From the Society for Clinical Vascular Surgery

Predictors of surgical site infection after open lower extremity revascularization

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Objectives: **Surgical site infection (SSI) after open surgery for lower extremity revascularization is a serious complication that may lead to graft infection, prolonged hospitalization, and increased cost. Rates of SSI after revascularization vary widely, with most studies reported from single institutions. The objective of this study was to describe the rate and predictors of SSI after surgery for arterial occlusive disease using national data, and to identify any association between SSI and length of hospital stay, reoperation, graft loss, and mortality.**

Methods: **Patients who underwent lower extremity arterial bypass or thromboendarterectomy from 2005-2008 were identified from the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) participant use files. Multivariate logistic regression identified predictors of SSI. Odds ratios were adjusted for patient demographics, comorbidities, preoperative laboratory values, and operative factors. The association between SSI and other 30-day outcomes such as mortality and graft failure was determined.**

Results: **Of 12,330 patients who underwent revascularization, 1367 (11.1%) were diagnosed with an SSI within 30 days. Multivariate predictors of SSI included female gender (odds ratio [OR], 1.4; 95% confidence interval [CI], 1.3-1.6), obesity (OR, 2.1; 95% CI, 1.8-2.4), chronic obstructive pulmonary disease (OR, 1.2; 95% CI, 1.0-1.5), dialysis (OR, 1.5; 95% CI, 1.1-2.1), preoperative hyponatremia (OR, 1.2; 95% CI, 1.0-1.4), and length of operation >4 hours (OR, 1.4; 95% CI, 1.2-1.6). SSI was associated with prolonged (>10 days) hospital stay (OR, 1.8; 95% CI, 1.4-2.1) and higher rates of 30-day graft loss (OR, 2.3; 95% CI, 1.7-3.1) and reoperation (OR, 3.7; 95% CI, 3.1-4.6). SSI was not associated with increased 30-day mortality.**

Conclusion: **SSI is a common complication after open revascularization and is associated with a more than twofold increased risk of early graft loss and reoperation. Several patient and operation-related risk factors that predict postoperative SSI were identified, suggesting that targeted improvements in perioperative care may decrease complications and improve outcomes in this patient population. (J Vasc Surg 2011;54:433-9.)**

Surgical site infection (SSI) after reconstruction for lower extremity arterial occlusive disease is a serious complication that leads to patient morbidity, prolonged length of stay, increased healthcare expenditures, graft failure, and limb loss. Numerous studies have reported risk factors for SSI after vascular surgery,[1-10] but few have utilized national data. We addressed this gap in the literature by analyzing the multi-institutional American College of Surgeons National Surgical Quality Improvement Project (ACS-NSQIP) database. The study results provide insight into the frequency, contributing factors, and consequences of wound infection after lower extremity revascularization.

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METHODS

Data acquisition and patient selection. The ACS-NSQIP provides risk-adjusted outcomes data to participating hospitals for the purpose of quality improvement. The program focuses on 30-day postoperative outcomes, including mortality and 21 categories of morbidity. Data collection at each participating institution is performed by a dedicated surgical clinical reviewer (SCR), with support and oversight from a nurse coordinator. The SCR, using medical chart extraction, 30-day interviews, and other methods, collects detailed data on patient demographics, comorbidities, laboratory values, operative variables, and postoperative outcomes, including 30-day complications, 30-day mortality rates, reoperation, and length of stay. Descriptions of the qualifications, training, and auditing of data collection personnel, case inclusion criteria, sampling and data collection strategy, and variable and outcome definitions are available online from the ACS-NSQIP Web site.[11]

Patients who underwent open bypass or thromboendarterectomy for infrainguinal occlusive disease were identified from the 2005-2008 ACS-NSQIP participant use files, which include data collected from 211 academic and community hospitals throughout the United States, using current procedural terminology codes.

Outcomes. The main outcome was SSI within 30-days of open revascularization. We defined SSI as a composite of the following ACS-NSQIP variables: superficial

SSI, deep SSI, organ/space SSI, and dehiscence (defined as separation of the layers of a surgical wound with disruption of the fascia within 30 days of the operation). Additional postoperative outcomes included reoperation, length of hospital stay (LOS) after surgery, 30-day graft failure, and 30-day mortality.

