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Has the Implementation of EVAR for Ruptured AAA Improved Outcomes?

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Objective: Previous studies have demonstrated improved outcomes with Endovascular Aneurysm Repair (EVAR) for the treatment of ruptured abdominal aortic aneurysms (rAAA). However, these data may not be generalizable to all regions.

Methods: Retrospective cohort study (2001-2005) using state inpatient data.

Results: 5,176 patients underwent repair of AAA. 700 repairs were performed for rAAA (618 [88%] with open surgery (OS) and 82 [12%] with EVAR). Mortality for rAAA was similar for EVAR and OS (45.1% vs. 52.4%, $P = 0.21$). Lack of insurance (OR = 5.1; 95%CI:

1.7-15.2) was a predictor of mortality. Cost of repair for rAAA was greater for EVAR ($\$51,339 \pm 51,719$ vs. $\$39,967 \pm 43,354$, $P = 0.03$) and hospital LOS was similar (14.08 ± 17.97 vs. 13.42 ± 18.18 ; $P = 0.8$).

Conclusion: EVAR did not offer a survival benefit in the state, had a similar hospital LOS, and was significantly more expensive. Further evaluation exploring explanations for inferior outcomes by region are required as EVAR becomes more commonly implemented for rAAA.

Keywords: ruptured; AAA; outcomes; population

Introduction

Endovascular aneurysm repair (EVAR) has now become a common procedure for the treatment of elective abdominal aortic aneurysms (AAA) with proven efficacy.¹⁻⁵ There has been increasing body of literature supporting the use of EVAR in the setting of ruptured abdominal aortic aneurysm (rAAA) repair.⁶⁻⁹ The majority of these studies have been single center series. Other studies have used administrative data to assess outcomes, but these studies have not focused on the regional and state outcomes that may be different than sampled data of the nation or the combination of multiple states data. We evaluated outcomes and hospital use with the implementation of EVAR for rAAA in the state.

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Materials and Methods

Data Sources

Publicly available New Jersey State Inpatient Databases (SID) from 2001 to 2005 that were developed as part of Healthcare Cost and Utilization Project (HCUP), sponsored by the Agency for Health Care Research and Quality (AHRQ).¹⁰ These databases include inpatient discharge abstracts from all acute care community hospitals in the state collected annually by the New Jersey Department of Health and Senior Services. The whole data set included 5 788 232 observations with 290 different variables.

Study Population

All adult patients (aged 18 years and older) with a principal or accompanying diagnosis of AAA who underwent either endovascular aneurysm repair (EVAR) or open surgery (OS). To identify patients with AAA, we used ICD-9-CM (*International Classification of Diseases, Ninth Revision, Clinical Modification*) diagnosis code 441.3 for rAAA and

441.4 for nonruptured AAA. Surgical procedures were identified with ICD-9-CM procedure codes 38.34, 38.44, and 38.64 for OS and 39.71 for EVAR.

Variables Specification

Of 290 variables in the database, we selected for analysis demographic data (age, gender, and race), principal and 8 secondary diagnoses, principal and 7 secondary procedures, admission source and type, disposition of patient at discharge, primary payer, total hospital charges, hospital length of stay (LOS), calendar year, and AHRQ comorbidity measures. Using the HCUP Cost-to-Charge Ratio Files, we translated hospital charges into actual costs. To fix the overtime changes in hospital costs by annual inflation rates, we used the consumer price index (CPI) inflation calculator provided by the US Department of Labor and adjusted the multiyears costs to the cost in 2001. Insurance status was identified as Medicare, Medicaid, private insurance, other insurance, and uninsured. Using Accreditation Council for Graduate Medical Education (ACGME) criteria descriptions, hospitals were classified as follows: major teaching (MT) hospitals if they had surgical residencies based at them or supported a vascular fellowship; teaching affiliates (TA) if residents rotate through these institutions; and nonteaching (NT) if residents and fellows are not present. Hospital mortality was defined as all causes mortality after rAAA repair during the same hospitalization. From the year 2005, New Jersey SID data includes 29 AHRQ comorbidity measures reported by Elixhauser et al.¹¹ To identify these comorbidities in the previous years, we used the Comorbidity Software developed as part of the HCUP.¹² The performance of the Elixhauser comorbidity measures in predicting patient outcomes have been well validated and has been established in the prediction of in-hospital and 1-year mortality among patients with congestive heart failure (CHF), diabetes, chronic renal failure (CRF), stroke, and patients undergoing coronary artery bypass grafting (CABG).¹³

