The effect of hospital factors on mortality rates after abdominal aortic aneurysm repair

Anahita Dua, MD, MS, MBA,[a] Courtney L. Furlough, BS,[b] Hunter Ray, BS,[b] Sneha Sharma, BS,[c] Gilbert R. Upchurch, MD,[d] and **Sapan S. Desai, MD, PhD, MBA,[e]** *Milwaukee, Wisc; Houston and Fort Worth, Tex; Charlottesville, Va; and Springfield, Ill*

Background: **Patient factors that contribute to mortality from abdominal aortic aneurysm (AAA) repair have been previously described, but few studies have delineated the hospital factors that may be associated with an increase in patient mortality after AAA. This study used a large national database to identify hospital factors that affect mortality rates after open repair (OAR) and endovascular AAA repair (EVAR) of elective and ruptured AAA.**
Methods: **A retrospective analysis was completed using the Nationwide Inpatient Sample from 1998 to 2011. International Classification of Disease, Ninth Revision codes were used to identify patients who underwent elective or ruptured AAA repair by OAR or EVAR. The association between mortality and hospital covariates, including ownership, bed size, region, and individual hospital volume for these patients was statistically delineated by analysis of variance, χ^2, and Mann-Kendall trend analysis.**
Results: **A total of 128,232 patients were identified over the 14-year period, of which 88.5% were elective procedures and 11.5% were performed acutely for rupture. Most hospitals that complete elective OAR do between one and 50 cases, with mortality between 0% and 40%. Hospitals with mortality >40% uniformly complete fewer than five elective OAR cases annually and fall in the bottom 2.5% of all hospitals for mortality. Most hospitals that complete elective EVAR do between one and 70 cases, with mortality between 0% and 13%. Hospitals with mortality >13% uniformly complete fewer than eight elective EVAR cases annually and fall in the bottom 2.5% of all hospitals for mortality. The majority of hospitals that complete OAR or EVAR for ruptured AAA have between 0% to 100% for mortality, indicative of the high mortality risk associated with rupture.**
Conclusions: **Hospitals that complete fewer than five OARs or eight EVARs annually have significantly greater mortality compared with their counterparts. Improved implementation of best practices, more detailed informed consent to include hospital mortality data, and better regional access to health care may improve survival after elective AAA repair. (J Vasc Surg 2014;60:1446-51.)**

The number of abdominal aortic aneurysm (AAA) repairs has remained constant at ∼45,000 cases annually. The significant increase in endovascular repairs of abdominal aneurysms (EVARs) has resulted in a decrease in volume of open AAA repairs (OARs).[1] By 2020, vascular surgeon trainees may complete only five OARs during their vascular residency or fellowship training.[2] This decrease in OAR volume may be associated with an increase in complication and mortality rates after OAR. Patient factors that contribute to mortality from aneurysm repair have been previously described, but few studies have delineated the hospital factors that may be associated with an increase in patient mortality after AAA repair.[1,3,4]

A report of data from a Medicare claims analysis found smaller hospitals with lower volume are associated with greater rates of morbidity and mortality after surgery. Hospitals that complete <18 OARs per year have a mortality that is at least 1.4 times greater than their counterparts who perform a minimum of 77 cases annually.[5] The LeapFrog Group established that a minimum of five OARs should be completed annually to minimize the risk of mortality but did not expand on the effect of hospital size, location, and region on mortality after AAA repair.[6] Although there are data on OAR, little is known about the minimum volume standards for EVAR. Further, little is known about the influence of hospital ownership, size, location, teaching status, and region on outcomes after AAA repair. This study used a large national database to identify hospital factors that affect mortality rates after OAR and EVAR of elective and ruptured AAA.

METHODS

Institutional Review Board approval was waived, and no patient consent was required for the research conducted in this study.