Explanatory and control variables. Independent variables included demographics, preoperative health status and comorbidities, preoperative laboratory values, and operative factors. Demographics consisted of age, gender, and race (white, black, or other). Variables related to preoperative health included functional status (independent vs totally or partially dependent), body mass index, weight loss (10% of total body weight in 6 months), smoking (in the last year), alcohol use (more than two drinks per day in the 2 weeks prior to surgery), corticosteroid use, and recent blood transfusion or operation. Factors related to peripheral vascular disease (PVD) included history of revascularization or amputation for PVD and critical limb ischemia (rest pain or gangrene). Comorbidities included diabetes mellitus, chronic obstructive pulmonary disease (COPD), coronary artery disease (history of angina, myocardial infarction, previous percutaneous cardiac intervention, or previous cardiac surgery), neurologic disease (history of stroke with or without residual deficit, transient ischemic attack, hemiplegia, paraplegia, or quadriplegia, central nervous system tumor, or impaired sensorium), dyspnea, pneumonia, congestive heart failure, disseminated cancer, chemotherapy (within 30 days prior to surgery), radiation therapy (within 90 days prior to surgery), and bleeding disorder. Operative variables included wound class, American Society of Anesthesiologists (ASA) class, number of blood transfusions, and length of operation.

Preoperative laboratory values consisted of white blood cell count, hematocrit, platelet count, international normalized ratio (INR), sodium, blood urea nitrogen, creatinine, and albumin. The standard ACS-NSQIP definitions of abnormal values for several laboratory variables were problematic when applied to our study population. For example, over 51% of the patients in the sample had hematocrit values <38%, the lower limit of normal for hematocrit in the standard ACS-NSQIP definition. Therefore, we analyzed the distribution of preoperative laboratory values in the study population and defined laboratory value categories based on percentiles. Each categorical laboratory variable included an indicator of missing data. This approach was supported over alternative methods such as single or multiple imputation by a study on missing data in ACS-NSQIP, which demonstrated that missing laboratory values are not missing at random in this database.[12] Variables with over 5% missing values in the analysis sample included albumin (52% missing), INR (17% missing), and BUN (6% missing).

Statistical analysis. The frequencies of the independent and dependent variables were determined in three groups: all patients, those without a 30-day postoperative SSI, and those with a 30-day postoperative SSI. Continuous variables were compared using the Wilcoxon rank-sum test or Mann–Whitney *U* test, and categorical variables with χ^2 tests. All variables with *P* values <.05 were eligible for inclusion in multivariate models for SSI. To avoid multicollinearity, only one variable was included from each set of intercorrelated variables when the Pearson coefficient was greater than 0.3 (or less than −0.3). Multivariate logistic regression was utilized to calculate adjusted odds ratios and 95% confidence intervals (CIs) for 30-day SSI. Analyses were performed using SAS 9.1.3 for Windows (SAS Institute, Cary, NC). All tests of significance were at the $P < .05$ level, and *P* values were two-tailed.

RESULTS

Patient characteristics. The study population consisted of 12,330 patients who underwent open surgery for lower extremity PVD. The mean age was 68 years, and 37% were female. Approximately 74% were white, 15% were black, and 12% another race. The majority (54%) of patients had a history of prior revascularization or amputation for PVD, and 46% had critical limb ischemia. Almost one-third (33%) of the patients had an open or infected wound before surgery. The prevalence of smoking was 42%. Approximately 18% had nonindependent functional status. The frequencies of obesity, diabetes, hypertension, and coronary artery disease were 28%, 7%, 83%, and 39%, respectively. Approximately 7% had a prior operation within 30 days.

Of 12,330 patients who underwent open revascularization, 1367 (11.1%) were diagnosed with an SSI within 30 days. The differences between patients that did not have SSI and those who did are shown in Table I. The SSI group was younger, more predominantly female, had a higher frequency of critical limb ischemia, and a history of prior revascularization or amputation for PVD. Approximately 23% of the SSI group had nonindependent functional status, compared with 18% in the no-SSI group ($P < .001$). The prevalence of the following comorbid conditions was higher in the SSI group: obesity, diabetes, dyspnea, COPD, coronary artery disease, hypertension, neurologic disease, dialysis, corticosteroid use, open or infected wound, and sepsis. There was no difference between the two groups in the use of tobacco or alcohol or in the frequency of preoperative congestive heart failure, acute renal failure, bleeding disorder, pneumonia, disseminated cancer, recent do not resuscitate (DNR) order, or prior operation within the past 30 days.

