# CLINICAL RESEARCH STUDIES

From the Society for Vascular Surgery

# Aortic anatomic severity grade correlates with resource utilization

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***Background:*** **Potential cost effectiveness of endovascular aneurysm repair (EVAR) compared with open aortic repair (OAR) is offset by the use of intraoperative adjuncts (components) or late reinterventions. Anatomic severity grade (ASG) can be used preoperatively to assess abdominal aortic aneurysms, and provide a quantitative measure of anatomic complexity. The hypothesis of this study is that ASG is directly related to the use of intraoperative adjuncts and cost of aortic repair.**

***Methods:*** **Patients who undergo elective OAR and EVAR for abdominal aortic aneurysms were identified over a consecutive 3-year period. ASG scores were calculated manually using three-dimensional reconstruction software by two blinded reviewers. Statistical analysis of cost data was performed using a log transformation. Regression analyses, with a continuous or dichotomous outcome, used a generalized estimating equations approach with the sandwich estimator, being robust with respect to deviations from model assumptions.**

***Results:*** **One hundred forty patients were identified for analysis, n = 33 OAR and n = 107 EVAR. The mean total cost (± standard deviation) for OAR was per thousand (k) \$38.3 ± 49.3, length of stay (LOS) 13.5 ± 14.2 days, ASG score 18.13 ± 3.78; for EVAR, mean total cost was k \$24.7 ± 13.0 ($P$ = .016), LOS 3.0 ± 4.4 days ($P$ = .012), ASG score 15.9 ± 4.13 ($P$ = .010). In patients who underwent EVAR, 25.2% required intraoperative adjuncts, and analysis of this group revealed a mean total cost of k \$31.5 ± 15.9, ASG score 18.48 ± 3.72, and LOS 3.9 ± 4.5, which were significantly greater compared with cases without adjunctive procedures. An ASG score of ≥15 correlated with an increased propensity for requirement of intraoperative adjuncts; odds ratio, 5.75 (95% confidence interval, 1.82-18.19). ASG >15 was also associated with chronic kidney disease, end stage renal disease, hypertension, female sex, increased cost, and use of adjunctive procedures.**

***Conclusions:*** **Complex aneurysm anatomy correlates with increased total cost and need for adjunctive procedures during EVAR. Preoperative assessment with ASG scores can delineate patients at greater risk for increased resource use. Patient comorbid factors are associated with anatomic complexity defined according to ASG. A critical examination of the relationship between anatomic complexity and finances is required within the context of aggressive endovascular treatment strategies and shifts toward value-based reimbursement. (J Vasc Surg 2016;63:569-76.)**

The first endovascular aneurysm repair (EVAR) was performed in 1991 by Parodi et al[1] and since then it has been established as a safe and less morbid option to treat abdominal aortic aneurysms (AAAs) compared with open aortic repair (OAR) in the short-term.[2-4] EVAR has become the standard for AAA repair in the United States over the past 10 years.[5] However, compared with OAR, EVAR is associated with an increased rate of graft-related complications and reinterventions. Lifeline Endovascular Registry and EUROpean collaborators on Stent/graft Techniques for aortic Aneurysm Repair (EUROSTAR) data indicate that EVAR is associated with a periprocedural endoleak frequency of 15%, and complication rates of 11%-20% at 1 year and up to 38% at 4 years.[6,7] Comparatively, historical data demonstrate that long-term graft-related complications associated with OAR are only 3%, although there might be other consequences to OAR such as hernia and bowel obstruction.[8] With consideration of the early secondary intervention rate associated with EVAR and the increased use of intraoperative adjunctive procedures, and the need for further diagnostic imaging and possible reinterventions, it is possible that the potential cost effectiveness of EVAR compared to OAR is lost over the long-term.

In 2002 the Committee for Standardized Reporting Practices in Vascular Surgery of the Society for Vascular Surgery/American Association for Vascular Surgery

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proposed an anatomic severity grade (ASG) score to categorized and defined anatomic factors as they relate to infrarenal AAA.[9] It has been suggested previously that ASG scores correlate with technical challenges during EVAR and an increase in resource utilization.[10] ASG has not yet been used to directly compare OAR vs EVAR with regard to total hospital costs and procedural challenges. In this study we propose that preoperative assessment of anatomic complexity using ASG scores can identify AAA repairs at risk for requiring adjunctive procedures and increased associated costs.

## METHODS

Patients who underwent elective infrarenal OAR and EVAR from July 2007 to July 2010 at the University of Rochester Medical Center were retrospectively identified using Current Procedural Terminology (American Medical Association, Chicago, Ill) codes 34800, 34802, 34803, 34804, and 34805. Patients were included if preoperative computed tomographic angiography scans of the abdomen and pelvis were available within 6 months before surgery. Patients who presented acutely with symptomatic or ruptured aneurysms or underwent aortic stent-graft placement for reasons other than aneurysmal disease were excluded. The institutional review board approved the study protocol. Informed consent was not required because the study protocol posed minimal risk to the subjects and acquisition of patient consent was not logistically feasible.

