Hospital-Level Factors Associated With Mortality After Endovascular and Open Abdominal Aortic Aneurysm Repair

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IMPORTANCE Endovascular technology has become ubiquitous in the modern care of abdominal aortic aneurysm (AAA), yet broad estimates of its efficacy among variable hospital and regional settings is not known.

OBJECTIVE To perform a preliminary analysis of hospital effects on mortality following open AAA repair (OAR) and endovascular AAA repair (EVAR).

DESIGN, SETTING, AND PARTICIPANTS A retrospective analysis of the American College of Surgeons National Surgical Quality Improvement Program database was conducted on all patients undergoing OAR or EVAR from July 1, 2010, to November 30, 2012, using Current Procedural Terminology codes.

MAIN OUTCOMES AND MEASURES Weight-adjusted 30-day observed to expected mortality ratios were compared based on hospital type (academic vs community) and size (100-299 beds vs 300-500 beds vs >500 beds).

RESULTS Data on 11,250 patients (2,466 underwent OAR and 8,784 underwent EVAR) were analyzed. Endovascular AAA repair was performed more frequently than OAR at both academic (78.8%) and community (68.2%) hospitals. Overall 30-day mortality was 14.0% for OAR and 4.3% for EVAR (P < .001). Hospital size was significantly associated with mortality for OAR (observed to expected mortality ratio: >500 beds, 0.88 vs 300-500 beds, 1.11 vs 100-299 beds, 1.59; P = .01) but not for EVAR (P = .27). In contrast, hospital type was significantly associated with mortality for EVAR (observed to expected mortality ratio: academic, 0.60 vs community, 2.60; P < .001) but not OAR (P = .46). Multivariable analysis of hospital-level factors suggested that, for all outcomes, academic hospital type was the single most significant predictor of reduced mortality following AAA repair (observed to expected mortality ratio: academic, 0.91 vs community, 2.00; P = .05).

CONCLUSIONS AND RELEVANCE Based on this preliminary report, outcomes for both OAR and EVAR appear to depend greatly on hospital-level effects. The relative safety of EVAR vs OAR may depend on appropriate patient selection and adequate access to multidisciplinary care in order to minimize failure to rescue rates and improve survival.
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Health care quality improvement initiatives are of increasing importance in today's political climate. Hospital reimbursements are being adjusted based on a variety of performance metrics deemed to act as surrogates for hospital performance. Among these metrics, mortality is an often-reported outcome because it is relatively straightforward to track and easy for the public to understand. However, the interpretation of mortality rate is probably not as straightforward as it seems. Both patient- and hospital-level effects have been shown to play a significant role in surgical outcomes in general and in vascular surgical procedure mortality outcomes in particular.

Hospital volume is one hospital-level effect that has been well studied in vascular surgery. Mortality following open abdominal aortic aneurysm (AAA) repairs (OAR) performed at high-volume hospitals is lower than mortality following OAR performed at low-volume institutions. The Leapfrog Group, a large employer-based health care quality coalition that represents more than 37 million individuals across the United States, advocates for a minimum volume criterion of 50 OAR cases or more per year as part of their evidence-based hospital referral safety standard. However, the effect of hospital volume on elective endovascular AAA repair (EVAR) is currently unclear. We sought to perform a preliminary analysis of hospital effects on mortality following OAR and EVAR.

Methods

Data on all patients undergoing elective infrarenal OAR or EVAR between July 1, 2010, and November 30, 2012, were extracted from the American College of Surgeons National Surgical Quality Improvement Program database. Eligible patients were identified using Current Procedural Terminology codes (EVAR, 34800, 34802, 34803, 34804, and 34805; OAR, 35081 and 35102). Patients undergoing urgent or emergency AAA repairs were excluded. Deidentified hospital-level data for mortality after AAA repair were abstracted via hospital benchmarking reports. Hospital practice type was defined according to the National Surgical Quality Improvement Program-reported comparison hospital category (academic = academic/teaching; and community = community—not for profit, community—for profit, and all community), which is a self-reported hospital classification consistent with that reported in the American Hospital Association database. The study was approved by the Johns Hopkins Institutional Review Board. No informed consent was obtained, as the data are publicly available through the American College of Surgeons National Surgical Quality Improvement Program database.

In accordance with the available data in the National Surgical Quality Improvement Program benchmarking report, we analyzed institutional-level data only. The primary outcome of the study was 30-day mortality. All raw data are presented as number with percentage. Statistical analyses were performed using \( \chi^2 \) tests. Weight-adjusted 30-day observed to expected (O:E) mortality ratios were calculated based on the contributing case proportions of each institution in the database and compared based on hospital type (academic vs community) and size (100–299 beds vs 300–500 beds vs >500 beds). Multivariable logistic regression was then performed to assess the relative effect of hospital type vs size on mortality following AAA repair overall. All statistical analyses were performed using JMP, version 9.0 (SAS Institute). Statistical significance was defined as \( P \leq .05 \).