The group diagnosed with SSI had a higher frequency of abnormally high (>90th percentile) preoperative creatinine and abnormally low (<10th percentile) sodium and albumin. There were no differences in preoperative values of WBC count, hematocrit, platelet count, INR, or BUN.

The SSI group had a higher ASA class, more intraoperative blood transfusions, and a longer mean length of operation (242 min vs 214 min, $P < .001$). Wound contamination classification was equivalent between the two groups.

Predictors of SSI. The independent variables that were associated with SSI at the $P < .05$ level in univariate

Table I. Univariate assessment of factors associated with surgical site infection (*SSI*) in 12,330 patients who underwent open lower extremity revascularization

Characteristic	*No SSI* *n = 10,963 (88.9%)*	*SSI* *n = 1367 (11.1%)*	P *value*
Demographics			
Age (years), mean (SD)	67.9 ± 12.0	66.8 ± 12.0	.001[a]
Female gender	35.8%	44.0%	<.001[a]
Race/ethnicity			.747
White	73.8%	73.3%	
Black	14.5%	15.3%	
Other	11.7%	11.4%	
Preoperative health and comorbidities			
Rest pain or gangrene	45.1%	53.3%	<.001[a]
History of revascularization or amputation	53.0%	57.2%	.004[a]
Current smoker	41.7%	42.0%	.816
Alcohol use (>2 drinks per day)	6.2%	5.3%	.207
Functional status: partially or totally dependent	17.5%	22.7%	<.001[a]
BMI (kg/m^2), mean (SD)	27.0 ± 6.1	29.2 ± 6.9	<.001[a]
Recent weight loss	1.7%	1.8%	.824
Diabetes mellitus	39.2%	48.1%	<.001[a]
Dyspnea	19.2%	22.4%	.005[a]
COPD	13.3%	15.7%	.021[a]
Coronary artery disease	38.7%	42.4%	.010[a]
Congestive heart failure	3.0%	3.7%	.133
Hypertension requiring medication	82.8%	86.8%	.000[a]
Neurologic disease or event	19.7%	22.4%	.018[a]
Acute renal failure	1.4%	2.1%	.052
Dialysis	6.2%	9.4%	<.001[a]
Steroids	4.1%	5.3%	.046[a]
Bleeding disorder	23.3%	25.3%	.097
Open or infected wound	32.4%	38.8%	<.001[a]
Pneumonia	0.5%	0.2%	.277
Sepsis	6.3%	8.7%	.001[a]
Disseminated cancer	0.6%	0.3%	.315
Chemo or radiation therapy	0.7%	0.4%	.374
DNR order	1.1%	0.9%	.576
Prior operation within 30 days	7.2%	8.3%	.156
Preoperative laboratory values			
WBC count > 12.2 cells/mm^3 (90th percentile)	9.4%	11.3%	.085
Hematocrit < 29.5 % (10th percentile)	9.4%	10.7%	.274
Platelet count, cells/mm3			.228
<156 (10th percentile)	9.6%	9.9%	
>388 (90th percentile)	9.4%	11.1%	
INR > 1.3 (90th percentile)	8.3%	8.3%	.447
Sodium, mmol/L			.016[a]
<134 (10th percentile)	12.3%	15.3%	
>142 (90th percentile)	7.6%	7.5%	
BUN > 37 mg/dL (90th percentile)	8.7%	10.0%	.254
Creatinine > 2.1 mg/dL (90th percentile)	9.2%	11.7%	.013[a]
Albumin < 2.6 mg/dL (10th percentile)	4.0%	5.4%	.024[a]
Operative variables			
Procedure			<.001[a]
Endarterectomy	14.8%	11.6%	
Femoral to femoral bypass	11.1%	8.9%	
Femoral to popliteal bypass	42.4%	43.0%	
Femoral to tibial vessel bypass	24.8%	28.2%	
Popliteal to tibial vessel bypass	7.0%	8.3%	
Type of bypass graft			<.001[a]
None (thromboendarterectomy)	14.8%	11.6%	
Reversed vein	43.4%	46.0%	
In situ vein	9.4%	12.6%	
Prosthetic	32.4%	29.8%	
Wound class			.081
Clean or clean-contaminated	92.3%	90.6%	
Contaminated	4.3%	5.4%	
Dirty or infected	3.4%	4.0%	

