, 334.2, 334.4, 334.8, 335.0, 335.1, 335.2, 335.8, 335.9, 336.0, 336.2, 343, 344.0, 348.1, 348.3, 344.2, 344.6, 345, 437.3, 437.4, 437.5, 437.6, 437.7
Hyperlipidemia	272
Cancer	140, 141, 142, 143, 144,145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158,159, 160, 161, 162, 163, 164, 165, 170, 171,172, 174, 175, 176, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203.0, 238.6
Rheumatoid arthritis	446, 701.0, 710.0, 710.1, 710.2, 710.3, 710.4, 710.8, 710.9, 711.2, 719.3, 714, 720, 725, 728.5, 728.89
Comorbidities: Preindex hospitalizations	
History of heart failure	398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.91, 404.13, 404.93, 425.4, 425.5, 425.7, 425.8, 425.9, 428
Cardiac arrhythmia	426, 427.0, 427.1, 427.2, 427.3, 427.4, 427.5, 785.0, 996.01, 996.04, V45.0, V53.3
Valvular disease	093.2, 394, 395, 396, 397, 424, V42.2, V43.3
Coronary disease	410, 412, 413, 414, 429.2
Pulmonary	415, 416, 417, 490, 491, 492, 493, 494, 495, 496, 500, 501, 502, 503, 504, 505, 506.0, 506.2, 506.4, 506.9, 508
Clinically significant lower extremity vascular diseases	440.22, 440.23, 440.24, 440.3, 444.22, 996.7, V43.4
Renal atherosclerosis	440.1, 445.81
Vascular intestine disease	557.1, 557.9
Hypertension	401, 402, 403, 404, 405, 458.0, 458.1, 458.8, 458.9
Hyperlipidemia	272
Cerebrovascular diseases and paralysis	342, 344.1, 344.3, 344.4, 344.5, 344.9, 362.30, 362.31, 362.34, , 433, 434, 435, 436, 437.8, 437.9, 438, 784.3
Other neurological diseases	330, 331, 332, 333, 334.0, 334.1, 334.2, 334.3, 334.4, 334.8, 334.9, 336.0, 335.0, 335.1, 335.2, 335.8, 335.9, 336.0, 336.2, 340, 343, 344.0, 344.2, 344.6, 345, 348.1, 348.3, 430, 431, 432, 437.3, 437.4, 437.5, 437.6, 437.7, 780.3
Diabetes	250
Dialysis	V45.1, V56.0, V56.1, V56.2, V56.3, V56.8, 585.6, 39.95
Renal failure without dialysis	403.01, 403.11, 403.91, 404.02, 404.03, 404.12, 404.13, 404.92, 404.93, 585 (w/o 585.6), 586, 588.0
Renal diseases	582, 583.0, 583.1, 583.2, 583.4, 583.6, 583.7
Liver disease	070.22, 070.23, 070.32, 070.33, 070.44, 070.54, 070.6, 070.9,456.0, 456.1, 456.2, 571, 572.2, 572.3, 572.4, 572.8, 573

Appendix Table O1 (online only). Continued

Variable	*ICD-9-CM code*
Cancer	140, 141, 142, 143, 144,145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158,159, 160, 161, 162, 163, 164, 165, 170, 171,172, 174, 175, 176, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203.0, 238.6
Kidney transplant	V42.0
Rheumatoid arthritis	446, 701.0, 710.0, 710.1, 710.2, 710.3, 710.4, 710.8, 710.9, 711.2, 719.3, 714, 720, 725, 728.5, 728.89, 729.30
Complications	
Cardiac	
Postoperative cardiac	997.1
Acute myocardial infarction	410.00, 410.01, 410.10, 410.11, 410.20, 410.21, 410.30, 410.31, 410.40, 410.41, 410.50, 410.51, 410.60, 410.61, 410.70, 410.71, 410.80, 410.81, 410.90, 410.91, 411.0, 411.1, 411.81, 411.89
Cardiac arrest	427.5
Acute CHF	428.21, 428.3, 428.31, 428.32, 428.41, 428.43
Acute dialysis	38.95
Pulmonary	
Postoperative respiratory	997.3
Pulmonary collapse	518.0
Pulmonary edema	518.4
Postoperative pulmonary insufficiency	518.4
Respiratory failure	528.81, 518.82, 518.84
Pneumonia	481, 482.0, 482.1, 482.2, 482.30, 482.31, 482.32, 482.39, 482.81, 482.82, 482.83, 482.84, 482.89, 482.9, 485, 486
Pulmonary heart complications	415.0, 415.11, 415.12, 415.19
Tracheostomy	31.1, 31.29
Arterial reinterventions (thrombectomy, embolectomy, catheter based and open reconstructions cross-referenced with diagnoses of AAA)	38.03, 38.04, 38.06, 38.08, 38.18, 38.38, 38.48, 38.86, 38.88, 39.24, 39.26, 39.49, 39.50, 39.59, 39.79, 39.90, 44.44, 88.42, 84.13, 84.14, 84.15, 84.16, 84.17, 88.42
Reinterventions for incision or laparotomy related complications (incisional, groin or abdominal wall hernia repairs, intestinal postoperative obstruction, postoperative adhesion)	53.0, 53.1, 53.2, 53.3, 53.5, 53.6, 54.1, 560.81, 568.0

