HHS Public Access
Author manuscript
J Vasc Surg. Author manuscript; available in PMC 2021 February 01.

Published in final edited form as:
J Vasc Surg. 2020 February ; 71(2): 374–381. doi:10.1016/j.jvs.2019.04.479.

Sex differences in perioperative outcomes after complex abdominal aneurysms repair

Livia E.V.M De Guerre, MD[1,2], **Rens R.B. Varkevisser, BS**[1], **Nicholas J. Swerdlow, MD**[1], **Patric Liang, MD**[1], **Chun Li, MD**[1], **Kirsten Dansey, MD**[1], **Joost A. van Herwaarden, MD**[2], **Marc L. Schermerhorn, MD**[1]

[1]Divisions of Vascular and Endovascular Surgery, Beth Israel Deaconess Medical Center, Boston MA [2]Department of Vascular Surgery, University Medical Center, Utrecht, The Netherlands

Abstract

Objective: Female sex is associated with worse outcomes following infrarenal abdominal aortic aneurysm (AAA) repair. However, the impact of female sex on complex AAA repair is poorly characterized. Therefore, we compared outcomes between female and male patients following open and endovascular treatment of complex AAA.

Methods: We identified all patients who underwent complex aneurysm repair between 2011 and 2017 in the American College of Surgeons National Surgical Quality Improvement Program Targeted Vascular Module. Complex repairs were defined as those for juxtarenal, pararenal or suprarenal aneurysms. We compared rates of perioperative adverse events between females and males, stratified by open and endovascular repair (EVAR). We calculated propensity scores and used inverse probability weighted logistic regression to identify independent associations between female sex and our outcomes.

Results: We identified 2,270 complex aneurysm repairs, of which 1,260 were EVARs (21.4%% female) and 1,010 were open repairs (30.7% female). Following EVAR, female patients had higher rates of perioperative mortality (6.3% vs 2.4%; P=.001) and major complications (15.9% vs. 7.6%, P<.001) compared to males. In contrast, following open repair, perioperative mortality was not significantly different (7.4% vs. 5.6%, P=.3) and the rate of major complications was similar (29.4% vs. 27.4%, P=.53) between females and males. Furthermore, even though perioperative mortality was significantly lower after EVAR compared to open repair for male patients (2.4% vs.

Corresponding Author/Reprints: Marc L. Schermerhorn, MD, FACS, Address: Beth Israel Deaconess Medical Center; 110 Francis Street, Suite 5B; Boston, MA 02215. Telephone: 617-632-9971, mscherm@bidmc.harvard.edu.

This work has been presented as a poster in the Karmody competition and won the Aortic Abdominal topic, whereafter it was presented in the final round of the competition at the Society for Clinical Vascular Surgery Annual Symposium 47th Annual Symposium.

Conflict of interest or funding statement:
JH is a consultant for Medtronic and Bolton Medical
MS is a consultant for Abbott Vascular, Cook Medical, Endologix, Medtronic, and Silk Road.

5.6%, P=.001), this difference was not significant for women (6.3% vs. 7.4%, P=.60). On multivariable analysis, female sex remained independently associated with higher perioperative mortality (OR, 2.5; 95% CI, 1.3–4.9; P=.007) and major complications (OR, 2.0; 95% CI, 1.3–3.2; P=.002) in patients treated with EVAR, but showed no significant association with mortality (OR, 0.9; 95% CI, 0.5–1.6; P=.69) or major complications (OR, 1.1; 95% CI, 0.8–1.5; P=.74) after open repair. However, the association of female sex with higher perioperative mortality in patients undergoing complex EVAR was attenuated when diameter was replaced with Aortic Size Index in the multivariable analysis (OR, 1.9; 95% CI, .9–3.9; P= .091). Conclusion: Female sex is associated with higher perioperative mortality and more major complications than male patients following complex EVAR, but not following complex open repair. Continuous efforts are warranted to improve the sex discrepancies in patients undergoing endovascular repair of complex AAA.

Table of content summary

In this NSQIP study of 2,270 complex aneurysm repairs a significant association of female sex was found with higher perioperative mortality and major complications after complex EVAR but not complex open repair. The authors suggest the use of ASI in determining the optimal threshold for complex AAA repair and more sex-specific research to reduce these discrepancies.

Keywords

Complex abdominal aortic aneurysm; female sex; clinical research study

Introduction:

Abdominal aortic aneurysms (AAAs) are 4–6 times more common in men than in women.[1] However, female sex is associated with a higher rupture risk and worse perioperative outcomes after infrarenal AAA repair.[2,3] Although the etiology of these differences is not fully understood, the influence of sex hormones, more complex anatomy, more graft related complications, and a higher incidence of undiagnosed cardiovascular disease, have all been suggested as potential causes.[4,5]

Abdominal aneurysms involving the renal and visceral segment of the aorta, also known as complex AAAs, present additional technical challenges to both open and endovascular aortic repair (EVAR). The introduction of new endovascular repair strategies such as fenestrated and branched endografts, or chimney and snorkel techniques, have made endovascular repair of these complex aneurysms possible with good results.[6–11] However, the previously reported promising outcomes for complex EVAR may not be applicable to the female population as females are typically underrepresented in these studies and are less likely to meet the necessary endograft anatomic criteria than male patients.[6–12]

As compared to infrarenal aneurysms, the impact of female sex on aneurysms involving the renal and visceral segment of the aorta is poorly characterized and studies have shown contradicting results.[13,14] Therefore, we evaluated the association of female sex and perioperative outcomes after endovascular and open complex AAA repair in a nationwide registry. We hypothesize that female sex will impact complex AAA outcomes even more than in infrarenal repair due to the more challenging procedures with stiffer devices in female patients with smaller vessels and more complex anatomy.

