From the Society for Vascular Surgery

The effect of surgeon and hospital volume on mortality after open and endovascular repair of abdominal aortic aneurysms

Sara L. Zettervall, MD, MPH,[a] Marc L. Schermerhorn, MD,[a] Peter A. Soden, MD,[a] John C. McCallum, MD,[a] Katie E. Shean, MD,[a] Sarah E. Deery, MD,[a] A. James O'Malley, PhD,[b] *and* Bruce Landon, MD, MBA,[c,d] *Boston, Mass; and Lebanon, NH*

ABSTRACT

Background: Higher hospital and surgeon volumes are independently associated with improved mortality after open repair of abdominal aortic aneurysms (AAAs) in the era before endovascular AAA repair (EVAR). The effects of both surgeon and hospital volume on mortality after EVAR and open repair in the current era are less well defined.

Methods: We studied Medicare beneficiaries who underwent elective AAA repair from 2001 to 2008. Volume was measured by procedure type during the 1-year period preceding each procedure and was further categorized into quintiles of volume for surgeon and hospital. Multilevel logistic regression models were used to evaluate the effect of surgeon volume, accounting for hospital volume, on mortality after adjusting for patient demographic and comorbid conditions as well as the analogous effect of hospital volume adjusting for surgeon volume. The multilevel models included random effects for surgeon and hospital to account for the clustering of multiple patients within the same surgeon and within the same hospital.

Results: We studied 122,495 patients who underwent AAA repair (open: 45,451; EVAR: 77,044). After EVAR, perioperative mortality did not differ by surgeon volume (quintile 1 [0-6 EVARs]: 1.8%; quintile 5 [28-151 EVARs]: 1.6%; $P = .29$), but decreased with greater hospital volume (quintile 1 [0-9 EVARs]: 1.9%; quintile 5 [49-198 EVARs]: 1.4%; $P < .01$). After open repair, perioperative mortality decreased with both higher surgeon volume (quintile 1 [0-3 open repairs]: 6.4%; quintile 5 [14-62 open repairs]: 3.8%; $P < .01$) and hospital volume (quintile 1 [0-5 open repairs]: 6.3%; quintile 5 [14-62 open repairs]: 3.8%; $P < .01$). After adjustment for other predictors, surgeon volume was not associated with perioperative mortality after EVAR (odds ratio [OR], 0.9; 95% confidence interval [CI], 0.7-1.1); however, hospital volume was associated with higher perioperative mortality (quintile 1: OR, 1.5; 95% CI, 1.2-1.9; quintile 2: OR, 1.3; 95% CI, 1.02-1.6; and quintile 3: OR, 1.2; 95% CI, 1.01-1.5, compared with 5). After open repair, higher surgeon volume was also associated with lower mortality (quintile 1: OR, 1.5; 95% CI, 1.3-1.8; quintile 2: OR, 1.3; 95% CI, 1.1-1.6; and quintile 3: OR, 1.2; 95% CI, 1.1-1.4, compared with 5). Risk of mortality also was higher for patients treated at lower-volume hospitals (quintile 1: OR, 1.3; 95% CI, 1.1-1.5; quintile 2: OR, 1.3; 95% CI, 1.1-1.5; and quintile 3: OR, 1.2; 95% CI, 1.1-1.4, compared with 5).

Conclusions: After EVAR, hospital volume is minimally associated with perioperative mortality, with no such association for surgeon volume. After open AAA repair, surgeon and hospital volume are both strongly associated with mortality. These findings suggest that open surgery should be concentrated in hospitals and surgeons with high volume. (J Vasc Surg 2016;■:1-9.)

Operative volume has been identified as an important predictor of patient morbidity and mortality after multiple complex surgical procedures.[1] After open repair of abdominal aortic aneurysms (AAAs), studies using data from Medicare, the National Inpatient Sample, and international databases, have all found improved mortality with increased volume.[1-6] More recent studies have attempted to evaluate both surgeon and hospital volumes to better assess the independent effect of each. Some have suggested

From the Department of Vascular and Endovascular Surgery, Beth Israel Deaconess Medical Center, Boston[a]; the Department of Biomedical Data Science and The Dartmouth Institute for Health Policy and Clinical Practice, Geisel School of Medicine at Dartmouth, Lebanon[b]; and the Department of Medicine, Beth Israel Deaconess Medical Center,[c] and the Department of Health Care Policy, Harvard Medical School,[d] Boston.

This work was completed with support from the National Institutes of Health Harvard-Longwood T32 Research Training in Vascular Surgery Grant HL-007734 to S.L.Z., J.C.M., P.A.S., K.E.S., and S.E.D., and was supported by National Heart, Lung, and Blood Institute grant 5R01-HL-105453-03.

