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Cohort Study of Risk Factors for 30-day Readmission after Abdominal Aortic Aneurysm Repair

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Abstract

Introduction: We conducted a retrospective cohort study of thirty-day readmission after abdominal aortic aneurysm (AAA) repair.

Methods: Inpatients (2009–2016) undergoing elective AAA repair were selected from the multicenter Cerner Health Facts® database using ICD-9 procedure codes. We identified characteristics associated with 30-day readmission with chi-square analysis and logistic regression.

Results: 4,723 patients undergoing elective AAA procedures were identified; 3,101 endovascular aneurysm repairs (EVAR) and 1,622 open procedures. Readmission differed by procedure type (6.5% EVAR vs. 9.3% open, $p = .0005$). Multivariable logistic regression found that patients undergoing EVAR were less likely to be readmitted (OR 0.71, 95% CI 0.54–0.92) than patients undergoing open repair. The following risk factors were associated with 30-day readmission following any AAA repair: surgical site infection during the index admission (OR 2.79, 95% CI 1.25–6.22), age (OR 1.03, 95% CI 1.01–1.05), receipt of bronchodilators (OR 1.34, 95% CI 1.06–1.70) or steroids (OR 1.45, 95% CI 1.04–2.02), serum potassium > 5.2 mEq/L (OR 1.89, 95% CI 1.16–3.06), and higher Charlson co-morbidity scores (OR 1.12, 95% CI 1.04–1.21). Subgroup analysis revealed that age (OR 1.02, 95% CI 1.01–1.04), higher Charlson comorbidity scores (OR 1.20, 95% CI 1.09–1.33), and receipt of post-operative bronchodilators (OR 1.39, 95% CI 1.03–1.88) were risk factors for 30-day readmission following EVAR. After open procedures, readmission was associated with surgical site infection during the index admission (OR 2.91, 95% CI 1.17–7.28), chronic heart failure (OR 2.18, 95% CI 1.22–3.89), and receipt of post-operative steroids (OR 1.92, 95% CI 1.24–2.96). The most common infections were pneumonia after open procedures and urinary tract infection after EVAR.

Conclusions: The risk factor most associated with 30-day readmission after elective AAA repair was surgical site infection. Awareness of these risk factors and vulnerable groups may help

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identify high-risk patients who could benefit from increased surveillance programs to reduce readmission.

INTRODUCTION

Readmission is a significant cause of healthcare-related costs and is a current focus for improving outcomes.¹ Hospital readmission within 30 days following surgical procedures has been labeled as a surrogate measure of the quality of healthcare delivery by a hospital system by The Centers for Medicare and Medicaid Services,² and has been proposed as a healthcare quality and cost-saving improvement measure.

Vascular surgery, specifically, has been linked with a readmission rate of almost 24%, much higher than the overall readmission rate for other types of surgery when all diagnoses and procedures are considered.^{3–5} Resources have been directed to identify and potentially mitigate preventable readmission, which in vascular surgery has been demonstrated to be a substantial cost burden to hospital systems when compared with other types of surgery.¹ Readmission following lower extremity endovascular procedures has been associated with features such as high body mass index, unplanned return to the operating room, diabetes, and emergency operation.^{6,7}

Complications such as an unplanned return to the operating room are routinely captured in registry datasets such as the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP). This is a potentially preventable postoperative complication that has been previously described as a risk-factor for readmission.⁸ There exists, therefore, considerable value to identifying and lowering costly readmission following vascular surgery. Abdominal aortic aneurysm repair is a major vascular operation with a well-described trend between surgical volume and patient outcome,^{9,10} but little has been studied with respect to the factors predisposing to readmission.

AIMS

In this present study, we conducted a retrospective cohort study to identify risk factors for 30-day all-cause hospital readmission after abdominal aortic aneurysm repair.

