Epidemiology of aortic aneurysm repair in the United States from 2000 to 2010

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Objective: **Broad application of endovascular aneurysm repair (EVAR) has led to a rapid decline in open aneurysm repair (OAR) and improved patient survival, albeit at a higher overall cost of care. The aim of this report is to evaluate national trends in the incidence of unruptured and ruptured abdominal aortic aneurysms (AAAs), their management by EVAR and OAR, and to compare overall patient characteristics and clinical outcomes between these two approaches.**

Methods: **A retrospective analysis of the cross-sectional National Inpatient Sample (2000-2010) was used to evaluate patient characteristics and outcomes related to EVAR and OAR for unruptured and ruptured AAAs. Data were extrapolated to represent population-level statistics through the use of data from the U.S. Census Bureau. Comparisons between groups were made with the use of descriptive statistics.**

Results: **There were 101,978 patients in the National Inpatient Sample affected by AAAs over the 11-year span of this study; the average age was 73 years, 21% were women, and 90% were white. Overall in-hospital mortality rate was 7%, with a median length of stay (LOS) of 5 days and median hospital charges of $58,305. In-hospital mortality rate was 13 times greater for ruptured patients, with a median LOS of 9 days and median charges of $84,744. For both unruptured and ruptured patients, EVAR was associated with a lower in-hospital mortality rate (4% vs 1% for unruptured and 41% vs 27% for ruptured; $P < .001$ for each), shorter median LOS (7 vs 2; 9 vs 6; $P < .001$) but a 27%-36% increase in hospital charges.**

Conclusions: **The overall use of EVAR has risen sharply in the past 10 years (5.2% to 74% of the total number of AAA repairs) even though the total number of AAAs remains stable at 45,000 cases per year. In-hospital mortality rates for both ruptured and unruptured cases have fallen by more than 50% during this time period. Lower mortality rates and shorter LOS despite a 27%-36% higher cost of care continues to justify the use of EVAR over OAR. For patients with suitable anatomy, EVAR should be the preferred management of both ruptured and unruptured AAAs. (J Vasc Surg 2014;59:1512-7.)**

Abdominal aortic aneurysms (AAAs) have a prevalence as high as 8%, depending on the criteria used for diagnosis.[1] Repair is indicated for symptomatic patients or any patient who can tolerate repair with an aneurysm larger than 5.0-5.5 cm as prophylaxis against rupture.[2] The mainstay of AAA repair has been open aneurysm repair (OAR) since 1951, when it was first described by Dubost, Cooley, and DeBakey.[3] OAR was the preferred approach, given its long-term durability and lack of a suitable alternative that could effectively treat this disease.[4]

The advent of endovascular aneurysm repair (EVAR) for AAA has led to a transformation in the management of this disease. Improved short-term mortality, shorter length of stay (LOS), and expanded use in critically ill patients have been realized with advancements in endograft technology.[5-7]

Although several trials have compared OAR with EVAR, the epidemiology and trends in management have not been documented at the population level in the endovascular era.[5,6,8,9] The national incidence of AAA disease, including the rates of ruptured aneurysm, the preferred modality for repair, and outcomes associated with various types of intervention, also remain unclear. This study aims to compare patient characteristics and outcomes for patients with AAAs who undergo EVAR to OAR through the use of a large national database over an 11-year period.

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METHODS

Database and selection. A retrospective analysis was completed with the use of the National Inpatient Sample (NIS), a part of the Health Care Utilization Project (HCUP) that is maintained by the Agency for Healthcare Research and Quality (AHRQ). The NIS is the largest all-payer inpatient database and includes a stratified 20% random sample of all nonfederal inpatient hospital admissions throughout the United States. Clinical records between 2000 and 2010 were derived into a two-step process with the use of the International Classification of Diseases,

Table I. ICD-9 diagnosis and procedure codes used to select patients from the NIS

ICD-9 code	*Description*
Diagnosis codes	
441.4	Abdominal aortic aneurysm without mention of rupture
441.9	Aortic aneurysm, not otherwise specified
441.3	Ruptured abdominal aortic aneurysm
441.5	Ruptured aortic aneurysm, not otherwise specified
441.6	Ruptured thoraco-abdominal aortic aneurysm
Procedure codes	
38.34	Aorta resection and anastomosis
38.44	Replacement of abdominal aorta
38.64	Excision of aorta
39.52	Other repair of aneurysm
39.71	Endovascular abdominal aorta repair

ICD-9, International Classification of Diseases, Ninth Revision; *NIS,* National Inpatient Sample.

