Unplanned readmissions after vascular surgery

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Objective: **Existing literature on readmission after vascular surgery is limited. The upcoming reduction in Medicare reimbursement for institutions with high readmission rates mandates an accurate understanding of this issue. In this study, we characterize the frequency and causes of 30-day unplanned readmissions after elective vascular surgery.**

Methods: **Patients who underwent elective carotid endarterectomy (CEA), endovascular aortic repair (EVAR), open abdominal aortic aneurysm (oAAA) repair, or infrainguinal bypass grafting (BPG) were identified from the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) 2011 database (n = 11,246). Multivariable logistic regression was used to determine variables that contributed to 30-day unplanned readmissions for each surgery type.**

Results: **The unadjusted unplanned readmission rates after the four vascular procedures ranged from 6.5% for CEA to 15.7% for BPG. In multivariable analyses, patient comorbidities were associated with unplanned readmission after BPG and CEA ($P < .05$), whereas postoperative complications were more consistently associated with unplanned readmission after EVAR and oAAA repair ($P < .05$). For all procedures, complications leading to readmission developed more frequently after discharge. Thirty-day mortality was significantly higher in readmitted patients after BPG (1.9% vs 0.3%), EVAR (3.9% vs 0.1%), and CEA (2.2% vs 0.2%; $P < .001$ for each), but not after oAAA repair.**

Conclusions: **Select comorbidities and postoperative complications contribute to unplanned readmissions after vascular surgery. The characteristics of readmitted patients vary with the type of procedure. Interventions designed to mitigate these factors have the potential to reduce unplanned readmissions but likely need to vary with the type of vascular treatment. (J Vasc Surg 2014;59:473-82.)**

Significant morbidity and costs are associated with 30-day readmissions after vascular procedures. Consequently, readmission is a target of health care reform. Jencks et al[1] found that seven conditions account for >30% of preventable readmissions; among them, vascular surgery is the most costly. Furthermore, the readmission rate for vascular surgery is 23.9% among Medicare beneficiaries, far higher than the overall surgical readmission rate of 15.6%.[1] As a result, the Center for Medicare and Medicaid Services (CMS) may introduce penalties in the form of reduced reimbursement to hospitals with higher-than-expected readmission rates for vascular procedures.[2] This penalty will have a significant effect on the landscape of vascular surgical practice.

Research characterizing readmission rates after vascular surgery is limited and rarely stratified by procedure, restricting implications for practice.[1,3] Additional studies that focus on readmissions for specific vascular procedures often consist of single-site or small multi-institution retrospective analyses[4-6] or analyses of large administrative data sets with limited clinical information.[7-9] Therefore, the results of these studies may not generalize to widespread clinical practice. Furthermore, most existing studies do not distinguish between planned and unplanned readmissions. This study complements existing research by examining the clinical characteristics of multiple vascular procedures using data from the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP), a clinically validated, multicenter data set.

The objective of this study is to characterize 30-day unplanned readmission rates for four common vascular procedures—open abdominal aortic aneurysm (oAAA) repair, endovascular abdominal aortic aneurysm repair (EVAR), infrainguinal bypass grafting (BPG), and carotid endarterectomy (CEA)—and analyze preoperative and postoperative factors associated with unplanned readmissions after these vascular procedures. Our findings suggest that chronic comorbidities and postoperative complications, such as surgical site infection and postoperative cardiac complications, are associated with early readmission. In addition, we found that readmission is associated with increased mortality. Our study offers a detailed picture of 30-day unplanned readmission after major arterial vascular interventions and identifies corresponding implications for clinical practice.

METHODS

Data set. Data were extracted from the 2011 ACS NSQIP Participant Use Data File. NSQIP is a multicenter, prospective database with 315 (in 2011) participating

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The American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) and the hospitals participating in the ACS NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors. This study does not represent the views or plans of the ACS or the ACS NSQIP.

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academic and community United States hospitals and data on >250 perioperative variables. In NSQIP, a participating hospital's surgical clinical reviewer (SCR) captures data using a variety of methods, one of which is medical record abstraction. Comprehensive strategies are used to identify events occurring after hospital discharge.[10] In addition to examining inpatient medical records and outpatient patient charts, a minimum of three attempts to contact the patient by telephone or mail are made to ensure accurate documentation of postdischarge events. If no response is obtained, the Social Security Death Index and the National Obituary Archives are queried to investigate the potential of a death. Hospitals are required to provide complete 30-day follow-up on at least 95% of patients.[10] Morbidity in NSQIP is identified by independent record review or patient encounter after patient discharge.

The NSQIP data are collected according to strict criteria formulated by a committee. To ensure the data collected are of a high quality, the NSQIP has developed different training mechanisms for the SCR and conducts an inter-rater reliability audit of participating sites. Inter-rater reliability audits showed that overall agreement rates on variables was 98.44% (>140,000 audited fields) in 2008.[11] The processes of SCR training, inter-rater reliability auditing, data collection, and sampling methodology are described in detail elsewhere.[12,13]

Cohort and variables. Patients undergoing elective EVAR, oAAA repair, CEA, and BPG in the NSQIP data set were identified using the Current Procedural Terminology (CPT) code (American Medical Association, Chicago, Ill) or the procedures in combination with appropriate International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9) diagnosis codes. EVAR was defined with an ICD-9 diagnosis of 441.4 in combination with any of the CPT codes 34800, 34802, 34803, 34804, 34805, or 34825. CEA was defined with an ICD-9 diagnosis of 443.10 or 443.11 in combination with CPT code 35301. oAAA repair was defined with a ICD-9 441.4 diagnosis code and CPT codes 35801 or 35102. Finally, BPG was defined with CPT codes 35556, 35566, 35571, 35583, 35585, 35587, 35656, or 35666.