MATERIALS AND METHODS

Data Source

ICD-9-CM diagnosis and procedure codes were used to identify patients who underwent non-ruptured open or EVAR repair between January 2009 and March 2016 from the Cerner Health Facts® database. Health Facts is a proprietary database comprised of electronic medical records from hospitals and hospital systems that use Cerner Corporation's electronic health record (EHR). It includes EHR data from over 400 acute-care hospitals and contains detailed information on diagnoses, procedures, laboratory studies, medications, patients, and encounters. We used these data to identify patients who had elective AAA procedures, determine readmissions within 30 days after each procedure, and discover patient, provider and hospital-related characteristics that are associated with readmission. Health Facts, being

EHR data, includes data for patients of all ages and also includes rich data on laboratory results, medications, and clinical data. The Agency for Healthcare Research and Quality's (AHRQ) Clinical Classifications Software was used to group diagnosis codes into clinically relevant groups. Rigorous validity checks are applied to the data and Cerner de-identifies and standardizes data before including them in Health Facts using methods compliant with the Health Insurance Portability and Accountability Act (HIPAA). Because Health Facts is de-identified, informed patient consent was not needed. The Health Sciences Institutional Review Board deemed our study exempt.

Study Population

We included patients who underwent an open (procedure codes: 38.44 or 39.25) or EVAR (procedure codes: 39.71) procedure for a non-ruptured infrarenal AAA repair (procedure code: 441.4). The ICD-9 procedure codes for open and EVAR refer to discrete numeric codes that identify the procedure performed for a particular patient (38.44 refers to resection of a vessel, aortic, abdominal). They were developed to identify procedures for billing, but are frequently used for research purposes. Patients were excluded from the study if they were less than 21 years old at admission, had an admission during which both EVAR and open procedures were performed, had admissions flagged as emergent or urgent, died in the hospital or were discharged to hospice, had encounters with an adjacent encounter within 3 hours of admission or discharge, or had no reported laboratory or medication data. We identified patients who were readmitted within 30 days of their discharge from the index admission. Fenestrated and branched EVAR, chimney and snorkel EVAR were not included.

Patient and Encounter Characteristics

Patient demographics (age, gender, race) and hospital characteristics such as total number of beds and whether or not it had a designation as a teaching facility were included in the study. Additionally acute and chronic problems at the index admission (e.g., arterial embolism and thrombosis, chronic heart disease, anemia, renal failure, hypertension, infection) were also considered (see Appendix I for the associated ICD-9 diagnosis codes). Post-operative medication and laboratory results were also included as covariates. Medications included ACE inhibitors, angiotensin II receptor antagonists, antiplatelet agents (non-aspirin), aspirin and aspirin combinations, beta blockers (cardio selective), beta blockers (non-cardio selective), bronchodilators, calcium channel blockers, insulin, other diabetes medications, diuretics, H2 blockers, HMG-CoA reductase inhibitors, nitroglycerin (sublingual), proton pump inhibitors, steroids, vasopressors, and vasodilators. Post-operative laboratory results included blood urea nitrogen (mg/dL), hemoglobin (gm/dL), platelet counts (1000/ μ l), serum glucose (mg/dL), serum potassium (mEq/L), serum sodium (mEq/L), and white blood cell counts (1000/ μ l).

Analysis

All analyses were performed in SAS version 9.4 (SAS Institute, Cary, NC). We used chi-square analysis to compare the characteristics of patients who received open or EVAR procedures and determine characteristics of the index admission associated with 30-day readmission. Relative risks (RR) and 95% confidence intervals (CI) were calculated. Because we excluded encounters with no medications, laboratory data or diagnoses, we

assumed these were not administered or present when they were not included in the encounter record. Missing or unknown race/ethnicity was analyzed as a separate category.

To account for nonrandom assignment of procedure type, a propensity model was used to adjust for the probability of receiving an open AAA procedure. Propensity model covariates included patient demographics (age, marital status, gender), hospital characteristics (bed-size, teaching facility), Charlson index (described below), acute and chronic conditions (atrial fibrillation, chronic heart failure and disease, circulatory and conduction disorders, chronic kidney failure, connective tissue disorders, COPD, diabetes, hypertension, disorders of lipid metabolism, and tobacco-related disorders), and pre-operative medications (ace inhibitors, angiotensin II receptor antagonists, antiplatelet agents -non-aspirin, aspirin and aspirin combinations, beta blockers – cardio-selective and non-cardio selective, bronchodilators, calcium channel blockers, diabetes medications type I and II, diabetes type II, diuretics, H2 blockers, HMG-CoA reductase inhibitors, nitroglycerin - sublingual, proton pump inhibitors, steroids, vasopressors, and vasodilators). The Charlson Comorbidity Index is a weighted index of 19 conditions that is associated with risk of death within 1 year. Each condition is assigned a weight from 1 to 6 based on the estimated 1-year mortality hazard ratio from a Cox proportional hazards model. These weights are summed to produce the Charlson comorbidity score. These covariates were entered into a stepwise logistic model to create a propensity score. The predicted probability of receiving open AAA repair was added to the readmission model to adjust for nonrandom procedure assignment.