Ninth Revision (ICD-9) diagnosis and procedure codes to ensure that the sample included patients who underwent treatment primarily for AAAs (Table I).

Variables. The independent variable was year, ranging from 2000 to 2010. The year 2000 was chosen for the start of the analysis because this is the first year that EVAR is coded separately in the NIS. Demographic covariates included age, sex, and race. Clinical covariates included comorbid conditions such as chronic obstructive pulmonary disease (COPD), diabetes mellitus (DM), and history of myocardial infarction (MI). Hospital covariates included in-hospital mortality, median LOS in days, and median hospital charges adjusted for 2010 U.S. dollars by use of the consumer price index.

Statistical analysis. Statistical analysis was completed with the use of analysis of variance for continuous variables (ie, age) and χ^2 test for categorical variables (ie, sex, race, and mortality). The Mann-Whitney *U* test was used for LOS and total charges. Data analysis and management were completed with the use of the IBM SPSS software package (SPSS version 21.0; SPSS Inc, Chicago, Ill). Statistical significance was set at a level of $P < .05$. Population estimates were made by means of discharge sampling weights included within the NIS and data published by the U.S. Census Bureau; these estimates were used to adjust for population growth over time and present in-hospital mortality data as incidence per 100,000 people. Values are presented as mean ± standard deviation for age or as median with interquartile range (IQR) in parentheses. Tests for significance when comparing EVAR results from 2000 to 2010 used numbers pooled from 2000 and 2001 compared with 2010 to achieve sufficient power; there was no significant difference between the 2000 and 2001 numbers.

RESULTS

Demographics, comorbidities, and hospital covariates. A total of 101,978 patients with AAAs were identified in the NIS between 2000 and 2010, of which 90,690 were unruptured and 11,288 were ruptured. The mean age for patients was 72.6 ± 8.7 years (Table II). Women comprised 21% of all patients and whites comprised 90%. The incidence of COPD was 32%; DM, 14%; and history of MI, 11%.

Table II. Demographics and outcomes for patients who underwent AAA repair in the NIS from 2000 to 2010

		Aneurysm type		
	Total	*Unruptured*	*Ruptured*	P *value*
Number	101,978	90,690	11,288	
Patient age in years ± SD	72.6 ± 8.7	72.5 ± 8.6	73.0 ± 9.3	<.001
Women, %	21	21	24	<.001
White, %	90	90	87	<.001
Comorbid conditions, %				
COPD	32	32	31	.177
DM	14	15	11	<.001
History of MI	11	12	5	<.001
In-hospital mortality rate	7	3.0	39	<.001
Median LOS (IQR), days	5 (2-8)	5 (2-8)	9 (3-17)	<.001
Median hospital charges (IQR)	$58,305 ($38,832-$90,508)	$56,537 ($38,178-$85,495)	$84,744 ($48,049-$158,226)	<.001

AAA, Abdominal aortic aneurysm; *COPD,* chronic obstructive pulmonary disease; *DM,* diabetes mellitus; *IQR,* interquartile range; *LOS,* length of stay; *MI,* myocardial infarction; *NIS,* National Inpatient Sample; *SD,* standard deviation.

Patients with unruptured AAAs had a 3% in-hospital mortality rate, median LOS of 5 days, and median hospital charges of $56,537. Patients with ruptured AAAs had a 39% in-hospital mortality rate, median LOS of 9 days, and median hospital charges of $84,744.

