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.

Invited Commentary page 636

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Hospital level factors and mortality after endovascular and open AAA repair

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 χ² 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 ≤ .05.

Results

There were 11 250 patients identified for analysis, of which 2466 (21.9%) underwent OAR and 8784 (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 al11 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. \(^2\) 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. \(^1\)\(^3\)\(^14\)

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. \(^5\)\(^7\)\(^15\)\(^16\) 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. \(^10\) Hospital volume associations for EVAR are less clear, as many studies tend to combine all AAA procedures into a single group \(^5\)\(^17\) and/or fail to distinguish between emergency and elective procedures. \(^17\) 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. \(^7\)\(^18\) This scenario is likely the case with our study; although we demonstrate a significant association between volume and mortality among OAR cases, we found no significant difference in outcomes after EVAR for high- vs low-volume hospitals. We predict that future analyses using alternative data sources that allow for both patient- and hospital-level risk adjustment will yield similar volume-related mortality.

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.10 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 skew 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.20 Indeed, the EVAR II Trial, which enrolled only high-risk patients undergoing AAA, reported an operative mortality of 9%,21 which is nearly 8-fold higher than that reported by Schermerhorn et al.10 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,17 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,22 and increased hospital experience is associated with a decrease in hospital mortality following high-risk surgical procedures.23 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.

REFERENCES


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