HHS Public Access
Author manuscript
J Vasc Surg. Author manuscript; available in PMC 2017 July 01.

Published in final edited form as:
J Vasc Surg. 2016 July ; 64(1): 76–82. doi:10.1016/j.jvs.2015.12.055.

Conversion from EVAR to Open Abdominal Aortic Aneurysm Repair

Klaas H.J. Ultee[1,2], **Peter A. Soden, MD**[1], **Sara L. Zettervall, MD MPH**[1], **Jeremy Darling, BA**[1], **Hence J.M. Verhagen, MD PhD**[2], and **Marc L. Schermerhorn, MD**[1]

[1]Department of Surgery, Division of Vascular and Endovascular Surgery, Beth Israel Deaconess Medical Center and Harvard Medical School, Boston, MA, USA [2]Department of Vascular Surgery, Erasmus University Medical Center, Rotterdam, the Netherlands

Abstract

Introduction—Previous studies have found conflicting results regarding the operative risks associated with conversion to open abdominal aortic aneurysm (AAA) repair after failed endovascular treatment (EVAR). The purpose of this study was to assess the outcome of patients undergoing a conversion, and compare outcomes to standard open AAA repair and EVAR. Additionally, we sought out to identify factors associated with conversion.

Methods—All patients undergoing a conversion to open repair, and those undergoing standard EVAR and open repair between 2005 and 2013 were included from the National Surgical Quality Improvement Program (NSQIP). Multivariable logistic regression analysis was used to identify factors associated with conversion, and to assess independent perioperative risks associated with conversion compared to standard AAA repair. Subanalysis for factors associated with conversion was performed among patients additionally included in the more detailed Targeted Vascular Module of the NSQIP.

Results—A total of 32,164 patients were included, with 300 conversions, 7188 standard open repairs, and 24,676 EVARs. Conversion to open repair was associated with a significantly higher 30-day mortality than standard open repair (10.0% vs. 4.2%, P<.001, OR: 2.4, 95% CI: 1.6 – 3.6), and EVAR (10.0% vs. 1.7%, P<.001, OR: 7.2, 95% CI: 4.8 – 10.9). Conversion surgery was additionally followed by an increased occurrence of any complication (OR: 1.5, 95% CI: 1.2 – 1.9 (open); OR: 7.8, 95% CI: 6.1 – 9.9 (EVAR)). Factors associated with conversion were young age (OR: 1.2 per 10 years decrease, 95% CI: 1.1 – 1.4), female gender (OR: 1.5, 95% CI: 1.2 – 2.0), and non-white race (OR: 1.8, 95% CI: 1.3 – 2.6). Conversely, BMI > 30 was negatively associated with (OR: 0.7, 95% CI: 0.5 – 0.9). Among anatomic characteristics captured in the Targeted Vascular data set (N=4555), aneurysm large diameter demonstrated to be strongly associated with conversion (OR: 1.1 per 1 cm increase, 95% CI: 1.03 – 1.1).

Corresponding Author / Reprints: Marc L. Schermerhorn, 110 Francis St. Suite 5B, Boston, MA 02215; Phone: 617-632-9971; mscherm@bidmc.harvard.edu.

Conclusion—Conversion to open repair after failed EVAR is associated with substantially increased perioperative morbidity and mortality compared to standard AAA repair. Factors associated with conversion are large diameter of the aneurysm, young age, female gender, and non-white race, while obesity is inversely related to conversion surgery.

Introduction

Owing to the perioperative benefits over open repair,[–] the use of endovascular treatment modalities (EVAR) for abdominal aortic aneurysm (AAA) repair has rapidly increased since its introduction.[–] EVAR is currently the primary mode of treatment for AAA, with over 80% of elective cases being performed through endovascular repair.[–] Although rare, a conversion to open repair is sometimes required.[,] A conversion can either be performed acutely, necessitated by intraoperative complications during EVAR, such as access-related problems and errors in endograft deployment,[–] or as a late reintervention following graft migration, persistent endoleak, graft thrombosis, or infection.[–]

Due to the rarity of the procedure, evidence on the frequency and prognostic implications of performing a conversion is largely limited to small retrospective series from mostly single-institution experiences.[, , –] These studies did show that conversion surgery was associated with substantial perioperative mortality, averaging 12% and 10% after acute and late conversion respectively. Consequently, many of these studies concluded that having to convert from EVAR to open repair is associated with worse outcomes than either standard open AAA repair or EVAR. Yet in the largest study to date using the National Quality Improvement Program (NSQIP) from 2005 to 2008 with 72 conversion patients, Newton et al. found no differences in perioperative outcomes between patients undergoing a conversion and those undergoing standard open AAA repair. The purpose of this study was to assess the outcome of patients undergoing conversion, and compare outcomes to standard open AAA repair and EVAR. Additionally, we aim to identify factors associated with conversion to open AAA repair using the regular NSQIP, as well as the newly available Targeted Vascular module.