From the Department of Surgery, Medical College of Wisconsin, Milwaukee[a]; the Department of Surgery, University of Texas Medical School at Houston, Houston[b]; the Medical School, Texas College of Osteopathic Medicine, Fort Worth[c]; the Department of Surgery, University of Virginia, Charlottesville[d]; and Department of Vascular Surgery, Southern Illinois University, Springfield.[e]
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Reprint requests: Sapan S. Desai, MD, PhD, MBA, Assistant Professor and Director, Department of Vascular Surgery, Director of the Quality Alliance and Predictive Analysis, Memorial Medical Center, Southern Illinois University, PO Box 19638, Springfield, IL 62794-9638 (e-mail: sdesai74@siumed.edu).
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Table I. International Classification of Diseases, Ninth Revision (*ICD-9*) diagnosis and procedure codes used to select patients from the National Inpatient Sample (NIS)

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

Database and selection. A retrospective analysis was completed using the Nationwide Inpatient Sample (NIS), a part of the Health Care Utilization Project that is maintained by the Agency for Healthcare Research and Quality. The NIS is the largest all-payer inpatient database and includes a stratified 20% random sample of all nonfederal inpatient hospital admissions throughout the United States (U.S.). Clinical records were obtained with the use of International Classification of Diseases, Ninth Revision (ICD-9) diagnosis and procedure codes to ensure that the sample included only patients who underwent treatment for AAA (Table I).

Variables. The database was queried between the years 1998 and 2011. Clinical covariates included the type of repair (OAR vs EVAR), elective vs ruptured classification, median cost of care in 2014 in U.S. dollars adjusted using the Consumer Price Index, median length of stay (LOS) in days, and inpatient mortality. Hospital covariates were also evaluated, including ownership (government, nonfederal; private, nonprofit; and private, for-profit hospitals), bed size (small, medium, and large; Table II), location (rural, and urban), teaching status (nonteaching, teaching), and region (Northeast, Midwest, South, and West; Tables III and IV).

Hospital ownership definitions are derived from the American Hospital Association survey results. Government, nonfederal hospitals are those that are owned by the state, county, or city. Hospitals owned by investors, such as by a corporation or partnership, are classified as private, for-profit, whereas those operated by a church or another non-for-profit entity are classified as private, nonprofit hospitals. The distinction between rural and urban is based off the Core Based Statistical Area derived from the 2000 U.S. Census data. The data presented are actual numbers recorded in the database and are not extrapolated to reflect population-level data.

Statistical analysis. Statistical analysis was completed using analysis of variance for continuous variables (number

Table II. Hospital bed size (small, medium, and large) as a function of location and teaching status as adapted from the National Inpatient Sample (NIS) Data Dictionary

Location and teaching status	*Hospital bed size categories*		
	Small, No.	*Medium, No.*	*Large, No.*
Northeast region			
Rural	1-49	50-99	≥100
Urban, nonteaching	1-124	125-199	≥200
Urban, teaching	1-249	250-424	≥425
Midwest region			
Rural	1-29	30-49	≥50
Urban, nonteaching	1-74	75-174	≥175
Urban, teaching	1-249	250-374	≥375
Southern region			
Rural	1-39	40-74	≥75
Urban, nonteaching	1-99	100-199	≥200
Urban, teaching	1-249	250-449	≥450
Western region			
Rural	1-24	25-44	≥45
Urban, nonteaching	1-99	100-174	≥175
Urban, teaching	1-199	200-324	≥325

of cases) and χ^2 for categoric variables (ie, hospital covariates, inpatient mortality). The Mann-Whitney *U* test was used for LOS and median total costs. Data analysis and management were completed using IBM SPSS 22.0 software (IBM Corp, Armonk, NY).

All values are presented as means except for LOS and total charges, which are presented as median values. The volume of elective and ruptured AAA repaired using OAR and EVAR methods for individual hospitals were plotted, and the 95% confidence intervals (CIs) were delineated for the *x*-axis and *y*-axis (Fig). Mann-Kendall trend analysis was completed to determine if trends outside the 95% CI were statistically significant; τ values and *P* values are reported in conjunction with odds ratios (ORs). Statistical significance was set at a probability of $P < .05$.

