Two decades of abdominal aortic aneurysm repair: Have we made any progress?

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Purpose: **Over the past 20 years, there have been numerous advances in our ability to detect and to treat abdominal aortic aneurysms (AAAs). We hypothesized that these advances would lead to (1) an increase in the rate of elective repair and a decrease in the incidence of ruptured AAA (rAAA) and (2) a decrease in operative deaths for both elective AAA (eAAA) and rAAA.**

Methods: **To test these hypotheses, we investigated the incidence and outcomes of eAAA and rAAA surgery between 1979 and 1997, using the National Hospital Discharge Survey. This data set is a randomized, stratified sample representing discharges from the nation's acute care, nonfederally funded hospitals. Codes from the *International Classification of Diseases, Ninth Revision* were used to identify our study population.**

Results: **Over the past 19 years, there has been no change in the incidence rate of eAAA repair (range, 44.1-77.9 per 100,000). Moreover, the incidence of rAAAs presenting to the nation's hospitals has not changed (range, 6.6-16.3 per 100,000). There has been no consistent improvement over time in operative deaths associated with either eAAA or rAAA repair (average rates over the study period: eAAA, 5.6%; rAAA, 45.7%). Significant predictors of death from eAAA in patients included an age older than 80 years, African American race, congestive heart failure (CHF), and diabetes (*P* < .0001 for all). Significant predictors of death from rAAA in patients included age older than 70 years, African American race, female sex, renal failure, and a hospital bed size more than 500 (*P* < .05 for all).**

Conclusion: **On a national level, over the past 19 years, our ability to identify and to treat patients with AAA has not improved. Advances in technology and critical care have not affected outcome. Regionalization of care, screening of high-risk populations, and endovascular repair are strategies that might allow further improvement in the outcome of patients with aneurysmal disease. (J Vasc Surg 2000;32:1091-100.)**

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Competition of interest: nil.

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Since its original description in the 1950s, surgical repair of abdominal aortic aneurysms (AAA) has become a safe and durable intervention. Although initial operative deaths were high, advances in technique and an improved understanding of the physiology of aneurysm repair rapidly produced substantial improvements in outcome.

Over the past 20 years, there have been a number of additional medical advances that should have a favorable impact on our ability to detect and treat abdominal aneurysms. Diagnostic imaging modalities including ultrasound scan, computerized axial tomography, and magnetic resonance angiography (MRA) allow earlier detection of smaller and asymptomatic aneurysms that escape diagnosis through physical examination. Our ability to prepare patients for aneurysm repair has also improved. Preoperative identification of concomitant atherosclerotic disease, particularly in the cerebral and cardiac circulations, allows institution of measures to prevent postoperative complications such as stroke and myocardial infarction. Gains have also been made in the perioperative treatment of patients with aneurysmal disease. The introduction of the Swan-Ganz catheter, the cell-saver, epidural analgesia, retroperitoneal exposure, and transesophageal echocardiography have all been proposed as measures that improve the intraoperative care of patients undergoing aneurysm repair. Finally, advances in intensive care medicine have allowed even elderly and infirm patients the potential to survive this complex surgical procedure.

With these advances in mind, we formulated the hypothesis that over the past 20 years, our ability to identify and treat AAAs has improved. More accurate methods of detection should lead to earlier diagnosis of aneurysms resulting in (1) an increase in the incidence of elective aneurysm repair and (2) a decrease in the number of ruptured aneurysms. We also hypothesized that significant advances in perioperative and critical care should improve patient outcome, thereby reducing the operative mortality rate of both elective and ruptured repairs. Although these questions have been previously addressed in single institution and regional studies, a chronologic evaluation of national trends in aneurysm repair is unavailable. To verify our hypotheses, we evaluated the incidence and outcome of AAA repair in the United States over a 19-year period using a well-established national database.

METHODS

The National Hospital Discharge Survey (NHDS) is a large national data set developed in 1965 by the National Center for Health Care Statistics. Information for this database is obtained through evaluation of inpatient records from acute care, nonfederally funded hospitals. Eligible hospitals include those institutions with at least six beds where the average length of stay for patients is less than 30 days. From the nation's approximately 6000 hospitals, a sample of approximately 500 is selected on a yearly basis. Hospital discharges are collected by means of a stratified system that is based on the annual number of discharges and geographic location of each institution. These discharges represent approximately one eighth of the US population.