Methods

Data Source

For this study, we used the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database. The NSQIP is a quality improvement initiative of the American College of Surgeons, and is designed to provide robust, reliable and risk-adjusted surgical outcomes intended to identify elements in current healthcare practice for quality improvement purposes. Dedicated surgical clinical nurse reviewers at each hospital prospectively collect preoperative and procedural risk factors, as well as 30-day postoperative outcomes according to standardized definitions.[,] The validity of the ACS NSQIP has been confirmed previously. The database contains de-identified data only without any protected health information. Therefore, Institutional Review Board approval and patient consent were waived. In order to identify anatomy-related factors associated with conversion, we performed a subanalysis among patients who are also captured in the Targeted Vascular data set of the ACS NSQIP. The Targeted Vascular data set is a newly available module, which includes additional disease and procedure specific characteristics, and procedure-related outcomes chosen by vascular surgeons. Additional information on the ACS NSQIP and the Targeted Vascular data set are available at www.acsnsqip.org.

Patients undergoing a conversion to open repair between January 2005 and December 2013 were included in the study. Procedures were identified using Current Procedural Terminology coding (CPT). CPT codes for conversion to open AAA repair are: 34830, 3481, and 34832, which respectively correspond to open AAA repair using tube, aortobiiliac, and aortobifemoral prostheses after unsuccessful EVAR. Since these same CPT codes are used for both acute and late conversions, we were unable to distinguish between conversions performed immediately after failed EVAR and those performed as late reinterventions. Therefore, we considered our cohort to comprise of both acute and late conversions. The CPT codes for conversion also encompass the attempted EVAR in case of an acute conversion, which precluded us from determining whether the conversion was immediate or not based on the time between the EVAR and conversion. Standard EVAR (CPT: 34800, 34802, 34803, 34804, 34805), and non-ruptured open AAA repair (CPT: 35081, 35102) patients were also included for comparison. Cases with a postoperative diagnosis indicating the treatment of a ruptured aneurysm, as defined by the International Classification of Diseases – 9th revision (ICD-9), were excluded (ICD-9: 441.3).

Conversion patients were compared to open repair and EVAR patients on baseline and intraoperative characteristics, as well as 30-day postoperative outcomes. Age was considered both as a categorical variable, and as a continuous variable, with 90+ coded as 90 to prevent individual patient identification. Body mass index (BMI) was calculated using height and weight data (kg/m^2). Postoperative outcomes included 30-day mortality and morbidity including acute kidney injury, respiratory complications, wound complications, myocardial infarction, sepsis, septic shock, and return to the operating room. Acute kidney injury was defined as a rise in creatinine of >2 mg/dl from preoperative value, and/or requirement of hemodialysis, peritoneal dialysis, hemofiltration, hemodiafiltration, or ultrafiltration within 30 days of the operation. A respiratory complication was defined as prolonged ventilator dependence (>48 hours), reintubation, or a postoperative pneumonia. Wound complications included superficial, deep, and organ space infections. Patients with systemic inflammatory response syndrome (SIRS), sepsis, or septic shock prior to surgery were not considered for postoperative sepsis and septic shock analysis. Additional anatomical characteristics assessed in the subanalysis among patients captured in the Targeted Vascular data set were aneurysm diameter, and distal aneurysm extent. In order to identify differences in postoperative morbidity aside from death, 30-day mortality was not included in the any complication measure.

Statistical analyses—Categorical variables are presented as counts and percentages. Normally distributed continuous variables are presented as mean ± standard deviation and non-parametric distributions as median and interquartile range. Differences between treatment groups were assessed using χ^2 and Fisher's exact testing for categorical variables and Student's t-test, and Mann Whitney U test for continuous variables, where appropriate. Trend analyses were performed with the Cochran-Armitage test for trend. Independent associations between conversion and adverse postoperative outcomes were established using multivariable logistic regression analysis. Baseline characteristics were univariately tested, and variables with a P-value ≤ .1 were subsequently entered into the multivariable model. Separate models were constructed for 30-day mortality, acute kidney injury, and the occurrence of any complication. To identify factors associated with conversion, differences in demographics, comorbidities, and aneurysm diameter were assessed using logistic regression analysis. Similar to the outcomes analysis, variables with a P-value ≤ .1 were added to the multivariable model. To avoid over-fitting in the subanalysis among patients captured in the Targeted Vascular data set (N=4555), a separate model was constructed. All tests were two-sided and significance was considered when P-value <0.05. Statistical analysis was performed using the SPSS Statistics 21 (IBM Inc., Chicago, IL).

Results

A total of 32,164 patients were included, with 300 patients who underwent a conversion to open repair, 7188 open repairs, and 24,676 EVARs. During the study period, the conversion rate was 1.2 per 100 EVAR cases (range: 0.8 – 1.5), with no apparent upward or downward trend over time (P=0.836).