RESULTS

A total of 128,232 patients with a diagnosis of AAA who underwent OAR or EVAR were identified from the NIS between 1998 and 2011. This represents 630,901 inpatient admissions for AAA in the U.S. within this 14-year period. Of these admissions, 88.5% were elective procedures, and 11.5% were performed acutely for rupture. Most elective AAA repairs are completed at private, nonprofit (57.2%), large (72.5%), teaching hospitals (56.7%) located in urban centers (93.8%). OAR is most common in the Midwest (26.6%) and at government, nonfederal hospitals (25.0%). Median LOS for elective repair varies between 2 and 3 days, likely skewed down because 73.4% to 79.7% of all cases are done by EVAR. Median total costs are highest in the West ($35,232). There are no differences in Diagnosis Related Groups mortality risk (1.8-1.9; $P > .05$) or inpatient mortality (1.6%-2.0%; $P > .05$; Table III).

Table III. Demographics and outcomes for patients who underwent repair for elective abdominal aortic aneurysm (*AAA*) from 1998 to 2011

Hospital variables	*Overall, %*	*OAR, %*	*EVAR, %*	*Elective admission, %*	*LOS, days*	*Costs, $*	*DRG mortality risk*	*Inpatient mortality, days*
Control/ownership								
Government, nonfederal	13.5[a]	25.0[a]	75.0[a]	83.2[a]	2.0	28,972	1.8	2.0
Private, nonprofit	57.2[a]	22.4[a]	77.6[a]	86.0[a]	2.0	30,473	1.8	1.6
Private, for-profit	29.3[a]	20.3[a]	79.7[a]	74.5[a]	2.0	28,081	1.8	2.0
Bed size								
Small	8.2[a]	21.7[a]	78.3[a]	83.4	2.0	30,477[a]	1.8	2.0
Medium	19.3[a]	21.2[a]	78.8[a]	83.7	2.0	27,925[a]	1.8	1.6
Large	72.5[a]	24.7[a]	75.3[a]	83.0	3.0	29,079[a]	1.8	1.9
Location								
Rural	6.2[a]	23.9	76.1	81.3[b]	2.0	30,593	1.7	1.7
Urban	93.8[a]	23.8	76.2	83.3[b]	2.0	28,867	1.8	1.8
Teaching status								
Nonteaching	43.3[b]	22.4[a]	77.6[a]	82.5[b]	2.0	28,952	1.8	1.8
Teaching	56.7[b]	24.9[a]	75.1[a]	83.6[b]	3.0	28,945	1.8	1.8
Region								
Northeast	18.9[a]	21.2[a]	78.8[a]	83.3[a]	3.0	27,583[a]	1.8	1.8
Midwest	25.4[a]	26.6[a]	73.4[a]	84.9[a]	2.0	28,651[a]	1.8	1.8
South	39.0[a]	23.3[a]	76.7[a]	80.6[a]	2.0	27,740[a]	1.8	1.8
West	16.7[a]	23.9[a]	76.1[a]	85.3[a]	2.0	35,232[a]	1.9	1.9

DRG, Diagnosis Related Group; *EVAR,* endovascular AAA repair; *LOS,* length of stay; *OAR,* open AAA repair.
[a] $P < .001$.
[b] $P < .05$.

Table IV. Demographics and outcomes for patients who underwent repair for ruptured abdominal aortic aneurysm (*AAA*) from 1998 to 2011

