

# Perioperative outcome of endovascular repair for complex abdominal aortic aneurysms

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## ABSTRACT

**Background:** As endovascular aneurysm repair (EVAR) continues to advance, eligibility of patients with anatomically complex abdominal aortic aneurysms (AAAs) for EVAR is increasing. However, whether complex EVAR is associated with favorable outcome over conventional open repair and how outcomes compare with infrarenal EVAR remains unclear. This study examined perioperative outcomes of patients undergoing complex EVAR, focusing on differences with complex open repair and standard infrarenal EVAR.

**Methods:** We identified all patients undergoing nonruptured complex EVAR, complex open repair, and infrarenal EVAR in the American College of Surgeons National Surgical Quality Improvement Program Targeted Vascular Module. Aneurysms were considered complex if the proximal extent was juxtarenal or suprarenal or when the Zenith Fenestrated endograft (Cook Medical, Bloomington, Ind) was used. Independent risks were established using multivariable logistic regression analysis.

**Results:** Included were 4584 patients, with 411 (9.0%) undergoing complex EVAR, 395 (8.6%) undergoing complex open repair, and 3778 (82.4%) undergoing infrarenal EVAR. Perioperative mortality was 3.4% after complex EVAR, 6.6% after open repair ( $P = .038$ ), and 1.5% after infrarenal EVAR ( $P = .005$ ). Postoperative acute kidney injuries occurred in 2.3% of complex EVAR patients, in 9.5% of those undergoing complex open repair ( $P < .001$ ), and in 0.9% of infrarenal EVAR patients ( $P = .007$ ). Compared with complex EVAR, complex open repair was an independent predictor of 30-day mortality (odds ratio [OR], 2.2; 95% confidence interval [CI], 1.1-4.4), renal function deterioration (OR, 4.8; 95% CI, 2.2-10.5), and any complication (OR, 3.7; 95% CI, 2.5-5.5). When complex vs infrarenal EVAR were compared, infrarenal EVAR was associated with favorable 30-day mortality (OR, 0.5; 95% CI, 0.2-0.9), and renal outcome (OR, 0.4; 95% CI, 0.2-0.9).

**Conclusions:** In this study assessing the perioperative outcomes of patients undergoing repair for anatomically complex AAAs, complex EVAR had fewer complications than complex open repair but carried a higher risk of adverse outcomes than infrarenal EVAR. Further research is warranted to determine whether the benefits of EVAR compared with open repair for complex AAA treatment are maintained during long-term follow-up. (J Vasc Surg 2017;■:1-9.)

Endovascular abdominal aortic aneurysm (AAA) repair (EVAR) is associated with lower perioperative mortality and lower rates of complications, need for transfusions, and length of stay compared with open repair.<sup>1-4</sup> These benefits have resulted in the rapid increase of EVAR use since its introduction in 1996,<sup>5</sup> with >80% of infrarenal AAA repairs now being performed using endovascular

treatment.<sup>6-8</sup> As a result of inadequate proximal seal zone, standard EVAR cannot be used for juxtarenal and suprarenal aneurysms (complex AAA), which has been reported to comprise as much as 20% of all AAAs.<sup>9-11</sup>

Through advancements in endovascular treatment techniques, including chimney, fenestrated, and branched stent grafts, EVAR can now be offered to patients with complex proximal neck anatomy.<sup>12</sup> A large national series from the United Kingdom demonstrated that fenestrated EVAR can be performed with a high degree of technical and clinical success.<sup>13</sup> However, most feasibility studies are institutional based and are therefore often limited to small numbers of patients.<sup>14-18</sup> Moreover, they usually did not compare outcomes of complex EVAR to that of conventional open repair. Efforts that did compare complex EVAR to open repair yielded conflicting results. Although one study demonstrated favorable perioperative outcomes after open repair,<sup>19</sup> two other studies showed reduced 30-day morbidity and mortality associated with EVAR.<sup>20,21</sup> Adding to the confusion, two systematic reviews found perioperative

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benefits favoring EVAR,<sup>22,23</sup> but another review demonstrated a pooled perioperative mortality of 4.1% after both EVAR and open repair, with no difference in the complication rate.<sup>24</sup>

In addition, the association of complex EVAR with an increased risk of postoperative renal failure compared with uncomplicated infrarenal EVAR has been suggested.<sup>25,26</sup> However, limited comparative data exist for infrarenal vs complex EVAR, and the presumed differences in renal complications could previously not be confirmed.<sup>27</sup>

The purpose of this study was to assess the perioperative outcome after EVAR for complex aneurysms, focusing on differences with complex open repair, the alternative treatment option, and standard infrarenal EVAR using the newly available American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) Targeted Vascular data set.