Baseline characteristics

Baseline characteristics are listed in Table I. Compared to open repair patients, those undergoing a conversion were older (72.6 vs. 70.5, P<.001), but were comparable in terms of gender (P=.801), and race (P=.072). Similarly, no differences were found in comorbidities. However, those undergoing a conversion were less frequently current smokers than standard open repair patients (32.7% vs. 43.8%, P<.001), and were more often classified as a class 4 or greater on the American Association of Anesthesiologists (ASA) physical status classification system (37.1% vs. 29.3%, P=.004).

When comparing the conversions to EVAR patients, we found that those undergoing conversion were younger (72.6 vs. 74.0 years, P=006), more often female (25.8% vs. 18.6%, P=.002), and more frequently of non-white race (12.0% vs. 6.8%%, P=.002). In addition, the conversion patients were less likely to have diabetes (11.0% vs. 15.7%, P=.026) or obesity (24.6% vs. 31.4%, P=.012). Also, conversion patients more often had a ASA class of 4 or greater (37.1% vs. 22.6%, P<.001).

Intraoperative differences

Operative details are listed in Table II. Conversion was associated with a significantly longer operative time compared to standard open repair (275 min. vs. 232 min, P<.001). In addition, conversion cases were more often classified as emergent compared to standard open repairs (10.0% vs. 6.4%, P=.013), and EVARs (3.9%, P<.001). There was no difference in proportion of cases performed by vascular surgeons with the vast majority for conversions and standard open repairs (96.3% vs. 96.1%, P=.832), as well as EVARs (96.5%, P=.892) being performed by this specialty.

Postoperative outcomes

Compared to standard open repair, 30-day mortality following a conversion was significantly higher (10.0% vs. 4.2%, P<.001, Table III). In addition, conversion patients were more likely to undergo new dialysis (6.0% vs. 3.5%, P=.024), cardiopulmonary resuscitation (5.3% vs. 1.9%, P<.001), postoperative blood transfusion (42.3% vs. 31.6%, P<.001), and have a myocardial infarction (5.0% vs. 2.2%, P=.001).

When comparing conversion patients to those undergoing EVAR, we found that 30-day mortality after a conversion was substantially higher (10.0% vs. 1.7%, P<.001). Similarly, conversion to open repair was associated with a higher rate of various adverse events, including acute kidney injury (7.3% vs. 1.4%, P<.001), respiratory complications (16.3% vs. 2.2%, P<.001), cardiac complications (8.7% vs. 1.4%, P<.001), wound complications (4.7% vs. 2.3%, P=.008), return to the operating room (9.3% vs. 4.5%, P<.001), and postoperative septic shock (3.7% vs. 0.6%, P<.001).

After adjustment for potential confounders, conversion to open repair proved to be associated with almost two-and-a-half times higher mortality risk compared to standard open repair (OR: 2.4, 95% CI: 1.6 – 3.6). Conversion surgery was additionally associated with increased risks for the occurrence of any complication (OR: 1.5, 95% CI: 1.2 – 1.9). Compared to EVAR, conversion to open repair was an independent predictor of 30-day mortality (OR: 7.2, 95% CI: 4.8 – 10.9), acute kidney injury (OR: 5.6, 95% CI: 3.5 – 8.9), and any complication (OR: 7.8, 95% CI: 6.1 – 9.9).

Factors associated with conversion

For multivariable analysis, demographics, comorbidities, and aneurysm diameter were considered. In the overall cohort, young age (OR: 1.2 per 10 years decrease, 95% CI: 1.1 – 1.4, Table IV), female gender (OR: 1.5, 95% CI: 1.2 – 2.0), and non-white race (OR: 1.8, 95% CI: 1.3 – 2.6) were associated with conversion. Conversely, BMI over 30 had a negative association with conversion (OR: 0.7, 95% CI: 0.5 – 0.9). For patients captured in the more detailed Targeted Vascular module (N=50 and N=4505, respectively for conversion and EVAR cases), additional subanalysis was performed. Among these patients, large diameter was strongly associated with conversion (mean diameter: 6.8cm vs. 5.7cm, P=.001; OR: 1.1 per 1 cm increase, 95% CI: 1.03 – 1.1).

Discussion

This study demonstrates that conversion to open repair is independently associated with an increased risk of mortality and other adverse outcomes during the postoperative period compared to standard open repair. In addition to almost a two-and-a-half fold increase in perioperative mortality, patients undergoing a conversion more often suffered adverse events, such as myocardial infarction, acute kidney injury requiring dialysis, need for CPR, and postoperative blood transfusion. Multivariable analysis showed that younger age, female gender, and non-white race were associated with conversion surgery, while obesity was inversely related to conversion. Inclusion of targeted module variables established that aneurysm diameter is also an important determinant of conversion.

