CLINICAL RESEARCH STUDIES

From the Society for Vascular Surgery

Decrease in total aneurysm-related deaths in the era of endovascular aneurysm repair

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Objective: **With the expansion of elective abdominal aortic aneurysm (AAA) repair after the introduction of endovascular aneurysm repair (EVAR), there is a concern that even with a lower operative mortality there could be an increasing number of aneurysm-related deaths. To evaluate this, we looked at national trends in AAA repair volume as well as mortality rates after intact and ruptured AAA repair encompassing the introduction of EVAR.**

Methods: **Patients with intact or ruptured AAA undergoing open repair or EVAR and all those with a diagnosis of ruptured AAA were identified within the 1993 to 2005 Nationwide Inpatient Sample database using International Classification of Diseases, 9th Revision, diagnosis and procedure codes. The number of repairs, number of rupture diagnoses without repair, number of deaths, and associated mortality rates were measured for each year of the database. Outcomes (mean annual volumes) were compared from the pre-EVAR era (1993 to 1998) with the post-EVAR era (2001 to 2005).**

Results: **Since its introduction, EVAR increased steadily and accounted for 56% of repairs yet only 27% of the deaths for intact repairs in 2005. The mean annual number of intact repairs increased from 36,122 in the pre-EVAR era to 38,901 in the post-EVAR era, whereas the mean annual number of deaths related to intact AAA repair decreased from 1693 pre-EVAR to 1207 post-EVAR ($P < .0001$). Mortality for all intact AAA repair decreased from 4.0% to 3.1% ($P < .0001$) pre-EVAR and post-EVAR, but open repair mortality was unchanged (open repair, 4.7% to 4.5%, $P = .31$; EVAR, 1.3%). During the same time, the mean annual number of ruptured repairs decreased from 2804 to 1846, and deaths from ruptured AAA repairs decreased from 2804 to 1846 ($P < .0001$). Mortality for ruptured AAA repair decreased from 44.3% to 39.9% ($P < .0001$) pre-EVAR and post-EVAR (open repair, 44.3% to 39.9%, $P < .001$; EVAR, 32.4%). The overall mean annual number of ruptured AAA diagnoses (9979 to 7773, $P < .0001$) and overall mean annual deaths from a ruptured AAA decreased post-EVAR (5338 to 3901, $P < .0001$).**

Conclusion: **Since the introduction of EVAR, the annual number of deaths from intact and ruptured AAA has significantly decreased. This coincided with an increase in intact AAA repair after the introduction of EVAR and a decrease in ruptured AAA diagnosis and repair volume. (J Vasc Surg 2009;49:543-51.)**

The introduction of endovascular aortic aneurysm repair (EVAR) has resulted in a significant change in the treatment of infrarenal aortic aneurysms. The first EVAR was reported by Juan Parodi in Argentina in 1990.[1] The widespread use of this technique did not come about until the beginning of the next decade after clinical device trials were completed and FDA approval was gained in 1999. Subsequently, a code for the procedure was developed for the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) in 2000.

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Previous studies have demonstrated that EVAR reduces the rate of complications and mortality compared with open repair even though EVAR patients as a group are older with more comorbidities.[2-4] In randomized controlled studies, perioperative mortality was 4.6% after open repair and 1.2% to 1.6% after EVAR.[3,4] In most series, EVAR accounts for 40% to 60% of all elective AAA repair.[2,5-9] In the Medicare population, EVAR volume surpassed open repair volume in 2003 for the first time and continues to increase for elective AAA repair.[2] More recently, EVAR has also been increasingly used for ruptured AAA repair and in small series appears to result in better perioperative survival.[10-13]

This study evaluated the effect of EVAR on the annual volume of aneurysm repair and on the overall annual number of aneurysm-related deaths in both elective and rupture repair as well as its impact on rupture occurrence.

METHODS

The Nationwide Inpatient Sample (NIS) from the years 1993 to 2005, the most recent year available, was used for this study. The NIS is maintained by the Healthcare Cost and Utilization Project (HCUP) of the Agency for Healthcare Research and Quality. The database is a 20% all-payer sample of hospital stays and contains sampling weights to allow for stratified calculation of total population estimates. The database was initialized in 1988 and has since been modified to adjust for changes in the population. Updated sampling weights reflecting these alterations to allow for comparison across years have been made available by HCUP and were used for the current study. The initial years of the database from 1988 to 1992 constituted the first release of the database and were excluded from the current study because significant alterations were made to the database between 1992 and 1993.[14]

The database was queried with SAS 9.1 software (SAS Institute, Cary, NC) using ICD-9 diagnosis codes for intact AAA (441.4, 441.9) and ruptured AAA (441.3, 441.5). Patients with a procedure code for open repair (38.25, 39.44) and EVAR (39.71) were included. Patients with both procedures performed within the hospitalization were recorded as EVAR patients and were assumed to be either pure EVAR cases with coding errors or conversions from EVAR to open repair. To allow for trend analysis and calculation of total volumes for the entire time period, we included those endovascular repairs done before the implementation of the ICD-9-CM code. For this, we queried the database for the ICD-9-CM code of 39.90 (insertion nondrug-eluting, noncoronary stent) if coupled with a primary diagnosis of one of the above aneurysm diagnosis codes. Patients aged <18 years were excluded.

