Factors Associated with Wound Complications after Open Femoral Artery Exposure for Elective Endovascular Abdominal Aortic Aneurysm Repair

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Abstract

We identified factors that would lead to wound complications after open femoral exposure for endovascular abdominal aortic aneurysm repair (oEVAR).

Using the National Surgical Quality Improvement Program dataset (2005–2014), we examined the patients who underwent oEVAR. Patients were stratified on whether they developed postoperative wound complications. Comparisons were made between group with wound complications and those without and adjusted analyses performed to identify variables that independently increased the risk of wound complications.

There were 14,868 patients in the study cohort and 2.6% (384 patients) developed wound complications after EVAR. Among those with wound complications, 94% (360 patients) of patients had superficial and deep surgical site infection. Patients who had wound complication were likely to be younger (72.6 vs. 73.7 years old ($p = 0.02$), functionally dependent (5.4 vs. 2.5%) ($p < 0.05$), smoker (3 vs. 2.4%, $p = 0.03$), female (4 vs. 2.2%), with significantly higher body mass index (31 vs. 28), and more commonly had diabetes (4 vs. 2.4%, $p < 0.001$) or renal failure (12 vs. 3%, $p < 0.001$). Although perioperative survival was similar, patients who had wound complications had significantly longer hospital length of stay (LOS) (7.3 ± 12 vs. 3.4 ± 5 days, $p < 0.001$).

Up to 3% patients developed wound complications after open femoral exposure during EVAR with significantly higher LOS and therefore cost utilization.

Keywords

- abdominal aortic aneurysm
- vascular access
- risk factors
- percutaneous
- endovascular repair
- endovascular procedure
- artery

Endovascular aortic aneurysm repair (EVAR) has become an established treatment for infrarenal abdominal aortic aneurysms (AAA).^{1–4} It has overtaken open surgical repair and becomes the preferred treatment approach for AAA with suitable anatomy.⁵ Traditionally, EVAR is performed via open vertical or horizontal groin incisions to gain exposure of the common femoral arteries.⁶ The arterial defects are repaired directly with nonabsorbable sutures following deployment of devices and the groin incisions are subsequently closed.

The rate of wound complications after groin incision for femoral endarterectomy and lower extremity revascularization is reported to be as high as 30 to 40% in vascular surgery patients.^{7–9} Wound complications including infection, lymphoceles, and dehiscence are associated with prolonged hospital length of stay (LOS) and higher resource utilization.⁹ More recently, total percutaneous technique without surgical incisions is being increasingly used in EVAR. The percutaneous technique utilizes suture-mediated closure devices

to close the defects in the femoral arteries.^{10,11} A major reason for the push toward percutaneous access in EVAR is the reduced overall wound complication rate and less patient discomfort in comparison to surgical cut-down.¹²⁻¹⁴ It is, however, unclear what is the risk of wound complications following open femoral exposure for EVAR in “real world” practice.

We utilized the American College of Surgeons National Surgical Quality Initiative Program (ACS-NSQIP) registry to analyze the outcomes following open femoral artery exposure for elective endovascular abdominal aortic aneurysm repair (oEVAR). The objective of the study is to identify the risk of wound complications as well as to study the clinical factors associated with wound complications following oEVAR.

Methods

Study Cohort

The NSQIP registry was queried from 2005 to 2014 for all patients who underwent oEVAR. The methodology of the NSQIP database has been described in detail previously in other publications.^{15,16} Briefly, the ACS-NSQIP is a nationally validated, risk-adjusted, outcomes-based program to measure and improve the quality of surgical care in the private sector (<http://site.acsnsqip.org>). Preoperative through 30-day postoperative data are collected on patients by trained clinical personnel at each individual participating site. Variable definitions are available on the web site. The Institutional Review Board at Louisiana State University Health Sciences Center has approved the use of the deidentified data for this study.