The first study assessing the outcome following a conversion from endovascular to open repair was published in 1997. With an incidence of almost 16% (11.5% acute, 4.5% late), the conversion rate was substantially higher than the 1.2% in the present study. The reduction is most likely the result of improved patient selection and surgeon experience, as well as technical advances in endovascular repair allowing for patients with more challenging anatomy to be successfully treated using endovascular treatment modalities. This is supported by a decline in conversion rates in more recent reports., In the 1997 study by Jacobowitz et al., the perioperative mortality following conversion –acute or chronic– was 17%. Mortality rates in subsequent studies have ranged between 0% and 28.5%. This variability is likely the result of the small sample sizes of these single-center studies.,,, A pooled data-analysis by Moulakakis et al. determined the perioperative mortality to be 12% and 10%, respectively for acute and late conversion. This is comparable to the 10% found in our study. Considering that this is over twice the norm for standard open AAA repair, our results –not surprisingly– showed that conversion surgery was associated with a significantly increased perioperative mortality risk compared to open repair, as well as EVAR. However, in the largest reported conversion cohort to date, which was obtained from the same database as the present study and included the same patients for the years 2005 to 2008, Newton et al. found no difference in mortality between conversion patients and those undergoing standard open AAA repair (4.2% vs. 3.2%, respectively). This difference in outcome appears to be result of a higher perioperative mortality following conversion to open repair in the later years of the past decade in this database. In the study by Newton et al., the mortality rate of 4.2% in a cohort of 72 patients corresponds to only 3 deaths in the perioperative period. Considering the consequent susceptibility to sample variability, the discrepancy with the present study may simply be the result of an increase in sample size. This highlights the value of reexamination when more data are available. An actual increase in mortality over time may be caused by an increase in the proportion of suprarenal bare-metal stents being explanted due to the rise in utilization of these stents in more recent years.

In regards to factors associated with conversion, some studies found no relation between patient factors and conversion to open repair., However, in the Lifeline registry, which described both acute and late conversions, it was found that female gender was strongly associated with conversion, in addition to large aneurysm diameter. Both of these factors were also associated with conversion in the present study. The relation between gender and conversion in the Lifeline registry was in large part driven by acute conversion rates, which fits with studies showing higher intraoperative complication rates among woman during EVAR –particularly access-related– due to complex anatomy and smaller artery diameters.– However, subsequent studies have also determined female gender to be a predictor of late conversion, which may also be the result of more complex aneurysm anatomy in females, as well as more late complications requiring reintervention, such as graft thrombosis., The positive correlation between diameter and conversion risk may also be different for acute and late conversions. For acute conversions the correlation is likely to represent the technical difficulty of establishing adequate seal in patients with large diameter aneurysms, while the larger diameter observed in late conversion patients is more likely the result of sac growth, which has prompted the decision for conversion to open repair. Cuypers et al. reported that low body weight was associated with higher conversion rates in a cohort consisting of both acute and late conversions. In the present study, we also found an inverse association between BMI and conversion. This may be related to a greater comorbidity burden and technical difficulty in obese patients with consequent higher complication rates. Cuypers et al. additionally showed that advanced age was a risk factor for conversion. In our study, however, young age was associated with an increased likelihood of conversion. The correlation with young age could suggest that our cohort consisted more of patients undergoing late conversions, as younger patients will live long enough to benefit from conversion surgery. The difference with the study by Cuypers et al. may therefore be related to the proportion of acute versus late conversions in each cohort. Similar to the explanation for the correlation between BMI and conversion, the association with young age may also be mediated by the fact that younger patients are more often deemed healthy enough to undergo conversion surgery compared to older patients.

This study has several limitations that should be addressed. First, since the data for this study were gathered through a prospective data registry, the potential exists for underreporting of events. Second, as the American Medical Association recommends the CPT coding for conversion to be used for acute and late conversions, we assumed our cohort to consist of both. Unfortunately, we were unable to differentiate between conversions performed immediately and those performed as a late reintervention. However, multicenter studies, as well as meta-analysis have shown the perioperative outcomes to be similar between these two groups., Third, previous studies have demonstrated that some older stent grafts are associated with graft migration, and other untoward events during follow-up. Since these grafts are no longer used, it should be noted that the possible inclusion of these grafts in the present study may have affected our results on the current conversion rate, as well as the factors associated with conversion. Also, baseline characteristics of conversion patients were obtained at the time of the conversion procedure. A more appropriate comparison would have included age and comorbidity at the time of the original EVAR. Unfortunately, these data were not available. Additionally, conversion to open repair may be an indicator of complex anatomy and more severe comorbidity. Despite adjustment for potential confounders in multivariable analysis, these factors may also have contributed to the poor outcome of conversion patients. In addition, the ACS NSQIP does not include long-term follow-up data, which precludes analysis on reintervention rates, late ruptures, and long-term survival. Finally, the anatomic-characteristics provided by the Targeted Vascular module were only available for a subset of our cohort. Consequently, we were unable to adjust for all the initially identified predictive factors in the subanalysis to avoid over-fitting the model. However, sensitivity analysis demonstrated that aneurysm diameter remained significant when adjusting for factors that were most predictive in the overall cohort (i.e. age, gender, non-white race, obesity).