Type of repair. A total of 42,642 patients underwent OAR and 48,048 patients underwent EVAR for unruptured AAAs (Table III). Patients who underwent EVAR were older (73.6 vs 71.3 years) and male (83% vs 76%) compared with those who had open repair. There was no racial bias. Patients who underwent EVAR were less likely to have COPD but more likely to have DM and a history of MI. In-hospital mortality rate was 1% for EVAR and 4% for OAR (odds ratio, 4.8; $P < .001$), with a median LOS of 2 days vs 7 days. Median total charges were 36% greater for EVAR compared with OAR.

A total of 9538 patients underwent OAR and 1750 underwent EVAR for ruptured AAAs (Table IV). Patients undergoing EVAR tended to be older (74.0 vs 72.9 years) compared with those undergoing OAR. There was no statistical difference with regard to age or race. Whereas there was no statistical difference in the incidence of COPD, patients who underwent EVAR for ruptured AAAs were more likely to have DM and a history of MI. Despite the higher incidence of comorbidities, in-hospital mortality rate was 27% for EVAR and 41% for OAR (odds ratio, 1.7; $P < .001$). Median LOS was lower for EVAR (6 vs 9), but median total charges were 27% greater.

Table III. Demographics of patients who underwent open vs endovascular repair for an unruptured AAA in the NIS from 2000 to 2010

	Aneurysm repair type		
	Open	*Endovascular*	P *value*
Number	42,642	48,048	
Patient age in years ± SD	71.3 ± 8.6	73.6 ± 8.4	<.001
Women, %	24	17	<.001
White, %	90	90	.628
Comorbid conditions, %			
COPD	35	31	<.001
DM	12	16	<.001
History of MI	9	13	<.001
In-hospital mortality rate	4	1	<.001
Median LOS (IQR), days	7 (5-10)	2 (1-4)	<.001
Median hospital charges (IQR)	$46,935 ($31,733-$77,073)	$63,623 ($45,954-$90,144)	<.001

AAA, Abdominal aortic aneurysm; *COPD,* chronic obstructive pulmonary disease; *DM,* diabetes mellitus; *IQR,* interquartile range; *LOS,* length of stay; *MI,* myocardial infarction; *NIS,* National Inpatient Sample; *SD,* standard deviation.

Table IV. Demographics of patients who underwent open vs endovascular repair for a ruptured AAA in the NIS from 2000 to 2010

	Aneurysm repair type		
	Open	*Endovascular*	P *value*
Number	9538	1750	
Patient age in years ± SD	72.9 ± 9.2	74.0 ± 10.0	<.001
Women, %	24	22	.181
White, %	87	85	.056
Comorbid conditions, %			
COPD	30	32	.207
DM	11	14	<.001
History of MI	4	7	<.001
In-hospital mortality rate	41	27	<.001
Median LOS (IQR), days	9 (3-18)	6 (3-14)	<.001
Median hospital charges (IQR)	$80,574 ($45,824-$154,735)	$101,928 ($66,016-$171,588)	<.001

AAA, Abdominal aortic aneurysm; *COPD,* chronic obstructive pulmonary disease; *DM,* diabetes mellitus; *IQR,* interquartile range; *LOS,* length of stay; *MI,* myocardial infarction; *NIS,* National Inpatient Sample; *SD,* standard deviation.

Trends from 2000 to 2010. There was a slight decrease in incidence of unruptured and ruptured AAA (unruptured AAA, 13.93 to 12.83/100,000; ruptured AAA, 2.10 to 1.39/100,000) (Fig 1). The overall number of AAAs in the U.S. population remained unchanged over this period after correcting for population growth (45,230 estimated total cases in 2000 vs 44,005 cases in 2010).

In 2000, 5.2% of all AAAs were repaired by EVAR (5.9% for unruptured and 0.8% of ruptured AAAs) (Fig 2). By 2010, 74.0% of all AAAs were repaired by EVAR (77.8% for unruptured and 38.4% of ruptured AAAs). Although in-hospital mortality rates remained stable for OAR in unruptured patients (3.8% to 4.8%; $P >$ .05), it declined for EVAR (1.8%-2.1% to 0.9%; $P =$ .001) (Fig 3). Over the same time period, mortality rates for ruptured AAAs repaired by means of OAR decreased from 44.5% to 33.4% ($P <$ .001); those patients undergoing EVAR had a similar decrease for in-hospital mortality rate (40.0%-40.8% to 19.8%; $P <$ .001).