Hospital variable	*Overall, %*	*OAR, %*	*EVAR, %*	*Elective admission, %*	*LOS, days*	*Costs, $*	*DRG mortality risk*	*Inpatient mortality, %*
Control/ownership								
Government, nonfederal	12.1[a]	83.5[a]	16.5[a]	4.4	7.0	41,648	4.0	40.9[b]
Private, nonprofit	60.6[a]	70.9[a]	29.1[a]	6.8	7.0	43,616	4.0	37.7[b]
Private, for-profit	27.3[a]	61.5[a]	38.5[a]	6.2	6.0	41,843	4.0	38.9[b]
Bed size								
Small	7.2[a]	66.7	33.3	7.5[b]	6.0[b]	43,744	4.0	36.5
Medium	19.1[a]	67.0	33.0	9.8[b]	8.0[b]	43,340	4.0	34.2
Large	73.7[a]	66.0	34.0	6.8[b]	8.5[b]	47,819	4.0	32.2
Location								
Rural	6.1[a]	83.3[a]	16.7[a]	7.4	9.0	44,040	4.0	32.1
Urban	93.9[a]	65.2[a]	34.8[a]	7.4	8.0	46,770	4.0	33.0
Teaching status								
Nonteaching	38.8[a]	72.2[a]	27.8[a]	5.8[b]	7.0[a]	42,206[a]	4.0	38.9[a]
Teaching	61.2[a]	62.5[a]	37.5[a]	8.5[b]	9.0[a]	49,572[a]	4.0	29.1[a]
Region								
Northeast	18.7[a]	64.0	36.0	5.5	8.0	41,240[a]	4.0	35.7
Midwest	26.5[a]	68.3	31.7	8.8	9.0	49,155[a]	4.0	31.2
South	35.4[a]	65.0	35.0	7.2	8.0	42,194[a]	4.0	31.6
West	19.3[a]	66.3	33.7	7.8	7.0	56,372[a]	4.0	34.8

DRG, Diagnosis Related Group; *EVAR,* endovascular AAA repair; *LOS,* length of stay; *OAR,* open AAA repair.
[a] $P < .001$.
[b] $P < .05$.

Most ruptured AAA were operated on at private, nonprofit (60.6%), large (73.7%), urban (93.9%), teaching hospitals (61.2%). OAR ranges from 61.5% (private, for-profit hospitals) to 83.5% (government, nonfederal hospitals). Rural centers and nonteaching hospitals are more likely to complete OAR for ruptured AAA (83.3% and 72.2%, respectively; $P < .001$). Median LOS varies from 6 to 9 days and is significantly longer at large hospitals