Two data collection procedures are used. In two thirds of the hospitals surveyed, information is obtained by hospital staff who transcribe the data to the NHDS medical abstract form. This form is then forwarded to the National Center for Health Care Statistics for coding, editing, and weighting. An automated system is used to collect data from approximately one third of the contributing hospitals. This involves the purchase of data from other organizations or selected state systems that collect similar information.

Data collected for each patient includes birth date, sex, race, ethnicity, marital status, zip code, and payment source. Also included are codes from the *International Classification of Diseases, Ninth Revision* (*ICD-9*) for a maximum of seven diagnoses and four procedures per patient. Data are also collected with regard to patient outcomes, length of stay, and disposition.

An ongoing quality control program is undertaken on a yearly basis whereby approximately 5% of the data sets are independently reevaluated by an NHDS coder. Discrepancies are resolved, and the rate of discrepancy is recorded. For example, the overall error rate for records manually compiled by an NHDS coder for the 1991 data year was 2.4% for diagnostic codings involving the *ICD-9* system and 0.6% for the coding of demographics.[1]

We identified our study population using the *ICD-9* diagnostic codes for elective AAA (eAAA) (441.4) and ruptured AAA (rAAA) (441.3) and the *ICD-9* procedural code for AAA repair (38.44) (when hospitals bill for procedures, an *ICD-9* procedural code is used rather than a code from the *Current Procedural Terminology*, which is specific for physician billing). There is only one *ICD-9* procedure code for AAA repair that does not distinguish between elective and ruptured procedures. To identify patients hospitalized for eAAA repair, we used the combination of 441.4 (any diagnosis) and 38.44 (any procedure). When evaluating the deaths associated with eAAA, we used the combination of 441.4 (primary diagnosis) and 38.44 (any procedure). We assumed that the overall incidence of rAAA paralleled the rate of hospitalization of rAAA, and we used the diagnostic code 441.3 (any diagnosis) to identify these patients. To identify patients undergoing repair of rAAA, we used the combination of 441.3 (any position) and 38.44 (any position).

The variables we examined included the year of admission or procedure, patient age, sex, race, hospital size, and the following comorbidities utilizing the *ICD-9* codes for identification: diabetes (250), hypertension (401-405), CHF (428), history of myocardial infarction (410.0-411.0, 412, 414.8), renal failure (584.9, 585, 403.91), emphysema (492), and tobacco use (305.1). To evaluate trends over time, we collected data from 1979-1997. We had available to us a complete data set for this period of time; data from more recent years are not yet available. With respect to age, because of the low incidence of AAA in younger patients, we focused only on patients older than 50 years. The following age categories were created: 50 to 59, 60 to 69, 70 to 80, and older than 80. Race was categorized as white, African American, American Indian, Asian, other, or unknown. We examined the effect of hospital size on operative deaths. Hospitals were stratified into the following bed size subdivisions: 6 to 99, 100 to 199, 200 to 299, 300 to 499, and more than 500. Annual volumes for specific surgeons were unavailable from the NHDS. We evaluated outcome parameters that included the incidence of eAAA repair, incidence of rAAA, and operative deaths associated with eAAA and rAAA.

The technique of linear regression was used in our model. For the analysis of death, we first examined data using univariate analysis with the Student *t* test for continuous variables and the Fisher exact test for discrete data. For the multivariable analysis, variables with a *P* value less than .25 were entered into a multiple logistic regression model. The final logistic model was corrected for overdispersion. This may occur during modeling of discrete data when the variance of the response variable exceeds what is expected. The statistical correction is the multiplication of all the SEs associated with the risk factor coefficients by the estimated dispersion parameter, which yields adjusted SEs. This will subsequently effect the corresponding *P* values and odds ratio CIs. Certain variables were then removed from the original unadjusted model, because of an overdispersion-adjusted *P* value of more than .05. We also tested for interactions.

Yearly incidence rates for rAAA and eAAA were adjusted by the method of Direct Standardization. Age-specific population values from the 1990 US census were used as the standard population. For all statistical analysis, data were analyzed with the SAS System software (SAS Institute, Inc, Cary, NC).[2]

RESULTS

Incidence of eAAA and rAAA

Over the 19-year study period, 358,521 patients underwent eAAA repair. The median age at admission for men and women was 70 and 73 years, respectively. Females comprised 22.7% of the total number of eAAA repairs. Annual variation of repair rates ranged from 44.1 to 72.9 per 100,000 US population. Although annual fluctuation was observed, no change in the incidence of eAAA repair over the 19-year period of study was apparent (Fig 1, *A*).

