Failure to rescue trends in elective abdominal aortic aneurysm repair between 1995 and 2011

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Objective: **Factors affecting mortality after abdominal aortic aneurysm (AAA) repair have been extensively studied, but little is known about the effects of the shift to endovascular aneurysm repair (EVAR) vs open repair on failure to rescue (FTR). This study examines the impact of treatment modalities on FTR for elective AAA surgery during the years 1995 to 2011.**

Methods: **Data for 491,779 patients undergoing elective AAA surgery were collected from Medicare files. Patient demographics, comorbidities, hospital volume, and repair type were collected. Primary outcome was FTR: the percentage of deaths in patients who had a complication within 30 days of surgery. Data were analyzed by univariate and multivariate analysis.**

Results: **Patients undergoing AAA surgery have become progressively more complex, with 84.96%, 89.33%, 93.76%, and 95.72% presenting with one or more comorbidities in 1995, 2000, 2005, and 2011, respectively. Despite this, overall FTR after AAA surgery was stable from 1995 to 2000 ($P = .38$) and decreased from 2.68% to 1.58% between 2000 and 2011 ($P < .001$). In addition, FTR in EVAR decreased from 1.70% to 0.58% from 2000 to 2006 ($P = .03$) and then stabilized at 0.88% ± 0.9% after 2007 ($P = .45$). Unlike for EVAR, FTR for open repair remained stable at 3.06% ± 0.17% to 2.74% ± 0.16% from 1995 to 2000 ($P = .38$) but increased to 4.51% ± 0.21% in 2011 ($P < .001$). Mortality was highest after transfusion (20.86%), prolonged ventilation (17.37%), and respiratory complications (29.78%) for all AAA surgeries. Of note, high-volume hospitals had lower FTR rates than low-volume hospitals for both open (2.73% vs 5.66%; $P < .001$) and endovascular (0.7% vs 1.69%; $P < .001$) repair. Multivariate analysis showed that high annual volume hospital status (odds ratio, 0.6; confidence interval, 0.58-0.63) and endovascular repair (odds ratio, 0.3; confidence interval, 0.28-0.31) were associated with decreased FTR.**

Conclusions: **The success in AAA surgery of rescuing patients from 30-day mortality after a complication is associated with increased volume of EVAR. This increased success can also be attributed to the improved FTR outcomes and complication rates when surgeries are performed at high-volume hospital centers. (J Vasc Surg 2014;60:1473-80.)**

Failure to rescue (FTR) is a measure of a hospital's ability to successfully treat patients who have had a complication after surgery. It is defined as the 30-day mortality rate in patients with one or more complications. To calculate FTR, the number of deaths is divided by the number of abdominal aortic aneurysm (AAA) cases with complications. FTR has emerged as a tool for assessing surgical quality since its original definition by Silber et al[1] in 1992. FTR has been used to assess surgical quality for a variety of procedures, including thoracic,[2-4] aortic abdominal,[5-7] and general surgical procedures.[8-11] It is currently one of the Agency for Healthcare Research and Quality Patient Safety Indicators (PSI 4).[12]

For more than 20 years, there has been a dramatic shift in the way in which AAA repair is performed. Since the mid-2000s, the majority of AAA surgeries have been endovascular.[13] No study to date has analyzed the effects of this shift on FTR outcomes in patients undergoing AAA surgery.

This study analyzes the trend in FTR between 1995 and 2011 in open and endovascular AAA repair. It seeks to identify factors associated with increased success in AAA surgery. We hypothesized that there would be a decreased trend in FTR for patients undergoing AAA repair, primarily because of an increased number of minimally invasive procedures being performed over time.

METHODS

Data were extracted from Medicare Inpatient Standard Analytical and Denominator files for patients undergoing elective AAA repair between 1995 and 2011. The patients were selected through International Classification of Diseases, Ninth Revision, Clinical Modification diagnosis codes for AAA and procedure codes for endovascular aneurysm repair (EVAR) and open AAA repair.[14] Patients who underwent thoracic, thoracoabdominal, or ruptured aortic aneurysm repair were excluded. The first hospitalization in which abdominal aneurysm repair was performed was defined as the index hospitalization.

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Author conflict of interest: none.

Presented as a poster at the 2014 Vascular Annual Meeting of the Society for Vascular Surgery, Boston, Mass, June 5-7, 2014.

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The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

0741-5214

http://dx.doi.org/10.1016/j.jvs.2014.08.106

Patient demographic data (age, sex, and race) were extracted from the index hospitalization. Patient baseline comorbidities were determined on the basis of the index hospitalization and hospitalizations 1 year before the index hospitalization. Codes for comorbidities are listed in Egorova et al.[14]

Complications were modified from studies analyzing severe complications[15] and surgical reinterventions.[7] These perioperative complications and interventions included but were not limited to cardiac arrest, vascular device implant and graft complications, amputation, and wound complication. See the Supplementary Table for complication codes that were used in our study. Analysis of trends in endovascular repair incorporates the years 2000 to 2011 because the procedure code for EVAR was introduced in the last quarter of 2000. Analysis of hospital volume was based on annual procedural volume for any hospital performing open or endovascular repair. Hospitals were subsequently categorized by tertile, with low-volume hospital denoting the lowest 33% and high-volume hospital denoting the highest 33% in annual procedural volume. This study was approved by the Centers for Medicare and Medicaid Privacy Board, and the patient consent/authorization form was waived.