Results

There were 11,250 patients identified for analysis, of which 2,466 (21.9%) underwent OAR and 8,784 (78.1%) underwent EVAR. Endovascular AAA repair was performed more frequently than OAR at both academic (78.8%) and community (68.2%) hospitals.

Overall 30-day mortality was 14.0% for OAR and 4.3% for EVAR \( (P < .001) \). Thirty-day mortality for OAR was similar at academic hospitals compared with community hospitals (13.5% vs 14.9%; \( P = .78 \)). For both academic and community hospitals, mortality for OAR was inversely associated with hospital size, with mortality increasing significantly as hospital size decreased \( (P < .01) \) (Figure 1). Thirty-day mortality for EVAR was significantly lower at academic hospitals compared with community hospitals (2.6% vs 11.2%; \( P < .001 \)). In contrast with OAR, there was no significant association between mortality and hospital size for EVAR at either academic or community hospitals \( (P = .36) \) (Figure 1).

Based on weight-adjusted O:E ratios (Figure 2), hospital size significantly affected mortality for OAR (O:E ratio: >500 beds, 0.88 vs 300–500 beds, 1.11 vs 100–299 beds, 1.59; \( P = .01 \)) but not EVAR \( (P = .27) \). In contrast, hospital type significantly affected mortality for EVAR (O:E ratio: academic, 0.60 vs community, 2.60; \( P < .001 \)) but not OAR \( (P = .46) \). Multivariable analysis of hospital-level factors suggested that, for all outcomes, academic hospital type was the single most significant predictor of reduced mortality following AAA repair (O:E ratio: academic, 0.91 vs community, 2.00; \( P = .05 \)).

Discussion

Endovascular technology has become ubiquitous in the modern care of AAA, yet broad estimates of efficacy among variable hospital and regional settings is not known. In our study, we sought to determine whether hospital type and size affects 30-day mortality following OAR and EVAR. Our data demonstrate that outcomes for both OAR and EVAR appear to depend greatly on hospital-level effects. Academic institutions appear to have better outcomes after elective AAA repair overall, and in particular after EVAR. In contrast, hospital size appears to have a more significant effect on 30-day mortality for OAR cases than for EVAR cases. These data make a preliminary argument in favor of AAA centers of excellence that deserves further investigation.

The association between hospital teaching status and mortality after elective AAA repair that we report is novel. Meguid et al\(^1\) have previously reported on the mortality benefits of a teaching hospital for in-hospital ruptured AAA repair, but, to
our knowledge, there are no data to date describing the effect of hospital type on elective AAA outcomes. In our study, we demonstrate a significant mortality benefit with both OAR and EVAR performed at academic institutions, regardless of hospital size. This effect appears to be highest among patients undergoing EVAR, which can potentially be explained by variations in endovascular training. Since 2001, there has been a reported 300% increase in the use of EVAR procedures in some states; many of the health care professionals who perform these procedures have been trained solely by manufacturers of a medical device rather than in formal training programs. Although surgical training volume for OAR is also variable, it is much more standardized than that for EVAR. Hospitals with any form of teaching status have been shown to have better outcomes in certain vascular procedures than those without, but teaching hospitals with surgical subspecialty training have superior outcomes.

The association between hospital volume and mortality that we demonstrate is consistent with previously reported studies. There is a strong association between hospital volume and outcomes following AAA repair that favors high-volume hospitals, especially in cases of OAR but not endovascular abdominal aortic aneurysm repair (EVAR) ($P < .001$). Based on these data, the Leapfrog Group has published evidence-based hospital referral volume criteria advising a minimum of 50 or more elective OAR cases per year. Hospital volume associations for EVAR are less clear, as many studies tend to combine all AAA procedures into a single group and/or fail to distinguish between emergency and elective procedures. High-volume hospitals are more likely to use endovascular approaches and frequently have higher case mix indices, which may bias the data and reduce perceived mortality benefits in unadjusted studies.

Overall 30-day mortality was 14.0% for open abdominal aortic aneurysm repair (OAR) and 4.3% for endovascular abdominal aortic aneurysm repair (EVAR) ($P < .001$). For both academic and community hospitals, 30-day mortality following OAR was inversely related to hospital size, with mortality increasing significantly as hospital size decreased ($P = .01$). In contrast, 30-day mortality for EVAR was significantly lower at academic hospitals compared with community hospitals ($P = .001$) regardless of hospital size.
outcomes in favor of high-volume institutions for both OAR and EVAR approaches.