Methods:

Data Source

We performed a retrospective cohort study including patients from the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) targeted vascular module. The NSQIP targeted vascular module is a multi-institutional collaboration with prospectively collected clinical data of patients undergoing vascular interventions. The data are collected by trained and certified surgical clinical reviewers and include demographics, comorbid conditions, intraoperative variables and 30-day mortality and complications. Moreover, the NSQIP database has previously been validated and the data are routinely audited for accuracy and reliability.[15,16] Further information is available at www.facs.org/quality-programs/acs-nsqip. The Beth Israel Deaconess Medical Center Institutional Review Board approved this study and waived the requirement for patient consent owing to the retrospective and deidentified nature of the NSQIP database.

Patient Cohort

We included patients undergoing endovascular or open repair of complex AAAs between 2011 and 2017 within the vascular targeted NSQIP database. We defined complex aneurysms as those with a proximal extent listed as juxtarenal, pararenal or suprarenal according to the predefined variable in the dataset. In addition, we considered open procedures coded as repair of a AAA involving visceral vessels (CPT 35091) and EVAR using the Cook Zenith Fenestrated Endovascular Graft (Cook Medical, Bloomington, IN) as complex repairs. We excluded patients undergoing open repair with an infrarenal proximal clamp position. We additionally excluded patients undergoing emergency repair (n=407), patients with prior AAA repair with unsatisfactory result (n=127), ruptured AAAs (n=54), and thoracoabdominal aneurysms (n=38).

Definitions and variables

The NSQIP registry codes age as a continuous variable. However, in order to maintain deidentification, all patients above the age of 89 are recorded as 90 years old. We calculated the estimated glomerular filtration rate (eGFR) in accordance with the Chronic Kidney Disease Epidemiology Collaboration equation using a single preoperative creatinine value.[17] We defined renal function categories as an eGFR value above 60 mL/min/1.73m^2, an eGFR between 30 and 60 mL/min/1.73m^2, and an eGFR below 30 mL/min/1.73m^2 or preoperative dialysis requirement. We calculated body mass index (BMI) and body surface area (BSA) according to the standard weight (kg)/$height^2$ (m) formula and Du Bois and Du Bois $weight^{0.425}$ (kg) x $height^{0.725}$ (cm) x 0.007184 formula respectively.[18] We classified BMI categories as underweight (BMI<18.5), normal (BMI 18.5 – 25), overweight (BMI 25–30) obese (BMI 30–40) and, morbidly obese (BMI>40). Aortic size index (ASI) was defined as aneurysm diameter/BSA.[19,20]

Our primary outcome was perioperative mortality and our secondary outcomes included any complication, major complications and its distinctive constituents which all occurred within 30 days after the index procedure. We defined major complications as the presence of one of the following: intraoperative or postoperative cardiac complications comprising cardiac arrest or myocardial infarction; major pulmonary complications including prolonged ventilator requirement (>48h); unplanned reintubation or intraoperative or postoperative pulmonary embolism; renal complications comprising acute renal failure requiring dialysis; progressive renal insufficiency, which is defined by NSQIP as a creatinine concentration increase >2 mg/dL from preoperative value; intraoperative or postoperative stroke; ischemic colitis; lower extremity ischemia requiring intervention; postoperative aneurysm rupture; any unplanned reoperation; or postoperative sepsis. Patients with preoperative dialysis requirement were excluded from analyses of postoperative renal complications.

Statistical Analysis

We univariately compared male and female patients baseline and operative characteristics, perioperative mortality, and postoperative complications, stratified by open and endovascular repair. We presented categorical variables as counts and percentages and continuous variables as median (interquartile range). We compared patient and operative characteristics between female and male patients using the χ^2 or Fischer exact test for categorical variables where appropriate, and the Wilcoxon rank-sum for continuous variables.