To eliminate any potentially nonelective patients and to improve generalizability, the following preoperative exclusion criteria were applied: ascites, esophageal varices, on ventilator before surgery, acute renal failure before the operation, impaired sensorium, coma, tumor involving the central nervous system, paraplegia/paraparesis, quadriplegia/quadriparesis, disseminated cancer, chemotherapy ≤30 days, radiotherapy ≤90 days, preoperative do-not-resuscitate status, preoperative transfusion of >4 units packed red blood cells, emergency case classification, preoperative systemic sepsis ≤48 hours, cases with a simultaneous procedure, and previous operation ≤30 days. Patients who died during their first hospitalization were also excluded from subsequent postdischarge analyses (EVAR, 13; CEA, 8; oAAA repair, 13; BPG, 17) as were patients with a 0-day postoperative length of stay (LOS) after oAAA repair and BPG.

Analysis variables included the sociodemographic characteristics of sex, age >75th percentile (EVAR, 80 years; CEA and oAAA repair, 78 years; BPG, 75 years), and race (white, black, Asian, Hispanic, other). Preoperative factors included body mass index (BMI), defined according to the Centers for Disease Control and Prevention as overweight with BMI between 25 and 29.9 kg/m^2 and obese at a BMI ≥30 kg/m^2, and indicator variables for smoking, diabetes (on medications or insulin), dyspnea (at rest or moderate exertion), functional dependence, being on hypertension medication, chronic corticosteroid use, and having a bleeding disorder. Also included in the analysis were indicator variables for having histories of chronic obstructive pulmonary disease (COPD), a cardiac event (angina, myocardial infarction, congestive heart failure, or cardiac surgery), peripheral revascularization or amputation, and stroke.

Preoperative laboratory results included indicators for elevated glomerular filtration rate (≤120 vs >120 $mL/min/1.73\ m^2$), which was calculated using the Modified Diet in Renal Disease equation[14] (eGFR = 186.3 × serum creatinine − 1.154 × age −0.203 × 1.212 [if patient is black] × 0.742 [if female]); and low hematocrit (<40.7% for men; <36.1% for women). Operative time was included in analysis as being >90th percentile for minutes in the operating room. Patients' American Society of Anesthesiologists (ASA) Physical Status Classification was included as being healthy or having mild disease (ASA class 1 or 2), severe disease (ASA class 3), or systemic disease/moribund (ASA class 4 or 5).

Postoperative characteristics included postoperative complications, including indicators for wound and surgical complications (surgical site and organ space infection, sepsis, urinary tract infections, wound dehiscence, or graft failure), respiratory complications (reintubation, failure to wean, or pneumonia), nervous system complications (postoperative stroke, coma, or peripheral nerve injury), venous thromboembolism (VTE), a cardiac event (cardiac arrest or myocardial infarction), transfusion, and renal complications (renal insufficiency or failure). Renal complications and VTE were combined in multivariable analysis as "other serious complication." Additional postoperative variables consisted of LOS in days, and discharge destination to home, rehabilitation, skilled care facility, and other.

Outcome. Our primary outcome of interest was an unplanned readmission ≤30 days after discharge after a qualifying surgical procedure, defined as any unplanned inpatient stay at the same or different institution. The association between 30-day readmission and subsequent 30-day mortality was also evaluated.

Analysis. Patients missing observations from variables with <5% missing were dropped from analysis. An additional subset of health history variables (stroke history, coronary event history, and history of surgically treated peripheral vascular disease) was missing 46% of observations. Following Hamilton et al,[15] an indicator for the missing values for these variables was included in all multivariable analysis.

Table I. Preoperative and sociodemographic characteristics

Variables	*BPG*	*EVAR*	*oAAA repair*	*CEA*
Observations, No.	2672	2369	515	5690
Age > 75th percentile,[a] %	26.5	28.5	24.8	28.6
Female, %	34.8	19.0	30.3	40.9
BMI				
Normal, %	30.3	23.5	26.2	22.9
Overweight, %	35.7	38.8	43.8	38.3
Obese, %	34.0	37.7	30.0	38.8
Diabetes, %	41.2	16.3	12.3	30.2
Smoker, %	43.6	31.1	42.4	27.6
Dyspnea, %	15.4	21.4	16.0	17.5
Functionally dependent, %	7.0	2.0	1.2	3.0
History of COPD, %	13.1	19.6	18.6	11.5
Cardiac event history, %	18.2	18.9	14.3	18.3
Hypertension medication, %	85.1	82.0	82.4	87.2
Peripheral vascular disease, %	33.3	3.3	3.4	5.5
Missing health history, %	46.3	45.7	51.5	47.8
Dialysis, %	3.9	1.0	NA	1.0
Corticosteroid treatment, %	3.1	3.8	2.8	2.1
History of stroke, %	9.0	6.8	6.3	19.0
Bleeding disorder, %	21.0	11.5	7.1	20.7
Normal GFR,[b] %	8.1	4.8	3.6	5.8
Low preoperative hematocrit, %	50.8	38.9	36.4	41.0
Race				
White, %	73.4	83.6	81.9	85.9
Asian, %	1.2	2.1	3.4	1.6
Black, %	15.9	3.6	4.2	3.5
Other, %	6.3	8.9	8.7	6.1
Hispanic or Latino, %	3.2	1.8	1.8	2.9
ASA class				
1 or 2, %	7.6	6.1	6.0	7.2
3, %	76.5	74.2	67.9	78.8
4 or 5,[c] %	15.9	19.7	26.1	14.0

ASA, American Society of Anesthesiologists; *BPG,* bypass grafting; *BMI,* body mass index; *COPD,* chronic obstructive pulmonary disease; *CEA,* carotid endarterectomy; *EVAR,* endovascular aneurysm repair; *GFR,* glomerular filtration rate; *NA,* not available; *oAAA,* open abdominal aortic aneurysm.

[a]Age >75th percentile: 80 years for EVAR, 78 years for CEA and oAAA, and 75 years for BPG.

[b]Normal GFR >120 mL/min/1.73 m^2.

[c]Only 1 patient was documented with ASA class 5.