Author conflict of interest: M.S. is a paid consultant for Endologix, Medtronic, W. L. Gore and Associates, and Cook.

Presented at the Society for Vascular Surgery 2016 Vascular Annual Meeting, National Harbor, Md, June 8-11 2016.

Correspondence: Marc L. Schermerhorn, MD, 110 Francis St, Ste 5B, Boston, MA 02215 (e-mail: mscherm@bidmc.harvard.edu).

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.2016.09.036

surgeon volume is the primary driver of improved mortality, and others have concluded that hospital and surgeon volume both have important effects on perioperative mortality.[1-3,7]

Importantly, previous studies have not evaluated the effect of surgeon and hospital volume on perioperative mortality after open repair in the endovascular era, and few studies have evaluated the association between volume and mortality after endovascular AAA repair (EVAR). Three studies assessing hospital volume identified an inverse relationship between volume and in-hospital mortality.[4,6,8] Alternatively, in one of the only studies to account for surgeon and hospital volume, neither surgeon nor hospital volume had a significant effect on in-hospital mortality. However, this study was unable to assess 30-day mortality due to limitations of the National Inpatient Sample (NIS).[3] Given these gaps in knowledge, this study evaluated the independent effect of both surgeon and hospital volume on perioperative mortality after EVAR and open repair.

ARTICLE HIGHLIGHTS

- **Significance:** This study provides a fresh look into the effect volume has on the mortality rate of aortic aneurysm repair, with respect to both the surgeon and hospital.
- **Type of Research:** Retrospective analysis of prospectively collected Medicare data of the National Inpatient Sample
- **Take Home Message:** After adjustment for patient comorbidities and hospital volume, surgeon's volume was strongly associated with mortality after elective open abdominal aortic aneurysm repair. Hospital volume was also significantly associated with mortality
- **Recommendation:** The authors recommend that to decrease perioperative mortality, open abdominal aortic aneurysm repair should be performed by high-volume surgeons. They also suggest that open repair maybe best performed in high-volume hospitals.
- **Strength of Recommendation:** 1. Strong
- **Level of Evidence:** B. Medium

METHODS

The Harvard Medical School Institutional Review Board approved this study. Patient consent was waived because this was a retrospective study.

Overview. We used comprehensive data from the Medicare program to identify all aortic aneurysm repairs that occurred between 2001 and 2008. Patients included open and EVAR of intact and ruptured abdominal and thoracoabdominal aneurysms. We used these data to calculate institutional and surgeon volume for EVAR and open repair for each year. To evaluate the relationship between surgical volume and mortality, we restricted our analyses to elective aneurysm repairs confined to the abdominal aorta to compare similar patients across institutions and surgeons.

Surgeon and hospital volume. Surgeon and hospital procedure volume were measured within each procedure type during the 365-day period preceding each operation. Surgeon and hospital volume were assessed independently. Because experience in treating ruptured and complex aneurysms contributes to surgeon and hospital experience, the total volume counts included all ruptured, thoracoabdominal, and intact aortic aneurysms. To calculate surgeon volume, the performing physician was identified using the unique physician identification number listed on each patient's Medicare claim. If two surgeons were identified in a single operation (EVAR: 53%; open: 35%), the higher volume was assigned to the patient when one surgeon was not identified as an assistant. No physician was identified for 6103 patients (4.7%), which were therefore excluded from analysis (EVAR: 2419; open: 3684). All other data were complete.

To simplify interpretation of results, hospital and surgeon volumes were divided into quintiles using cutoffs that most closely separated the patients into groups of equal size. The quintiles were set using average annual volume across all of the years, which meant that the proportion of patients assigned to each quintile varied across years. We computed volume cutoffs based on open and endovascular repair separately, and at each time point, assigned each hospital and surgeon to a volume quintile.

Study population and outcomes assessment. For the assessment of outcomes, we applied several restrictions to the above population to create a homogenous sample and thus minimize the influence of confounding by patient mix. To do so, we focused on the repair of intact AAAs among patients aged ≥67 years with a discharge diagnosis of AAA without rupture (International Classification of Diseases-9th Edition-Clinical Modification, code 441.4) who also had a procedure code for open surgical repair (38.44, resection of abdominal aorta with replacement; 39.25, aortoiliac-femoral bypass), or for endovascular repair (39.71, endovascular implantation of graft). We excluded all those with diagnosis codes for AAA rupture (441.3), thoracic aneurysm (441.1, 441.2), thoracoabdominal aortic aneurysm (441.6, 441.7), or aortic dissection (441.0) and those with procedure codes for repair of the thoracic aorta (38.35, 38.45, 39.73) or visceral/renal bypass (38.46, 39.24, 39.26).

We examined outcomes for Medicare patients for whom we had at least 2 years of claims history before