We investigated the independent associations between female sex and our outcomes, stratified by EVAR and open repair. We also examined independent associations between endovascular and open repair with the outcomes, for female and male patients separately. We calculated propensity scores using logistic regression models and used these propensity scores to create inverse probability weights. We opted for propensity scores instead of multivariable regression as the relatively low event rates of our primary outcome precluded us from robust multivariable adjustment. This allowed us to adjust for all a priori selected covariates without the risk of overfitting our model. Our primary model was adjusted for demographics, comorbid conditions and aneurysm diameter; However, in a secondary model, BMI and diameter were replaced with ASI. The model included age, race (white, black, other or unknown), BMI category, smoking status, insulin dependent diabetes mellitus (IDDM), hypertension, congestive heart failure (CHF), chronic obstructive pulmonary disease (COPD), renal function, steroid use for a chronic condition, weight loss (>10% in the 6 months prior to surgery), bleeding disorders, systemic inflammatory response syndrome (SIRS) within 48 hours prior to surgery, symptomatic aneurysm, and diameter. By not adjusting for variables reflecting the anatomical complexity, we allowed the inherent anatomical differences between female and males to persist. All variables had less than 5% missing data except race for which we used an indicator variable. We tested the propensity scores for adequacy of overlap by plotting the distribution of propensity scores between the study groups. To adjust for extreme weights, we truncated weights below the 5^{th} and above the 95^{th} percentile. After weighting, all the standardized differences showed minimal imbalance (≤10%). Statistical significance was assumed at a P-value below .05. We performed additional sensitivity analyses using a subgroup of the study cohort excluding patients with symptomatic aneurysms. Statistical analyses were performed using Stata 15 software (StataCorp LP, College Station, Texas).

Results:

Patient Characteristics

We identified 2,270 complex aneurysm repairs, of which 1,010 were EVARs and 1,260 open repairs. Complex EVAR was performed in 270 females (21.4%) complex open repair was performed in 310 females (30.7%). Female patients were older (median age 75, [IQR: 69–80] vs. 73 [67–79], P=.002), were less commonly overweight (60.5% vs. 70.6%, P<.001), were more often current smokers (46.9% vs. 37.0%, P<.001), less commonly had normal renal function (55.6% vs. 65.7%, P<.001), and were more often symptomatic (12.8% vs. 7.6%, P<.001). (Table I).

Operative characteristic

Female patients who underwent EVAR had a longer operative time, though this difference did not reach statistical significance (152 [110–252] vs. 146 [103–234], P=.055). AAA diameter in females was not significantly different compared to men (5.5 [5.1–6] vs. 5.6 [5.1–6.2], P=.087), however female patients had a higher ASI (3.3 [2.8–3.8] vs. 2.8 [2.5–3.2], P<.001). Use of percutaneous access (32.6% vs. 35.3%, P=.4), iliac conduit (8.1% vs. 7.2%, P=.6) and brachial arterial access (5.2% vs. 4.7%, P=.8) was similar between female and male patients. Also, female patients less often underwent complex EVAR with a Cook Zenith Fenestrated (ZFEN) device than male patients (17.9% vs. 25.7%, P=.008).

Female patients who underwent open repair had a shorter operative time (235 [176–299] vs. 242 [191–314], P=.049). Females in the open cohort had a smaller AAA diameter compared to male patients (5.7 [5.2–6.4] vs. 6 [5.5–6.8], P<.001), however, they had a higher ASI (3.4 [3–3.9] vs. 3 [2.7–3.5], P<.001). Also, female patients underwent repair with a retroperitoneal approach more often than men, but this was not statistically significant (47.2% vs. 40.6%, P=.052) (Table II).

Outcomes

When comparing the outcomes of females and males among the patients treated with EVAR, perioperative mortality was higher in female patients (6.3% vs 2.4%; P=.001). Also, the rates of any complication (19% vs 9.7%; P<.001) and major complications (15.9% vs. 7.6%, P<.001) were higher in female patients. Significantly different rates of individual major complications were major respiratory complications (4.8% vs 1.8%, P=.012), renal complications (4.4% vs 1.4%, P=.006), ischemic colitis (2.2% vs 0.5%, P=.016), aneurysm rupture (1.1% vs 0.1%, P=.033), and return to the operating room (7.8% vs 3.7%, P=.008). The most common reasons for reoperations were lower extremity revascularization (15.5%), bleeding (12.1%), ischemic colitis (10.3%), and aneurysm related (5.2%). No significant differences were found between female and male patients for these reoperation subcategories.

Among patients treated with open repair, perioperative mortality was 7.4% in female patients and 5.6% in males (P=.30), and there was no significant difference in any complications (35.5% vs. 31.9%, P=.26) and major complications (29.4% vs. 27.4%, P=.53) rates (Table III).

When comparing the perioperative events between EVAR and open repair, for female and male patients separately, perioperative mortality for male patients was significantly lower after EVAR compared to open repair (2.4% vs. 5.6%, P=.001), while this difference was not seen for female patients (6.3% vs. 7.4%, P=.60).

Multivariable analysis

After adjustment with inverse-probability weighted logistic regression, in patients undergoing EVAR, female sex was significantly associated with higher perioperative mortality (OR, 2.5; 95% CI, 1.3–4.9; P=.007), any complication (OR, 2.1; 95% CI, 1.4–3.2; P<.001), major complication (OR, 2.0; 95% CI, 1.3–3.1; P=.002), reoperation (OR, 1.9; 95% CI, 1.0–3.6; P=.047), major respiratory complication (OR, 2.6; 95% CI, 1.2–5.6; P=.017), renal complication (OR, 3.1; 95% CI, 1.4–7.2; P=.007) and ischemic colitis (OR, 4.1; 95% CI, 1.2–14.1; P=.025) (Table IV). However, when we replaced BMI and diameter with ASI in the propensity score, the association between female sex and perioperative mortality rate attenuated and was no longer statistically significant (OR, 1.9; 95% CI, .9–3.9; P= .091).