Totals were calculated per year of hospitalization. Intact AAA repair (open and EVAR), ruptured AAA repair (open and EVAR), and all ruptured AAA diagnoses (repaired and unrepaired) were recorded. The primary outcomes were in-hospital death and the respective mortality rates for each group. Age, gender, race (white vs other), length of stay, discharge disposition (home vs rehabilitation or other facility), and hospital charges were also measured.

Statistical analysis. Statistical analysis was performed using survey analysis programs with Stata 8 software (StataCorp, College Station, Tex). Total population estimates for each subgroup are reported by applying the sampling weight for each observation within Stata calculations. Means and standard deviations are reported for parametric data and median values and ranges for nonparametric data. Statistical significance was assigned at value of $P <$ .05. Comparisons between cohorts were done using the Wilcoxon ranked sum test for nonparametric continuous data, the *t* test for parametric continuous data, and the χ^2 test for categoric and count data.

Groups were stratified by repair method as well as by intact vs ruptured status. Annual number of AAA repairs and AAA-related deaths from the period representing the pre-EVAR era (1993 to 1998) were compared with the period during which EVAR coding had been fully incorporated (2001 to 2005). The years 1999 to 2000 were omitted from this comparison because United States Food and Drug Administration (FDA) approval was first attained in 1999 and the ICD-9-CM code was introduced in October 2000. Mean annual population totals rather than cumulative totals are reported for this subanalysis because the year ranges are unequal. As an additional test, the slope of the linear regression line from the pre-EVAR era was compared with the post-EVAR era by analysis of the interaction effect.

Study approval was obtained from the Institutional Review Board at Beth Israel Deaconess Medical Center. Data use agreements for use of the NIS data were made with HCUP.

RESULTS

More than half a million aneurysms (555,577 intact and ruptured) were repaired between 1993 and 2005, with 50,261 deaths attributable to aneurysm repair. Overall repairs (41,831 in 1993 to 41,185 in 2005) stayed relatively stable due to an increase in elective repair that was offset by a decrease in ruptured aneurysm repair (Fig 1). During this time, annual AAA repair-related deaths decreased by 42% (4477 to 2618; Fig 2). A mean 3036 annual repair-related deaths occurred in the post-EVAR era (years 2001 to 2005), which was fewer than the 4496 that occurred in the pre-EVAR era (years 1993 to 1998; $P < .0001$).

Intact AAA repair. Between 1993 and 2005, 482,625 intact AAA repairs were performed. An average of 37,125 repairs were performed per year (Table I), and 19,131 patients died (4.0% mortality). The number of intact AAA repair-related deaths per year decreased by 43% (1775 to 1013) from 1993 to 2005 ($P < .0001$; Fig 2).

The average number of repairs per year rose after EVAR was established. In the pre-EVAR era, the mean annual number of repairs performed for intact AAA was lower than in the post-EVAR era (36,122 vs 38,901, $P < .0001$; Table II). Patients were older in the post-EVAR era. There was a greater proportion of patients aged >80 years in the post-EVAR cohort as well as a decreased proportion of white patients. Men comprised most of the repair population, and there was no difference in this percentage pre-EVAR or post-EVAR.

The mean annual number of deaths associated with intact AAA repair was lower in the post-EVAR era despite the increase in the number of repairs (Table II). The mortality rate was significantly decreased (4.7% to 3.1%, $P < .0001$). The mortality rate associated with open repair was equivalent before and after EVAR was introduced (4.7% vs 4.5%, $P = .31$).

Median length of stay was decreased by 2 days in the later time period for all repairs. Open repairs had a smaller decrease in length of stay comparing pre-EVAR and post-EVAR eras (8 days vs 7 days, $P < .0001$). Discharge to home was more likely in the pre-EVAR era (89.3% vs post-EVAR 87.6%, $P < .0001$), with a more prominent decrease in home discharges after open repair (89.3% vs 82.8%, $P < .0001$).

EVAR vs open repair of intact AAA. The number of endovascular repairs performed eclipsed the number of open repairs by the year 2004 (Fig 3). In 2005, EVAR accounted for 56% of intact AAA repairs but only 27% of the deaths.