In conclusion, this study demonstrated that conversion to open repair after failed EVAR is associated with substantially increased perioperative mortality, as well as a higher rate of complications such as myocardial infarction and need for dialysis. Multivariable analysis showed that in addition to large diameter of the aneurysm, young age, female gender, and non-white race are associated with conversion surgery, while obesity is inversely related to conversion.

Acknowledgments

Supported by grant 5R01HL105453-03 from the NHLBI and the NIH T32 Harvard-Longwood Research Training in Vascular Surgery grant HL007734.

References

1. Schermerhorn ML, O'Malley AJ, Jhaveri A, Cotterill P, Pomposelli F, Landon BE. Endovascular vs. open repair of abdominal aortic aneurysms in the Medicare population. N Engl J Med. 2008; 358(5):464–474. [PubMed: 18234751]
2. Prinssen M, Verhoeven EL, Buth J, Cuypers PW, van Sambeek MR, Balm R, et al. A randomized trial comparing conventional and endovascular repair of abdominal aortic aneurysms. N Engl J Med. 2004; 351(16):1607–1618. [PubMed: 15483279]
3. Lederle FA, Freischlag JA, Kyriakides TC, Padberg FT Jr, Matsumura JS, Kohler TR, et al. Outcomes following endovascular vs open repair of abdominal aortic aneurysm: a randomized trial. JAMA. 2009; 302(14):1535–1542. [PubMed: 19826022]
4. Greenhalgh RM, Brown LC, Kwong GP, Powell JT, Thompson SG, participants Et. Comparison of endovascular aneurysm repair with open repair in patients with abdominal aortic aneurysm (EVAR trial 1), 30-day operative mortality results: randomised controlled trial. Lancet. 2004; 364(9437): 843–848. [PubMed: 15351191]
5. Parodi JC, Palmaz JC, Barone HD. Transfemoral intraluminal graft implantation for abdominal aortic aneurysms. Ann Vasc Surg. 1991; 5(6):491–499. [PubMed: 1837729]
6. Kent KC. Clinical practice. Abdominal aortic aneurysms. N Engl J Med. 2014; 371(22):2101–2108. [PubMed: 25427112]
7. Lifeline Registry of EPC. Lifeline registry of endovascular aneurysm repair: long-term primary outcome measures. J Vasc Surg. 2005; 42(1):1–10. [PubMed: 16012445]
8. Schermerhorn ML, Bensley RP, Giles KA, Hurks R, O'Malley AJ, Cotterill P, et al. Changes in abdominal aortic aneurysm rupture and short-term mortality, 1995–2008: a retrospective observational study. Ann Surg. 2012; 256(4):651–658. [PubMed: 22964737]
9. Chadi SA, Rowe BW, Vogt KN, Novick TV, Harris JR, Derose G, et al. Trends in management of abdominal aortic aneurysms. J Vasc Surg. 2012; 55(4):924–928. [PubMed: 22226189]
10. Lederle FA, Freischlag JA, Kyriakides TC, Matsumura JS, Padberg FT Jr, Kohler TR, et al. Long-term comparison of endovascular and open repair of abdominal aortic aneurysm. N Engl J Med. 2012; 367(21):1988–1997. [PubMed: 23171095]
11. Moulakakis KG, Dalainas I, Mylonas S, Giannakopoulos TG, Avgerinos ED, Liapis CD. Conversion to open repair after endografting for abdominal aortic aneurysm: a review of causes, incidence, results, and surgical techniques of reconstruction. J Endovasc Ther. 2010; 17(6):694–702. [PubMed: 21142475]
12. 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; 373(4):328–338. [PubMed: 26200979]
13. Jimenez JC, Moore WS, Quinones-Baldrich WJ. Acute and chronic open conversion after endovascular aortic aneurysm repair: a 14-year review. J Vasc Surg. 2007; 46(4):642–647. [PubMed: 17764870]
14. Verzini F, Cao P, De Rango P, Parlani G, Xanthopoulos D, Iacono G, et al. Conversion to open repair after endografting for abdominal aortic aneurysm: causes, incidence and results. Eur J Vasc Endovasc Surg. 2006; 31(2):136–142. [PubMed: 16359884]
15. Millon A, Deelchand A, Feugier P, Chevalier JM, Favre JP. University Association for Research in Vascular S. Conversion to open repair after endovascular aneurysm repair: causes and results. A French multicentric study. Eur J Vasc Endovasc Surg. 2009; 38(4):429–434. [PubMed: 19589700]
16. Tiesenhausen K, Hessinger M, Konstantiniuk P, Tomka M, Baumann A, Thalhammer M, et al. Surgical conversion of abdominal aortic stent-grafts--outcome and technical considerations. Eur J Vasc Endovasc Surg. 2006; 31(1):36–41. [PubMed: 16226904]