Tests of significance included Mann-Whitney *U* tests for continuous variables and the χ^2 test or the Fisher exact test for categoric variables. Multivariable analyses involved logistic regression with Huber-White robust standard error estimates. Descriptive statistics are presented as medians and interquartile ranges (IQRs) for continuous variables and as percentages for categoric variables. We report odds ratios (ORs) with associated robust 95% confidence intervals (CIs) and associated *P* values. The C-statistic details model fit. All analyses were performed using STATA 10 software (StateCorp LP, College Station, Tex). A *P* value of <.05 was considered significant.

RESULTS

Elective vascular operations were performed in 11,242 patients (65.6% men), consisting of BPG in 2672, EVAR in 2369, oAAA repair in 506, and CEA in 5690. Demographic characteristics, comorbidities, and laboratory values for these patients are listed in Table I. Postoperative descriptive characteristics are summarized in Table II.

Table II. Postoperative characteristics

Variables	*BPG*	*EVAR*	*oAAA repair*	*CEA*
Observations, No.	2672	2369	515	5690
Events within 30 days				
Unplanned readmission, %	15.7	7.6	8.0	6.5
Reoperation, %	13.1	3.6	7.6	3.1
Death, %	0.6	0.4	0.6	0.3
Operation time >90th percentile,[a] %	10.3	10.1	10.1	10.1
Wound/graft complication or UTI, %	3.8	1.2	6.9	0.5
Respiratory infection, %	1.2	1.1	10.9	1.4
Renal complication, %	0.2	0.3	3.2	0.1
Cardiac complication, %	1.7	0.5	2.6	1.0
Stroke or nerve injury, %	0.3	NA	NA	0.7
Post-op transfusion, %	20.9	10.7	63.4	2.3
Post-op hospital LOS, mean (IQR) days	4 (3)	2 (2)	7 (4)	1 (1)
Discharged to				
Home, %	81.9	94.3	83.4	97.0
Rehabilitation facility, %	7.0	2.4	8.7	1.2
Skilled nursing facility, %	11.1	3.3	7.9	1.8
VTE, %	NA	0.2	1.0	NA

BPG, Bypass grafting; *CEA,* carotid endarterectomy; *EVAR,* endovascular aneurysm repair; *IQR,* interquartile range *LOS,* length of stay; *NA,* not available; *oAAA,* open abdominal aortic aneurysm; *UTI,* urinary tract infection; *VTE,* venous thromboembolism.

[a]Operation time >90th percentile: 228 minutes for EVAR, 167 minutes for CEA, 355 minutes for oAAA, and 346 minutes for BPG.

Infrainguinal BPG. For all patients undergoing this intervention, the median postoperative hospital LOS was 4 days (IQR, 3 days). In-hospital postoperative wound/graft complications occurred in 4% (n = 102) of the patients, in-hospital cardiac complications in 1.7% (n = 45), respiratory complications in 1.2% (n = 32), and renal complications in 0.2% (n = 5). In-hospital VTE did not occur. Thirteen percent (n = 350) of the patients had reoperation. The overall readmission rate was 16.4% (n = 438), and 15.7% (n = 420) had an unplanned readmission. Preoperative characteristics and postoperative complications according to unplanned readmissions after BPG are summarized in Tables III and IV.

Of the patients who experienced an unplanned readmission, 67.9% (n = 285) did not experience a complication in the inpatient setting. The Fig displays the timing of complications relative to discharge for patients readmitted with BPG. All complications more frequently developed after discharge, with postoperative infection being the most common. Nevertheless, the occurrence of a complication in the inpatient setting increased the likelihood of an unplanned readmission postdischarge (14.0% to 20.6%; $P < .001$). Those patients who had an unplanned readmission experienced a higher likelihood of reoperation (47.4% vs 6.8%; $P < .001$) and death (1.9% vs 0.3%; $P < .001$) ≤30 days of surgery.

Table III. Preoperative and sociodemographic univariable characteristics

	BPG			*EVAR*		
Variables	*Readmitted*	*Not readmitted*	P[a]	*Readmitted*	*Not readmitted*	P[a]
Observations, No.	418	2254		180	2189	
Age >75th percentile, %	26.4	26.6	.90	35.6	27.9	.03
Female, %	37.9	34.2	.17	24.4	18.6	.06
BMI						
Normal, %	27.1	30.9	.02	20.6	23.8	.45
Overweight, %	33.3	36.1		37.8	38.9	
Obese, %	39.5	32.9		41.7	37.3	
Diabetes, %	50.0	39.5	<.001	21.1	15.9	.07
Smoker, %	40.2	44.2	.13	38.3	30.6	.03
Dyspnea, %	19.8	14.5	<.001	27.8	20.8	.03
Functionally dependent	11.9	6.0	<.001	5.6	2.0	<.001
History of COPD, %	17.6	12.3	<.001	27.8	18.9	<.001
Cardiac event history, %	23.1	17.2	<.001	24.4	18.5	.05
Hypertension medication, %	87.6	84.5	.10	88.9	81.5	.01
PVD, %	35.7	32.9	.29	3.9	3.2	.62
Dialysis, %	6.4	3.4	<.001	1.7	1.0	.36
Corticosteroid treatment, %	4.5	2.8	.06	6.1	3.7	.10
History of stroke, %	10.0	8.9	.42	11.7	6.4	.01
Bleeding disorder, %	23.1	20.6	.23	17.2	11.0	.01
Normal GFR,[b] %	9.0	7.9	.39	2.8	4.9	.19
Low pre-op hematocrit, %	55.7	50.0	.04	45.6	38.0	.04
Race						
White, %	72.6	73.6	.02	82.8	83.7	.08
Asian, %	0.5	1.3		2.2	2.1	
Black, %	18.6	15.4		6.1	3.4	
Other, %	3.8	6.8		5.6	1.0	
Hispanic, %	4.5	3.0		3.3	1.7	
ASA class						
1 or 2, %	4.0	8.3	<.001	3.9	6.3	.32
3, %	72.9	77.1		73.9	74.3	
4 or 5, %	23.1	14.7		22.2	19.4	

ASA, American Society of Anesthesiologists; *BMI,* body mass index; *BPG,* bypass grafting; *CEA,* carotid endarterectomy; *COPD,* chronic obstructive pulmonary disease; *EVAR,* endovascular aneurysm repair; *GFR,* glomerular filtration rate; *oAAA,* open abdominal aortic aneurysm; *PVD,* peripheral vascular disease.
[a]*P* for variables with multiple categories represents joint significance.
[b]Normal GFR >120 mL/min/1.73 m^2.