We included patients who underwent open femoral artery exposure during elective EVAR using current procedure terminology codes (34812). Patients who underwent EVAR for rupture AAA and cases with iliac conduit were excluded. There were 14,868 patients who meet the study criteria and were included in the study cohort.

Outcome and Clinical Variable

Patients were stratified based on whether or not they had postoperative wound complications following oEVAR, defined as surgical site infection (SSI) or wound dehiscence. Outcomes of patients with postoperative wound complications and those without were compared. Demographics compared included age, gender, race, body mass index (BMI), and smoking status. Comorbidities included were diabetes, hypertension, respiratory disease, congestive heart failure, and renal failure or dialysis. Functional status was also included. American Society of Anesthesiologists classification and total operation time were reviewed.

Statistical Analysis

The baseline demographics, medical history, procedure characteristics, and outcomes were evaluated using a chi-square test for categorical variables and a Student's t-test for continuous variables. Follow-up was 30 days, as is standard for NSQIP data. Adjusted analysis using odds ratios (OR) in a

logistic regression model was performed to identify variables that independently increased the risk of wound complications after oEVAR. Factors that were significant in bivariate analyses and those determined to be clinically important were included in the models. *p*-values of < 0.05 were considered to indicate statistical significance. Analysis was performed using SAS 9.3 software (SAS Institute INC., Cary, NC).

Results

There were 14,868 patients who underwent oEVAR for AAA between the years 2005 and 2014. Of those, 384 (2.6%) developed wound complications after EVAR. Majority of wound complications (94%) were SSI. Among those with SSI, 68% had superficial SSI, 21% had deep incisional SSI, and 5% classified as organ space SSI. The remaining non-SSI wound complications were wound dehiscence (6%).

Patients with wound complications were more likely to be female (4.0 vs. 2.2%, *p* < 0.001) and had higher BMI (31.2 ± 7.5 vs. 28.2 ± 5.8, *p* < 0.001). They were also more likely to have diabetes (3.9 vs. 2.4%, *p* < 0.001), respiratory disease (3.6 vs. 2.3%, *p* < 0.001), renal failure (11.9 vs. 2.5%, *p* < 0.001), or on dialysis (6.2 vs. 2.5%, *p* = 0.005). Patients who were totally dependent having higher rates than those who were fully independent (5.4 vs. 2.5%, *p* = 0.023). Patients who developed wound complications also had longer operation times (193.4 ± 101.2 vs. 155.1 ± 73.2, *p* < 0.001) (► **Table 1**).

Patients who developed wound complications following oEVAR were associated with increased perioperative pneumonia (4.7 vs. 1.6%, *p* = 0.001), deep venous thrombosis/thrombophlebitis (1.8 vs. 0.6%, *p* = 0.008), or sepsis (11.2 vs. 0.9%, *p* < 0.001). Although perioperative mortality was similar between the cohorts (2.1 vs. 1.7%, *p* = 0.549), patients with wound complications had significantly longer total hospital LOS (7.3 ± 11.7 vs. 3.4 ± 5.3, *p* < 0.001) (► **Table 2**).

In multivariable analysis, factors associated with wound complications were female gender (OR = 1.833, 95% confidence interval (CI): 1.445, 2.324, *p* < 0.001), higher BMI (OR = 1.055, 95% CI: 1.040, 1.070, *p* < 0.001), smoking (OR 1.294, 95% CI: 1.031, 1.623, *p* = 0.026), diabetes (OR = 1.464, 95% CI: 1.127, 1.902, *p* = 0.004), pulmonary disease (OR = 1.368, 95% CI: 1.068, 1.752, *p* = 0.013), and longer operative times (OR = 1.004, 95% CI: 1.003, 1.005, *p* < 0.001) (► **Fig. 1**).