No significant difference was found with regard to LOS, in-hospital mortality rates, and total charges for unruptured AAAs, ruptured AAAs, EVAR, and OAR from 2000 to 2010. For this reason, the data presented in Tables II through IV are presented as means for the entire time period. Comparisons between groups remained valid for all years.

DISCUSSION

AAA disease remains most common in older white men, with rupture leading to aneurysm repair in approximately 11% of all patients admitted to the hospital. Those who present with rupture are more likely to be older, female, and nonwhite compared with unruptured AAAs. Nonwhite women in particular may be more likely to present with rupture as the result of rupture occurring at relatively smaller aneurysm diameters and limited access to care because of health insurance status.[10,11] Racial disparities are less than previously estimated, whereas sex

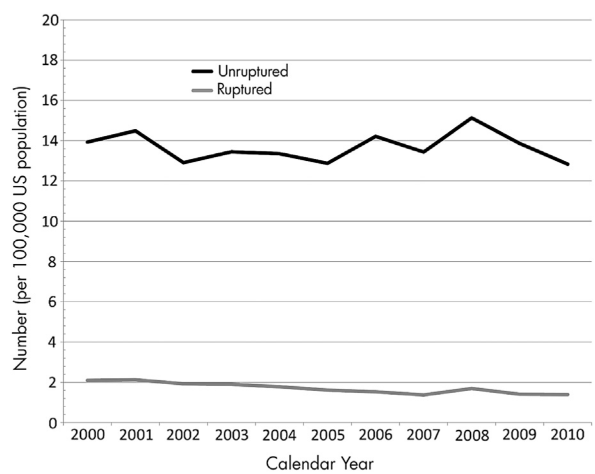

Fig 1. Population estimates for unruptured (*dark line*; *top*) and ruptured (*light line*; *bottom*) abdominal aortic aneurysms (AAAs) treated in the United States from 2000 to 2010. The number of unruptured AAAs decreased from 13.93 cases per 100,000 people to 12.83 cases per 100,000 people from 2000 to 2010. A similar trend in ruptured AAAs cases was also seen, declining from 2.10 cases per 100,000 people in 2000 to 1.39 cases per 100,000 people in 2010.

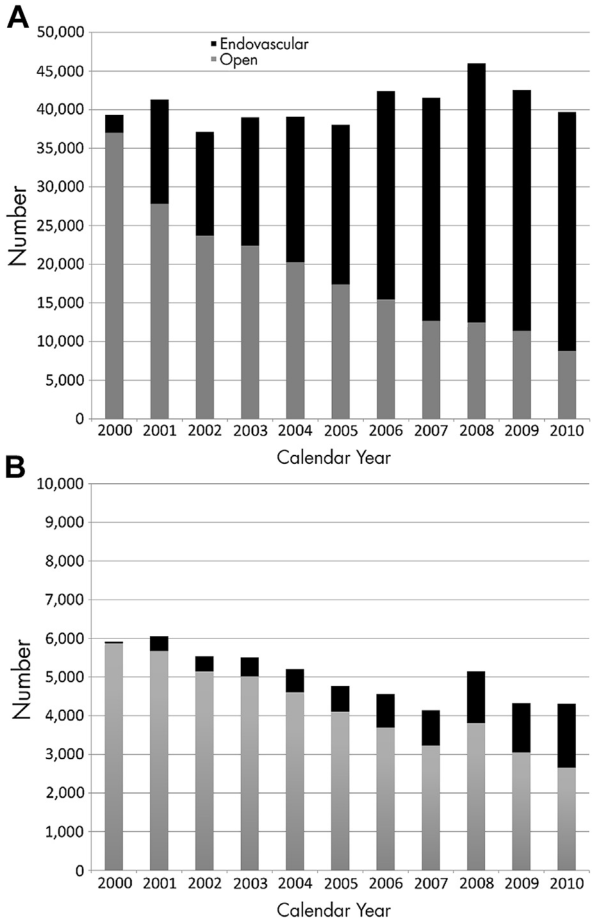

Fig 2. Estimated number of endovascular (*dark boxes*; *top*) and open (*light boxes*; *bottom*) abdominal aortic aneurysm (AAA) repairs performed in the United States from 2000 to 2010. **A,** Unruptured AAAs; **B,** ruptured AAAs.