In multivariable analysis (Table V), unplanned readmission was associated with preoperative functional dependence (OR, 1.77; 95% CI, 1.22-2.56), obesity (OR, 1.36; 95% CI, 1.02-1.80), a history of COPD (OR, 1.45; 95% CI, 1.07-1.96), history of cardiac events (OR, 1.41; 95% CI, 1.04-1.91), and ASA class 4 to 5 vs 1 to 2 (OR, 2.11; 95% CI, 1.19-3.72). Prolonged operative time was also associated with unplanned readmission (OR, 1.93; 95% CI, 1.40-2.67).

EVAR. For the overall cohort, the median postoperative hospital LOS was 2 days (IQR, 2 days) for EVAR patients. In-hospital postoperative wound/graft complications occurred in just >1% (n = 28) of the patients. In-hospital cardiac complications occurred in 0.4% (n = 9), renal in 0.3% (n = 7), VTE in 0.2% (n = 5), and respiratory in 1.1% (n = 26). Reoperation was required in 4% (n = 85). The overall readmission rate was 8.2% (n = 194), and 7.6% (n = 180) had an unplanned readmission. Preoperative characteristics and in-hospital postoperative complications based on unplanned readmissions after EVAR are summarized in Tables III and IV.

Of patients who experienced unplanned readmission, 76.1% (n = 137) did not experience a complication in the inpatient setting. The Fig displays complications relative to discharge for patients readmitted with EVAR. Patients undergoing EVAR experienced complications most commonly after discharge; however, the occurrence of a complication in the inpatient setting increased the likelihood of an unplanned readmission (6.6% to 14.4%; $P <$ .001). Those who experienced an unplanned readmission had an increased likelihood of reoperation (27.8% vs 1.6%; $P <$ .001) and death (3.9% vs 0.1%; $P <$ .001) ≤30 days of surgery.

In multivariable analysis (Table V), unplanned readmission was associated with age >75th percentile (>80 years; OR, 1.50; 95% CI, 1.05-2.13), history of stroke (OR, 1.89; 95% CI, 1.10-3.25), smoking in the year before surgery (OR, 1.73; 95% CI, 1.21-2.46), postoperative cardiac arrest or myocardial infarction (OR, 3.70; 95% CI, 1.09-12.6), VTE or renal failure (other serious complication; OR, 6.14; 95% CI, 1.41-26.81),

Table III. Continued.

oAAA repair			*CEA*		
Readmitted	*Not readmitted*	P[a]	*Readmitted*	*Not readmitted*	P[a]
41	474		370	5320	
26.8	24.9	.79	29.7	28.5	.62
39.0	29.3	.20	39.7	41.0	.62
36.6	25.9	.23	22.7	22.9	.96
43.9	43.2		38.9	38.3	
19.5	30.8		38.4	38.8	
9.8	12.4	.61	38.6	29.6	<.001
41.5	42.6	.90	26.8	27.7	.69
19.5	15.8	.52	22.4	17.2	.01
4.9	0.8	.02	4.9	2.9	.03
17.1	19.0	.78	15.1	11.3	.02
14.6	14.3	.96	18.1	18.3	.09
92.7	81.4	.07	86.5	87.3	.66
9.8	2.7	.02	8.1	5.4	.03
0.0	0.6	.61	2.2	0.9	.02
4.9	2.5	.37	3.0	2.1	.26
12.2	6.1	.13	23.5	18.7	.02
12.2	6.1	.22	29.7	20.1	.00
4.9	3.4	.62	4.1	5.9	.13
43.9	36.3	.32	48.1	40.5	<.001
82.9	81.2	.52	86.2	85.8	.97
7.3	3.2		1.9	1.6	
2.4	4.6		3.2	3.5	
4.9	9.3		6.2	6.1	
2.4	1.7		2.4	2.9	
4.9	5.9	.96	5.7	7.3	.03
68.3	67.9		76.0	79.0	
26.8	26.2		18.4	13.8	

and discharge to a skilled nursing facility (OR, 2.06; 95% CI, 1.03-4.14).

oAAA repair. The median postoperative hospital LOS was 7 days (IQR, 4 days). In-hospital postoperative wound/graft complications occurred in 7% (n = 36) of the patients, cardiac in 2.6% (n = 13), renal in 3.2% (n = 16), VTE in 1.0% (n = 5), and respiratory in 10.9% (n = 56). Eight percent of the patients had 30-day reoperation. The overall readmission rate was 8.1% (n = 42), and 8.0% (n = 41) of patients had an unplanned readmission. Preoperative characteristics and postoperative complications based on unplanned readmissions after oAAA repair are summarized in Tables III and IV.

Of those who experienced an unplanned readmission, 87.8% (n = 36) also experienced a complication in the inpatient setting. In addition, the occurrence of a complication in the inpatient setting increased the likelihood of unplanned readmission (3.0% to 10.3%; $P < .001$). The Fig displays the number of complications relative to discharge for patients readmitted with oAAA repair. Rates of renal and respiratory complications were comparable in the inpatient and postdischarge settings, whereas wound and urinary tract infection rates were higher after discharge. Those who experienced a postdischarge unplanned readmission had a more than threefold likelihood of reoperation (22.0% vs 6.3%; $P < .001$). Only three patients died ≤30 days of surgery.

In multivariable analysis (Table V), unplanned readmission was associated with postoperative VTE and postoperative renal failure (OR, 12.4; 95% CI, 2.27-68.0), postoperative wound/graft complication or urinary tract infection (OR, 4.80; 95% CI, 1.27-18.12), and postoperative transfusion of >4 units of packed red blood cells (OR, 4.34; 95% CI, 1.71-11.0). Obesity (OR, 0.34; 95% CI, 0.13-0.88) was associated with a lower rate of unplanned readmission.