Discussion

In this study, 3% of patients developed wound complications following oEVAR and majority were due to wound infection. This is similar to the 2% rate of wound complications found on recent meta-analysis.¹⁷ Of these, the majority (94%) were wound infection. Patients who developed wound complications following oEVAR tended to be female, have higher BMIs, and/or have a history of diabetes, chronic obstructive pulmonary disease (COPD), or renal failure. Patients who were

Table 1 Demographics and comorbidities associated with development of wound complications following oEVAR

Characteristic	Overall (n = 14,868)	Wound complications (n = 384)	No wound complications (n = 14,484)	p-Value
Demographics				
Age, years				
Mean ± SD	73.6 ± 8.5	72.6 ± 9.3	73.7 ± 8.5	0.018
Gender, n (%)				
Male	12,061 (81.1%)	271 (2.2%)	11,790 (97.8%)	<0.001
Female	2,807 (18.9%)	113 (4.0%)	2,694 (96.0%)	
Race, n (%)				
White	13,005 (92.0%)	336 (2.6%)	12,669 (97.4%)	0.081
Black	638 (4.5%)	12 (1.9%)	626 (98.1%)	
Hispanic	241 (1.7%)	11 (4.6%)	230 (95.4%)	
Other	259 (1.8%)	3 (1.2%)	256 (98.8%)	
Race, n (%)				
White	13,005 (92.0%)	336 (2.6%)	12,669 (97.4%)	0.624
Non-White	1,138 (8.0%)	26 (2.3%)	1,112 (97.7%)	
BMI, kg/m ²				
Mean ± SD	28.3 ± 5.8	31.2 ± 7.5	28.2 ± 5.8	<0.001
BMI, n (%)				
Less than 30	9,852 (67.8%)	178 (1.8%)	9,674 (98.2%)	<0.001
30–40	4,188 (28.8%)	145 (3.5%)	4,043 (96.5%)	
40 and more	496 (3.4%)	48 (9.7%)	448 (90.3%)	
Current smoking, n (%)	4,778 (32.1%)	144 (3.0%)	4,634 (97.0%)	0.027
Medical history				
Diabetes	2,249 (15.1%)	87 (3.9%)	2,162 (96.1%)	<0.001
Hypertension, n (%)	11,771 (79.2%)	317 (2.7%)	11,454 (97.3%)	0.111
Respiratory disease, n (%)	2,943 (19.8%)	106 (3.6%)	2,837 (96.4%)	<0.001
Congestive heart failure, n (%)	227 (1.5%)	10 (4.4%)	217 (95.6%)	0.089
End-stage renal failure, n (%)	67 (0.5%)	8 (11.9%)	59 (88.1%)	<0.001
Functional status, n (%)				
Independent	14,215 (95.8%)	357 (2.5%)	13,858 (97.5%)	0.023
Partially dependent	505 (3.4%)	20 (4.0%)	485 (96.0%)	
Totally dependent	111 (0.7%)	6 (5.4%)	105 (94.6%)	
Procedure				
ASA classification, n (%)				
No/mild disturb	908 (6.1%)	14 (1.5%)	894 (98.5%)	0.009
Severe disturb	10,220 (68.8%)	252 (2.5%)	9,968 (97.5%)	
Life threat/moribund	3,730 (25.1%)	118 (3.2%)	3,612 (96.8%)	
Total operation time, minutes				
Mean ± SD	156.0 ± 74.2	193.4 ± 101.2	155.0 ± 73.1	<0.001
Median and range	140.0 (0.0–1,260.0)	169.0 (35.0–920.0)	140.0 (0.0–1260.0)	

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; SD, standard deviation.