Table I. Continued

Characteristic	*No SSI* *n = 10,963 (88.9%)*	*SSI* *n = 1367 (11.1%)*	P *value*
ASA class			<.001[a]
No or mild disturbance	8.4%	5.9%	
Severe disturbance	72.7%	71.1%	
Life-threatening disturbance or moribund	19.0%	23.0%	
Blood transfusions			<.001[a]
None	83.3%	77.8%	
1-2 units	12.7%	16.0%	
3 or more	4.0%	6.1%	
Length of operation (min), mean (SD)	214 ± 103	242 ± 104	<.001[a]
Emergency operation	7.3%	9.0%	.025[a]
Work relative value units, mean (SD)	23.5 ± 5.1	24.0 ± 5.0	<.001[a]

ASA, American Society of Anesthesiologists; *BMI,* body mass index; *BUN,* blood urea nitrogen; *COPD,* chronic obstructive pulmonary disease; *DNR,* do not resuscitate; *INR,* international Normalized Ratio; *SD,* standard deviation; *WBC,* white blood cell.
[a]Statistically significant at the $P < .05$ level.

analysis were used to construct a multivariate model. Logistic regression was utilized to calculate adjusted odds ratios and 95% CIs for SSI. The results of this analysis are displayed in Table II. After adjusting for other variables, the significant predictors of SSI consisted of female gender (OR, 1.44; 95% CI, 1.28-1.63), overweight (OR, 1.28; 95% CI, 1.10-1.49), obesity (OR, 2.08; 95% CI, 1.78-2.43), COPD (OR, 1.23; 95% CI, 1.03-1.44), dialysis (OR, 1.51; 95% CI, 1.08-2.11), hyponatremia (<134 mg/dL; OR, 1.20; 95% CI, 1.02-1.42), and length of operation >4 hours (OR, 1.42; 95% CI 1.24-1.63).

Association between SSI and LOS, reoperation, and graft failure. The SSI group had a higher frequency of prolonged LOS (22.8% vs 12.2%), reoperation (40.2% vs 15.0%), and 30-day graft failure (10.8% vs 4.7%). These differences were all highly statistically significant ($P < .001$). After adjusting for potential confounders, the predicted probabilities of these adverse outcomes were still significantly different between the two groups (Table III). We were not able to determine the reason for reoperation using NSQIP data.

Association between SSI and 30-day mortality. SSI was associated with decreased 30-day mortality (1.6% vs 2.9%, $P = .005$). In a multivariate model, the adjusted predicted probability of 30-day mortality in patients who had SSI was 1.6% (95% CI, 1.5%-1.8%), compared with 2.7% (95% CI, 2.6%-2.8%) in those who did not have the complication (Table III). Further analysis revealed an interaction between age, SSI, and mortality. For patients less than age 80, there was no significant association between SSI and mortality. For those 80 and older, however, the rate of 30-day mortality was lower in patients who did have SSI compared with those who did not (1.4% vs 5.8%, $P = .003$). In this age group, 218 of 2256 patients were diagnosed with SSI, and the median number of days from surgery until diagnosis was 15. Of the 2256 patients aged 80 or older, 112 died within 30 days, and the median day of death was 13. When patients aged 80 and older were excluded from the cohort, there was no significant association between SSI and mortality.

DISCUSSION

In this study based on the multi-institutional ACS-NSQIP database, we determined the rate, predictors, and consequences of SSI in a real-world experience of patients undergoing open lower extremity revascularization surgery. In the current study, independent predictors of SSI included patient factors (female gender, critical limb ischemia, obesity and overweight, COPD, dialysis, preoperative hyponatremia) and operation time >4 hours.

Other investigators have noted the association between prolonged operative time and SSI, underscoring the importance of minimizing operative time when possible.[6,13] For long operations, factors that may underlie the association with SSI include patient hypothermia,[14] hyperglycemia,[15] inadequate redoing of antibiotics,[16] retractor-related tissue trauma, and breaks in sterile technique. Targeting these factors may provide important strategies for decreasing the rate of SSI after long operations and improving outcomes.[17] Attention to these factors may be particularly important for complex reconstructions for which long operative times can be anticipated.