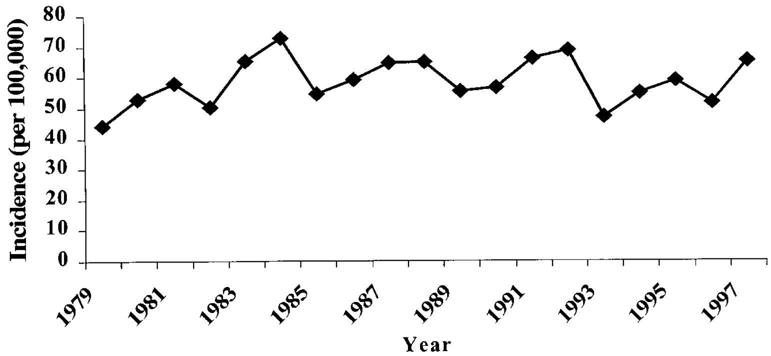
From 1979 to 1997, 67,751 patients presented to this nation's acute care, nonfederally funded hospitals with an admission diagnosis of a rAAA. We evaluated patients with the admitting diagnosis of rAAA versus those treated operatively so as not to exclude patients who died en route to the operating room. The median age for men was 72 years and for women, 78 years. Over the 19-year study period, women comprised 22.4% of the total number of annual admissions for rAAA. Annual rates of rAAA ranged from 6.6 to 16.3 per 100,000 US population. Although there was annual fluctuation in this rate over the 19-year period of observation, no overall statistical change in the annual incidence of rAAA was apparent (Fig 1, *B*).

Operative deaths

Elective AAA. We calculated the annual operative mortality rate associated with repair of eAAA for 1979 to 1997 (Fig 2, *A*). The average mortality rate over this 19-year period was 5.6% with no statistically significant change during the overall period of observation. Although we could identify variations in annual mortality rates, no consistent trend over the 19 years that were evaluated was apparent.

Ruptured AAA. We next calculated the annual operative mortality rate associated with repair of rAAA for 1979 to 1997 (Fig 2, *B*). The average annual operative mortality rate was 45.7%. A decrease in death was observed over the last 3 years of the period of observation (1994-1997), suggesting a possible downward trend. However, overall, no statistically significant decrease in death for repair of rAAA over the 19 years that were evaluated was apparent.

We also determined the percentage of patients hospitalized with rAAA who died before operation. This number ranged from 3.7% to 7.2%; there was no significant change in this incidence



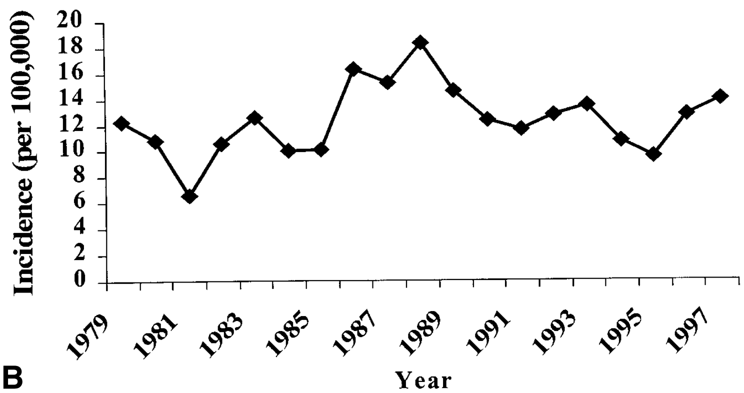


Fig 1. A, National trends in incidence of elective aneurysm repair, 1979-1997. Data obtained from NHDS. Incidence rates are age and population adjusted. **B,** National trends in incidence of rAAAs, 1970-1997. Data obtained from NHDS. Incidence rates are age and population adjusted.

over the study period. These data suggest that in-hospital triage and resuscitation efforts have not improved over the two decades of this study.

Mortality rate of eAAA repair and associated variables

Sex. The overall eAAA operative mortality rate for men and women was 5.1% and 7.7%, respectively. Despite this numerical difference, using multiple logistic regression we did not find a statistical association between female sex and operative death after eAAA repair (Table I).

Age. The following age cohorts were created: 50 to 59, 60 to 69, 70 to 80, and older than 80. Multivariable analysis revealed a significant increase in operative mortality for elective repair in the older-than-80 age group ($P < .0001$) (Table I).