Adjusted analysis for open repair showed no significant associations of female sex with perioperative mortality (OR, 0.9; 95% CI, 0.5–1.6; P=.69), any complications (OR, 1.2; 95% CI, 0.9–1.7; P=.22) or major complications (OR, 1.1; 95% CI, 0.8–1.5; P=.74) (Table IV). Replacing diameter with ASI in the model showed similar results.

Sensitivity analyses excluding symptomatic patients showed similar associations with perioperative mortality and major complications in the open and EVAR cohort.

When comparing the outcomes between EVAR and open repair in male patients, after adjustment for demographics, comorbid conditions and diameter, the patients undergoing EVAR experienced lower rate of perioperative mortality compared to open repair (OR, 0.4; 95% CI, 0.2–0.7; P=.003). However, this difference was not observed in the female subgroup (OR, 0.8; 95% CI, 0.4–1.7; P=.61). Lower major complication rates were associated with EVAR in both male patients and female patients.

Discussion:

In this study, we demonstrated that females experienced higher rates of complications and mortality following complex EVAR when compared to males. However, when substituting ASI for diameter in the model, no significant association was found with perioperative mortality. Following open repair, the rate of perioperative mortality and major complications were similar between female and male patients. Furthermore, the benefit in terms of perioperative mortality of EVAR over open repair in male patients was not seen in female patients.

Our findings in female patients undergoing complex EVAR are consistent with the demographics and results found in studies focusing on the influence of sex on infrarenal aneurysm repair. In a previous study using the NSQIP database, we showed that female sex was associated with a higher mortality and major complication rates in patients undergoing infrarenal EVAR.[2] Our findings in female patients undergoing EVAR for complex aneurysms are further supported by the study of Rieß et al., who studied sex disparities following fenestrated and branched EVAR using health insurance claims in Germany.[13] However, compared to our results, they reported a higher 30-day mortality rate of 12.3% in female patients and 5.4% in male patients (compared to the 6.3% in females and 2.4% in males we found).[13] This difference is likely explained by their inclusion of thoracic and thoraco-abdominal AAA and patients with dissection. In contrast to this previous study, Timaran et al. did not find a significant difference in major adverse events between female and male patients after FEVAR apart from more severe renal function impairment (defined as a 30% or greater increase of serum creatinine from baseline).[14] However, this single center study was limited by a small sample size, with only 16 female patients included in the analysis, and therefore may have lacked power to detect a difference in major adverse events.

Despite the older age and more prevalent comorbid conditions in our female population, adjustment for these factors did not alter our conclusion. However, replacing aortic diameter with ASI in the multivariate model attenuated our results, supporting the idea that the use of ASI is a more accurate measurement than diameter alone to determine optimal threshold for repair in female patients. We have previously shown that, unlike in men where aortic diameter is the most predictive determinant, ASI is more predictive of rupture in female patients.[20] Prior data have shown that patients with a larger aneurysm diameter have worse outcomes and it has previously been shown with NSQIP data that obesity was not associated with worse perioperative mortality after EVAR.[21,22] Therefore we believe that the attenuation of the mortality difference when we account for ASI rather than diameter reflect that a specific aneurysm diameter represents a proportionately greater aortic dilatation in female patients compared to male patients.[19] Therefore, female patients would have a more progressed aortic aneurysm at a similar diameter. We therefore suggest that ASI should be taken into account when identifying a treatment plan for female patients with complex AAAs.

The benefits of infrarenal EVAR over open repair are predicated in several randomized controlled trials and large retrospective studies showing lower mortality and complications after EVAR.[23–25] For treatment of complex AAA repair it was found that EVAR was associated with a lower incidence of 30-day mortality and adverse outcomes than open repair.[26] However, our study found that females did not experience the benefit in perioperative mortality following complex EVAR that the male cohort experienced. A factor which has been hypothesized to contribute to this disparity in outcomes is that female patients have smaller access vessels possibly making an endovascular intervention more challenging.[27] The available data in our study do not clearly support this as the use of an iliac conduit and use of percutaneous access was similar in female and male patients. However, the trend towards longer operative times in female patients undergoing EVAR but shorter operative times in female patients undergoing open repair could indicate a more complex endovascular procedure, a factor which may contribute to the differences in outcomes between these two procedures in female patients. Also, we found that women less often underwent complex EVAR with a ZFEN device than men (17.9% vs. 25.7%) which could be an indication that women are less likely to meet ZFEN instructions-for-use criteria due to their smaller access vessels and higher angulations. As ZFEN devices have been shown to have low perioperative mortality this could contribute to the sex disparities we found.[11] This shows the importance of focusing on sex disparities when developing endovascular procedures and highlights an important target for improvement of the accessibility and quality of endovascular repair.