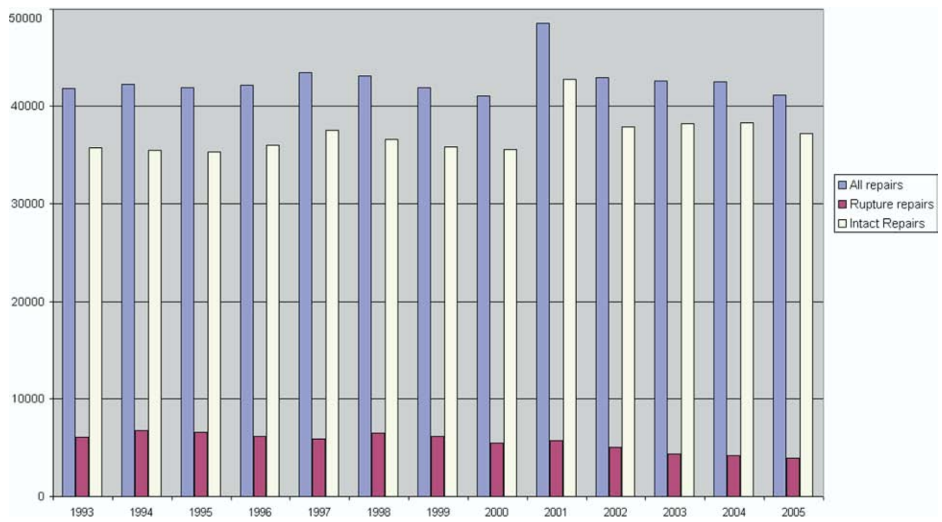

Fig 1. Abdominal aortic aneurysm repairs from 1993 to 2005 in the Nationwide Inpatient Sample. There was an increase in repairs for intact aneurysms but a decrease in repairs for ruptured aneurysms over time.

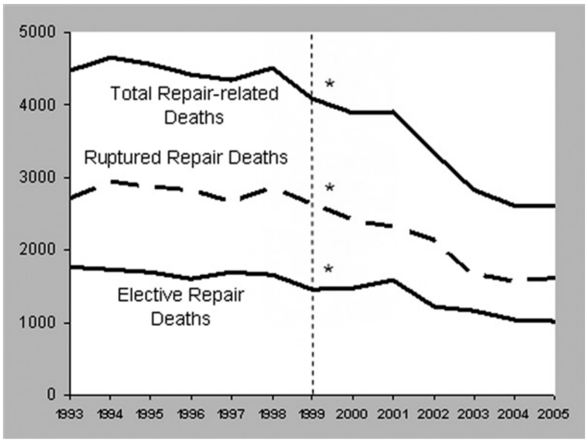

Fig 2. Annual deaths from 1993 to 2005 after abdominal aortic aneurysm repair (total, ruptured, and elective). An *asterisk* indicates that the decline in deaths after the introduction of endovascular repair was greater than the decline before endovascular repair ($P < .0001$).

In 2001 to 2005, patients undergoing EVAR were an average of 2 years older than those undergoing open repair (Table I). Mortality was 1.3% for EVAR and 4.5% for open repair. In the year 2005, overall mortality was 2.7%, the lowest among all years analyzed. Median length of stay was shorter after EVAR, and more patients were discharged to home. Median hospital charges were higher with EVAR.

Ruptured AAA diagnosis. The total number of admissions for a diagnosis of ruptured AAA decreased by 30%, from 9807 to 6921 per year from 1993 to 2005, with the greatest rate of decline after the introduction of EVAR ($P <$ .0001; Fig 4). The mean annual number of ruptured AAA diagnoses pre-EVAR was 9979 vs 7773 post-EVAR ($P <$ .0001).

Overall, 63% of patients had repair of their ruptured aneurysm. Patients who did not undergo repair of a ruptured AAA were older and more likely to be women compared with those undergoing repair (Table III).

The mean annual number of deaths associated with a diagnosis of ruptured AAA was 5338 pre-EVAR and 3891 post-EVAR ($P < .0001$).

Ruptured AAA repair. Between 1993 and 2005, 72,952 ruptured AAA repairs were performed, with an average of 5612 repairs performed per year (Table IV). The number of repairs for ruptured AAA decreased by 35%, from 6091 in 1993 to 3966 in 2005, again with a more significant rate of decline post-EVAR ($P < .0001$; Fig 4).

The mean annual number of ruptured AAA repairs decreased from 6335 pre-EVAR to 4667 post-EVAR ($P <$ .0001; Table V). The mean age of patients was similar between time periods; however, a greater proportion of octogenarians underwent repair in the post-EVAR era.