Table 2 Perioperative outcomes associated with wound complications following oEVAR

Outcome	Overall (n = 14,868)	Wound complications (n = 384)	No wound complications (n = 14,484)	p-Value
30-day mortality, n (%)	373 (2.5%)	14 (3.6%)	359 (2.5%)	0.182
Pneumonia, n (%)	249 (1.7%)	18 (4.7%)	231 (1.6%)	<0.001
Myocardial infarct, n (%)	186 (1.3%)	5 (1.3%)	181 (1.2%)	0.816
DVT/Thrombophlebitis, n (%)	89 (0.6%)	7 (1.8%)	82 (0.6%)	0.008
Pulmonary embolism, n (%)	37 (0.2%)	3 (0.8%)	34 (0.2%)	0.070
Cerebrovascular accident/stroke, n (%)	74 (0.5%)	4 (1.0%)	70 (0.5%)	0.124
Sepsis, n (%)	170 (1.1%)	43 (11.2%)	127 (0.9%)	<0.001
Days from operation to discharge, days				
Mean $\pm$ SD	3.1 $\pm$ 5.0	6.6 $\pm$ 11.3	3.0 $\pm$ 4.7	<0.001
Median and range	2.0 (0.0–114.0)	3.0 (1.0–103.0)	2.0 (0.0–114.0)	
Length of total hospital stay, days				
Mean $\pm$ SD	3.5 $\pm$ 5.6	7.3 $\pm$ 11.7	3.4 $\pm$ 5.3	<0.001
Median and range	2.0 (0.0–114.0)	3.0 (1.0–104.0)	2.0 (0.0–114.0)	

Abbreviations: DVT, deep vein thrombosis; SD, standard deviation.

more dependent, and who went through longer operative times, also had higher wound complications. In the multivariate adjusted analysis, female gender, higher BMIs, diabetes, COPD, renal failure, and longer operative times all independently increased the odds for potential wound complication following oEVAR. These patients had significantly longer LOS, and therefore cost utilization. This is clinically important as it may help identify patients who may be inherently at greater postoperative risk of wound complication following oEVAR, and allows for more advance planning in cases undergoing open femoral exposure, such as extra surgical preparation, or modification of antibiotic regimen. It also gives the surgeon another factor to think about in

deciding upon using open femoral exposure versus the increasingly used percutaneous access in any given EVAR patient, with the ultimate hope of improving patient outcomes, decreasing LOS, and decreasing cost utilization.

With the increasing use and complexity of EVAR, wound closure complications continue to be a major concern. Since 1999 the use of percutaneous access in EVAR has expanded due to its decreased invasiveness, decreased procedural morbidity, and reduction in wound complications. The percutaneous approach is also associated with lower wound infection rates, with rates quoted as low as 0.2%, in comparison to a > 2% wound infection rate seen in femoral cut-down.¹⁸ Interestingly, a recent Cochrane review comparing total percutaneous

Fig. 1 Clinical variables independently associated with wound complication following oEVAR. Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; CHF, chronic heart failure; COPD, chronic obstructive pulmonary disease; NSQIP, National Surgical Quality Initiative Program.

approach versus femoral cut-down revealed no wound infections in either the percutaneous or cut-down groups across the two studies included in the review.¹² However, the longest follow-up in either study was 6 months, and in the other, no follow-up was reported. In comparison to the two studies involved in the analysis, our study was more powered (384 patients vs 151 and 30 patients, respectively), but with only postoperative data through 30 days, which may have also accounted for these differences.

Femoral cut-down continues to be used in more than half of all EVAR cases, whether it be due to noncompatible arterial anatomy, groin scarring, or calcification, or surgeon preference.^{18,19} There also continues to be risk for failure of percutaneous EVAR (pEVAR), ultimately requiring conversion to femoral cut-down. While the inherent higher risk for infection is obvious in open femoral cut-down due to its more invasive nature, specific risk factors for wound infection following oEVAR still had not been elucidated.