Associations of index admission diagnoses, post-operative medications and laboratory results with 30-day readmission were then modeled using three separate logistic regression models – one model for all patients and separate models for EVAR and open AAA procedures. We initially created a base model that included the propensity score, procedure type (EVAR vs. open), patient characteristics (age, sex, race/ethnicity, and Charlson index), and hospital characteristics (teaching facility). The procedure-specific base models excluded the propensity score and procedure type. Comorbid diagnoses, post-operative medications and laboratory values, and encounter characteristics were allowed to enter into each base model using stepwise selection, using $p = .10$ as the significance level for variable entry and retention. Backwards elimination models were also run to determine whether the same variables were retained in the final models. Odds ratios and 95% confidence intervals were calculated. Model discrimination was assessed with the c-statistic, where 1 indicates perfect fit and .5 is no better than a coin toss. Model calibration was assessed with the Hosmer-Lemeshow goodness-of-fit test, where $p > .05$ indicates adequate fit over the range of predicted readmission.

RESULTS

Overall

We identified 4,723 patients in 86 hospitals who underwent elective AAA repair between 2009 and 2016; 66% ($n = 3,101$) underwent endovascular aneurysm repair (EVAR) and 34% ($n = 1,622$) had an open surgical repair. We excluded 113 patients who died in the hospital, 53 who were discharged to hospice, and 57 who had both endovascular and open procedures in the same admission. Characteristics of the study population by readmission status are

reported in Table 1. There were 355 patients (7.5%) who required readmission within 30 days from the index AAA procedure. The average age of patients undergoing AAA repair was 69.8 years and no difference was noted between those patients who were readmitted and those who were not. Readmission within 30 days differed by procedure type (6.5% EVAR vs. 9.3% open, $p < .001$). The majority of patients were male (73.5%) or Caucasian (89%). Female patients were readmitted more often than males (33% vs. 26%, respectively; $p = .004$). A higher proportion of African American than Caucasian patients were readmitted (11.2% vs. 7.3%; $p = .03$). Patients who were readmitted within 30-days had higher Charlson scores than non-readmitted patients (2.4 vs. 2.1 respectively, $p < .0001$). Larger hospital facilities (>500 beds) performed the largest proportion of AAA procedures, with no significant difference between readmission rates seen with hospital size. Most (68.4%) procedures were performed at teaching facilities. Patients who were readmitted had a longer index length of stay than those who were not (6.9 vs. 4.3 days; $p < .0001$).

Table 2 details the association of diagnoses and conditions during the index hospital admission with readmission. Unadjusted analyses revealed a higher percentage of readmitted patients suffered from acute renal failure (14.4% vs. 7.4%; RR 1.94, $p < .0001$), respiratory problems (16.9% vs. 11.5%; RR 1.50, $p = .002$), and fluid/electrolyte disorders (17.7% vs. 13.6%; RR 1.34, $p = .02$). Similarly pre-existing chronic kidney disease (17.7% vs. 11.2%; RR 1.62, $p = .0002$), anemia (13.8% vs. 9.7%; RR 1.44, $p = .01$) and congestive heart failure (11.0% vs. 7.1%; RR 1.55, $p = .006$) were seen more frequently in readmitted patients. Infection as an overarching diagnosis was strongly associated with readmission in bivariable analysis (RR 1.82; $p = .0001$). A surgical site infection was associated with a 3.48 relative risk of readmission ($p < .0001$); other infections, sepsis or pneumonia during the index admission were also associated with readmission. Hemorrhage or hematoma during the index admission was seen in 5.6% of readmitted patients compared with 2.9% of patients who were not readmitted (RR 1.88, $p = .003$).