Of the total repairs for ruptured AAA, 43% of patients died. The number of ruptured AAA repair-related deaths per year decreased over time, from 2702 in 1993 to 1605 in 2005 ($P < .0001$; Fig 4). The mean annual number of deaths associated with ruptured AAA repair was significantly lower post-EVAR (1846 vs 2804, $P < .0001$) along with a decrease in mortality (39.9% vs 44.3%, $P < .0001$). The open repair mortality rate was lower in the post-EVAR era (40.8% vs 44.3%, $P < .001$). Length of stay was unchanged; however, discharge to home was more likely in the pre-EVAR era.

EVAR vs open repair of ruptured AAA. In 2005, the latest year available, EVAR was performed in 17% of ruptured AAA repairs. Mortality with EVAR decreased from 42.9% in 2001 to 30.3% in 2005 ($P < .0001$). During the post-EVAR era (2001 to 2005), mortality was 32.3% after EVAR for ruptured AAAs and 40.8% after open repair (Table IV). Length of stay was shorter after EVAR, and

Table I. Intact abdominal aortic aneurysm repairs[a]

Variable	*Total 1993-2005*	*Total 2001-2005*	*EVAR*	*Open*	P[b]
Patients, No.	482,624	194,507	85,125	109,382	
Mortality, %	4.0	3.1	1.3	4.5	<.0001
Age, mean ± SD, y	71.7 ± 8.1	72.2 ± 8.4	73.5 ± 8.2	71.1 ± 8.4	<.0001
>80 y, %	16.4	19.5	24.7	15.3	<.0001
Male, %	79.0	79.2	83.1	76.2	<.0001
White race, %	92.2	90.3	91.0	89.8	<.001
LOS, median (range), d	7 (0-369)	6 (0-306)	2 (0-210)	7 (0-306)	<.0001
Discharge to home, %	88.0	87.5	93.3	82.8	<.0001
Total hospital charge, median $ (range)	35,690 (58-1,314,799)	47,415 (58-982,080)	51,755 (58-926,145)	43,232 (258-982,080)	<.0001

EVAR, Endovascular aortic aneurysm repair; *SD,* Standard deviation; *LOS,* length of stay.
[a]The total number of repairs from 1993 to 2005 is reported as well as a subset of repairs from 2001 to 2005 stratified by EVAR vs open repair.
[b]Comparing EVAR with open repair.

Table II. Comparison of intact abdominal aortic aneurysm repairs before and after the introduction of endovascular repair

Variable	*Pre-EVAR 1993-1998*	*Post-EVAR 2001-2005*	P
Mean annual			
Repairs, total No.	36,122	38,901	<.0001
Deaths, No.	1693	1207	<.0001
Mortality, %	4.7	3.1	<.0001
Open repairs, No.	35,756	21,879	<.0001
Deaths, No.	1,687	992	.31
Mortality, %	4.7	4.5	.31
EVAR, No.	. . .	17,025	. . .
Deaths, No.	. . .	215	. . .
Mortality, %	. . .	1.3	. . .
Age, mean ± SD, y	71.3 ± 7.7	72.2 ± 8.4	<.0001
<60 y, %	7.0	7.3	.13
60-69 y, %	31.5	27.7	<.0001
70-79 y, %	47.6	45.6	<.0001
≥80 y, %	14.0	19.4	<.0001
Male, %	79.3	79.2	.60
White race, %	93.8	90.3	<.0001
LOS, median (range), d	8 (0-369)	6 (0-306)	<.0001
Discharge to home, %	89.3	87.5	<.0001

EVAR, Endovascular aortic aneurysm repair; *LOS,* length of stay; *SD,* standard deviation.

patients were more likely to be discharged home. Total hospital charges were similar.

Ruptured AAA without repair. Patients admitted with a diagnosis of ruptured AAA who did not undergo repair comprised 37% (3645) of all ruptured AAA diagnosis pre-EVAR and 40% (3105) of those post-EVAR. Mortality rates (without repair) pre-EVAR and post-EVAR were 69.6% and 65.9%, respectively ($P < .001$).

Total AAA-related mortality. The overall number of AAA-related deaths (intact repair, ruptured repair, ruptured unrepaired) from 1993 to 2005 was 79,955. From 1993 to 2005, the number of annual deaths decreased by 38%, with the mean annual number of deaths post-EVAR decreasing to 5108 from 7031 ($P < .0001$). In addition, a downward trend continued, with 4498 deaths in 2005.