Statistical analysis. Statistical analysis included the Student *t*-test for analysis of continuous variables and χ^2 test for categorical variables. We used SAS Proc AutoReg (SAS Institute, Carey, NC) to account for autocorrelation between consecutive years for trend analysis. Multivariate logistic regression analysis was used to determine factors associated with major complications and FTR. The dependent variables in the logistic regression models were sepsis, septic shock, acute dialysis, prolonged ventilation, perioperative stroke, pulmonary embolism, arterial complications, transfusion, respiratory failure, and FTR. The following baseline confounders were included in the model as independent variables: age, gender, race, comorbidities, hospital annual volume, and year of the surgery. Odds ratios (ORs) were provided with 95% confidence intervals (CIs). Statistical significance was attributed to results when $P < .05$. SAS 9.3 software (SAS Institute) was used to perform the analysis.

RESULTS

Elective AAA repair was performed in 491,779 patients. Among them, 295,851 patients underwent open repair and 195,928 underwent endovascular repair. The majority of AAA repairs were open from 1995 to 2004. In 2005, 55.28% of AAA repairs were endovascular. The percentage of AAA repairs that were endovascular increased from 6.00% in 2000 to 90.35% in 2009 and stabilized at 88% in 2010-2011 (Fig 1).

Trend in comorbidities. Table I shows trend in comorbidities for patients undergoing AAA repair. The percentage of patients with any comorbidity before surgery has increased for open repair (from 1995 to 2011; $P = .01$), EVAR (from 2000 to 2011; $P < .001$), or any AAA surgery (from 1995 to 2011; $P < .001$). From 1995 to 2011, the number of patients undergoing any AAA repair with congestive heart failure ($P < .001$), neurologic comorbidity ($P < .001$), peripheral arterial disease ($P < .001$), diabetes ($P < .001$), hypertension ($P < .001$), or hyperlipidemia ($P < .001$) has significantly increased. The number of patients undergoing endovascular repair from 2000 to 2011 with these comorbidities (except congestive heart failure) as well as pulmonary comorbidity ($P = .003$) and liver disease ($P = .01$) has increased by 7.55% and 0.89%, respectively. Finally, the number of patients undergoing open repair with neurologic ($P < .001$) comorbidities as well as peripheral arterial disease ($P < .001$), diabetes ($P = .001$), cancer ($P = .007$), hypertension ($P = .01$), and hyperlipidemia ($P = .01$) increased between 1995 and 2011.

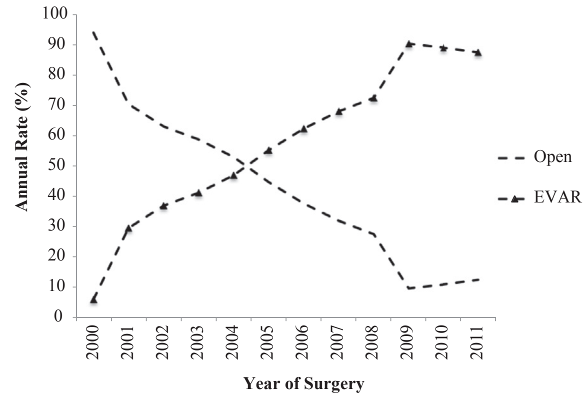

Fig 1. Percentage of endovascular aneurysm repair (*EVAR*) ($P < .001$) vs open repair ($P < .001$) performed annually.

Trends in complication rates. From 1995 to 2000, complication rates for patients undergoing AAA repair were stable (Fig 2) at 29.51% ± 0.46% and 28.71% ± 0.46% ($P = .4$). Complication rates decreased from 29.71% to 19.24% from 2000 to 2011 ($P < .001$). Complication rates for patients undergoing endovascular repair remained stable at 14.94% ± 0.36% and 12.24% ± 0.33% between 2000 and 2011. Whereas complication rates for open repair were stable at 29.51% ± 0.46% and 28.71% ± 0.46% between 1995 and 2000, complication rates for these patients increased from 28.71% to 49.98% between 2000 and 2011 ($P < .001$).

Trends in FTR. There was increased success in saving patients from 30-day mortality after complication of any AAA repair between 2000 and 2011. FTR in patients undergoing AAA repair was stable from 1995 to 2000 ($P = .38$) but decreased from 2.68% to 1.58% between 2000 and 2011 ($P < .001$; Fig 3). There was increased success in preventing deaths after complications among patients undergoing EVAR. FTR in these patients decreased from 1.70% to 0.58% from 2000 to 2006 ($P = .03$) and then stabilized at 0.58% ± 0.08% to 0.88% ± 0.9% after 2007 ($P = .45$). In contrast to trends of success in endovascular repair, there was decreased trend in saving patients from 30-day mortality after complications from open repair