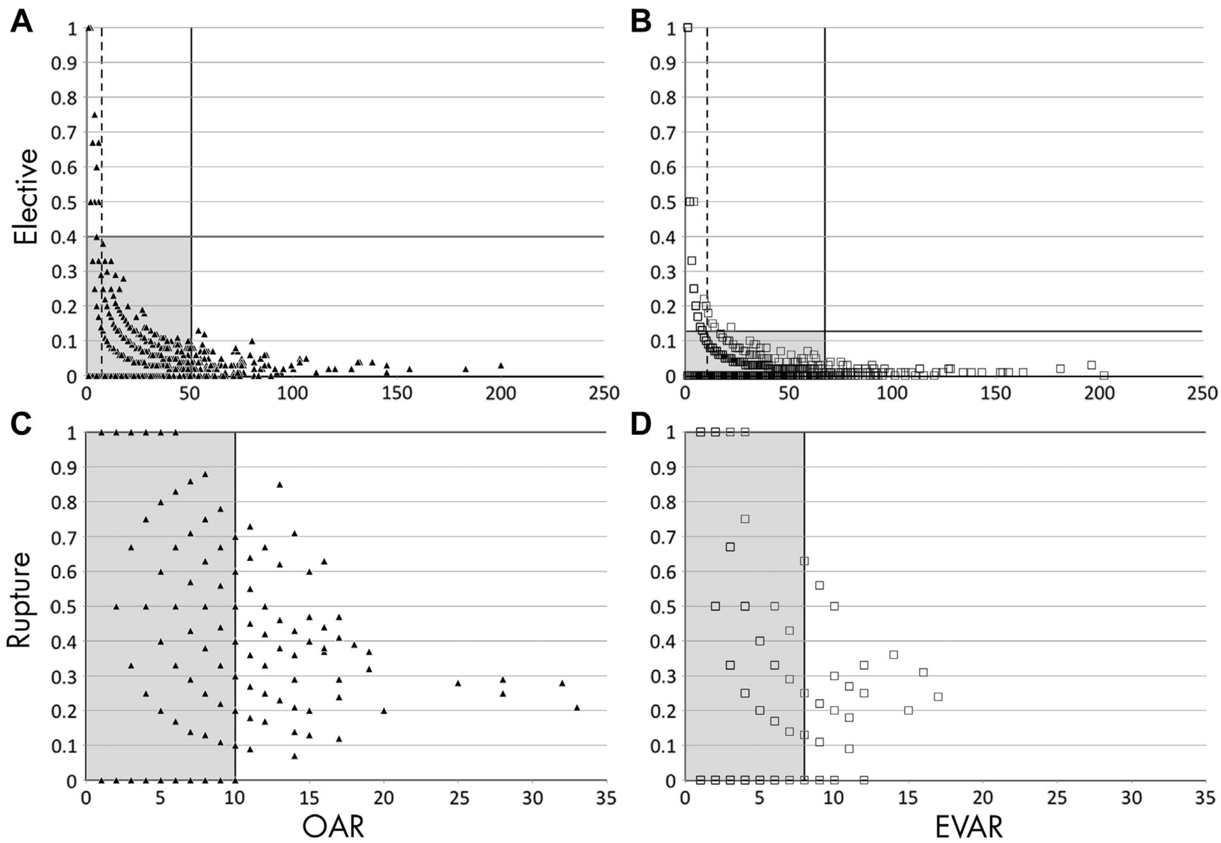

Fig. Open abdominal aortic aneurysm (AAA) repair (*OAR*) and endovascular AAA repair (*EVAR*) cases completed for unruptured and ruptured AAA for individual hospitals between 1998 and 2011. **A,** OAR for unruptured AAA. **B,** EVAR for unruptured AAA. **C,** OAR for ruptured AAA. **D,** EVAR for ruptured AAA. Elective AAA repairs are located in the *top row* and ruptured AAA repairs in the *bottom row*. The *first column* demarcates OAR and the *second column* EVAR. The *volume* for each hospital is shown on the *x*-axis and *inpatient mortality* on the *y*-axis. Individual hospital volume and mortality data are presented by *triangles* for OAR and *squares* for EVAR. The *shaded box* indicates the ranges that include 95% of the hospitals by volume and by inpatient mortality. The limits of that box are extended as *horizontal* and *vertical lines* for each of the four groups. The *single dashed vertical line* for the elective AAA repairs is based off the threshold between low-volume and high-volume hospitals, as determined by trend analysis. For clarity, please note that the *x*-axes are different for elective vs rupture cases.

(8.5 days; $P < .05$) and teaching hospitals (9 days; $P < .05$). Median total costs are highest at teaching hospitals ($49,572) and in the Midwest ($49,155). Diagnosis Related Groups mortality risk is 4, regardless of hospital covariate, and inpatient mortality varies from 29.1% (teaching hospitals) to 40.9% (government, nonfederal hospitals; Table IV).

Elective and ruptured AAA volume repaired using OAR and EVAR at individual hospitals was determined (Fig). Most hospitals that complete elective OARs do between one and 50 cases (95% CI), with mortality between 0% and 40% (95% CI). Hospitals with mortality >40% uniformly complete fewer than five elective OARs annually and fall in the bottom 2.5% of all hospitals for mortality (Fig, *A*). These hospitals have a mortality of up to 100% (OR, 2.5 to 10.6 when compared to the mean ± two standard deviations of all hospitals or the middle 95% of all hospitals; $\tau = 0.20$-0.84; $P < .001$).