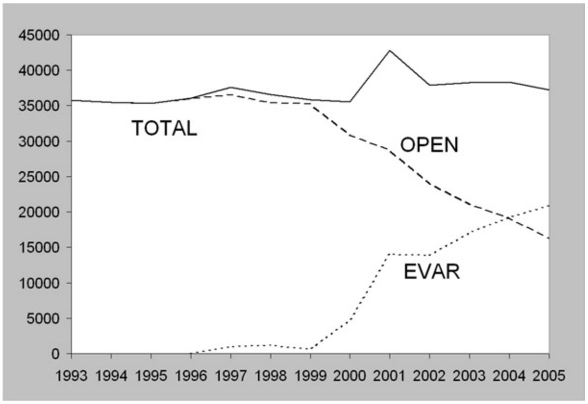

Fig 3. Total, open, and endovascular repairs *(EVAR)* of intact aortic aneurysms from 1993 to 2005.

DISCUSSION

Abdominal aortic aneurysm is a disease of the elderly. With the aging of the United States population, it would be expected that the volume of AAA repair as well as AAA-related mortality would increase. Our current study shows that after the introduction of EVAR, elective repairs have increased, ruptured AAAs have decreased, and procedure-related mortality has decreased for both intact and ruptured AAA. This has led to a decrease in overall AAA-related deaths despite an unchanged mortality rate for elective open repair.

Heller et al[15] examined trends in AAA-related mortality from the National Hospital Discharge Survey and found no improvement in the number of aneurysm repair deaths from 1979 to 1997. They also found an unchanged incidence of ruptured aneurysms and ruptured aneurysm repair.[15] Cowan et al[16] found stable rates of repair using NIS data up to 2003. This background, along with the current finding that the open repair mortality rate remains the same, suggests that the decrease in annual AAA-related deaths of 38% seen in this study is not a continuing effect of medical advancement in general, but a result of the new technique of repair.

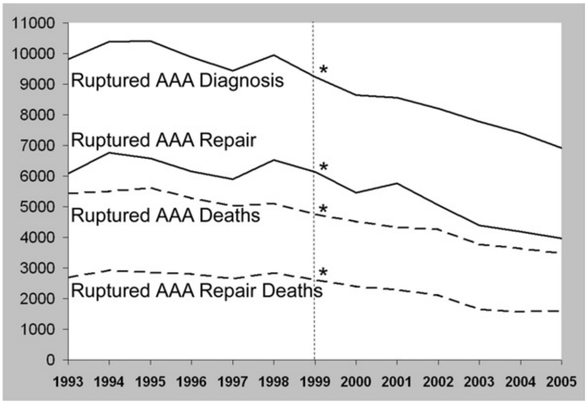

Fig 4. Ruptured abdominal aortic aneurysms *(AAA)* from 1993 to 2005 after AAA repair (total diagnoses, repairs, total deaths, repair deaths). An *asterisk* indicates that the decline in diagnoses, repairs, and deaths after the introduction of endovascular repair was greater than the decline before endovascular repair ($P < .0001$).

The increased age of those repaired in the post-EVAR era (as well as EVAR vs open) suggests the expansion to an older and perhaps sicker patient population that may not have been considered for open surgery but were still at risk for rupture. The shift of repair to EVAR has driven an increase in intact aneurysm repair volume and a subsequent reduction in the number of ruptures overall. In this NIS population, EVAR volume was slightly greater than open repair volume in 2004 and accounted for 56% of repairs by 2005. In the Medicare population, EVAR volume overtook open repair volume by 2003.[2] This difference is likely due to the age difference of the data sets, given that EVAR patients (and Medicare patients) are typically older. Although EVAR now is more common than open repair, with its low elective mortality, its contribution to elective deaths was only 27% in 2005.

We previously have reported that even when patient populations are matched closely to control for confounders, EVAR has a lower in-hospital mortality rate in the US Medicare population than open repair (1.2% vs 4.8%). This difference is still significant, 1.3% vs 4.6%, when comparing the entire (unadjusted) Medicare population even though EVAR patients are older and have more comorbidities.[2] The outcome of this lower mortality as we see here is an overall decrease in population deaths as EVAR becomes the favored repair.

As with intact AAA repair, mortality with EVAR for ruptured aneurysms is lower compared with open repair (32% vs 43%). Less can be concluded from this finding in a retrospective study, because there is the potential for selection bias that cannot be assessed with this administrative database. With proper utilization, however, it is believable that the method could lead to overall improved outcomes. Our finding that the mortality rate within the US population has decreased to just below 40% for ruptured aneurysm repair shows progress compared with prior studies for the past 5 decades.[17] Institutional "EVAR first" programs have been promising, with lower mortality using EVAR for ruptured aneurysm repair.[11,18,19] Mehta et al[11] reported the results of a hospital-wide initiative to facilitate EVAR for ruptured aneurysms. Their program resulted in an 18% mortality rate after EVAR, with 47% of patients receiving an endovascular graft rather than open repair when presenting with ruptured aneurysms.[11]

Cowan et al[16] found that the mortality rate associated with repair of ruptured aneurysms decreased from 1993 to 2003 for open repair (46.5% to 40.7%). Dillavou et al[20] evaluated outcomes from the same time period using a 5% inpatient sample from the Medicare population. They reported an unchanged mortality rate for ruptured repair overall (male average, 44.2%; female average, 52.8%).[20] With the inclusion of more recent years of data, we show that the ruptured repair mortality rate has decreased from an annual average of 44.3% before EVAR to 39.9% for all repairs and to 40.8% for open repair. The decrease in open repair deaths during this time indicates that EVAR is not entirely responsible for the decreased mortality rate of ruptured aneurysm repair; however, there is a contribution that could be expected to increase as volume continues to rise.