Female gender,[8,18-21] obesity,[3,4,21,22] and renal failure requiring dialysis[5,23,24] are well-described risk factors for SSI and other adverse outcomes after peripheral vascular surgery. Potential explanations for the link between female gender and increased infrainguinal wound infections include gender-related differences in the amount and distribution of body fat and native skin flora.[8] Greater thickness of poorly vascularized subcutaneous fat, increased traction-related trauma, and higher groin crease bacterial density may account in part for the increased incidence of SSI in obese patients. Altered levels of molecules such as leptin and adiponectin in obese patients may also contribute to proinflammatory states and predisposition to infection.[25] The association between end-stage renal disease requiring dialysis and increased risk for infection is well established.[26,27] Uremia has been shown to depress the immune system, and patients undergoing chronic hemodialysis may

Table II. Multivariate model of predictors of surgical site infection (*SSI*) after open lower extremity revascularization, with adjusted odds ratios (*ORs*) and 95% confidence intervals (*CIs*)

Characteristic	*Adjusted OR (95% CI) for SSI*
Demographics	
Age	
Younger than 50	Reference
50-59	1.05 (0.81-1.35)
60-69	0.84 (0.65-1.08)
70-79	0.83 (0.65-1.07)
80 and older	0.77 (0.59-1.02)
Gender	
Male	Reference
Female	1.44 (1.28-1.63)[a]
Preoperative health and comorbidities	
Rest pain or gangrene	
No	Reference
Yes	1.25 (1.11-1.41)[a]
History of revascularization or amputation	
No	Reference
Yes	1.12 (0.99-1.26)
Functional status	
Independent	Reference
Partially or totally dependent	1.16 (0.99-1.36)
BMI (kg/m^2)	
<18.5 (underweight)	0.79 (0.55-1.12)
18.5 to 24.9 (normal weight)	Reference
25 to 29.9 (overweight)	1.28 (1.10-1.49)[a]
30 or greater (obese)	2.08 (1.78-2.43)[a]
Diabetes mellitus	
No	Reference
Yes	1.06 (0.94-1.21)
Dyspnea	
No	Reference
Yes	1.07 (0.92-1.24)
COPD	
No	Reference
Yes	1.23 (1.03-1.45)[a]
Coronary artery disease	
No	Reference
Yes	1.07 (0.95-1.22)
Hypertension	
No	Reference
Yes	1.19 (1.00-1.42)
Neurologic disease	
No	Reference
Yes	1.08 (0.94-1.25)
Dialysis	
No	Reference
Yes	1.51 (1.08-2.11)[a]
Steroids	
No	Reference
Yes	1.26 (0.96-1.64)
Wound infection or open wound	
No	Reference
Yes	1.08 (0.94-1.23)
Sepsis	
No	Reference
Yes	1.12 (0.90-1.41)
Preoperative laboratory values	
Sodium (mg/dL)	
<134 (10th percentile)	1.20 (1.02-1.42)[a]
134-142 (10th-90th percentile)	Reference
>142 (90th percentile)	1.03 (0.82-1.28)
Missing	1.13 (0.73-1.74)
Creatinine (mg/dL)	
2.1 or less	Reference
>2.1 (90th percentile)	0.77 (0.57-1.04)
Missing	0.95 (0.58-1.55)
Albumin (mg/dL)	
2.6 or greater	Reference
<2.6 (10th percentile)	1.04 (0.78-1.37)
Missing	0.97 (0.86-1.10)
Operative variables	
Type of graft	
None (thromboendarterectomy)	Reference
Reversed vein	1.39 (1.02-1.88)
In situ vein	1.83 (1.27-2.63)
Prosthetic	1.19 (0.95-1.49)
ASA class	
No or mild disturbance	Reference
Severe disturbance	1.20 (0.93-1.54)
Life-threatening disturbance or moribund	1.27 (0.96-1.69)
Blood transfusions	
0 units	Reference
1-2 units	1.11 (0.94-1.32)
>2 units	1.28 (0.98-1.68)
Length of operation	
Less than 4 hours	Reference
4-6 hours	1.42 (1.24-1.63)[a]
Greater than 6 hours	1.43 (1.16-1.75)[a]
Emergency operation	
No	Reference
Yes	1.21 (0.97-1.51)