Similarly, most hospitals that complete elective EVARs do between one and 70 cases (95% CI) with mortality between 0% and 13% (95% CI). Hospitals with mortality >13% uniformly complete fewer than eight elective EVARs annually and fall in the bottom 2.5% of all hospitals for mortality (Fig, *B*). These hospitals also have a mortality of up to 100% (OR, 7.7 to 33.2 when compared to the mean ± two standard deviations of all hospitals; $\tau = 0.21$-0.93; $P < .001$).

Hospitals that complete OAR or EVAR for ruptured AAA have a 95% CI of 0% to 100% for mortality, indicative of the high mortality risk associated with rupture (Fig, *C* and *D*). Most hospitals complete one to 10 OARs and one to eight EVARs for ruptured AAA. Although not as pronounced as elective AAA cases, hospitals that complete >10 OARs or eight EVARs for ruptured AAA have mortality between 20% and 40%. These trends are not statistically significant ($\tau = -0.02$ for OAR; $\tau = -0.07$ for EVAR; $P = .05$).

LOS, costs, and inpatient mortality were determined for smaller hospitals after excluding patients who were transferred out, and no statistically significant difference was identified ($P > .05$). A similar evaluation for patients transferred into other centers was completed, and no significant differences were identified in this cohort compared with patients who were primary admissions at the hospital ($P > .05$).

DISCUSSION

Morbidity and mortality from AAA repair can be significant, and multiple studies have described patient factors that may contribute to worse patient outcomes in this population.[7,8] However, less is known about the effect hospital factors have on mortality rates in patients undergoing AAA repair. A national Medicare claims database separated hospitals into quintiles over a 10-year period to determine the correlation between hospital volume and postprocedural patient mortality.[5] Low OAR volume was defined as the bottom 20%, where <18 OAR cases were performed annually, whereas high volume (top 20%) was defined as completing >77 OAR cases in a year.[5] Mortality was 1.4 times greater at the low-volume hospitals than at the high-volume hospitals (3.85% vs 2.74%, respectively), and the LeapFrog group has also reported similar trends for low-volume hospitals, especially those institutions that complete fewer than five OAR cases annually.[6-8]

Referring patients to regional centers with higher volume has been shown to decrease mortality by up to 23%.[6,9,10] Low surgeon volumes have been tied to low hospital OAR volumes, and both are independent predictors of inpatient mortality.[11] The results of our study suggest that the differences between low-volume centers and their counterparts are more significant than previously recognized.[5,6] Hospitals that completed fewer than five elective OAR cases per year (bottom 2.5%) have mortality rates that are up to 2.5 times greater than hospitals that do more than five cases (95% CI) and are 10.6 times greater than hospitals that do >50 cases (top 2.5%).

Hospital volume has also been shown to affect morbidity and mortality after EVAR. A study that used the Medicare claims database reported that hospitals in the top decile had lower rates of postoperative surgical site infection after EVAR compared with lower volume hospitals; but to our knowledge, no studies have been published that have used a national database to evaluate the effect of volume on mortality after elective AAA repair by EVAR.[12,13] Our study found that hospitals where fewer than eight elective EVARs (bottom 2.5%) are performed have a mortality up to 7.7 times greater than hospitals that do more than eight cases (middle 95% of all hospitals) and 33.2 times greater compared with hospitals that do >70 cases (top 2.5%). Data from the OAR and EVAR group suggest that in patients where transfer is possible, lower volume centers should potentially send patients to regional centers of excellence with higher AAA repair numbers to ensure optimal patient survival rates.

For elective AAA repair, hospital factors other than volume typically do not influence LOS or inpatient mortality. However, total cost of care is greater at small hospitals and those in the West. Although there are differences in the rate of EVAR, they are not substantial enough to influence inpatient mortality rates. Rural centers have outcomes similar to urban centers when controlled for volume, unlike what has been previously reported (Table III).[14]