Patients who developed a wound complication following oEVAR tended to have substantial medical comorbidities such as diabetes, obesity, respiratory disease, and renal failure. This is consistent with similar studies on wound complications in other areas over the past few decades. Wound complications also more than doubled going from independent to totally dependent functional status (2.5–5.4%, $p = < 0.001$). Wound complications following an invasive surgery in patients with medical comorbidities are not unexpected. For instance, the role of diabetes in SSIs and wound complications has been well chronicled.²⁰ The exact reason for this finding is unclear to date, but is believed that diabetes is a marker for other conditions that may put a patient at risk of infection, including vascular changes and white blood cell dysfunction. Perioperative hyperglycemia and subsequent immune suppression may also play a role.²¹ Obesity is felt to be a risk factor in both percutaneous access and open exposure for EVAR. Obese patients overall demonstrate higher rates of wound complications compared with nonobese patients.^{22–24} In a study comparing percutaneous access versus cut-down in obese patients at Yale, there was a decreased overall rate of wound complications in the percutaneous group versus the cut-down group, with complications being defined as wound disruption, deep or superficial SSIs, or organ space SSIs (5.5 vs. 9.4%, $p = 0.039$).²⁵

Renal failure was by far the most predictable risk factor with the greatest odds for wound complication (11.9% in wound complication patients vs. 2.5% without, OR = 3.3, CI = 0.033). This is an unsurprising finding considering renal failure is a well-known risk factor for infection due to its effects on overall impairment of immune function, through both decreased innate and adaptive immune responses and predisposition to inflammation.²⁶ Although no study has directly studied SSI following EVAR, the study by Davis et al did identify renal failure as a significant risk factor for SSI in their study of 3,033 patients following open lower extremity bypasses (OR 4.35; 95% CI: 2.74–6.72, $p < 0.001$).²⁷ O'Hare et al also revealed higher wound infections in patients with severe renal failure (on dialysis) following NSQIP-documented lower extremity revascularization.²⁸

The association of COPD with wound complications following oEVAR was also an expected finding due to its previous association with SSI in other types of vascular surgery such as lower extremity bypass.^{29,30} This is thought to be due to COPD's association with tissue hypoxia. Females tended to have much higher rates of wound complications following oEVAR compared with men. Female gender was also found to be an independent associated risk factor for wound complications. The reason for this is unknown. However, an educated assumption is that pH differences influencing the stratum corneum layer of the skin (the skin's barrier function) may contribute differently to a women's potential skin flora,³¹ possibly effecting chances for wound infection. Much work needs to be done in this area.

Finally, oEVAR was shown to be associated with longer operative times, and was associated with longer hospital stays.^{32–34} Buck et al in a high-quality, large sample size (4,112 patients) study revealed longer stays in their oEVAR group versus pEVAR (1 vs. 2 days). Our results reveal even greater disparity in LOS when the variable of wound complications is included (7.3 ± 12 vs. 3.4 ± 5 days, $p < 0.001$).¹⁴

This study does have important limitations. First, this was an observational study from a prospectively collected database. The retrospective nature of this study is not ideal in comparison to randomized controlled trial studies. NSQIP data also only tracks outcomes for the first 30 days post-operatively, and although two-thirds of infections occur after the patient leaves the hospital within the first 2 weeks, any potential wound complications occurring after 30 days were not considered. We also did not track the ultimate treatment outcomes of the patients selected, and their ultimate outcomes past 30 days.

Even with the aforementioned limitations, we were able to use the ACS-NSQIP dataset to evaluate a large cohort of patients to determine specific clinical factors associated with wound complications following oEVAR. Specific clinical factors such as female gender, higher BMI, diabetes, renal failure, and longer operative times were all found to be independently associated with increased wound complication following oEVAR. Overall, up to 3% patients develop wound complications after oEVAR with significantly higher LOS and therefore cost utilization. Careful attention should be paid to patients who are at high risk of oEVAR and careful planning should be performed to avoid these complications, and every effort should be made to decrease duration of surgery.

Conclusion

Up to 3% patients may develop wound complications following open femoral exposure during EVAR with significantly higher LOS and therefore cost utilization. Specific clinical factors independently associated with increased wound complication include female gender, higher BMI, diabetes, renal failure, and longer operative times. Careful attention should be paid to patients who are at high risk of oEVAR and careful planning should be performed to avoid these complications, and every effort should be made to decrease duration of surgery.

Conflict of Interest
None.

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