Appendix Table O2. (online only). Demographics and comorbidities of matched patients undergoing open (*OAR*) or endovascular (*EVAR*) elective repair of aortic abdominal aneurysm

	Women			*Men*		
Variable	*OAR (n = 9080)*	*EVAR (n = 9080)*	P	*OAR (n = 33,240)*	*EVAR (n = 33,240)*	P
Age, years	76.7	76.8	.3841	75.4	75.5	.1271
Age groups, %						
70-74	24.7	25.0	.655	27.0	27.5	.1743
75-79	29.4	29.4	.935	27.7	27.8	.7674
80-84	21.2	21.0	.7714	17.8	17.1	.0377
≥85	9.5	9.4	.7796	6.1	6.3	.2663
White race, %	90.4	90.8	.4142	94.8	94.9	.3998
Comorbidities, %						
Hypertension	77.1	76.5	.3486	70.9	69.9	.0064
Atherosclerosis	20.4	20.8	.5691	16.9	16.8	.6105
PAD	26.1	27.3	.0721	20.2	20.4	.4699
Pulmonary	43.6	43.0	.4412	37.5	37.4	.7597
Coronary	41.4	41.4	.952	55.2	54.7	.1823
Valvular	10.6	10.6	.9809	9.4	9.3	.6693
Arrhythmia	22.0	22.1	.8994	28.2	27.9	.3764
CHF	16.3	16.4	.8568	15.6	15.6	.9915
Hyperlipidemia	40.1	38.8	.0824	40.2	38.3	<.0001
Neurologic disorder	4.7	4.7	.8611	4.6	4.6	.9556
Renal failure	6.0	6.0	1	6.4	6.0	.027
Liver disease	1.1	1.2	.8897	1.2	1.1	.6343
Cancer	4.8	4.6	.5984	7.7	8.0	.1979
Diabetes	14.2	14.1	0.8806	15.6	15.1	.0836
Annual volume in OAR						
Surgeon	7.29	7.01	.0028	7.93	7.66	<.0001
Hospital	25.47	25.57	.7894	27.64	27.83	.3711
Annual volume in EVAR						
Surgeon	8.14	9.28	<.0001	6.79	7.97	<.0001
Hospital	24.23	24.83	.0827	21.91	22.65	<.0001

CHF, Congestive heart failure; *PAD,* peripheral arterial disease.

Appendix Table O2 (online only). Continued

EVAR			*OAR*		
Men (n = 13,710)	*Women (n = 13,710)*	P	*Men (n = 59,279)*	*Women (n = 59,279)*	P
77.4	77.4	.8964	75.4	75.4	.0252
22.3	23.0	.129	29.4	29.4	.8937
27.4	28.2	.1705	28.8	28.8	1
23.7	22.4	.0093	16.4	16.4	.7751
12.3	12.5	.6887	5.9	5.8	.6276
90.9	90.9	.9603	92.7	92.5	.0472
78.1	78.2	.8571	68.5	68.2	.3835
21.3	21.5	.6542	19.7	19.9	.464
27.0	27.8	.1345	26.9	27.7	.0017
42.5	41.9	.3089	41.4	41.6	.5458
42.4	42.4	.9411	37.9	38.2	.3764
10.6	10.7	.8445	9.6	9.7	.5312
20.2	20.7	.323	22.7	22.9	.2803
15.8	16.0	.5531	17.7	17.9	.4552
40.5	41.3	.1727	24.0	24.4	.1004
4.9	5.0	.8895	3.7	3.8	.6022
5.9	6.1	.4893	4.1	4.1	.8378
1.3	1.1	.247	1.2	1.2	.9574
4.9	4.8	.6536	3.8	3.9	.6264
15.1	14.9	.6823	9.8	10.0	.1675
6.64	6.66	.8257	10.72	10.76	.5635
25.22	25.24	.951	34.22	34.51	.0914
14.48	14.42	.7576	1.91	1.95	.1699
32.81	32.80	.9777	7.00	7.11	.2345

Appendix Table O3 (online only). Demographics and comorbidities of matched patients undergoing open (*OAR*) or endovascular (*EVAR*) repair of ruptured aortic abdominal aneurysm (*rAAA*)