Statistical Analysis

SAS 9.1 software (SAS Institute, Cary, NC) was used for the analysis of the database and all statistics. To test the difference between groups, we used chi-square analysis with calculating odds ratio (OR) and

95% confidence interval (95% CI) for categorical variables, Student *t* test for continuous variables, and calculated the *z* ratio for the significance of the difference between 2 independent proportions. The means are accompanied by the standard deviations (SD). We used a chi-square Cochran-Armitage trend test to track the use of surgical procedures overtime or with aging. A value of 2-sided *P* < .05 was considered significant. Stepwise logistic regression analysis was performed to identify independent predictors of EVAR use and hospital mortality. For adjustment for comorbidities, we used Elixhauser comorbidities measures.¹¹ In addition, we calculated a score for each observation as a sum of Elixhauser comorbidities in this observation. All means are presented with the SD. A value of 2-sided *P* < .05 was considered significant.

Results

A total of 5176 adults aged >18 years had AAA repair in New Jersey acute care hospitals from 2001 to 2005. The mean age at admission for all AAA was 73.2 ± 8.25 years, 14.7% patients were younger than 65 years, and Medicare paid the largest share of hospital costs for all AAA including rAAA. Ruptured AAA repairs accounted for 700 (13.5%) admissions over the study period. The majority of ruptured aneurysms (618; 88.3%) were repaired with OS (*P* < .0002).

Trends for the use of EVAR and OS for repair of AAA and rAAA in New Jersey from 2001 to 2005 were evaluated (Table 1). During this period, the total number of elective EVAR in the state increased from 256 (24.2% of all AAA repairs) to 760 (66.5%; *P* = .0067). At the same time, OS use decreased from 803 cases (75.8%) to 377 (33.2%; *P* = .0036). As well, the use of EVAR for rAAA has significantly increased in the state over the study period, whereas the use of open repair has significantly decreased (*P* < .0002). A significant negative correlation was noted between increased elective EVAR use and the subsequent number of ruptured aneurysms in the state (Spearman correlation coefficient $\rho = -1.0$; *P* < .0001).

Evaluation of mortality after AAA repair (Table 2) demonstrated that the overall mortality was 10.3. Open surgery was 8.0 times (95% CI: 6.34-10.19) more likely to be performed in patients with rAAA, with a greater mortality compared to nonruptured AAA (OR = 26.5; 95% CI: 21.42-32.75). Among patients with rAAA, mortality rates in those who

Table 1. Trends in Surgical Procedures for Repair of AAA, New Jersey, 2001-2005

	2001	2002	2003	2004	2005	Total
All AAA repairs	1059	1059	922	999	1137	5176
EVAR	256	400	416	560	760	2392
Open	803	659	506	439	377	2784
rAAA repairs	186	164	126	105	119	700
EVAR	11	12	14	20	25	82
Open	175	152	112	85	94	618

NOTES: AAA = abdominal aortic aneurysms; EVAR = endovascular aneurysm repair; rAAA = ruptured abdominal aortic aneurysms.

Table 2. Mortality after AAA repair, New Jersey, 2001-2005

Mortality	Total	EVAR	OR
All AAA (%)	10.3	3.2	16.4
		$P < .0002$	
Ruptured (%)	51.6	45.1	52.4
		$P = .2135$	
Nonruptured (%)	3.9	1.7	6.2
		$P < .0002$	

NOTES: AAA = abdominal aortic aneurysms; EVAR = endovascular aneurysm repair; OR = odds ratio.

underwent EVAR (45.1%) and OS (52.4%) did not differ significantly ($P = .2135$).