17. Phade SV, Keldahl ML, Morasch MD, Rodriguez HE, Pearce WH, Kibbe MR, et al. Late abdominal aortic endograft explants: indications and outcomes. Surgery. 2011; 150(4):788–795. [PubMed: 22000192]

18. Kelso RL, Lyden SP, Butler B, Greenberg RK, Eagleton MJ, Clair DG. Late conversion of aortic stent grafts. J Vasc Surg. 2009; 49(3):589–595. [PubMed: 19135829]

19. Kouvelos G, Koutsoumpelis A, Lazaris A, Matsagkas M. Late open conversion after endovascular abdominal aortic aneurysm repair. J Vasc Surg. 2015; 61(5):1350–1356. [PubMed: 25817560]

20. May J, White GH, Yu W, Waugh R, Stephen M, Sieunarine K, et al. Conversion from endoluminal to open repair of abdominal aortic aneurysms: a hazardous procedure. Eur J Vasc Endovasc Surg. 1997; 14(1):4–11. [PubMed: 9290553]

21. Jacobowitz GR, Lee AM, Riles TS. Immediate and late explantation of endovascular aortic grafts: the endovascular technologies experience. J Vasc Surg. 1999; 29(2):309–316. [PubMed: 9950988]

22. Verhoeven EL, Tielliu IF, Prins TR, Zeebregts CJ, van Andringa de Kempenaer MG, Cina CS, et al. Frequency and outcome of re-interventions after endovascular repair for abdominal aortic aneurysm: a prospective cohort study. Eur J Vasc Endovasc Surg. 2004; 28(4):357–364. [PubMed: 15350556]

23. Pitoulias GA, Schulte S, Donas KP, Horsch S. Secondary endovascular and conversion procedures for failed endovascular abdominal aortic aneurysm repair: can we still be optimistic? Vascular. 2009; 17(1):15–22. [PubMed: 19344578]

24. Chaikof EL, Lin PH, Brinkman WT, Dodson TF, Weiss VJ, Lumsden AB, et al. Endovascular repair of abdominal aortic aneurysms: risk stratified outcomes. Ann Surg. 2002; 235(6):833–841. [PubMed: 12035040]

25. Newton WB 3rd, Shukla M, Andrews JS, Hansen KJ, Corriere MA, Goodney PP, et al. Outcomes of acute intraoperative surgical conversion during endovascular aortic aneurysm repair. J Vasc Surg. 2011; 54(5):1244–1250. discussion 50. [PubMed: 21820835]

26. Khuri SF, Daley J, Henderson W, Hur K, Demakis J, Aust JB, et al. The Department of Veterans Affairs' NSQIP: the first national, validated, outcome-based, risk-adjusted, and peer-controlled program for the measurement and enhancement of the quality of surgical care. National VA Surgical Quality Improvement Program. Ann Surg. 1998; 228(4):491–507. [PubMed: 9790339]

27. Fink AS, Campbell DA Jr, Mentzer RM Jr, Henderson WG, Daley J, Bannister J, et al. The National Surgical Quality Improvement Program in non-veterans administration hospitals: initial demonstration of feasibility. Ann Surg. 2002; 236(3):344–353. discussion 53-4. [PubMed: 12192321]

28. CPT Assistant: American Medical Association. 2008 [cited 18 07-13-2015] updated October 2008; Available from: https://http://www.supercoder.com/cpt_assistant/cpt_assistant_details/1938 - sthash.OQPg9q3X.dpuf.

29. Brewster DC, Jones JE, Chung TK, Lamuraglia GM, Kwolek CJ, Watkins MT, et al. Long-term outcomes after endovascular abdominal aortic aneurysm repair: the first decade. Ann Surg. 2006; 244(3):426–438. [PubMed: 16926569]

30. Birkmeyer JD, Siewers AE, Finlayson EV, Stukel TA, Lucas FL, Batista I, et al. Hospital volume and surgical mortality in the United States. N Engl J Med. 2002; 346(15):1128–1137. [PubMed: 11948273]

31. Lo RC, Bensley RP, Hamdan AD, Wyers M, Adams JE, Schermerhorn ML, et al. Gender differences in abdominal aortic aneurysm presentation, repair, and mortality in the Vascular Study Group of New England. J Vasc Surg. 2013; 57(5):1261–1268. 8 e1–8 e5. [PubMed: 23384493]