CEA. For patients undergoing CEA, the median postoperative hospital LOS was 1 day (IQR, 1 day). In-hospital postoperative wound/graft complications occurred in 0.5% (n = 28) of the patients. In-hospital cardiac complications

Table IV. Postoperative univariate characteristics

	BPG			EVAR		
Variables	*Readmitted*	*Not readmitted*	P[a]	*Readmitted*	*Not readmitted*	P[a]
Observations, No.	418	2254		180	2189	
Events ≤30 days						
Reoperation, %	47.4	6.8	<.001	27.8	1.6	<.001
Death, %	1.9	0.3	<.001	3.9	0.1	<.001
Operation time >90th percentile, %	17.1	9.0	<.001	16.1	9.7	<.001
Wound/graft complication or UTI, %	5.2	3.6	.13[b]	0.6	1.2	.72[b]
Respiratory infection, %	1.9	1.1	.14[b]	2.8	1.0	.05[b]
VTE, %	0.0	0.1	1.00[b]	1.7	0.1	<.001[b]
Renal complication, %	0.2	0.2	1.00[b]	0.6	0.3	.43[b]
Cardiac complication, %	1.9	1.6	.68[b]	1.7	0.4	.05[b]
Stroke or nerve injury, %	0.2	0.3	1.0[b]	0.0	0.1	1.00[b]
Post-op transfusion, %	28.1	19.6	<.001[b]	20.0	10.1	<.001
Post-op hospital LOS, median (IQR), days	4 (4)	4 (4)	<.001	2 (2.5)	2 (2)	<.001
Discharged to						
Home, %	78.1	82.5	.09	87.2	94.8	<.001
Rehabilitation, %	8.1	6.9		4.4	2.3	
SNF, %	13.8	10.5		8.3	2.9	

BPG, Bypass grafting; *CEA,* carotid endarterectomy; *EVAR,* endovascular aneurysm repair; *IQR,* interquartile range; *LOS,* length of stay; *oAAA,* open abdominal aortic aneurysm; *SNF,* skilled nursing facility; *UTI,* urinary tract infection; *VTE,* venous thromboembolism.
[a]*P* for variables with multiple categories represents joint significance.
[b]Indicates Fisher exact test rather than χ^2 test.

occurred in 1.0% (n = 57) of the patients, renal in 0.2% (n = 11), VTE in 0.1% (n = 6), and respiratory in 1.5% (n = 85). Three percent (n = 176) of the patients had a 30-day reoperation. Overall readmission rate was 8.0% (n = 455), and 6.5% (n = 370) had an unplanned readmission. Preoperative characteristics and postoperative complications based on unplanned readmissions after CEA are summarized in Tables III and IV.

Of patients who experienced an unplanned readmission, 91.3% (n = 338) did not experience a complication in the inpatient setting. The Fig displays the number of complications relative to discharge for patients readmitted with CEA. Complications were markedly more common after discharge after CEA. However, the occurrence of a complication in the inpatient setting increased the likelihood of occurrence of unplanned readmission after discharge (6.2% to 12.1%; $P < .001$). Those patients who experienced a postdischarge unplanned readmission had an increased likelihood of reoperation (19.2% vs 2.0%; $P < .001$) and death (2.2% vs 0.2%; $P < .001$) ≤30 days of surgery.

In multivariable analysis (Table V), unplanned readmission was associated with preoperative conditions posing higher bleeding risk (OR, 1.63; 95% CI, 1.28-2.07), diabetes mellitus (OR, 1.44; 95% CI, 1.15-1.81), a history of peripheral revascularization or amputation (OR, 1.54; 95% CI, 1.02-2.33), and history of stroke (OR, 1.48; 95% CI, 1.10-2.01). Unplanned readmission was also associated postoperative cardiac complication (OR, 2.99; 95 CI, 1.29-6.96), and discharge to a rehabilitation facility (OR, 2.68; 95% CI, 1.18-6.08) or skilled nursing facility (OR, 2.05; 95% CI, 1.08-3.86).

DISCUSSION

The readmission rates after vascular procedures in NSQIP differ from those previously reported rates using Medicare data. We found overall (planned and unplanned) readmission rates of 16.4%, 8.2%, 8.1%, and 8.0% after BPG, EVAR, oAAA repair, and CEA, respectively. Jencks et al,[1] using 2003 to 2004 Medicare claims data, found a much higher readmission rate of 23.9% for patients undergoing vascular surgery. Moreover, our own group found overall readmission rates of 13.3% for EVAR and 12.8% for oAAA repair using the 2004 to 2006 CMS Chronic Conditions Warehouse. Alternatively, Jackson et al,[6] in a single-institutional evaluation, recently reported rates similar to those in the present study, with overall (unplanned) 30-day readmission rates of 11.9% (8.9%) for vascular surgery patients and 14.6% for patients after BPG. These differences are likely related to differences in the NSQIP vs CMS (Medicare) databases. Interestingly, a recent study[16] compared NSQIP and Medicare readmission data with hospital records and found that both had excellent accuracy (>99% for both), but only NSQIP categorizes readmission as planned or unplanned (95.7% accuracy). Given the accuracy of both data sets, the higher rate of readmission seen in the Medicare population is at least partly related to the inclusion of planned readmissions in the Medicare analyses. Moreover, a higher burden of morbidity among older Medicare patients may also contribute to a higher rate of readmission; our analysis of NSQIP data included a significant number of patients aged <65 years.[17]

Another important factor that may contribute to the lower readmission rates in NSQIP is that NSQIP-defined

Table IV. Continued.