ASA, American Society of Anesthesiologists; *BMI,* body mass index; *COPD,* chronic obstructive pulmonary disease.
[a]Statistically significant at the $P < .05$ level.

have higher rates of colonization by potential pathogens such as methicillin-resistant *Staphylococcus aureus.*[28]

We found a significant interaction between patient age, frequency of SSI, and 30-day mortality. The adjusted predicted probability of 30-day mortality was lower in the group of patients who had SSI compared with those who did not (1.4% vs 5.8%). This was due to a high rate of early postoperative mortality in patients aged 80 and older. In this subgroup of older patients, the median postoperative day of death was 13, compared with 15 for the median postoperative day of SSI diagnosis. Thus, a substantial number of older patients died of other serious complications early in the postoperative period, before they could develop SSI. The study confirms that older adults represent a high-risk population for open revascularization.

Curiously, prosthetic grafts appeared to be less prone to SSI than vein grafts. Although this finding may represent a type 1 statistical error, it is more likely to reflect unmeasured confounding variables. For example, the presence of gangrene could not be captured with this dataset. The presence of gangrene may increase bias toward revascularization with autogenous graft but may also increase the risk

Table III. Frequencies and adjusted predicted probabilities of adverse outcomes in 12,330 patients who underwent open lower extremity revascularization and incidence of surgical site infection (*SSI*)

Adverse outcome	*All patients (n = 12,330) frequency*	*No SSI (n = 10,963) frequency*	*SSI (n = 1367) frequency*	P *value*	*No SSI probability (95% CI)*[a]	*SSI probability (95% CI)*[a]
Prolonged LOS (>10 days)	13.4%	12.2%	22.8%	<.001	11.8% (11.6%-12.1%)	22.8% (21.9%-23.8%)
30-day reoperation	17.8%	15.0%	40.2%	<.001	14.9% (14.7%-15.1%)	40.1% (39.2%-41.0%)
30-day graft loss	5.4%	4.7%	10.8%	<.001	4.6% (4.6%-4.7%)	10.8% (10.5%-11.1%)
30-day mortality	2.7%	2.9%	1.6%	.005	2.7% (2.6%-2.8%)	1.6% (1.5%-1.8%)

CI, Confidence interval; *LOS,* length of hospital stay after surgery.
[a]Predicted probabilities and CIs are adjusted for sex, age, body mass index, functional status, chronic obstructive pulmonary disease, dyspnea, prior revascularization or amputation, critical limb ischemia, coronary artery disease, hyptertension, neurologic disease, dialysis, steroids, open/infected wound, sepsis, creatinine, sodium, albumin, American Society of Anesthesiologists class, blood transfusions, operation time, graft type, and emergency surgery.

of SSI. Additionally, results could not be adjusted for the number, length, or presence of undermined incisions, which would be more likely to be associated with autogenous vein harvesting and may also increase the likelihood of SSI.

ACS-NSQIP has numerous advantages for the study of vascular surgery outcomes. ACS-NSQIP includes laboratory values as well as information regarding smoking, alcohol use, and functional status. These are not available in administrative databases such as the Healthcare Cost and Utilization Project Nationwide Inpatient Sample (HCUP-NIS) and the Medicare database. ACS-NSQIP is based on prospective medical record extraction and reliably captures precisely-defined postoperative complications. Complications not resulting in reoperation or other secondary procedures are often not recorded in administrative databases.[29] Another significant advantage of the ACS-NSQIP is that it measures 30-day outcomes, not just events that occur during the surgical hospital stay. In addition to reviewing the medical record for the hospital stay and clinic follow-up, the clinical reviewer also searches death registries and conducts phone interviews. The ability of ACS-NSQIP to capture 30-day outcomes regardless of hospital admission status is a major strength compared with other databases such as HCUP-NIS, which do not monitor events that occur after hospital discharge. Finally, an additional benefit of ACS-NSQIP is the multi-institutional data that is captured. In 2008, the ACS-NSQIP participant use data file contained data from 211 academic and community hospitals nationwide. Findings based on this multi-institutional data have greater external validity than those based on the experience of individual specialized academic centers.