Hospital factors do influence outcomes in patients who undergo ruptured AAA repair. Inpatient mortality is significantly lower in private, nonprofit hospitals and private, for-profit hospitals compared with government, nonfederal hospitals. Similar to what was reported in an NIS study between 1998 and 2004 by Meguid et al,[15] teaching hospitals also appear to confer a survival advantage, but this is associated with a longer LOS (9.0 vs 7.0 days). Their report found a difference for inpatient mortality of 39.3% at teaching hospitals compared with 44.5% at nonteaching hospitals. Our sample extends to 2011 and includes the decrease in overall mortality seen in ruptured AAA repair and thus is the reason for the difference in inpatient mortality of 29.1% teaching hospitals compared with 38.9% in nonteaching hospitals.[1] More variability is seen in the median LOS with regard to hospital factors for patients who undergo AAA repair. The shortest LOS is seen in private, for-profit hospitals and small hospitals (6.0 days), and the longest LOS is seen in large hospitals (8.5 days), rural hospitals, teaching hospitals, and hospitals located in the Midwest (9.0 days). There is no association between LOS and inpatient mortality. Elective vs emergency admission or transfer status (data not shown) also do not affect inpatient mortality (Table IV).

High-volume centers have also been shown to improve outcomes for patients who present with ruptured AAA regardless of whether the procedure was performed by EVAR or OAR. A retrospective institutional study identified low surgeon volume (<20 cases) as an independent risk factor for mortality for ruptured AAA, with an overall institutional mortality of 38.2%.[16] This is true for OAR and EVAR. A report that stratified hospital volume into thirds found that high EVAR volume for ruptured AAA (>40 cases per year) had an inpatient mortality 5.4 times greater than low-volume (<19 cases per year) centers.[17] Our study found that although up to 100% mortality from ruptured AAA is expected at low-volume centers (<10 OARs and less than eight EVARs), better outcomes are expected from centers with greater volume. There appears to be a volume-dependent relationship, and hospitals that perform >20 OAR or EVAR cases for ruptured AAA have mortality that approaches 20%.

The relationship between hospital volume and outcomes is well documented in other specialties as well. Low-volume centers that complete renal transplants have a 1.65 times the risk of severe sepsis.[18] Similar relationships between operator volume and outcomes after percutaneous coronary interventions, patient morbidity after obstetric deliveries at low-volume centers, and morbidity and mortality after total hip arthroplasty have also been found.[19-21] Most of these studies have identified a threshold below which morbidity or mortality, or both, suddenly increase.[18,20,21] Although most studies conclude that lower volume centers should refer these patients to hospitals with more experience, one study concludes that promulgation of best practices and improving access to outcomes information to patients is preferable.[18] In the case of elective AAA repair, a combination of better implementation of best practices, improving informed consent of patients by including hospital mortality information, and improving regional access to health care may help to decrease mortality.

This study has some limitations. The results obtained through use of an administrative database may be confounded by incomplete data entry, missing values, and miscoding that may arbitrarily affect the CIs and exact cutoff values. The use of a 95% CI and trend analysis, multiple database years, and diagnosis and procedure ICD-9 codes to select patients helps to offset this potential variability. Furthermore, this analysis is limited to individual hospitals and cannot be directly extrapolated to individual surgeon volume because these data are not uniformly coded within the NIS. A distinction between "free rupture" and "contained rupture" could not be made due to the limitations associated with ICD-9 coding. Finally, monitoring patients long-term is not possible, so this study captures only in-patient mortality during the hospital stay in which the surgery was performed. This may have resulted in underreporting of mortality rates overall.

CONCLUSIONS

Hospitals that complete fewer than five OARs or eight EVARs annually have significantly greater mortality compared with their counterparts. Improved implementation of best practices, more detailed informed consent to include hospital mortality data, and better regional access to health care may reduce mortality after elective AAA repair.

AUTHOR CONTRIBUTIONS

Conception and design: AD, CF, HR, SS, GU, SD
Analysis and interpretation: AD, CF, HR, SS, GU, SD
Data collection: AD, CF, HR, SS
Writing the article: AD, CF, HR, SS, GU, SD
Critical revision of the article: AD, CF, HR, SS, GU, SD
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