Race. After the controlling for other variables, there was a statistically significant increase in elective operative mortality for African Americans compared with all other races ($P < .0001$). The overall operative mortality rate after eAAA repair for African Americans was 11.3% versus 5.5% for whites. The median age at presentation for African Americans and whites was 73 and 70 years, respectively (Table I).

Bed size. Bed size was stratified into the following subdivisions: less than 100, 100 to 199, 200 to 299, 300 to 499, and more than 500. After controlling for other variables in multiple logistic regression, we found that bed size did not predict operative death after eAAA repair (Table I).

Comorbidities. We examined the following comorbidites in our model: CHF, hypertension, tobacco use, emphysema, type 1 and type 2 diabetes mellitus, and renal failure. Patients with CHF had an increased likelihood of death after eAAA repair ($P < .0001$). Diabetes also proved to be an independent predictor of death ($P < .03$). We found that patients with a history of hypertension were protected against death. Patients without hypertension were more likely to die after eAAA repair than their hypertensive counterparts ($P < .0003$) (Table I).

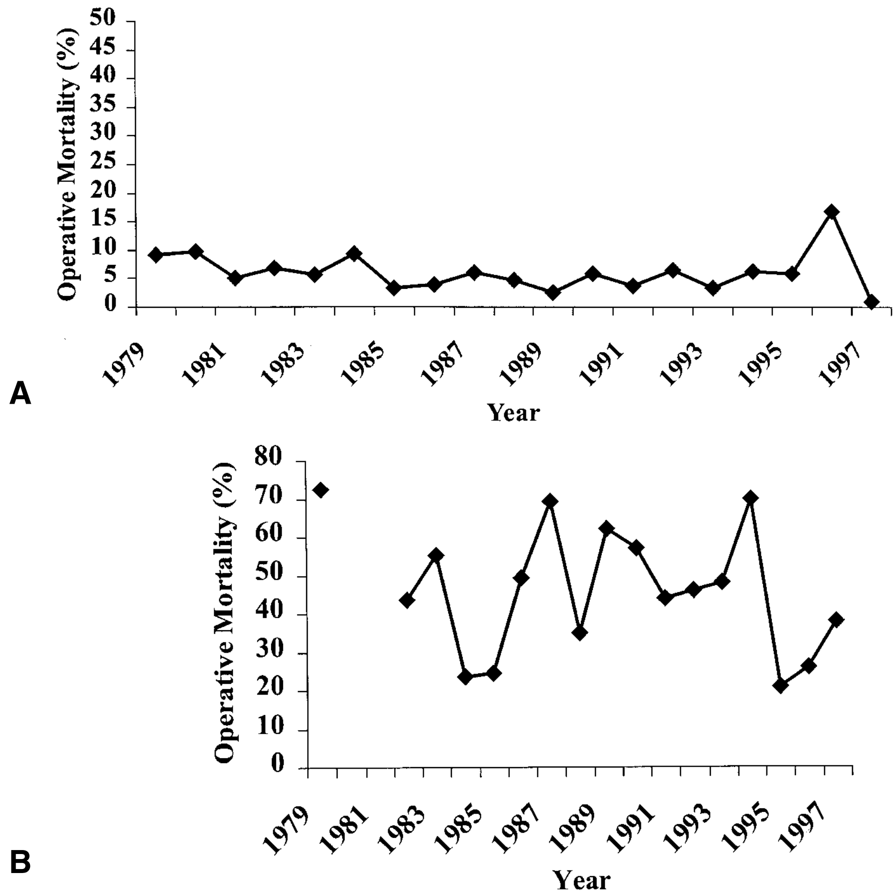


Fig 2. A, National trends in operative death after eAAA repair, 1979-1997. Data obtained from NHDS. **B,** National trends in operative death after rAAA repair, 1979-1997. Data obtained from NHDS. (Trends from 1980 and 1981 are not plotted in the graph because of insufficient data in these years).

Mortality rate of rAAA repair and associated variables

Sex. Women constituted 22.5% of the entire cohort. The overall rAAA operative mortality rate for men and women was 41.6% and 64.8%, respectively ($P < .0001$) (Table II).

Age. We evaluated death using the following age cohorts: 50 to 59 years, 60 to 69 years, 70 to 80 years, and older than 80 years. We found a significant association between age older than 70 years and increased operative death ($P < .0001$) (Table II).