32. Wolf YG, Arko FR, Hill BB, Olcott Ct, Harris EJ Jr, Fogarty TJ, et al. Gender differences in endovascular abdominal aortic aneurysm repair with the AneuRx stent graft. J Vasc Surg. 2002; 35(5):882–886. [PubMed: 12021702]

33. Chung C, Tadros R, Torres M, Malik R, Ellozy S, Faries P, et al. Evolution of gender-related differences in outcomes from two decades of endovascular aneurysm repair. J Vasc Surg. 2015; 61(4):843–852. [PubMed: 25595407]

34. Oshin OA, Fisher RK, Williams LA, Brennan JA, Gilling-Smith GL, Vallabhaneni SR, et al. Adjunctive iliac stents reduce the risk of stent-graft limb occlusion following endovascular

aneurysm repair with the Zenith stent-graft. J Endovasc Ther. 2010; 17(1):108–114. [PubMed: 20199276]

35. Gloviczki P, Huang Y, Oderich GS, Duncan AA, Kalra M, Fleming MD, et al. Clinical presentation, comorbidities, and age but not female gender predict survival after endovascular repair of abdominal aortic aneurysm. J Vasc Surg. 2015; 61(4):853–861. e2. [PubMed: 25595402]

36. Cuypers PW, Laheij RJ, Buth J. Which factors increase the risk of conversion to open surgery following endovascular abdominal aortic aneurysm repair? The EUROSTAR collaborators. Eur J Vasc Endovasc Surg. 2000; 20(2):183–189. [PubMed: 10944101]

Table I

Baseline characteristics

	Conversion	Open repair	EVAR	P-value	
	N=300	***N=7188***	***N=24,676***	***Conversion vs. OR***	***Conversion vs. EVAR***
Age – years (sd)	72.6 (9.3)	70.5 (9.1)	74.0 (8.8)	<.001	.006
Categories – N (%)				<.001	.003
<59 years	30 (10.0)	795 (11.1)	1363 (5.5)		
60–69	75 (25.0)	2333 (32.5)	6126 (24.8)		
70–79	118 (39.3)	2888 (40.2)	9986 (40.5)		
80–89	76 (25.3)	1133 (15.8)	6618 (26.8)		
90+	1 (0.3)	39 (0.5)	583 (2.4)		
Female gender – N (%)	77 (25.8)	1896 (26.4)	4587 (18.6)	.801	.002
Race				.001	.001
White	239 (79.7)	5957 (82.9)	20920 (84.8)	.072	.002
Non-white	36 (12.0)	593 (8.2)	1683 (6.8)		
Unknown	25 (8.3)	638 (8.9)	2073 (8.4)		
Comorbidities					
Hypertension – N (%)	250 (83.3)	5865 (81.6)	19752 (80.0)	.446	.156
Diabetes – N (%)	33 (11.0)	910 (12.7)	3872 (15.7)	.396	.026
Insulin dependent diabetes – N (%)	4 (1.3)	179 (2.5)	785 (3.2)	.204	.068
COPD – N (%)	49 (16.3)	1386 (19.3)	4707 (19.1)	.204	.229
eGFR - ml/min/1.73m2	69.9 (25.8)	72.0 (26.6)	71.7 (27.2)	.179	.255
Heart failure – N (%)	2 (0.7)	79 (1.1)	392 (1.6)	.478	.343
Dialysis– N (%)	5 (1.7)	63 (0.9)	292 (1.2)	.157	.443
BMI >30 – N (%)	72 (24.6)	1942 (27.6)	7622 (31.4)	.260	.012
Current smoking – N (%)	98 (32.7)	3146 (43.8)	7498 (30.4)	<.001	.393
ASA class > III – N (%)	111 (37.1)	2103 (29.3)	5567 (22.6)	.004	<.001

Table II

Intraoperative characteristics

	Conversion	Open repair	EVAR	P-value	
	N=300	*N=7188*	*N=24,676*	*Conversion vs. OR*	*Conversion vs. EVAR*
Operative time – min (± sd)	275 (124)	232 (99)	152 (75)	<.001	<.001
Anesthesia type – N (%)				.814	<.001
General	296 (98.7)	7100 (98.8)	21493 (87.1)		
Regional, other	4 (1.3)	85 (1.2)	3181 (12.9)		
Emergency procedure – N (%)	30 (10.0)	459 (6.4)	964 (3.9)	.013	<.001
Surgeon specialty – N (%)				.832	.892
Vascular surgeon	289 (96.3)	6907 (96.1)	23807 (96.5)		
Other	11 (3.7)	281 (3.9)	869 (3.5)		