oAAA repair			CEA		
Readmitted	*Not readmitted*	P[a]	*Readmitted*	*Not readmitted*	P[a]
41	474		370	5320	
22.0	6.3	<.001[b]	19.2	2.0	<.001
2.4	0.4	.22	2.2	0.2	<.001
9.8	10.1	.94	11.4	10.0	.37
14.6	6.5	.10[b]	0.3	0.5	1.00[b]
12.2	11.6	.80[b]	3.0	1.4	.02[b]
4.9	0.6	.05[b]	0.0	0.1	1.00[b]
7.3	2.7	.13[b]	0.5	0.1	.11[b]
2.4	3.0	1.00[b]	3.2	0.8	<.001[b]
0.0	1.3	1.00[b]	0.5	0.7	1.00[b]
85.4	62.2	<.001[b]	4.9	2.2	.01
8 (3)	7 (4)	.02	1 (1)	1 (1)	<.001
73.2	84.0	.17	93.5	97.2	<.001
12.2	8.6		2.7	1.1	
14.6	7.4		3.78	1.67	

readmissions are measured 30 days from the surgical procedure (including the postoperative LOS), whereas Medicare readmission is measured 30 days from the date of discharge. Thus, depending on the hospital LOS, the period of measurement for Medicare may be substantially longer than for NSQIP, where the time measured after hospital discharge will be significantly less than 30 days (less the hospital LOS, which for oAAA repair, for example, is 7 days).

Practice-based interventions designed to reduce readmission rates require a thorough grasp of the contributing clinical factors. With this in mind, we analyzed four major vascular procedures. Preoperative functional status and higher ASA class were associated with unplanned readmissions after BPG. These characteristics have been previously associated with 30-day mortality.[18] Obesity and history of cardiac events were also associated with unplanned readmissions after BPG. Obesity was associated with decreased readmissions after oAAA repair. Although the reasons are uncertain, obesity has largely not been shown to be associated with postoperative morbidity and mortality after oAAA repair.[8,19] COPD and smoking were associated with higher readmissions after BPG and EVAR, probably due to a greater number of pulmonary complications. Diabetes mellitus was associated with unplanned readmissions after CEA; previous studies have documented an increased incidence of restenosis, occlusion, stroke, and death after CEA for patients with diabetes.[6,20,21] As expected, patients with preoperative conditions posing a higher bleeding risk and symptomatic patients had a higher readmission risk after CEA. Although racial disparity in surgical outcomes is well documented, race was not consistently associated with unplanned readmission in our analyses.[22]

Similar to preoperative comorbidities, postoperative complications had a strong association with postoperative unplanned readmissions. Postoperative wound and urinary tract complications were associated with a four times adjusted higher risk of an unplanned readmission for oAAA repair. Measures to reduce infection rates may lead to a corresponding reduction in unplanned readmissions. More importantly, when infection is recognized, better management might mitigate the need for readmission. Although postoperative VTE and renal failure were uncommon (<1% of patients) and occurred most commonly after discharge, these complications were strongly associated with readmission risk. Routine chemical and mechanical prophylaxis of hospitalized patients and postdischarge prophylaxis of at-risk patients may further reduce readmission.[23] As expected, postoperative myocardial infarction and renal failure were also associated with readmission for selected vascular procedures.

Similar to our prior findings,[8] multivariate analyses showed discharge to a skilled nursing or rehabilitation facility was associated with readmission after EVAR and CEA but not BPG and oAAA repair. Age, functional status, and postoperative complications may mediate the relationship between discharge disposition and readmission after BPG and oAAA repair. The C-statistics for our multivariate analyses ranged from 0.63 for CEA to 0.79 for oAAA repair. This is consistent with the model fit reported for similar models using clinical and claims data to predict 30-day readmissions.[24]

An interesting study finding was that complications eventually leading to readmission more often developed after discharge than during the index admission. For those

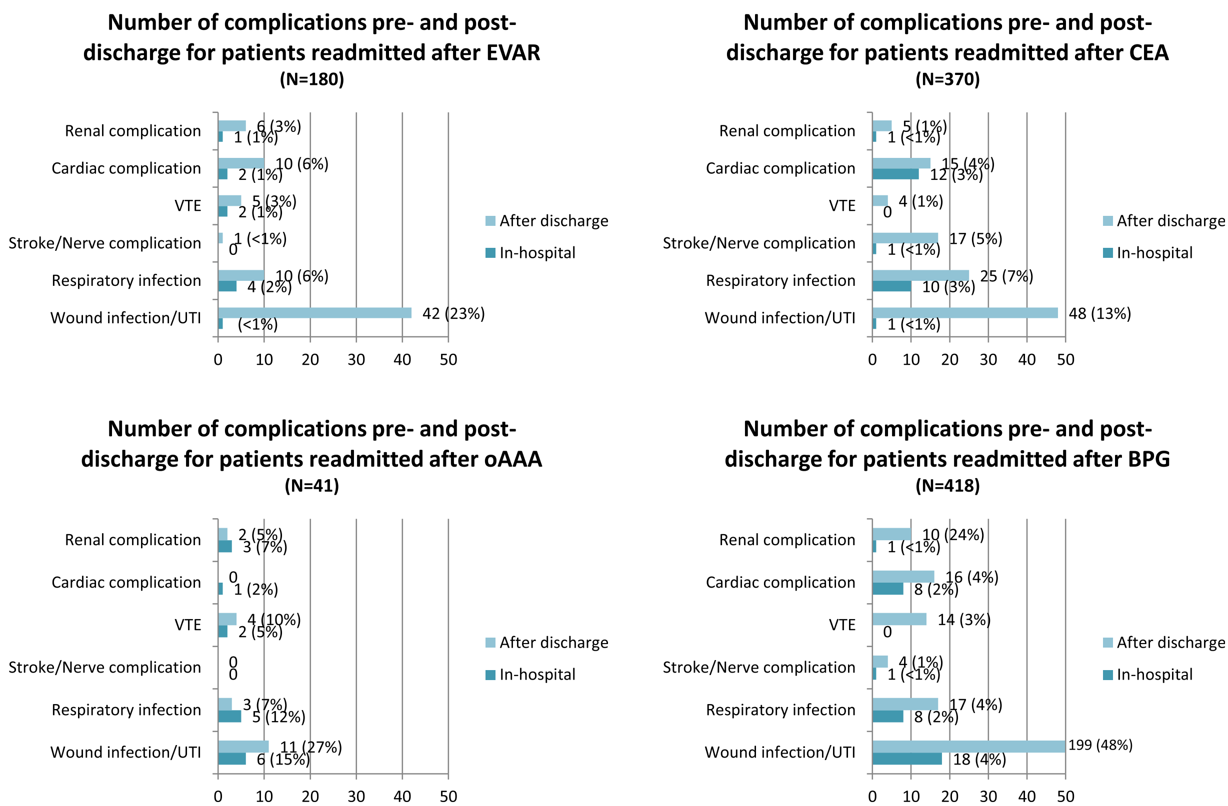

Fig. Incidence of complications in the hospital and after discharge by procedure. *BPG,* Bypass grafting; *CEA,* carotid endarterectomy; *EVAR,* endovascular aneurysm repair; *oAAA,* open abdominal aortic aneurysm; *UTI,* urinary tract infection; *VTE,* venous thromboembolism.