	Women			Men		
Variable	*OAR (n = 495)*	*EVAR (n = 495)*	P	*OAR (n = 1421)*	*EVAR (n = 1421)*	P
Year of AAA repair	2004	2004	.0005	2004	2004	<.0001
Age, years	78.3	78.7	.03845	77.3	77.4	.07916
Age groups, %						
65-69	13.7	13.7	1	16.7	16.0	.6465
70-74	18.6	17.4	.6242	23.6	23.4	.9304
75-79	27.1	23.6	.2211	22.9	24.3	.3805
80-84	23.0	26.5	.2374	22.6	22.0	.715
≥85	17.6	18.8	.6242	14.2	14.1	.9578
Race, %						
White	89.1	87.7	.4861	92.8	92.5	.8307
Black	7.9	10.5	.1585	5.2	5.3	.8685
Hispanic	1.0	0.4	.2568	0.7	0.8	.8273
Other race	2.0	1.4	.4669	1.3	1.3	1
Comorbidities, %						
Coronary	33.5	30.3	.2807	38.0	36.7	.4761
Valvular	9.1	7.9	.4969	8.4	8.1	.7835
Arrhythmia	37.8	33.5	.1596	34.3	33.3	.5529
CHF	25.1	26.5	.6008	22.4	22.4	1
Pulmonary	39.8	38.0	.5467	37.9	39.1	.5116
Cerebrovascular	8.7	7.5	.4969	8.3	6.8	.1366
Neurologic	7.3	6.7	.7009	5.9	6.3	.6394
Renal failure	12.5	11.7	.6949	11.2	11.5	.8104
PAD	13.3	15.2	.4171	14.5	12.9	.2287
Diabetes	11.7	12.1	.8383	9.8	10.8	.374
Liver disease	2.0	1.6	.6171	1.5	1.3	.5164
Cancer	6.3	6.1	.8946	7.1	7.5	.7175
Hypertension	65.5	63.8	.601	60.9	58.8	.2186
Hyperlipidemia	25.3	21.8	.2013	18.9	19.4	.7267
Annual volume						
rAAA hospital	5.5	5.1	.0917	5.29	5.12	.2266
rAAA surgeon	2.1	2.1	.9247	2.10	2.11	.8096
OAR surgeon	6.5	5.9	.1317	5.81	5.56	.2111
EVAR surgeon	9.7	10.2	.1875	8.73	9.34	.0129
OAR hospital	25.6	23.9	.2458	23.42	23.17	.7753
EVAR hospital	28.1	28.3	.9198	26.10	26.66	.5316

CHF, Congestive heart failure; *PAD,* peripheral arterial disease.

Appendix Table O3 (online only). Continued

EVAR			*OAR*		
Men (n = 499)	*Women (n = 499)*	P	*Men (n = 10,911)*	*Women (n = 10,911)*	P
2004	2004	.07734	2000	2000	.04701
78.7	78.7	9749	78.0	78.1	.1532
11.8	13.6	.3843	12.8	13.2	.3241
18.8	17.2	.4576	21.5	21.4	.7437
23.6	23.4	.9414	25.9	26.0	.8705
28.5	26.7	.5082	22.7	22.7	.9171
17.2	19.0	.4317	17.1	16.7	.4073
87.6	87.8	.9126	91.4	91.0	.3039
11.0	10.4	.729	6.2	6.3	.5221
0.6	0.6	1	0.5	0.5	.6222
0.8	1.2	.5271	2.0	2.1	.5055
33.7	31.1	.3494	24.3	24.5	.6632
7.8	8.0	.9104	6.6	6.7	.7419
35.1	33.3	.5394	26.9	26.8	.9003
25.3	26.3	.7055	23.4	24.3	.1254
38.3	38.1	.9503	37.5	37.2	.6071
7.8	7.8	1	6.3	6.3	.8878
5.4	7.0	.2935	5.9	6.6	.032
9.2	11.8	.1869	6.5	6.5	.7835
15.2	15.6	.8575	11.7	11.5	.6085
12.4	12.0	.846	9.4	9.4	.8888
1.4	1.6	.7963	1.1	1.2	.7513
6.6	6.6	1	3.1	3.0	.5977
63.3	63.7	.8886	52.6	52.6	.9882
24.6	22.0	.3285	10.5	10.6	.7238
5.098196	5.116233	.9403	4.6	4.6	.5611
2.188377	2.120241	.4668	2.0	2.0	.7032
6.066132	5.923848	.7506	7.1	7.2	.3662
11.83968	11.31864	.5843	1.4	1.4	.5202
24.19038	24.18637	.998	25.1	25.5	.3707
31.10421	29.88176	.5747	6.2	6.0	.3712