This study should be interpreted in the context of its design. The NSQIP only collects data of patients undergoing AAA repair, precluding us from commenting on patients with complex AAAs who did not undergo surgery and the influence of surgical choice. Given the lack of technical data in the NSIQP database, we were unable to account for the exact technical approaches. Therefore, the effect of the specific complex repair technique could not be evaluated. Also, the NSQIP does not include anatomical data other than maximum diameter, specifically aortic neck length, angulation, and access vessel diameter, and therefore, we could not show the anatomical differences between female and male patients. Finally, follow-up data after 30 days are not recorded in NSQIP. Future studies assessing the association of female sex with long-term outcomes in complex repair are warranted, and future research initiatives should aim at determining causation of these sex differences and implementing sex-specific treatment strategies.

Conclusion:

Female sex is independently associated with higher perioperative mortality and complications after complex endovascular repair, even after adjustment for demographics, comorbid conditions, and aneurysm diameter, and this association is not seen following complex open repair. The use of ASI in determining the optimal threshold for complex AAA repair and more sex-specific research may help reduce these sex discrepancies.

Acknowledgment:

This work was conducted with support from Harvard Catalyst | The Harvard Clinical and Translational Science Center (National Center for Advancing Translational Sciences, National Institutes of Health Award UL 1TR002541) and financial contributions from Harvard University and its affiliated academic healthcare centers. The content is solely the responsibility of the authors and does not necessarily represent the official views of Harvard Catalyst, Harvard University and its affiliated academic healthcare centers, or the National Institutes of Health.

Other author notes: PL is supported by the Harvard-Longwood Research Training in Vascular Surgery NIH T32 Grant 5T32HL007734–22

References:

1. Starr JE, Halpern V. Abdominal aortic aneurysms in women. J Vasc Surg. 2013 4;57(4):3S–10S.
2. Deery SE, Soden PA, Zettervall SL, Shean KE, Bodewes TCF, Pothof AB, et al. Sex differences in mortality and morbidity following repair of intact abdominal aortic aneurysms. J Vasc Surg. 2017 4;65(4):1006–13. [PubMed: 27986477]

3. Lo RC, Bensley RP, Hamdan AD, Wyers M, Adams JE, Schermerhorn ML. Gender differences in abdominal aortic aneurysm presentation, repair, and mortality in the Vascular Study Group of New England. J Vasc Surg. 2013 5;57(5):1261–1268.e5. [PubMed: 23384493]
4. Makrygiannis G, Courtois A, Drion P, Defraigne J-O, Kuivaniemi H, Sakalihasan N. Sex Differences in Abdominal Aortic Aneurysm: The Role of Sex Hormones. Ann Vasc Surg. 2014 11;28(8):1946–58. [PubMed: 25106102]
5. Machado R, Teixeira G, Oliveira P, Loureiro L, Pereira C, Almeida R. Endovascular Abdominal Aneurysm Repair in Women: What are the Differences Between the Genders? Braz J Cardiovasc Surg. 2016;31(3):232–8. [PubMed: 27737406]
6. Greenberg RK, Haulon S, Lyden SP, Srivastava SD, Turc A, Eagleton MJ, et al. Endovascular management of juxtarenal aneurysms with fenestrated endovascular grafting. J Vasc Surg. 2004 2;39(2):279–87. [PubMed: 14743126]
7. Lee JT, Greenberg JI, Dalman RL. Early experience with the snorkel technique for juxtarenal aneurysms. J Vasc Surg. 2012 4;55(4):935–46. [PubMed: 22244859]
8. Ohrlander T, Sonesson B, Ivancev K, Resch T, Dias N, Malina M. The Chimney Graft: A Technique for Preserving or Rescuing Aortic Branch Vessels in Stent-Graft Sealing Zones. J Endovasc Ther. 2008 8;15(4):427–32. [PubMed: 18729550]
9. Starnes BW. Physician-modified endovascular grafts for the treatment of elective, symptomatic, or ruptured juxtarenal aortic aneurysms. J Vasc Surg. 2012 9;56(3):601–7. [PubMed: 22554425]
10. Suckow BD, Goodney PP, Columbo JA, Kang R, Stone DH, Sedrakyan A, et al. National trends in open surgical, endovascular, and branched-fenestrated endovascular aortic aneurysm repair in Medicare patients. J Vasc Surg. 2018 6;67(6):1690–1697.e1. [PubMed: 29290495]
11. Varkevisser RRB, O'Donnell TFX, Swerdlow NJ, Liang P, Li C, Ultee KHJ, et al. Fenestrated endovascular aneurysm repair is associated with lower perioperative morbidity and mortality compared with open repair for complex abdominal aortic aneurysms. J Vasc Surg [Internet]. 2018 12 [cited 2018 Dec 19]; Available from: https://linkinghub.elsevier.com/retrieve/pii/S0741521418322687
12. Carpenter JP, Baum RA, Barker CF, Golden MA, Mitchell ME, Velazquez OC, et al. Impact of exclusion criteria on patient selection for endovascular abdominal aortic aneurysm repair. J Vasc Surg. 2001 12;34(6):1050–4. [PubMed: 11743559]
13. Rieß HC, Debus ES, Schwaneberg T, Sedrakyan A, Kölbel T, Tsilimparis N, et al. Gender disparities in fenestrated and branched endovascular aortic repair. Eur J Cardiothorac Surg [Internet]. [cited 2018 Dec 19]; Available from: http://academic.oup.com/ejcts/advance-article/doi/10.1093/ejcts/ezy249/5049092
14. Timaran DE, Knowles M, Soto-Gonzalez M, Modrall JG, Tsai S, Kirkwood M, et al. Gender and perioperative outcomes after fenestrated endovascular repair using custom-made and off-the-shelf devices. J Vasc Surg. 2016 8;64(2):267–72. [PubMed: 27316411]
15. Davis CL, Pierce JR, Henderson W, Spencer CD, Tyler C, Langberg R, et al. Assessment of the Reliability of Data Collected for the Department of Veterans Affairs National Surgical Quality Improvement Program. J Am Coll Surg. 2007 4;204(4):550–60. [PubMed: 17382213]
16. Shiloach M, Frencher SK, Steeger JE, Rowell KS, Bartzokis K, Tomeh MG, et al. Toward Robust Information: Data Quality and Inter-Rater Reliability in the American College of Surgeons National Surgical Quality Improvement Program. J Am Coll Surg. 2010 1 1;210(1):6–16. [PubMed: 20123325]
17. Levey AS, Stevens LA, Schmid CH, Zhang Y (Lucy), Castro AF, Feldman HI, et al. A New Equation to Estimate Glomerular Filtration Rate. Ann Intern Med. 2009 5 5;150(9):604. [PubMed: 19414839]
18. Du Bois D, Du Bois EF. A formula to estimate the approximate surface area if height and weight be known. 1916. Nutr Burbank Los Angel Cty Calif. 1989 10;5(5):303–11; discussion 312–313.
19. Davies RR, Gallo A, Coady MA, Tellides G, Botta DM, Burke B, et al. Novel Measurement of Relative Aortic Size Predicts Rupture of Thoracic Aortic Aneurysms. Ann Thorac Surg. 2006 1;81(1):169–77. [PubMed: 16368358]