Another of the promising findings of this study is that hospital admission for the diagnosis of a ruptured AAA has decreased since EVAR. In the Medicare population, Dillavou et al[20] found ruptured aneurysms declined 23%, from 7300 in 1994 to 5640 in 2003. We report a 30% decrease within our time frame, with a rate of decrease that was more rapid after the introduction of EVAR. Given that rupture repair deaths are the larger contributor to overall aneurysm repair deaths, the population benefit is substantial.

The overall mortality rate associated with a diagnosis of ruptured AAA without repair was lower than expected, raising questions about the accuracy of the diagnosis. This highlights a limitation of the database in that it relies on accurate coding of conditions to identify cases. Pairing concomitant procedures within the hospitalization increases the accuracy of the diagnosis. Some patients are likely admitted with an initial diagnosis of ruptured AAA and an alternative diagnosis is ultimately determined. This database retains the admitting diagnosis as well as any subsequent final diagnoses. This should not affect rupture repair rate and mortality calculations, nor should it affect intact repair. We allowed ruptured AAA diagnosis without repair as an end point because the observed trends in diagnoses and related deaths mirrored those seen in ruptured AAA with repairs (Fig 4) and there was no identifiable reason why coding accuracy would change over time.

The limitations of the current study include the data source along with its retrospective design. The NIS is designed to analyze health care trends and outcomes, and as such, it is ideal for a study of this nature; however, the database relies on accurate and uniform coding and on sampling weights to derive total population estimates. The weights are designed to control for sampling bias and are derived from hospital region and patient characteristics. Analysis of only actual NIS cases without using the sam-

Table III. Ruptured abdominal aortic aneurysm diagnoses and repairs

Variable	*RAAA diagnosis*	*Repair*	*No repair*	P[a]
No. (%)	111,611	72,952 (63)	43,661 (37)	
Age, mean ± SD, y	74.6 ± 9.5	73.1 ± 8.7	77.0 ± 10.3	<.0001
Male, %	74.1	79.5	65.1	<.0001
White race, %	90.2	90.9	89.1	<.001
LOS, median (range), d	7 (0-329)	9 (0-329)	2 (0-248)	<.0001
Mortality, %	52.2	42.7	68.1	<.0001

LOS, Length of stay; *RAAA,* ruptured abdominal aortic aneurysm; *SD,* standard deviation.
[a]Comparing repair with no repair.

Table IV. Ruptured abdominal aortic aneurysm repairs[a]

Variable	*Total 1993-2005*	*Total 2001-2005*	*EVAR*	*Open*	P[b]
No.	72,952	23,336	2499	20,836	
% of RAAA Dx	63	60	. . .	. . .	
Mortality, %	42.7	39.9	32.3	40.8	<.001
Age, mean ± SD, y	73.1 ± 8.7	73.1 ± 9.0	73.8 ± 9.5	73.0 ± 8.9	<.05
Age >80 y, %	24.0	25.5	32.0	24.7	<.001
Male, %	79.5	77.3	77.9	77.3	.74
White race, %	90.9	88.9	86.6	89.2	.14
LOS, median (range), d	9 (0-329)	9 (0-191)	7 (0-104)	10 (0-191)	<.0001
Discharge to home, %	61.1	56.3	69.0	54.6	<.0001
Total hospital charge, median $ (range)	52,740 (1-1,237,327)	72,395 (670-998,554)	74,740 (1,811-804,808)	72,141 (670-998,554)	.60

Dx, Diagnosis; *EVAR,* endovascular aortic aneurysm repair; *LOS,* length of stay; *RAAA,* ruptured abdominal aortic aneurysm; *SD,* standard deviation.
[a]The total number of repairs from 1993 to 2005 is reported as well as a subset of repairs from 2001 to 2005 stratified by EVAR vs open repair.
[b]Comparing EVAR with open.