complications leading to readmission that were initially recognized at the time of the index admission, it could be argued that more aggressive initial or on going management might lead to fewer readmissions. This could include hospitalizing patients longer or, alternatively, patients with recognized in-hospital postoperative complications might be discharged to skilled nursing facilities so their ongoing medical or surgical issues could be more aggressively managed.

Complications leading to readmission that develop after discharge may need to be addressed in a different manner. Early recognition of these complications would be optimal at a point where they might be managed on an outpatient basis before becoming sufficiently problematic that hospitalization is required. For example, wound infections leading to readmission appear to develop frequently after hospital discharge. Measures that would allow early recognition of wound infection and appropriate outpatient treatment might prevent these infections from progressing to a stage where intravenous antibiotics or wound drainage becomes necessary. This might be accomplished by early follow-up or improved patient education with the goal of enhancing early recognition.

It is also possible that the complications that are first identified after discharge are actually present during the index admission but not recognized. For example, a patient may have shortness of breath that is not recognized at the time of discharge; the patient then presents 24 hours later in florid pulmonary edema.

These findings suggest that strategies to prevent readmission will need to be tailored according to whether complications develop during the initial hospitalization or after the patient is discharged. Although it is inductive, further study is needed to be certain that early identification and management of complications would result in reduced unplanned readmission rates.

Unplanned readmission was frequently associated with reoperation. Although EVAR and CEA had low rates of 30-day reoperation, 28% of unplanned readmissions after EVAR and 19% after CEA were associated with a reoperation. Thirty-day reoperations were more common after oAAA repair (7.6%) and BPG (13.1%), with 23% of unplanned readmissions after oAAA repair and 47% of unplanned readmissions after BPG being associated with a reoperation. Careful evaluation of patients with postoperative complications and close postdischarge surveillance might decrease returns to the operating room and unplanned readmission. It is important to note that for BPG patients, many of the unplanned returns to the operating room may have been for amputations.

Our results must be interpreted in the context of several limitations. In NSQIP, the exact timing of readmission is