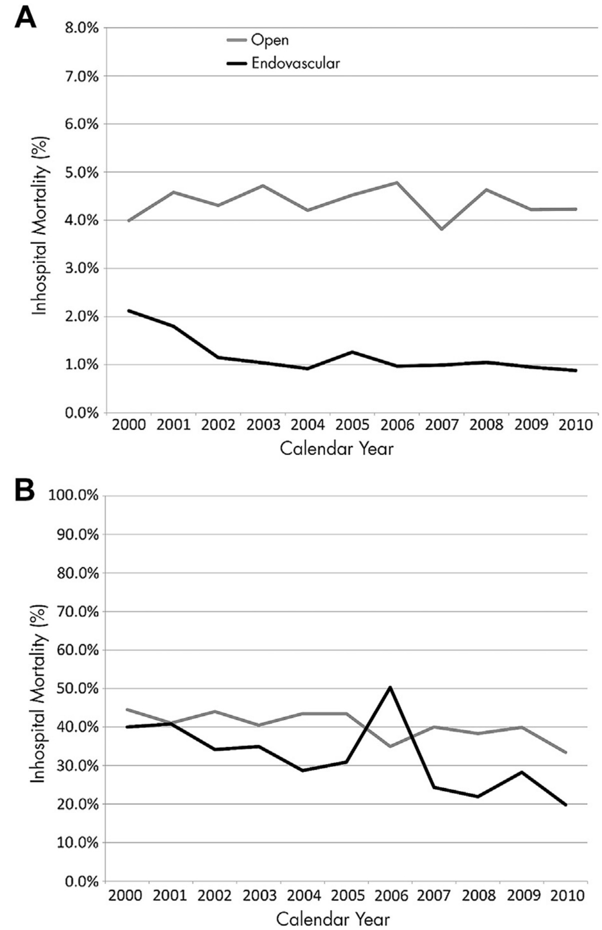

Fig 3. In-hospital mortality rates by endovascular (*dark line*) and open (*light line*) repair for unruptured abdominal aortic aneurysms (AAAs) **(A)** and ruptured AAAs **(B)**. In-hospital mortality rates from open cases for unruptured AAAs increased slightly from 3.8% to 4.8% ($P > .05$) from 2000 to 2010. During this same period, in-hospital mortality rates from EVAR declined from 2.1% to 0.9% ($P > .05$). For ruptured aneurysms, mortality rates from open repair declined from 44.5% to 33.4% ($P < .05$) from 2000 to 2010 and from a peak of 50.3% in 2006 to 19.8% in 2010 ($P > .05$).

disparities appear to be greater than expected.[12] This is consistent with other studies that have shown that women with AAAs are more likely than men to present with rupture.[2,13] Despite the higher incidence of ruptured AAAs in nonwhites, this racial disparity does not appear to influence procedure type with regard to EVAR vs OAR. Sex differences are also muted, with only OAR more likely to be performed in women with unruptured AAAs. This latter finding may reflect the difficult and often smaller iliac artery access issues found in women that preclude endovascular management, a trend that is beginning to change with the introduction of low-profile devices.