Table V. Comparison of ruptured abdominal aortic aneurysm repairs before and after the introduction of endovascular repair

Variable	*Pre-EVAR 1993-1998*	*Post-EVAR 2001-2005*	P
Mean annual			
Total repairs, No.	6335	4667	<.0001
Deaths, No.	2,804	1,856	<.0001
Mortality, %	44.3	39.9	<.0001
Open repairs, No.	6335	4167	<.0001
Deaths, No.	2804	1695	<.001
Mortality, %	44.3	40.8	<.001
EVAR, No.	. . .	500	. . .
Deaths, No.	. . .	161	. . .
Mortality, %	. . .	32.3	. . .
Age, mean ± SD, y	73.0 ± 8.5	73.1 ± 9.0	.64
<60 y, %	6.0	7.2	<.05
60-69 y, %	27.4	26.2	.15
70-79 y, %	43.8	41.2	<.01
≥80 y, %	22.8	25.5	<.001
Male, %	80.8	77.3	<.0001
White race, %	92.0	88.9	<.0001
LOS, median (range), d	10 (0-329)	9 (0-191)	.87
Discharge to home, %	65.9	56.3	<.0001

EVAR, Endovascular aortic aneurysm repair; *LOS,* length of stay; *SD,* standard deviation.

pling weights resulted in the same outcome. The NIS has undergone multiple changes since its introduction that include changes in state participation as well as data element inclusion. We used the published supplemental trend file weights to discount any effect these changes may have in comparisons across years.[14] In addition, administrative data do not include anatomic data such as AAA diameter or extent (infrarenal vs pararenal); so, stratification along those criteria is not possible.

The inclusion of the peripheral stent code in combination with a primary diagnosis of AAA was done to capture some of the EVARs performed before the introduction of the specific procedure code. We believe that this still underestimates the true number of EVARs performed in the transition period however, and thus those years were excluded for the comparative analyses so that more accurate conclusions could be reached.

Other factors may have an effect on aneurysm repair and ruptures in the United States today, including health care patterns and risk factor prevalence. Increased patient and physician awareness of AAAs as a result of screening programs may have an effect on the number of patients presenting with rupture.[21] In 2004 the Society for Vascular Surgery Consensus Statement recommended ultrasound screening for patients aged >50 years with a family history of AAA or for men age 60 to 85 years and women 60 to 85 years with cardiovascular risk factors.[22] Screening for AAA did not become a benefit offered by Medicare until January 2007, and then only for male smokers or patients with a family history of aneurysm at the time of their "Welcome to Medicare" visit.

Risk factors including smoking and hypertension have been associated with the diagnosis or rupture of AAA.[23,24] Smoking has decreased in the US population by 50% during the past 4 decades and from 25% to 21% from 1993 to 2005.[25] This may account for some of the observed decrease in ruptures and may decrease the prevalence of AAA over time. The prevalence of hypertension unchanged from 1999 to 2006 (28% to 30%). In 2005 to 2006, 68% of hypertensive adults in the United States used antihypertensive medication; however, only 64% of those achieved an adequate blood pressure goal.[26,27] Less than half of patients entering a large multicenter trial for infrainguinal bypass were using β-blockers or lipid-lowering therapy.[28]

With new technology, the threshold for repair may be lowered to include older, sicker patients who were not candidates for open repair yet were still at risk for rupture. In addition, the threshold may be lowered for smaller diameter aneurysms although these data cannot confirm any potential benefit in these subgroups.

CONCLUSION

The introduction of EVAR has led to an increase in elective AAA repair with lower mortality rates. There has been a coincident decrease in AAA rupture as well as a decrease in total aneurysm related deaths.

AUTHOR CONTRIBUTIONS

Conception and design: KG, FP, AH, AJ, MS
Analysis and interpretation: KG, MS
Data collection: KG, AJ
Writing the article: KG, FP, AH, MW, AJ, MS
Critical revision of the article: FP, AH, MW, MS
Final approval of the article: KG, FP, AH, MW, MS
Statistical analysis: KG, MS
Obtained funding: FP, MS
Overall responsibility: KG, MS

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DISCUSSION

Dr Robert Rutherford (Corpus Christi, Tex). My question has to do with your stated primary end point of aneurysm-related death. It is a long-term end point, not a perioperative end point. Although it is a soft end point whose accuracy depends on whether the death was really witnessed or an autopsy was done and tends to perpetuate any perioperative advantage that EVAR [endovascular aneurysm repair] might have, my point is that you are really comparing postoperative mortality from this NIS [Nationwide Inpatient Sample] data, aren't you?

Dr Kristina Giles. The NIS is an administrative database that is primarily based upon hospital discharge information. The patients that we are able to capture in the NIS are patients that present to a hospital and then are diagnosed with either an intact AAA [abdominal aortic aneurysm] or a ruptured AAA. Further in our study, intact patients were included if they went on to have a repair, whereas ruptured AAA patients we measured whether or not they went on to repair. We do not have autopsy information and make the assumption that there should not be a significant change in the number of patients that die of aneurysm rupture before making it to a hospital.