The main limitations of our study are related to the source of the data. The ACS-NSQIP is a voluntary program and the 211 participating sites include many academic and high-volume hospitals. Therefore, the program does not represent a statistically valid national sample of all hospitals in the United States. The database contains a wealth of clinical variables, but essentially no information on patient socioeconomic status. Hospital identifiers as well as geographic information are not included in the participant use file. Therefore, it is not possible to determine the association of hospital procedure volume on surgical outcomes using this database. The database also does not include information on surgeon experience or procedure volume. Currently, ACS-NSQIP only collects information on procedures that are performed in the operating room. Thus, the program is not an optimal data source for the study of percutaneous interventions, which are often performed in cardiovascular procedure suites. Unlike the Medicare database, ACS-NSQIP does not provide longitudinal data for individual patients. Therefore, it is not possible to determine whether the operations in this study were primary or reoperative.

Despite these limitations, the study has important implications. In this large sample drawn from over 210 academic and community hospitals nationwide, approximately one in nine patients suffered the complication of SSI after open surgery for vascular disease, confirming that wound infection remains a common cause of morbidity. Furthermore, SSI was strongly associated with prolonged LOS, reoperation, and graft failure. We identified several patient and operative factors that predict SSI. While some risk factors such as female gender and obesity are not modifiable in the preoperative setting, others represent targets for the development of interventions that may decrease the incidence of SSI in high-risk patients. Optimizing the perioperative medical management of comorbidities such as COPD, and redoing antibiotics during long operations are examples of measures that may decrease the rate of wound infections and improve outcomes in this patient population.

AUTHOR CONTRIBUTIONS

Conception and design: DG, MM
Obtained funding: DG, MM
Data collection: DG, VR, MM
Statistical analysis: DG, VR, MM
Analysis and interpretation: DG, VR, MM
Writing the article: DG, MM
Critical revision of the article: DG, MM
Final approval of the article: DG, VR, MM
Overall responsibility: DG, MM