Race. African Americans comprised 4.2% of the total cohort of ruptured aneurysm repairs. African Americans presented at a median age of 78 years, whereas whites presented at a median age of 72 years. We found a significant association between the African American race and increased operative death after rAAA repair ($P < .0001$) (Table II). Over the 19-year study period, crude operative mortality rates after rAAA repair were 84.5% for African Americans and 44.9% for whites (Table II).

Bed size. We found that patients undergoing repair of a rAAA had a significantly greater likelihood of death in hospitals with less than 500 beds ($P < .0001$) (Table II).

Comorbidities. We examined the following comorbidites: CHF, tobacco use, emphysema, type 1 and type 2 diabetes mellitus, and renal failure. Renal failure was the only comorbidity that was independently associated with increased death after rAAA repair ($P = .006$) (Table II).

DISCUSSION

We initiated this study with the assumption that technologic advancements and the accrual of experience over a 19-year period would greatly

Table I. Predictors of operative death after eAAA repair

Variable	*Crude mortality rate*	*Odds ratio*	*95% CI*	P *value*
Age > 80 y	Age > 80 y: 24.7% Age < 80 y: 3.6%	8.3	5.4-12.6	< .0001
African American race	African American race: 11.3% White race: 5.5%	3.2	1.1-7.7	.02
CHF	CHF: 13.4% No CHF: 5.0%	2.9	1.7-4.9	< .0001
DM	DM: 9.0% No DM: 5.5%	2.2	1-4.5	.03

CHF, Congestive heart failure; *DM,* diabetes mellitus; *eAAA,* elective abdominal aortic aneurysm.

Table II. Predictors of operative death after rAAA repair

Variable	*Crude mortality rate*	*Odds ratio*	*95% CI*	P *value*
Age > 70 y	Age > 70 y: 56.2% Age < 70 y: 25.0%	4.8	3-78	< .0001
African American race	African American race: 84.5% White race: 44.9%	16.6	3.2-176.8	.003
Female sex	Female sex: 64.8% Male sex: 41.6%	3	1.7-5.2	< .0001
RF	RF: 68.7% No RF: 42.8%	2.5	1.3-4.9	.006
BS < 500	BS < 500: 47.9% BS > 500: 34.3%	2	1.1-3.6	.019

BS, Bed size; *rAAA,* ruptured abdominal aortic aneurysm; *RF,* renal failure.

enhance our ability to diagnose and treat AAAs. We hypothesized that detection of smaller or asymptomatic aneurysms with ultrasound scan, computerized axial tomography, or MRA would increase the rate of elective aneurysm repair and ultimately decrease the incidence of aneurysm rupture. Moreover, we anticipated that improvements in the preoperative evaluation and perioperative care of patients with aneurysms would diminish operative morbidity and death. Much to our surprise, we found that over the past 19 years there has been no significant change in (1) the rate of eAAA repair, (2) the incidence of ruptured aneurysms presenting to our nation's hospitals, and (3) the death associated with repair of either eAAAs or rAAAs.

These trends have been previously analyzed with several regional databases and a review of the nation's Veterans Administration (VA) hospitals (Table III).[3-9] During the 1980s an increase in the number of eAAA repairs was noted in Michigan (24% increase, 1980-1990) and New York (94% increase, 1982-1987).[7,8] However, over similar time periods there was no change in the frequency of eAAA repair in California, Maryland, Florida, and the VA hospital systems.[3,5,6,9] With regard to the incidence of rAAAs, studies revealed increases in Michigan and New York, but not California, Florida, Maryland and the nation's VA hospitals.[4-9] In none of these studies was a decrease in the incidence of rAAA observed that would be the logical sequelae of advancements in our ability to diagnose and treat aneurysmal disease. Death associated with eAAA and rAAA repair was addressed in these same studies. With regard to elective repair, a decrease was reported in two states (California, 3% over 12 years, and Michigan, 8% over 10 years),[5,7] but in Maryland, Florida, and the nation's VA hospitals, the mortality rate associated with elective repair was unchanged during the periods of observation.[3,6,9] For rAAA, with the exception of Maryland, the incidence of death was constant over time.[4-9] A review of the NHDS database has been previously published by Lawrence et al.[10] However, in this study, only the years 1990 and 1994 were reviewed; most of the