## METHODS

The ACS NSQIP is a multi-institutional collaboration with 102 participating hospitals in the United States that prospectively collect clinical data of patients undergoing major surgery. The NSQIP database includes demographics, comorbidities, intraoperative characteristics, and 30-day postoperative outcomes. For this study, we used the ACS NSQIP Targeted Vascular data set, a recently added module that includes additional disease and procedure-specific characteristics and procedure-related outcomes chosen by vascular surgeons. All data collection is performed by trained clinical nurse reviewers and data abstractors. The validity of the ACS NSQIP has been confirmed in previous reports.<sup>28-30</sup> The database contains deidentified data only, without any protected health information; therefore, Institutional Review Board approval and patient consent were waived. Additional information on the ACS NSQIP and the Targeted Vascular data set are available at [www.acsnsqip.org](http://www.acsnsqip.org).

From the Targeted Vascular data set for years 2011 to 2013, we identified all elective open and EVARs by the treatment indication variable. The study excluded thoracoabdominal aneurysms, procedures coded as repair of a ruptured AAA (Current Procedural Terminology [CPT]; American Medical Association, Chicago, Ill) code 38082, 35092, 35103), and cases with a postoperative diagnosis code for a ruptured AAA (International Classification of Diseases (ICD), Ninth Revision: 441.3). In addition, late conversions were excluded from the analysis of complex open repairs (CPT: 34830, 34831, 34832). Results on this group have been reported previously.<sup>31</sup> Early conversions were considered an outcome for EVAR patients and are therefore included in all analyses as EVAR patients.

The remaining cohort was subsequently divided in three groups in accordance with treatment modality and proximal aneurysm extent: complex EVAR, complex open repair, and infrarenal EVAR. A complex aneurysm was defined as an aneurysm with a juxtarenal or suprarenal proximal extent. Aneurysms coded as pararenal, which is separately defined as an AAA involving the origin of the renal arteries according to the NSQIP, were also considered complex. Data on the proximal extent of the aneurysm were obtained directly from operative reports by trained clinical reviewers. All aneurysms treated with the Zenith Fenestrated endograft (Cook Medical, Bloomington, Ind), which is currently the only fenestrated graft approved by the United States Food and Drug Administration, were also considered complex.

Complex open repair patients with infrarenal aortic clamping were excluded. For patients undergoing open repair, a visceral vessel reconstruction was defined as mentioning of a CPT code for visceral vessel reconstruction (35361) or mentioning of a visceral vessel reconstruction in the Targeted Vascular module.

Groups were compared on baseline and operative characteristics as well as postoperative outcomes. Postoperative outcomes included 30-day mortality and in-hospital adverse outcomes such renal function deterioration, ischemic colitis, leg ischemia, wound complications, shock, sepsis, and intensive care unit (ICU) and hospital length of stay. Renal function deterioration was defined as either or both of a rise in creatinine of >2 mg/dL from the preoperative value or requirement of hemodialysis, peritoneal dialysis, hemofiltration, hemodiafiltration, or ultrafiltration ≤30 days of the operation. Patients on dialysis preoperatively were excluded for analysis of renal outcomes. Ischemic colitis was defined as having symptoms of ischemic colitis or confirmation of the diagnosis on diagnostic sigmoidoscopy or colonoscopy, or both. Patients with systemic inflammatory response syndrome, sepsis, or septic shock preoperatively were not included for postoperative sepsis and shock analysis. Wound complications included superficial, deep, and organ space infections. To identify differences in postoperative morbidity aside from death, 30-day mortality was not included in the any complication variable.

**Statistical analyses.** Categorical variables are presented as counts and percentages and continuous variables as mean (standard deviation). Differences between treatment groups were assessed using  $\chi^2$  and Fisher exact tests for categorical variables and the Student *t*-test for continuous variables, where appropriate. To assess independent risks associated with treatment approaches, we used multivariable logistic regression analysis. Baseline characteristics were univariately tested, and predictors with a *P* value of <.1 were added to the multivariable model. Age was included in all models,

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