Table V. Multivariable logistic regression predicting unplanned readmission

	BPG (n = 2672[a])		*EVAR (n = 2369[a])*		*oAAA repair (n = 506[a])*		*CEA (n = 5690[a])*	
Variables	*OR[b] (95% CI)*	P	*OR[b] (95% CI)*	P	*OR[b] (95% CI)*	P	*OR[b] (95% CI)*	P
Female	1.12 (0.89-1.41)	.35	1.26 (0.85-1.88)	.25	1.25 (0.61-2.55)	.55	0.99 (0.77-1.24)	.91
Age >75th percentile	0.9 (0.68-1.18)	.44	1.50 (1.05-2.13)	.03	0.83 (0.34-2.03)	.55	0.99 (.077-1.28)	.96
BMI								
Overweight	1.03 (0.77-1.37)	.84	1.36 (0.87-2.11)	.14	0.67 (0.29-1.55)	.35	1.05 (0.79-1.39)	.75
Obese	1.36 (1.02-1.80)	.03	1.55 (0.98-2.45)	.06	0.34 (0.13-0.88)	.03	0.94 (0.70-1.27)	.7
Diabetes	1.21 (0.96-1.53)	.11	1.22 (0.82-1.82)	.32	0.77 (0.20-2.96)	.70	1.44 (1.15-1.81)	.002
Smoker	0.89 (0.70-1.13)	.32	1.73 (1.21-2.46)	.003	0.91 (0.41-2.05)	.83	0.96 (0.74-1.25)	.77
Dyspnea	1.21 (0.91-1.61)	.19	1.23 (0.82-1.83)	.31	1.36 (0.45-4.05)	.59	1.29 (0.99-1.69)	.06
Functionally dependent	1.77 (1.22-2.56)	.003	1.59 (0.71-3.55)	.26	1.07 (0.17-6.85)	.94	1.19 (0.70-2.02)	.53
History of COPD	1.45 (1.07-1.96)	.02	1.27 (0.85-1.90)	.24	0.90 (0.31-2.62)	.85	1.23 (0.89-1.68)	.21
Cardiac event history	1.41 (1.04-1.91)	.03	1.33 (0.86-2.03)	.20	0.54 (0.17-1.68)	.29	0.8 (0.58-1.10)	.17
Hypertension medication	0.99 (0.71-1.37)	.94	1.57 (0.94-2.61)	.08	4.27 (0.98-18.6)	.05	0.81 (0.59-1.12)	.21
Peripheral vascular disease	1.29 (0.92-1.80)	.14	0.78 (0.32-1.94)	.60	2.66 (0.52-13.5)	.24	1.54 (1.02-2.33)	.04
Missing health history	1.49 (1.08-2.05)	.01	1.06 (0.73-1.55)	.76	0.51 (0.21-1.23)	.13	1.27 (0.95-1.70)	.1
Dialysis	1.29 (0.79-2.12)	.30	1.72 (0.49-5.97)	.39	NA		1.75 (0.78-3.91)	.17
Corticosteroid treatment	1.58 (0.90-2.79)	.11	1.64 (0.85-3.18)	.14	2.08 (0.30-14.6)	.46	1.36 (0.72-2.60)	.35
History of stroke	0.98 (0.67-1.43)	.90	1.89 (1.10-3.25)	.02	1.66 (0.52-5.31)	.39	1.48 (1.10-2.01)	.01
Bleeding disorder	1.04 (0.80-1.35)	.79	1.51 (0.98-2.32)	.06	1.87 (0.67-5.23)	.24	1.63 (1.28-2.07)	0
Normal GFR[c]	1.3 (0.89-1.90)	.18	0.54 (0.22-1.35)	.19	2.24 (0.34-14.9)	.41	0.66 (0.39-1.11)	.12
Low preoperative hematocrit	1.01 (0.79-1.28)	.96	1.18 (0.83-1.67)	.35	1.18 (0.55-2.54)	.67	1.22 (0.97-1.53)	.09
Operation time >90th percentile	1.93 (1.40-2.67)	0	1.41 (0.87-2.31)	.16	0.49 (0.10-2.34)	.37	1.09 (0.77-1.55)	.62
Wound/graft complication or UTI	1.22 (0.72-2.07)	.47	0.28 (0.03-2.92)	.29	4.80 (1.27-18.12)	.02	0.28 (0.05-1.69)	.16
Respiratory infection	1.43 (0.56-3.64)	.45	1.20 (0.33-4.45)	.78	0.67 (0.15-2.95)	.60	1.35 (0.55-3.31)	.52
Other serious complication	0.48 (0.05-4.69)	.53	6.14 (1.41-26.81)	.02	12.4 (2.27-68.0)	.01	0.90 (0.22-3.57)	.88
Cardiac complication	0.95 (0.39-2.31)	.91	3.70 (1.09-12.58)	.04	0.50 (0.05-4.87)	.55	2.99 (1.29-6.96)	.01
Stroke or nerve injury	0.61 (0.07-5.29)	.65	NA		NA		0.52 (0.09-3.01)	.46
Postoperative transfusion	1.19 (0.91-1.56)	.21	1.55 (0.96-2.52)	.07	4.34 (1.71-10.99)	.002	1.28 (0.71-2.31)	.42
Postoperative hospital LOS	0.99 (0.97-1.01)	.33	0.97 (0.90-1.03)	.22	0.93 (0.86-1.01)	.09	0.98 (0.93-1.03)	.35
Race								
Asian	0.34 (0.07-1.62)	.18	1.29 (0.43-3.85)	.65	3.41 (0.91-12.81)	.07	1.16 (0.52-2.60)	.72
Black	1.15 (0.86-1.54)	.34	1.54 (0.75-3.15)	.24	0.40 (0.04-3.76)	.41	0.78 (0.42-1.44)	.42
Other	0.55 (0.32-0.95)	.03	0.65 (0.33-1.26)	.15	0.37 (0.08-1.81)	.22	1.02 (0.65-1.60)	.92
Hispanic	1.51 (0.87-2.60)	.14	2.33 (0.91-5.97)	.07	2.32 (0.40-13.32)	.35	0.73 (0.37-1.46)	.38
ASA class								
3	1.57 (0.94-2.62)	.08	1.23 (0.56-2.73)	.61	1.17 (0.26-5.32)	.84	1.04 (0.65-1.66)	.87
4 or 5	2.11 (1.19-3.72)	.01	1.13 (0.48-2.66)	.79	0.9 (0.17-4.69)	.9	1.19 (0.70-2.01)	.52
Discharged to								
rehabilitation	0.91 (0.59-1.41)	.64	1.40 (0.56-3.49)	.47	1.2 (0.39-3.66)	.75	2.68 (1.18-6.08)	.02
SNF	1.09 (0.77-1.54)	.65	2.06 (1.03-4.14)	.04	1.74 (0.50-6.03)	.38	2.05 (1.08-3.86)	.03
Area under ROC curve	0.65		0.69		0.80		0.63	

ASA, American Society of Anesthesiologists; *BMI,* body mass index; *BPG,* bypass grafting; *CEA,* carotid endarterectomy; *COPD,* chronic obstructive pulmonary disease; *EVAR,* endovascular aneurysm repair; *GFR,* glomerular filtration rate; *LOS,* length of stay; *NA,* not available; *oAAA,* open abdominal aortic aneurysm; *SNF,* skilled nursing facility; *ROC,* receiver operating characteristic; *UTI,* urinary tract infection.
[a]Indicates number of observations.
[b]Reference categories: normal BMI, white race, ASA class 1 or 2, discharged to home.
[c]Normal GFR >120 mL/min/1.73 m^2.

not specified, and confounders, such as patient socioeconomic status and hospital-level and region-level variation, are not available. Moreover, outcomes >30 days are not available in NSQIP, limiting our ability to assess long-term surgical outcomes. Being an observational study, causality cannot be determined.

Interestingly, the preoperative comorbidities or postoperative complications that predisposed to unplanned readmission were different for all four vascular procedures studied. This implies that factors predisposing patients to readmission vary depending on the surgical procedure and raises the possibility that interventions to reduce readmissions may be different for each of these interventions. Consistent with this finding, interventions to reduce readmissions have produced variable results in distinct patient populations and clinical care settings.[25]

CONCLUSIONS

Although vascular surgery has the highest readmission rate second only to congestive heart failure,[1] there is a lack of national and clinically relevant information on this subject. This study uses validated, multicenter data to characterize the clinical correlates of unplanned readmission after four commonly performed vascular operations—BPG, EVAR, oAAA repair, and CEA. Select comorbidities and other postoperative adverse events unduly contribute to the unplanned readmissions after vascular surgery. Interventions designed to mitigate these factors will likely reduce unplanned readmissions as well as the corresponding mortality for vascular patients and the associated health-care costs.

AUTHOR CONTRIBUTIONS

Conception and design: PG, BR
Analysis and interpretation: ST, TE, CK
Data collection: PG, BR
Writing the article: PG, ST, BR, TE
Critical revision of the article: CK
Final approval of the article: PG, ST, BR, TE, CK
Statistical analysis: PG, ST, BR
Obtained funding: Not applicable
Overall responsibility: PG

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