Elixhauser comorbidity measures were used for adjustment in multivariate logistic regression analysis with the hospital mortality as an outcome variable (Table 3). The model included age, gender, race, insurance status, and the 29 Elixhauser comorbidities as independent variables. Predictors of mortality for rAAA were increasing age, female gender, and lack of insurance.

Overall hospital mortality after all AAA repairs in New Jersey was reduced from 13.0% in 2001 to 7.8% in 2005 ($P < .0002$). However, this trend was significant only for elective nonruptured AAA repairs ($P < .0001$); hospital mortality for rAAA was not changed overtime ($P = .18$).

To evaluate disparities in rAAA outcome, we analyzed teaching status of the institution. Teaching status was defined as MT, TA, or NT as defined by ACGME criteria. We found that MT hospitals were 2.7 times more likely to use EVAR for rAAA than NT hospitals (95%CI: 1.5-4.7). For rAAA repair, teaching status had no significant impact on mortality for EVAR or open repair of rAAA. The mortality

Table 3. Risk Factors for Mortality After rAAA Repair, New Jersey, 2001-2005

Covariates	Adjusted OR ^a	95% CI
Age 60-69 years	2.9	1.20-7.06
Age 70-79 years	5.1	2.13-12.11
Age >80 years	8.2	3.36-19.94
Female	1.59	1.12-2.26
Uninsured	5.2	1.84-14.74

NOTES: EVAR = endovascular aneurysm repair; rAAA = ruptured abdominal aortic aneurysms

a. Model adjusted using Elixhauser Comorbidities. References: Age: 18-59; Race: White; Gender: Male; Insurance: Private; Procedure: EVAR; AAA: ruptured; Teaching status: Nonteaching.

at MT versus NT for OS or EVAR was not significant (55.7% vs 50.4%, $P = \text{NS}$ and 44.2% vs 48.8%, $P = \text{NS}$, respectively).

The volume of centers and the number of centers performing rAAA repair was also evaluated. A total of 80 acute care community hospitals were identified in the state. All 80 hospitals in the state were found to have performed at least 1 repair for a rAAA. Of the state hospitals, all performed open repair and 41 (51.3%) performed repair for rAAA using EVAR. The maximum number of repairs using EVAR was 14 at any 1 center, and the majority (59%) of centers using EVAR for rAAA repair performed only 1 or 2 repairs in 5 years. Higher volume repair centers (being only 11-14 EVAR in 5 years) composed only 20% of the rAAA EVAR cohort. Of the higher volume centers for all rAAA defined as >40 procedures in the period, 1 was a MT facility and 1 was a TA. The mortality of the 2 high volume centers was 51.5% compared to 68.4% at the low volume centers, which performed 1 or 2 repairs for rAAA in the study period, although this did not reach statistical significance ($P = .17$).

Finally, hospital resource use for patients who survived after rAAA repair was estimated to evaluate outcomes (Table 4). The LOS was calculated, and no difference was noted between EVAR and OS for rAAA in the state (14.08 ± 17.97 vs 13.42 ± 18.18 , $P = \text{NS}$). As well, EVAR was found to be significantly more expensive for rAAA than open repair ($51\,339 \pm 51\,719$ vs $39\,967 \pm 43\,354$, $P = .03$).

Discussion

The use of EVAR for the treatment of rAAA has increased dramatically in the United States. Multiple

Table 4. Hospital Resource Use for Ruptured AAA

	EVAR	OR	P Value
LOS	14.08 $\pm$ 17.97	13.42 $\pm$ 18.18	.8373
Cost	51 339 $\pm$ 51 719	39 967 $\pm$ 43 354	.0257

NOTES: AAA = abdominal aortic aneurysms; EVAR = endovascular aneurysm repair; LOS = length of stay; OR = odds ratio.

single center series have shown an advantage to EVAR for the repair of rAAA.^{6,14,15} Tertiary single center series have been instrumental in leading the trend for EVAR in rAAA but may not be generalizable to the population at large as they may have different referral patterns, are centers of excellence, and have specific protocols in place for rAAA similar to trauma.^{14,16} Recent studies using national sampling data have also suggested a benefit with the use of EVAR for rAAA, although the Nationwide Inpatient Sample (NIS) data may not reflect regional variation for specific geographic areas.⁶