ASG scores were calculated by independent blinded reviewers who used Philips Intellispace Portal (Koninklijke Phillips Electronic NV, Andover, Mass). A semiautomated template within the Intellispace Portal software was independently developed to extract measurements that corresponded to individual ASG score categories, as shown in Supplementary Table I according to the Society for Vascular Surgery/American Association for Vascular Surgery (SVS/AAVS) guidelines.[9] The ASG score breaks down infrarenal AAA anatomy into three broad categories; the aortic neck, the aneurysm sac, and iliac artery. Examples of a low (9) and high (24) ASG-scored AAA can be seen in Fig 1. Measurements were subsequently entered into a formatted Excel version 14.4.8 spreadsheet (Microsoft Corp, Redmond, Wash) with automated calculation of total ASG scores and individual subgroups. Total time for documentation and scoring was on average approximately 10 minutes per patient. To adjust for any intraobserver or interobserver variability, a cohort of 100 AAAs from the total study population were selected and scored by a second blinded reviewer. In $\kappa$ analysis there was high interrater reliability ($\kappa = 0.61$-$0.8$) in the assessment of ASG.

Patient demographic characteristics, preoperative comorbidities, pre- and postoperative laboratory values, medications, length of stay (LOS) and surgical details were extracted through a retrospective review of patient electronic medical records. Use of intraoperative adjunctive procedures was noted within each cohort and is listed in Supplementary Table II. The adjunctive procedures of thrombectomy and endarterectomy during OAR were included because they were not part of the routine uncomplicated procedure. Patients who met the inclusion criteria were then subjected to hospital billing/accounting database queries to ascertain revenue and hospital costs directly associated with each elective surgical admission. Total cost represented the variable and fixed costs associated with the inpatient stay only.

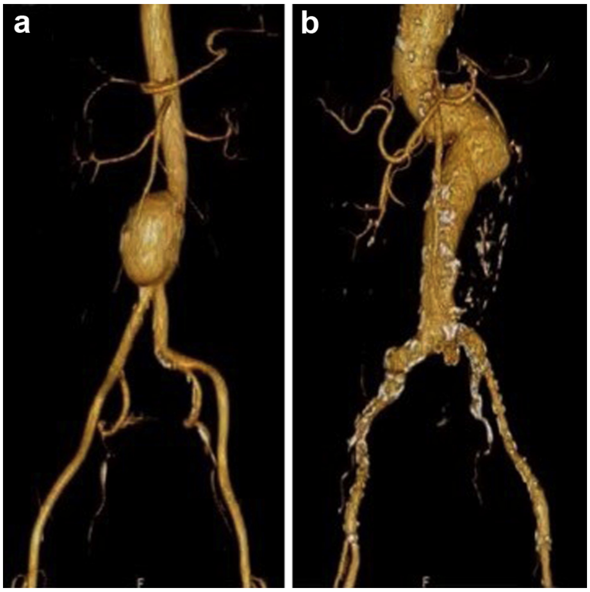


**Fig 1.** Aortic aneurysm with low and high anatomic severity grade (ASG) score. **a,** Abdominal aortic aneurysm (AAA) with ASG score of 9 (aortic neck, 2; aortic aneurysm, 3; iliac artery, 4). **b,** AAA with ASG score of 24 (aortic neck, 7; aortic aneurysm, 7; iliac artery, 10).

Univariate analysis was performed to identify variable association with total cost and ASG scores. The Pearson $\chi^2$ test was used to analyze categorical variables, Student $t$ test was used to analyze continuous variables, and Fisher exact test was used as appropriate. Factors that met criteria of $P < .15$ were assessed for inclusion into a manual stepwise multivariable binary logistic regression for each analysis. Factors that met $P < .05$ in the final model were retained. Graphical inspection of the cost data suggested a log transform to attempt to normalize the distribution. Regression analyses, with a continuous or dichotomous outcome, used a generalized estimating equations approach with the sandwich estimator, which is robust with respect to deviations from model assumptions. All analyses were carried out using SAS 9.4 (SAS Institute Inc, Cary, NC).

## RESULTS

From July 2007 to July 2010, six vascular surgeons performed either EVAR or OAR on 347 patients, of whom 140 (33 OAR, 107 EVAR) patients met our inclusion criteria. Two hundred seven patients were excluded from analysis; secondary to incomplete hospital records, unavailable preoperative computed tomography angiography scans within the hospital-imaging database or outside