Of note, the 30-day mortality rates for both OAR and EVAR that we report are higher than anticipated. For example, Schermerhorn et al. reported 30-day mortality of 1.2% after EVAR and 4.8% after OAR, which are approximately one-third the rates that we report. However, that study and others are based on data from sources that tend to limit enrollment to high-volume institutions or individual tertiary care centers, which likely skews the mortality rates lower than would be expected for a study inclusive of all reporting institutions. Recent data have shown that results reported from randomized clinical trials of OAR and EVAR may not be applicable to real-world vascular surgical practice because high-risk patients are often excluded from analysis. Indeed, the EVAR II Trial, which enrolled only high-risk patients undergoing AAA, reported an operative mortality of 9%, which is nearly 8-fold higher than that reported by Schermerhorn et al. and 2-fold higher than our study. As such, we assume that the high operative mortality that we report is a reflection of a sicker patient population that needs to be better defined in the future by expanding on this preliminary analysis using a data source that allows linking of both hospital- and patient-level data.

Outcomes for both OAR and EVAR appear to depend greatly on hospital-level effects in our preliminary study. Although the precise etiologies driving our findings remain to be determined, we predict that major contributing factors include differences in resource availability, a lack of multidisciplinary care in smaller community centers that results in higher rates of failure to rescue, and differences in formalized training protocols. Hospital size was a significant predictor of mortality only in OAR, alluding to a possible system-level effect. In contrast, academic hospital status was the single biggest predictor of mortality for EVAR and OAR combined, suggesting that the multidimensional care available at tertiary centers, including dedicated intensive care units and specialty teams, may be essential to successful aneurysm repair. Failure to rescue patients from severe postoperative complications drives a significant proportion of in-hospital deaths following AAA repair, suggesting that hospital mortality following OAR and EVAR may be more dependent on postoperative management than intraoperative details. Consistent with this notion, failure-to-rescue rates tend to be lower at teaching hospitals compared with nonteaching hospitals, and increased hospital experience is associated with a decrease in hospital mortality following high-risk surgical procedures. It is also possible that endovascular expertise has diffused into community centers at a slower rate than the available technology, which may contribute to physician-level differences in performance and would indicate the need for standardized EVAR training. These issues merit further study, but our preliminary data on the topic advocate for the potential establishment of centers of excellence for both OAR and EVAR that would allow for dedicated resource allocation, dedicated intensive care unit monitoring, and the involvement of a multidisciplinary approach to postoperative care by subspecialists. By regionalizing AAA repairs to specialty centers, we could reduce failure to rescue events and thereby improve mortality rates following elective AAA repair on a national level.

Conclusions

Based on this preliminary report, outcomes for both OAR and EVAR appear to depend greatly on hospital-level effects. The relative safety of EVAR vs OAR may depend on appropriate patient selection and adequate access to multidisciplinary care in order to minimize failure to rescue rates and improve survival.

ARTICLE INFORMATION

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Author Contributions: Dr Malas had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Hicks, Freischlag, Malas. Acquisition, analysis, or interpretation of data: Hicks, Wick, Canner, Black, Arhuidese, Qazi, Obeid, Freischlag.

Drafting of the manuscript: Hicks, Arhuidese, Qazi, Freischlag.

Critical revision of the manuscript for important intellectual content: Wick, Canner, Black, Obeid, Freischlag, Malas.

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REFERENCES


11. Meguid RA, Brooke BS, Perler BA, Freischlag JA. Impact of hospital teaching status on survival from
In this issue, Hicks and colleagues’ outline results achieved for abdominal aortic aneurysm repair in the National Surgical Quality Improvement Program registry in recent years. Patients undergoing endovascular repair in community hospitals were more likely to die perioperatively compared with patients at academic hospitals, and smaller hospitals had poorer results with open abdominal aortic aneurysm repair. Even more concerning was the fact that overall rates of mortality were nearly 5% for endovascular repair and nearly 15% for open abdominal aortic aneurysm repair.

Why would mortality be so high? It is difficult to know; the authors hypothesize that smaller hospitals may have difficulty rescuing patients more readily when complications occur. This hypothesis certainly may be correct. However, several reports have shown that the technical aspects of open and endovascular abdominal aortic aneurysm repair—clamping below the visceral arteries, avoiding intraoperative hemorrhage, and understanding aneurysm anatomy to limit surgical and endovascular misadventures—are more likely the key to achieving good results. Unfortunately, the data elements provided in this study—Current Procedural Terminology codes alone—are limited in providing the technical details necessary to bring mortality risk into sharp relief. The National Surgical Quality Improvement Program’s development of procedure-specific modules and detailed national registries, such as the Society for Vascular Surgery’s Vascular Quality Initiative, are definite steps in the right direction.

Whether the data are limited or extensive, one fact is clear: mortality rates exceeding 10% are too high for elective aortic aneurysm repair. Perhaps these patients were facing dramatic rupture risk from very large aneurysms, or their repairs were technically difficult because they involved the renal or intestinal arteries. These details, and many others, will be a key and requisite part in guiding how we assess vascular practice patterns and outcomes.

**ARTICLE INFORMATION**

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