Dr Rutherford. So you are really presenting just perioperative mortalities?

Dr Giles. Yes.

Dr Jon Matsumura (Chicago, Ill). Aneurysm-related mortality normally includes the periprocedural (inpatient and within 30 days) deaths after initial treatment and reintervention and from rupture. Since your group has done great work looking at these reinterventions after endo and open repairs, were you also counting aneurysm-related mortality after these secondary interventions in this study?

Dr Giles. This is inpatient only database; therefore, we don't have follow-up data with this particular study. We are unable to look at deaths related to secondary interventions, unless they were still in the hospital at the time.

Dr Anton Sidawy (Washington, DC). Any addition, Dr Schermerhorn?

Dr Marc Schermerhorn. We will have that for you in the near future with the deaths related to reinterventions, but using a different database.

Dr Sidawy. Am I correct that the total number of aneurysms repaired over time has remained constant?

Dr Giles. It has remained relatively stable when you account for both intact and ruptured aneurysms. The mean annual volume has increased by approximately one thousand from a pre-endovascular to postendovascular time point.

Dr Sidawy. That indicates that the appropriate operation continues to be performed for the appropriate indication and that surgeons have not changed or relaxed their indication for AAA repair just because EVAR is somewhat simpler and less time consuming. Also, some of us think that since after EVAR the aneurysms done with open repair are the more difficult ones; therefore, the results of open repair may be getting worse. However, I gather that your results have not confirmed this assumption, since mortality rate even for open repair has gone down over the years.

Dr Giles. Correct, even for open the mortality has decreased slightly. When you look at a pre-endovascular to postendovascular period, the mortality rate was 4.7% vs 4.5%. So open repair mortality is certainly not going up.

Dr Schermerhorn. And I'll just back up your comment, Dr Sidawy. We were concerned because when laparoscopic cholecystectomy came out, the procedure volume went up so much that despite the lower operative mortality there was no decrease in cholecystectomy-related death. So we were worried that perhaps we are expanding AAA repair to patients who are so old they are going to die before rupture or their AAA is so small they don't need a repair, but that does not seem to be the case. So we are happy to see these results.

Dr Wilhelm Sandmann (Düsseldorf, Germany). As I understand the message of your paper, it is to use more endovascular treatment and you will have lower mortality rates. I don't think that your paper can prove this because, since endovascular treatment arrived on the market, there are a lot more small aneurysms being repaired, which probably have lesser mortality with either open repair or EVAR. So my suspicion is that the number, which increased in the second period, has to do with better patients and better outcome. Do you know if those aneurysms which are appearing in the second period have the same morbidity and mortality criteria as in the first period?

Dr Giles. We don't have any anatomic data from this database, so I can't tell you if they are smaller or not. However, we do know from prior studies that an EVAR cohort typically has a greater number of comorbidities and is older than an open repair cohort. In this study, the age for all repairs is increasing over time. The average age in the postendovascular era, with the aging population, has actually increased by about 2 years. So just extrapolating from that, you would assume that some of these patients are more ill after EVAR became an option. So I would not conclude that it is a healthier population that is being operated on based on that.

Dr Krish Soundararajan (Philadelphia, Pa). I believe that NIS data that you have chosen for your study categorizes the hospitals based on the region and case volume. There are several reports that in general suggest better outcome of vascular interventions in the high-volume centers. Were you able to see any such difference based on the regions or volume in your analysis?

Dr Giles. We did not look at regional variations for this study; however, that is something that could be done in future work. NIS data have been used in the past to show a volume–outcome relationship, with higher volume associated with lower mortality rates for both open repair and EVAR for intact aneurysms. We did not repeat this in the current study. We did however analyze the hospital volume–outcome relationship for ruptured aneurysms in a separate study that will be presented also at this meeting. This showed that there was a mortality benefit for higher-volume centers.

INVITED COMMENTARY

Thomas S. Huber, MD, PhD, *Gainesville, Fla*

Dr Schermerhorn and colleagues have documented the changes in procedural volume and in-hospital mortality for abdominal aortic aneurysm (AAA) repair in the United States after the introduction of endovascular aneurysm repair (EVAR) using the National Inpatient Sample. They reported that the introduction of EVAR was associated with approximately a 40% reduction in the number of AAA-related deaths encompassing patients undergoing repair of intact aneurysms, ruptured aneurysms, and those with ruptured aneurysms that were not repaired. Somewhat surprisingly, the total number of repairs performed annually (both open and EVAR) has not increased significantly, but there has been an increase in the number of intact repairs and a corresponding decrease in ruptured repairs. The authors have documented that most intact AAA repairs are currently performed using the endo-