Table III

Postoperative outcomes

	Conversion	Open repair	EVAR	P-value	
	N=300	*N=7188*	*N=24,676*	*Conversion vs. OR*	*Conversion vs. EVAR*
30-day mortality – N (%) $^{\alpha}$	30 (10.0)	299 (4.2)	415 (1.7)	<.001	<.001
Creat rise >2 mg/dl – N (%) $^{\beta}$	*22 (7.3)*	400 (5.6)	334 (1.4)	.194	<.001
Requiring dialysis – N (%)	*18 (6.0)*	253 (3.5)	215 (0.9)	.024	<.001
Respiratory complication	49 (16.3)	1018 (14.2)	549 (2.2)	.292	<.001
Pneumonia – N (%)	*29 (9.7)*	559 (7.8)	342 (1.4)	.233	<.001
>48 hour on ventilator	*41 (13.7)*	772 (10.7)	338 (1.4)	.110	<.001
Reintubation – N (%)	*22 (7.3)*	500 (7.0)	384 (1.6)	.801	<.001
Cardiac complication	*26 (8.7)*	271 (3.8)	340 (1.4)	<.001	<.001
Myocardial infarction – N (%)	*15 (5.0)*	156 (2.2)	232 (0.9)	.001	<.001
CPR – N (%)	*16 (5.3)*	133 (1.9)	128 (0.5)	<.001	<.001
Wound complication	*14 (4.7)*	319 (4.4)	577 (2.3)	.851	.008
Wound infection – N (%)	*11 (3.7)*	239 (3.3)	530 (2.1)	.747	.072
Wound dehiscence – N (%)	*3 (1.0)*	103 (1.4)	64 (0.3)	.801	.047
Return to OR – N (%)	*28 (9.3)*	639 (8.9)	1114 (4.5)	.792	<.001
Pulmonary embolism – N (%)	2 (0.7)	39 (0.5)	53 (0.2)	.680	.141
Stroke – N (%)	*3 (1.0)*	55 (0.8)	106 (0.4)	.505	.144
Sepsis – N (%)	*13 (4.3)*	263 (3.7)	195 (0.8)	.544	<.001
Septic shock – N (%)	*11 (3.7)*	258 (3.6)	152 (0.6)	.944	<.001
Graft failure – N (%)	*3 (1.0)*	39 (0.5)	132 (0.5)	.236	.221
≥1 postoperative transfusion	127 (42.3)	2270 (31.6)	1795 (7.3)	<.001	<.001
Any complication – N (%) $^{\gamma}$	174 (58.0)	3375 (47.0)	3756 (15.2)	<.001	<.001
Any complication – N (%) $^{\delta}$	95 (31.7)	1912 (26.6)	2485 (10.1)	.052	<.001
Mean length of stay – days (sd)	10.7 (11.2)	9.8 (9.3)	3.3 (5.4)	.165	<.001
Median length of stay – days (IQR)	8 (5–11)	7 (5–11)	2 (1–3)`	.371	<.001

[α]Odds ratio conversion vs. open repair: 2.4 (95% CI: 1.6 – 3.6); Odds ratio conversion vs. EVAR: 7.2 (95% CI: 4.8 – 10.9) (adjusted for: age, gender, race, hypertension, insulin dependent diabetes, obstructive pulmonary disease, heart failure, estimated GFR <30 ml/min/1.73m2, preoperative dialysis, and obesity (BMI>30), emergency procedure)

[β]Odds ratio conversion vs. open repair: 1.3 (95% CI: 0.8 – 2.0), Odds ratio conversion vs. EVAR: 5.6 (95% CI: 3.5 – 8.9) (adjusted for: age, gender, race, hypertension, insulin dependent diabetes, obstructive pulmonary disease, heart failure, estimated GFR <30 ml/min/1.73m2, and current smoking, emergency procedure)

[γ]Odds ratio conversion vs. open repair: 1.5 (95% CI: 1.2 – 1.9), Odds ratio conversion vs. EVAR: 7.8 (95% CI: 6.1 – 9.9) (adjusted for: age, gender, race, hypertension, insulin dependent diabetes, obstructive pulmonary disease, heart failure, estimated GFR <30 ml/min/1.73m2, preoperative dialysis, obesity (BMI>30), and current smoking, emergency procedure)

[δ]incidence of any complication excluding postoperative blood transfusion

Table IV

Factors associated with conversion

Overall cohort	*OR*	*95% CI*	*P-value*
Age (per 10 year decrease)	1.2	1.1 – 1.4	.001
Female gender	1.5	1.2 – 2.0	.002
Race			
non-white	1.8	1.3 – 2.6	.001
unknown	1.1	0.8 – 1.7	.531
Diabetes	0.7	0.5 – 1.0	.074
BMI >30	0.7	0.5 – 0.9	.008
Targeted Variables$^{\alpha}$			
Aneurysm diameter	1.1	1.0 – 1.1	0.002

A subanalysis of patients captured in the Targeted NSQIP (N=50 and N=4505, respectively for conversion and EVAR cases)