Table III. eAAA and rAAA repair: review of population-based surveys

Study	*Region*	*Observation (y)*	*eAAA incidence*	*eAAA operative mortality rate*	*rAAA incidence*	*rAAA operative mortality rate*
Dardik et al	Maryland	1990-1995	↔	↔		
Dardik et al	Maryland	1990-1995			↔	↓ 16%
Manheim et al	California	1982-1994	↔	↓ 3%	↔	↔
Kazmers et al	Veteran's hospitals	1991-1993	↔	↔	↔	↔
Katz et al	Michigan	1980-1990	↑ 24%	↓ 8%	↑ 8%	↔
Hannan et al	New York	1982-1987	↑ 94%	↔	↑ 68%	↔
Pearce et al	Florida	1992-1996	↔	↔		

data were derived from the year 1994. Although a great amount of information is available from this analysis, trends in AAA treatment were not evaluated. Although there is significant variation in the findings of these prior studies, in general, most of the data support our observation that little progress has been made over the past two decades in the diagnosis and treatment of AAA.

The final common goal when treating aneurysms is to save lives by preventing rupture. Although surveillance and treatment programs for aneurysms can be evaluated with numerous outcomes, the ultimate end point should be a diminution in the rate of aneurysm rupture in the population under study. In this analysis we assume that the incidence of patients hospitalized with ruptured abdominal aneurysms parallels the true incidence of aneurysm rupture. However, the number of patients hospitalized is likely only a small fraction of the patients who rupture their aneurysm; most will die before they can receive medical attention. It would be impossible, then, to ever acquire data regarding the true incidence of rAAA because in patients who die of this disease, the true cause of death is seldom discovered. Despite our inability to measure the total number of ruptured aneurysms, the absence of a reduction in the number of patients hospitalized for rAAA during the 19-year period of observation strongly implies that we have made little impact on the overall mortality rate associated with this disease process.

There are a number of single institution studies that reveal diminished mortality rates for eAAA repair. Mortality rates as low as 2% have been reported by a number of investigators.[11-14] How does one reconcile the discrepancy between these findings and those on a national level? Interestingly, for ruptured repairs, lower mortality rates were associated with institutions with 500 or more beds. Perhaps large hospitals that are trauma centers and have both experienced personnel and advanced triage systems are best able to manage ruptured aneurysms. Alternatively, larger hospitals could be referral centers that accept transfer of patients from the outlying communities. Referral patients would then be more likely to have "stable" contained ruptures, an entity that is associated with a less significant operative mortality rate. A number of investigators have shown that hospital and surgeon volume is a critical factor in outcome after AAA repair.[3,5,8,15] Whether it is hospital size, surgeon experience, or a combination of the two, our data reveal a dramatic difference between the national outcomes for AAA repair and those reported from single institutional studies. These data would argue strongly for the need to regionalize care of patients with AAAs.

For both elective and ruptured aneurysm repair, we discovered that age was a significant predictor of death. An increased risk for elective repair was observed in patients older than 80 years. An inverse correlation between age and death was also observed in patients with rAAA, although this relationship developed a decade earlier. An association between advancing age and increasing operative death for both eAAA and rAAA repair has been documented extensively by other investigators.[3,4,5,8,15]

We observed in women a twofold to fourfold increase in the risk of death from rAAA. However, we were unable to demonstrate for women an increase in the operative mortality rate for eAAA. This relationship has been explored with other databases. Katz et al,[7,16] using data from Michigan, found an approximately 1.5% increase in the mortality rate for women undergoing both eAAA and rAAA repair. Alternatively, Dardik et al[3,4] reported an increased operative mortality rate among women undergoing eAAA but not rAAA repair. This and the higher occurrence of comorbidities in female patients may account for these observed higher operative mortality rates.

To date, the association between race and outcome after vascular surgical procedures has been reported in few studies. We discovered that the mortality rate increases in African Americans after both eAAA and rAAA repair. Dardik et al,[3] using the Maryland database, also evaluated race as a factor in eAAA outcome and found that the mortality rate increased in African Americans after eAAA but not rAAA repair. Possible explanations for this increased mortality rate in African Americans may include (1) a greater number of associated comorbidities in African Americans or (2) diminished access to health care.

Since the 1950s, we have made tremendous progress in our ability to diagnose and to treat aneurysmal disease. The lack of continued progress over the past two decades, however, should be a stimulus for our specialty to explore new strategies to improve the care of these patients. Screening programs for the earlier detection of AAAs should be considered. Wilmink et al[17] prospectively studied screened and unscreened populations and found a decrease of 49% in the incidence of rupture in the screened group. Although several studies suggest that screening for AAA is not cost-effective, this issue has not been addressed in high-risk populations. The use of endovascular stents may decrease operative death, particularly in those patients with numerous comorbidities. Finally, regionalization of the care of patients with aortic aneurysms may serve to lower overall operative death and morbidity.