20. Lo RC, Lu B, Fokkema MTM, Conrad M, Patel VI, Fillinger M, et al. Relative importance of aneurysm diameter and body size for predicting abdominal aortic aneurysm rupture in men and women. J Vasc Surg. 2014 5;59(5):1209–16. [PubMed: 24388278]
21. Giles KA, Wyers MC, Pomposelli FB, Hamdan AD, Avery Ching Y, Schermerhorn ML. The impact of body mass index on perioperative outcomes of open and endovascular abdominal aortic aneurysm repair from the National Surgical Quality Improvement Program, 2005–2007. J Vasc Surg. 2010 12 1;52(6):1471–7. [PubMed: 20843627]
22. Huang Y, Gloviczki P, Duncan AA, Kalra M, Oderich GS, Fleming MD, et al. Maximal aortic diameter affects outcome after endovascular repair of abdominal aortic aneurysms. J Vasc Surg. 2017;65(5):1313–1322.e4. [PubMed: 28034585]
23. Powell JT, Sweeting MJ, Ulug P, Blankensteijn JD, Lederle FA, Becquemin J-P., et al. Meta-analysis of individual-patient data from EVAR-1, DREAM, OVER and ACE trials comparing outcomes of endovascular or open repair for abdominal aortic aneurysm over 5 years. Br J Surg. 2017 2;104(3):166–78. [PubMed: 28160528]
24. Schermerhorn ML, Buck DB, O'Malley AJ, Curran T, McCallum JC, Darling J, et al. Long-Term Outcomes of Abdominal Aortic Aneurysm in the Medicare Population. N Engl J Med. 2015 7 23;373(4):328–38. [PubMed: 26200979]
25. Schermerhorn ML, Cotterill P. Endovascular vs. Open Repair of Abdominal Aortic Aneurysms in the Medicare Population. N Engl J Med. 2008;11.
26. Ultee KHJ, Zettervall SL, Soden PA, Darling J, Verhagen HJM, Schermerhorn ML. Perioperative outcome of endovascular repair for complex abdominal aortic aneurysms. J Vasc Surg. 2017 6;65(6):1567–75. [PubMed: 28216344]
27. Velazquez OC, Larson RA, Baum RA, Carpenter JP, Golden MA, Mitchell ME, et al. Gender-related differences in infrarenal aortic aneurysm morphologic features: Issues relevant to Ancure and Talent endografts. J Vasc Surg. 2001 2;33(2):77–84. [PubMed: 11137927]

ARTICLE HIGHLIGHTS

Type of research:

Retrospective analysis of prospectively collected National Surgical Quality Improvement Program (NSQIP) targeted vascular module data.