This study demonstrates no survival or resource advantage with the implementation of EVAR in a state population for the repair of rAAA. This is contrary to previous publications⁶⁻⁹ and insight into regional variation for outcomes of rAAA after EVAR is warranted. This study demonstrates little difference between the two methods for rAAA repair in the state with the evaluation of hospital resource use. No advantage in LOS or intensive care unit (ICU) days was noted, and cost was found to be significantly greater for EVAR of rAAA compared to OS.

Lee et al. demonstrated in a single center study that overall mortality was no different from historical values with the use of EVAR for rAAA. They suggested that we are simply selecting patients with the greatest chance of survival to undergo EVAR.¹⁷ Of note from this population study is that physician bias is inherent in the cohort as it is not randomized. This makes our findings more dramatic and concerning. Even with surgeon bias and patient selection for survival, participants undergoing EVAR for rAAA did not have improved outcomes in the state.

Reasons for the difference in New Jersey state outcomes compared to other single center or multi-state data using EVAR for rAAA are not clear. The explanation is likely multifactorial and includes components such as hospital to population density, referral patterns, and current triage systems in the state. New Jersey was found to have a large number of hospitals performing repair of rAAA with EVAR

and OS. The large number of hospitals in a relatively small region may have led to increased repair of rAAA in many hospitals. In other regions of the country, fewer hospital facility choices may exist creating high volume centers or different patterns of triage that may improve outcomes. Previous studies have demonstrated improved outcomes for rAAA with high-volume surgeons.¹⁸

Areas with high hospital to population ratios and shorter travel distances to hospitals such as New Jersey may not offer superior outcomes. This suggests that systems of triage or transfer to specific high volume centers may offer a survival benefit, although no significant difference was seen in volume status or teaching status in the state for the treatment of rAAA. As well, transfer to tertiary centers in New Jersey for open AAA repair has been previously shown to increase patient ICU requirements with no overall survival benefit.¹⁹

Studies in the trauma literature have shown the advantage of triage systems and referral to tertiary high volume centers.²⁰⁻²² Improvements in outcome in a regionalized trauma systems are secondary to a combination of elements, which may include prehospital protocols and performance improvement programs.²³ Although evaluation of rAAA outcomes in states with well-established trauma triage systems showed no advantage for open rAAA repair,²⁴ this may not be true with EVAR. As well, previous studies have also shown the importance of dedicated endovascular teams²⁵ and protocols^{7,14} to improve outcomes for rAAA, which may not exist in all centers in the state.

Finally, less tangible factors influencing outcomes for rAAA may include patient insurance status. Insurance status has been associated with level of care in other areas of surgery and medicine.^{26,27} We have demonstrated that the uninsured were 5 times more likely to die with a rAAA in the state when compared to patients with private insurance. Reasons for this disparity may be the extent of disease when treated, access to AAA screening, or care in the state during an emergent event.

This study has several limitations. The New Jersey State Inpatient Databases does not include patients in military hospitals or VA medical centers. Administrative data originally were intended primarily for reimbursement, but recent reports suggest that studies based on administrative data can be appropriate for profiling outcomes.²⁸ The potential for inclusion bias based on limited coding schemes for the

many clinical entities cannot be entirely excluded. As well, the Elixhauser Index is intended to adjust for comorbid illnesses and it does not incorporate the degree of illness or has it been specifically applied to the population of patients undergoing aneurysm repair.

In conclusion, this population study suggests that EVAR for the treatment of rAAA may not improve mortality or be beneficial in all areas. The current literature may not be generalizable to all regions or populations. Evaluation of geographic areas, population densities, and proximity to health care facilities may yield further insight in reducing rAAA mortality. Other considerations to improve outcomes for rAAA may include evaluation of triage patterns and the implementation of protocols standardizing care in all facilities. To improve overall outcomes for the treatment of rAAA, explanation of regional variation will need to be addressed in further detail.

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