The median LOS remains shorter for EVAR patients regardless of rupture status. The difference is most marked when comparing median LOS in unruptured patients, in whom the median LOS was 2 days (IQR, 1-4 days) for EVAR compared with 7 days (IQR, 5-10 days) for OAR. The differences fade somewhat when comparing median LOS for ruptured patients, with EVAR at 6 days (IQR, 3-14 days) and OAR at 9 days (IQR, 3-18 days); this is similar to what has been found in several long-term trials.[5,7-9]

Median hospital charges are 36% greater for patients undergoing EVAR for unruptured AAAs and 27% greater for patients undergoing EVAR for ruptured AAAs when compared with OAR. When combined with the results of two recent meta-analyses, the long-term charges for EVAR are likely to be even greater, given a 56% greater intermediate reintervention rate and 243% greater long-term reintervention rate.[7,14] Although long-term survival after AAA repair is similar between EVAR and AAA for unruptured AAA, the greater survival in EVAR patients within the first 2 years may confer some overall cost savings when taking into account the value of a statistical life analysis.[15,16] When considering EVAR for ruptured AAAs, there is a statistically significant long-term survival benefit to EVAR, which may compensate for the higher cost of care associated with EVAR.[17]

Inpatient mortality rate is significantly lower for EVAR patients regardless of rupture status. Patients undergoing OAR for unruptured AAAs are 4.8 times more likely to die in the hospital than are EVAR patients, even though EVAR patients are more likely to be older and have more comorbidities. A less pronounced difference is found for ruptured AAA patients, in which OAR patients are 1.7 times more likely to die compared with EVAR.[9,17]

In 2010, patients with ruptured AAAs who undergo OAR are nearly eight times more likely to die than are their counterparts who undergo elective repair. Those who undergo EVAR for rupture are nearly 22 times more likely to die than those who undergo elective EVAR. Overall, patients are 15 times more likely to die with a ruptured AAA than if they undergo elective repair.

Overall, the total number of AAA cases remains stable at approximately 45,000 cases per year, primarily as the result of the size threshold for repair being held constant despite the ease of repair offered by endovascular therapy. There is, however, a 72% decline in OAR from 2000 to 2010, with EVAR comprising 74% of the AAA repair volume in 2010. Overall, in-hospital mortality rates have declined for EVAR in ruptured and unruptured patients and for OAR when completed for rupture. In-hospital mortality rates remain relatively unchanged for elective OAR for patients with AAAs.

Our findings are comparable to what has been reported through the use of another large database.[18] A recent study evaluated prospectively collected outcomes data for EVARs completed within the Kaiser Permanente health care system in North California between 2000 and 2010. In this study, 1736 patients underwent EVAR and 3382 patients underwent open repair, with EVAR rising from 9% of all AAA cases in 2000 to 55% in 2010. Overall demographic data with regard to sex, age, ethnicity, and comorbidities are also similar. We found a 0.9% in-hospital mortality rate for EVAR, similar to the 1.2% 30-day mortality reported by Chang et al.[18]

Limitations. This study uses an administrative database, which by its nature is limited with regard to the number of variables that can be measured. Follow-up data and long-term outcomes are unavailable. This also limits the ability to calculate costs associated with EVAR follow-up.

Some level of selection bias exists within this study. Initial endografts were limited with regard to the size of aneurysm that could be treated, and more technically challenging aneurysms may therefore have been repaired with the use of the open approach. Furthermore, there is a learning curve associated with EVAR, and the slight elevation in in-hospital mortality rates for EVAR in 2000 may reflect these circumstances.

CONCLUSIONS

The use of EVAR has risen 14-fold over the past decade, even though the total number of AAA cases remains stable at 45,000 per year. Since 2000, in-hospital mortality rates for both ruptured and unruptured AAAs have fallen by more than 50%. EVAR is associated with a lower mortality rate and lower LOS compared with OAR; however, EVAR has a significantly greater in-hospital cost of care. Sex and racial discrepancies continue to exist with regard to the incidence of ruptured AAAs but generally do not influence procedure selection. The mortality rate in patients who undergo OAR for ruptured AAAs continues to be eightfold greater than patients who undergo EVAR. In-hospital mortality rates have not changed in the past 10 years for patients who undergo elective OAR.

AUTHOR CONTRIBUTIONS

Conception and design: AD, SK, CL, GU, SD
Analysis and interpretation: AD, SK, CL, GU, SD
Data collection: AD, SK, SD
Writing the article: AD, SK, CL, GU, SD
Critical revision of the article: AD, SK, CL, GU, SD
Final approval of the article: AD, SK, CL, GU, SD
Statistical analysis: AD, SD
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Overall responsibility: SD

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