REFERENCES

1. Johnson JA, Cogbill TH, Strutt PJ, Gundersen AL. Wound complications after infrainguinal bypass. Classification, predisposing factors, and management. Arch Surg 1988;123:859-62.
2. Wengrovitz M, Atnip RG, Gifford RR, Neumyer MM, Heitjan DF, Thiele BL. Wound complications of autogenous subcutaneous infrainguinal arterial bypass surgery: predisposing factors and management. J Vasc Surg 1990;11:156:61; Discussion:161-3.
3. Kent KC, Bartek S, Kuntz KM, Anninos E, Skillman JJ. Prospective study of wound complications in continuous infrainguinal incisions after lower limb arterial reconstruction: incidence, risk factors, and cost. Surgery 1996;119:378-83.
4. Lee ES, Santilli SM, Olson MM, Kuskowski MA, Lee JT. Wound infection after infrainguinal bypass operations: multivariate analysis of putative risk factors. Surg Infect Larchmt 2000;1:257-63.
5. Treiman GS, Copland S, Yellin AE, Lawrence PF, McNamara RM, Treiman RL. Wound infections involving infrainguinal autogenous vein grafts: a current evaluation of factors determining successful graft preservation. J Vasc Surg 2001;33:948-54.
6. Chang JK, Calligaro KD, Ryan S, Runyan D, Dougherty MJ, Stern JJ. Risk factors associated with infection of lower extremity revascularization: analysis of 365 procedures performed at a teaching hospital. Ann Vasc Surg 2003;17:91-6.
7. Pounds LL, Montes-Walters M, Mayhall CG, Falk PS, Sanderson E, Hunter GC, et al. A changing pattern of infection after major vascular reconstructions. Vasc Endovasc Surg 2005;39:511-7.
8. Nguyen LL, Brahmanandam S, Bandyk DF, Belkin M, Clowes AW, Moneta GL, et al. Female gender and oral anticoagulants are associated with wound complications in lower extremity vein bypass: an analysis of 1404 operations for critical limb ischemia. J Vasc Surg 2007;46:1191-7.
9. Beirne C, Martin F, Hynes N, Sultan S. Five years' experience of transverse groin incision for femoral artery access in arterial reconstructive surgery: parallel observational longitudinal group comparison study. Vascular 2008;16:207-12.
10. Brothers TE, Robison JG, Elliott BM. Predictors of prosthetic graft infection after infrainguinal bypass. J Am Coll Surg 2009;208:557-61.
11. American College of Surgeons National Surgical Quality Improvement Program website Available at: https://acsnsqip.org Accessed: November 1, 2010.
12. Hamilton BH, Ko CY, Richards K, Hall BL. Missing data in the American College of Surgeons National Surgical Quality Improvement Program are not missing at random: implications and potential impact on quality assessments. J Am Coll Surg 2010;210:125:139.e2.
13. LaMuraglia GM, Conrad MF, Chung T, Hutter M, Watkins MT, Cambria RP. Significant perioperative morbidity accompanies contemporary infrainguinal bypass surgery: an NSQIP report. J Vasc Surg 2009;50:304:304.e14.
14. Kurz A, Sessler DI, Lenhardt R. Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. Study of Wound Infection and Temperature Group. N Engl J Med 1996;334:1209-15.
15. Ata A, Lee J, Bestle SL, Desemone J, Stain SC. Postoperative hyperglycemia and surgical site infection in general surgery patients. Arch Surg 2010;145:858-64.
16. Miliani K, L'Heriteau F, Astagneau P, INCISO Network Study Group. Non-compliance with recommendations for the practice of antibiotic prophylaxis and risk of surgical site infection: results of a multilevel analysis from the INCISO surveillance network. J Antimicrob Chemother 2009;64:1307-15.
17. Forbes SS, Stephen WJ, Harper WL, Loeb M, Smith R, Christoffersen EP, et al. Implementation of evidence-based practices for surgical site infection prophylaxis: results of a pre- and postintervention study. J Am Coll Surg 2008;207:336-41.
18. Magnant JG, Cronenwett JL, Walsh DB, Schneider JR, Besso SR, Zwolak RM. Surgical treatment of infrainguinal arterial occlusive disease in women. J Vasc Surg 1993;17:67-76; Discussion:76-8.
19. Nguyen LL, Hevelone N, Rogers SO, Bandyk DF, Clowes AW, Moneta GL, et al. Disparity in outcomes of surgical revascularization for limb salvage: race and gender are synergistic determinants of vein graft failure and limb loss. Circulation 2009;119:123-30.
20. Crawford RS, Cambria RP, Abularrage CJ, Conrad MF, Lancaster RT, Watkins MT, et al. Preoperative functional status predicts perioperative outcomes after infrainguinal bypass surgery. J Vasc Surg 2010;51: 351:8; Discussion: 358-9.
21. Giles KA, Hamdan AD, Pomposelli FB, Wyers MC, Siracuse JJ, Schermerhorn ML. Body mass index: Surgical site infections and mortality after lower extremity bypass from the National Surgical Quality Improvement Program 2005-2007. Ann Vasc Surg 2010;24:48-56.
22. Davenport DL, Xenos ES, Hosokawa P, Radford J, Henderson WG, Endean ED. The influence of body mass index obesity status on vascular surgery 30-day morbidity and mortality. J Vasc Surg 2009;49:140:7: 147.e1; Discussion:147.
23. Albers M, Romiti M, De Luccia N, Brochado-Neto FC, Nishimoto I, Pereira CA. An updated meta-analysis of infrainguinal arterial reconstruction in patients with end-stage renal disease. J Vasc Surg 2007;45: 536-42.
24. Chambon JP, Alarcon B, N'Guyen HD, Gaillard R, Pagniez D, Dumont A. [Results of infrainguinal revascularization in patients with end-stage renal disease.] Ann Chir 2005;130:26-31.
25. Falagas ME, Kompoti M. Obesity and infection. Lancet Infect Dis 2006;6:438-46.
26. Cheung AH, Wong LM. Surgical infections in patients with chronic renal failure. Infect Dis Clin North Am 2001;15:775-96.
27. Dalrymple LS, Go AS. Epidemiology of acute infections among patients with chronic kidney disease. Clin J Am Soc Nephrol 2008;3:1487-93.
28. Vandecasteele SJ, Boelaert JR, De Vriese AS. *Staphylococcus aureus* infections in hemodialysis: what a nephrologist should know. Clin J Am Soc Nephrol 2009;4:1388-400.
29. Morris AM, Baldwin LM, Matthews B, Dominitz JA, Barlow WE, Dobie SA, et al. Reoperation as a quality indicator in colorectal surgery: a population-based analysis. Ann Surg 2007;245:73-9.

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