In summary, we have found that technologic and treatment advances over the past 19 years have not had an impact on the outcomes of patients with AAAs. The use of a national database has enabled us to evaluate trends over time and also to examine how surgeons throughout the nation are performing. Although significant progress has been made at many individual centers, on a national level, we should explore strategies that might lead to further improvements in outcome.

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DISCUSSION

Dr Bruce J. Brener (Millburn, NJ). My comments will center around three conclusions presented by the authors. First, physicians should identify more aneurysms in the population. Second, the mortality rate for surgery for elective and ruptured aneurysms has not improved during the last two decades. And third, women and blacks have a higher mortality rate than white males. Each of these messages, if true, is unacceptable.

The failure of the medical community to easily identify patients with aneurysms through screening is in my opinion a failure of communication. It is a failure of public relations. We have failed to focus attention on this public health issue. I believe that we are going to need a public foundation, like the American Heart Association or the Cancer Association, some American Vascular Association, to increase awareness of this disease. Ultrasound examination is accurate and inexpensive. We need to treat this illness as a high-profile disease like HIV or breast cancer or prostate cancer. I think that's the only way we're going to make any progress.

I'm not surprised that the operative mortality for aortic resection is not lower; there are so many causes of postoperative death. For example, we may be selecting higher-risk patients because we are a little better at perioperative management. I'm not sure that major breakthroughs in technique, risk stratification, anesthesia management, and perioperative care have occurred during the 1980s and 1990s. In fact, the major advances that have lowered the mortality of aortic surgery, namely, minimal dissection and elimination of resection of the aorta, occurred in the 1960s and 1970s. While the use of epidural catheters for pain management has enhanced aortic surgery, it probably has not affected the mortality rate. Perhaps the use of endovascular techniques will provide a safer operation.

And finally, our inability to treat women and blacks with the same safety as white males is an unacceptable conclusion, and I think it requires some soul-searching on our part as well as some action.

I have a few questions. What statistical biases are present in this kind of methodology? Do you know how many unoperated aortic aneurysms that are 5 cm or greater are present in the United States population? What high-risk groups should be screened for aneurysms? What changes in medical management do you think should have lowered the operative mortality over the last 20 years? Do you think endovascular repair of aneurysms will lower the mortality of high-risk patients? Will we be able to use these techniques for aortic aneurysm rupture?

Dr Jennifer A. Heller. Thank you, Dr. Brener, for your kind comments and questions.

I do have to preface my responses to the comments and questions with the fact that we truly were very surprised with the results that we discovered on this national database. We truly expected to see some form of improvement and some progress over time over the past 19-year period. So this was a very thought-provoking topic for us as well.

Just briefly in response to some of your initial comments, it is interesting to suggest that the patient population as a whole has changed over time, and certainly there is much literature within our field to suggest that that is the case. For example, Bredenberg et al report similar epidemiologic changes in their evaluation of patients with chronic renal artery occlusive disease.

We tried to counter these problems in our study. When we examined incidence rates for both elective and ruptured repairs, we adjusted for age and population.

With regard to the innovations over the past 19 years, I will contest that there are innovations over the past 19 years that should have actually improved our ability to certainly treat and to detect aneurysms. With regard to detection, certainly ultrasound is our gold standard for diagnostic screening. But the MRA as well as CT angiography and other modalities should have been able to pick up asymptomatic unexpected aneurysms. As well, Bushey et al in the 1980s discussed in *JAMA* an innovative way of noninvasively screening for cardiac disease with the stress thallium test. And as Hertzer and many others have described extensively, the prevention and the treatment of significant coronary disease prior to elective aneurysm repair certainly improve aneurysm outcome. So I think that those two issues are significant innovations that need to be addressed.

The great advantage about this national dataset is that it afforded us with the opportunity to examine outcomes from all surgeons who perform abdominal aortic aneurysm repair, not just board-certified vascular surgeons with more experience and potentially more ancillary resources. And because of this, our data are different from single institutions studies.