Key Finding:

In this study of 2,270 complex aneurysm repairs, female sex was independently associated with perioperative mortality (OR, 2.5; 95% CI, 1.3–4.9; P=.007) and major complications (OR, 2.0; 95% CI, 1.3–3.2; P=.002) compared with male patients following complex EVAR, but not following complex open repair.

Take Home Message:

Female patients have worse perioperative outcomes after complex EVAR. However, this association is not seen following complex open repair. The use of ASI in determining the optimal threshold for complex AAA repair and more sex-specific research may help reduce these discrepancies.

Table I.

Baseline characteristics.

	Complex Repair (n=2,270)		
	Female (n=580)	**Male (n= 1,690)**	**P-value**
Age	75 (69, 80)	73 (67, 79)	**0.002**
Race			0.11
White	479 (82.6%)	1373 (81.2%)	
Black	29 (5.0%)	62 (3.7%)	
Other	4 (0.7%)	29 (1.7%)	
Unknown	68 (11.7%)	226 (13.4%)	
BMI categories			**<0.001**
Normal (BMI 18.5–25)	193 (33.7%)	459 (27.5%)	
Underweight (BMI <18.5)	33 (5.8%)	31 (1.9%)	
Overweight (BMI 25–30)	199 (34.7%)	690 (41.3%)	
Obese (BMI 30–40)	125 (21.8%)	452 (27.1%)	
Morbidly obese (BMI >40)	23 (4.0%)	37 (2.2%)	
Smoker	272 (46.9%)	625 (37.0%)	**<0.001**
IDDM	14 (2.4%)	43 (2.5%)	0.86
Hypertension	465 (80.2%)	1387 (82.1%)	0.31
CHF	10 (1.7%)	39 (2.3%)	0.40
COPD	129 (22.2%)	333 (19.7%)	0.19
Renal Function			**<0.001**
eGFR >60	315 (55.6%)	1076 (65.7%)	
eGFR 30–60	218 (38.4%)	485 (29.6%)	
eGFR <30 or on dialysis	34 (6.0%)	77 (4.7%)	
Steroid Use	29 (5.0%)	59 (3.5%)	0.10
Weight loss	10 (1.7%)	15 (0.9%)	0.096
Bleeding disorders	66 (11.4%)	188 (11.1%)	0.87
SIRS symptoms	11 (1.9%)	22 (1.3%)	0.30
Symptomatic	74 (12.8%)	128 (7.6%)	**<0.001**

EVAR: endovascular aneurysm repair; AAA: abdominal aortic aneurysm; Age (years); BMI: Body Mass Index (kg/m2); IDDM: Insulin Dependent Diabetes Mellitus; CHF: chronic hearth failure; COPD: chronic obstructive pulmonary disease; eGFR: estimated glomerular filtration rate; SIRS: systemic inflammatory response syndrome.

Values are median (inter quartile range) or total events (percentages)

Values of polytomous variables may not sum to 100% due to rounding

Boldface P values represent significance (P<.05).

Table II.

Operative characteristics.

	Complex EVAR (n=1,260)			Complex Open AAA repair (n=1,010)		
	Female (n=270)	**Male (n=990)**	**P-value**	**Female (n=310)**	**Male (n=700)**	**P-value**
Diameter	5.5 (5.1, 6)	5.6 (5.1, 6.2)	0.087	5.7 (5.2, 6.4)	6 (5.5, 6.75)	**<0.001**
Aortic Size Index	3.3 (2.8, 3.8)	2.8 (2.5, 3.2)	**<0.001**	3.4 (3, 3.9)	3 (2.7, 3.5)	**<0.001**
Distal Aneurysm Extent			0.17			0.13
Aortic	82 (35.8%)	245 (29.0%)		170 (63.7%)	343 (55.1%)	
Common iliac	86 (37.6%)	348 (41.2%)		88 (33.0%)	248 (39.9%)	
External iliac	24 (10.5%)	81 (9.6%)		5 (1.9%)	15 (2.4%)	
Internal iliac	37 (16.2%)	171 (20.2%)		4 (1.5%)	16 (2.6%)	
Operative time	152 (110,252)	146 (103, 234)	0.055	235 (176, 299)	242 (191, 314)	**0.049**
Percutaneous Access	88 (32.6%)	348 (35.3%)	0.41	-	-	-
Hypogastric Embolization	18 (6.7%)	70 (7.1%)	0.82	-	-	-
Iliac Conduit	22 (8.1%)	71 (7.2%)	0.59	-	-	-
Iliac Branched Device	46 (17.0%)	184 (18.6%)	0.56	-	-	-
Brachial Arterial Access	14 (5.2%)	47 (4.7%)	0.77	-	-	-
Retroperitoneal Approach	-	-	-	145 (47.2%)	280 (40.6%)	0.052

EVAR: endovascular aneurysm repair; AAA: abdominal aortic aneurysm; Diameter (cm).

Values are median (inter quartile range) or total events (percentages).

Values of polytomous variables may not sum to 100% due to rounding.