With regard to the statistical biases, however, there is going to be sampling error. When we performed our statistical analysis, however, our sampling errors were relatively small. When we did have cohorts, however, that did have small sample size, we left them out of the equation. And that was rare and few between, but we did do that so that we could prevent any miscoding or errors that could occur.

The last issue with regard to statistical bias has to do with miscoding errors, which, unfortunately, are prevalent with every database that exists in this country. This has been looked at extensively with regards to the Medicare and Medicaid and the HCFA databases, and they note a significant amount of miscoding errors, particularly in the *ICD-9* diagnosis areas, and they note rates as high as 26% to 30%. However, when they did, with respect to the HCFA data set, when they took a look at these coding errors for diagnosis, particularly with AAAs, they noticed that the accuracy rates were as high as 97%.

As far as what high-risk groups should be screened, I think it's important to take note that there have been some minimal cost-effective studies that have been performed to examine whether or not ultrasound is a cost-effective measure. And the subgroups that are at high risk have not been effectively determined in these analyses. And the subgroups who are at high risk, who should be analyzed, I believe, are male siblings who have a first-order relative who has an abdominal aneurysm, males over 50, any patient who exhibits a smoking history be it remote or present, as well patients who have manifestations of cardiac as well as peripheral vascular disease.

Do I believe that endovascular interventions will improve the outcome in the high-risk patient? I certainly hope so. I think that we're early on the horizon in expecting that, but I think that that's an exciting endeavor that we can look to in the future.

Dr Alan Dardik (Baltimore, Md). I applaud your study, and I think it's an excellent one. It reflects on a national level certainly what we found in Maryland. We found that the incidences of both elective and ruptured aneurysm repairs haven't changed. Our numbers are remarkably similar to yours on the national level.

However, we showed for ruptured aneurysms that mortality has been decreasing. Although we don't advocate sending all the patients to Maryland, we think that regionalization of our care may have already occurred in the state of Maryland and this may be a reason for our declining mortality. Have you noticed any changes in hospital volume trends over the course of your study that might account for this?

Second, have you noticed any differences between community and tertiary care institutions in your study?

Thirdly, we use hospital size really as a surrogate for surgeon volume and thus, surgical experience. Were you able to examine this in your database?

And lastly, I absolutely agree that we should screen aneurysms. The British literature has demonstrated that it reduces mortality. The only problem is that the National Health Service itself doesn't pay for screening and they only screen by research protocols, as I understand. How would we screen our population for aneurysms?

Thank you.

Dr Heller. With regard to your questions on regionalization of care, the issues that the national hospital discharge survey database has, unfortunately, are very few. The only characteristic that we were able to obtain was with respect to hospital bed size. The way the hospitals initially are brought into the equation is that there is a national resource of approximately 6000 hospitals in the nation and then from that a sample size is acquired from which they obtain their database. And the data are actually transferred over once they pick the particular hospitals from the nation's sample. And those hospital characteristics that you mentioned, unfortunately, are not recorded. So we can't do a true "practice makes perfect" as Hannon did. We can't take a look at individual surgeons. We're not able to take a look at hospital volumes with respect to individual cases per year of aneurysms.

Groups in Britain, particularly Wilmek et al, prospectively studied the effect of mass screening and noticed a decrease in the rupture repair rate. Certainly, protocols need to be developed to establish screening programs.

Dr Anton N. Sidawy (Washington, DC). I would like to express some concern regarding getting data from these huge databases. Looking at your graphs, actually if you draw a line across the graphs, it would be a horizontal line, so it will give you the impression that there is no change in mortality. However, if you compare one time period to another, the variance in mortality is tremendous: you're looking at 20% and up to 70%. What did you do to assure yourself that the data are accurate?

Dr Heller. Thank you very much, actually, for bringing that up, because it was something that we were very concerned about as we were investigating this project, and I didn't really have time to go into this in detail in my presentation.

With respect to trends over time, we were very concerned, as you said, that all we had to really do was draw a line. We divided our 19-year study period into 5-year intervals and used the last 3 years of the study as our baseline for comparison. No changes over time existed, although variance was observed in one time set versus another. In addition, our statistical analysis was tested by using overdispersion.

Dr Anthony J. Comerota (Philadelphia, Pa). That was a beautiful presentation.

Could you focus on the use of the odds ratio for an adverse outcome? Let's assume that a white with a ruptured aneurysm had a mortality of 25%. How could a black patient have a mortality 14 times that?

Dr Heller. The odds ratio refers to probablilities or likelihood and is not a representation of numerical comparison.