Boldface P values represent significance ($P<.05$).

Table III.

Perioperative outcomes.

	Complex EVAR (n=1,260)			Complex Open AAA repair (n=1,010)		
	Female (n=270)	**Male (n=990)**	**P-value**	**Female (n=310)**	**Male (n=700)**	**P-value**
Perioperative Mortality	17 (6.3%)	24 (2.4%)	**0.001**	23 (7.4%)	39 (5.6%)	0.26
Any Complication	51 (19.0%)	96 (9.7%)	**<0.001**	110 (35.5%)	223 (31.9%)	0.26
Major Complication	43 (15.9%)	75 (7.6%)	**<0.001**	91 (29.4%)	192 (27.4%)	0.53
Cardiac complication	8 (3.0%)	17 (1.7%)	0.22	18 (5.8%)	52 (7.4%)	0.42
Major Respiratory Complication	13 (4.8%)	18 (1.8%)	**0.012**	48 (15.5%)	92 (13.1%)	0.32
Renal complication	12 (4.4%)	14 (1.4%)	**0.006**	25 (8.1%)	58 (8.3%)	1.00
Stroke	4 (1.5%)	7 (0.7%)	0.26	0 (0.0%)	4 (0.6%)	0.32
Ischemic Colitis	6 (2.2%)	5 (0.5%)	**0.016**	17 (5.5%)	31 (4.4%)	0.52
Lower Extremity Ischemia	7 (2.6%)	15 (1.5%)	0.29	8 (2.6%)	19 (2.7%)	1.00
Aneurysm Rupture	3 (1.1%)	1 (0.1%)	**0.033**	1 (0.3%)	1 (0.1%)	0.52
Reoperation	21 (7.8%)	37 (3.7%)	**0.008**	41 (13.2%)	93 (13.3%)	1.00
Sepsis	0 (0.0%)	4 (0.4%)	0.58	8 (2.6%)	11 (1.6%)	0.32

EVAR: endovascular aneurysm repair; AAA: abdominal aortic aneurysm; Major complications (cardiac complications, major pulmonary complications, renal complications, stroke, ischemic colitis, lower extremity ischemia requiring intervention, postoperative aneurysm rupture, an unplanned reoperation, or postoperative sepsis).

Values are total events (percentages).

Boldface P values represent significance ($P<.05$).

Table IV.

Odds Ratios (95% Confidence Intervals) for female patients undergoing open AAA repair or EVAR and perioperative outcomes

	Complex EVAR (n=1,260)			Complex Open (n=1,010)		
	OR	P-value	95% CI	OR	P-value	95% CI
Mortality, perioperative	2.5	**0.007**	1.3 – 4.9	0.9	0.69	.5 – 1.6
Any complication	2.1	**<0.001**	1.4 – 3.2	1.2	0.22	.9 – 1.7
Major Complication	2.0	**0.002**	1.3 – 3.1	1.1	0.74	.8 – 1.5
Reoperation	1.9	**0.047**	1.0 – 3.6	0.9	0.49	.6 – 1.3
Cardiac complication	1.1	0.8	.4 – 2.9	0.7	0.19	.4 – 1.2
Major Respiratory						
Complication	2.6	**0.017**	1.2 – 5.6	1.1	0.60	.7 – 1.7
Renal complication	3.1	**0.007**	1.4 – 7.2	1.0	0.88	.6 – 1.8
Stroke *	1.8	0.356	.5 – 6.5	-	-	-
Ischemic Colitis	4.1	**0.025**	1.2 – 14.1	1.0	0.98	.5 – 1.9
Lower Extremity Ischemia	2.5	0.074	.9 – 6.8	0.7	0.48	.3 – 1.8
Aneurysm Rupture	8.0	0.074	.8 – 78.6	1.8	0.68	.1 – 28.9
Sepsis *	-	-	-	1.3	0.58	.5 – 3.8

EVAR: endovascular aneurysm repair; AAA: abdominal aortic aneurysm; OR: Odds Ratio; CI: Confidence Interval; Major complications (cardiac complications, major pulmonary complications, renal complications, stroke, ischemic colitis, lower extremity ischemia requiring intervention, postoperative aneurysm rupture, an unplanned reoperation, or postoperative sepsis).

The model is adjusted for age (years), race (white (ref), black, other, unknown), body mass index category (BMI<18.5, BMI 18.5–25(ref), BMI 25–30, BMI 30–40, BMI>40 kg/m2), current smoking status, insulin dependent diabetes mellitus, hypertension requiring medication, congestive heart failure, chronic obstructive pulmonary disease, renal function (eGFR>60(ref), eGFR30–60, eGFR<30 or preoperative dialysis), steroid use for a chronic condition, weight loss (> 10% in the 6 Months Prior to Surgery), bleeding disorders, systemic inflammatory response syndrome within 48 Hours Prior to Surgery, symptomatic aneurysm and diameter. Boldface P values represent significance (P<.05).

* Results not shown given the lack of any septic events among female patients undergoing EVAR and any stroke among female patients undergoing open repair.