Subgroup analysis

Unadjusted analysis of the group of patients who underwent EVAR revealed that renal failure (RR 2.65, 95% CI 1.73–4.05), chronic kidney disease (RR 1.89, 95% CI 1.37–2.62), arterial embolism and thrombosis (RR 1.94, 95% CI 1.17–3.23), and hemorrhage or hematoma (RR 1.84, 95% CI 1.01–3.34) were associated with 30 day readmission (Table 3). For the group undergoing open AAA (Table 4), congestive heart failure (RR 1.94, 95% CI 1.27–2.96), infection (21.7% vs. 13.4%; RR 1.67, $p = .005$), sepsis (7.2% vs. 3.0%; RR 2.18, $p = .007$) and surgical site infection (4.6% vs. 1.5%; RR 2.65, $p = .005$) were associated with readmission.

The most common diagnoses present during the readmission stay (Table 5) included hypertension (63.4%), chronic heart disease (41.7%), disorders of lipid metabolism (40.6%), and infection (26.5%). Of the 94 patients with an infection during the readmission stay, only 18 had this diagnosis during the index stay, leaving 76 patients who had an infection only during the readmission encounter. Diagnoses present upon readmission demonstrated several differences between the EVAR and open groups. Compared with patients who received open AAA repair during the index admission, arterial embolism/thrombosis (RR 1.47, 95% CI

1.16–1.87), acute cardiac/MI (RR 1.45, 95% CI 1.16–1.83), chronic kidney disease (RR 1.28, 95% CI 1.07–1.55), chronic anemia (RR 1.22, 95% CI 1.01–1.46), conduction disorders (RR 1.47, 95% CI 1.16–1.87), urinary tract infections (RR 1.41, 95% CI 1.10–1.81) and complications of hemorrhage/hematoma (RR 1.37, 95% CI 1.10–1.70) were more common among patients readmitted following EVAR. Patients following EVAR had fewer surgical site infections at readmission than open repair (RR 0.60, 95% CI 0.39–0.92).

Multivariable analysis

Results of multivariable analysis of 30-day readmission are shown in Table 6. Patients who underwent EVAR were less likely to be readmitted within 30 days (OR 0.71, 95% CI 0.54–0.92) than patients who had open procedures. Several factors were associated with increased risk of 30-day readmission following any AAA repair: surgical site infection during the index admission (OR 2.79, 95% CI 1.25–6.22), age (OR 1.03, 95% CI 1.01–1.05), receipt of bronchodilators (OR 1.34, 95% CI 1.06–1.70) or steroids (OR 1.45, 95% CI 1.04–2.02), serum potassium > 5.2 mEq/L (OR 1.89, 95% CI 1.16–3.06), and higher Charlson scores (OR 1.12, 95% CI 1.04–1.21). Use of statins (OR 0.65, 95% CI 0.52–0.82), H2 blockers (OR 0.76, 95% CI 0.60–0.96) or vasodilators (OR 0.78, 95% CI 0.61–1.00) were associated with lower risk of readmission.

Analysis by procedure type revealed that age (OR 1.02, 95% CI 1.01–1.04), higher Charlson scores (OR 1.20, 95% CI 1.09–1.33), and receipt of post-operative bronchodilators (OR 1.39, 95% CI 1.03–1.88) were risk factors for 30-day readmission following an EVAR procedure. Statins (OR 0.71, 95% CI 0.53–0.96) and vasodilators (OR 0.68, 95% CI 0.48–0.95) were associated with lower readmission risk following EVAR. After open AAA procedures, 30-day readmission was associated with a surgical site infection during the index admission (OR 2.91, 95% CI 1.17–7.28), chronic heart failure (OR 2.18, 95% CI 1.22–3.89), and receipt of post-operative steroids (OR 1.92, 95% CI 1.24–2.96). Statins were also associated with lower readmission after open AAA procedures (OR 0.55, 95% CI 0.38–0.79).

DISCUSSION

Our analysis demonstrated a difference in readmission rates for AAA procedures, with open AAA repair associated with more readmissions than EVAR. While this appears to be an intuitive finding, there are inherent selection biases between treatment modalities for aneurysm repair. EVAR poses less surgical stress to patients and therefore could be expected to be associated with a lower rate of readmission due to the less invasive mode of repair when compared with open repair. The patient populations, however, are generally burdened with a greater degree of comorbidity. Additionally, the perceived lower operative stress of EVAR may have facilitated repair in higher risk patients who were more prone to post-operative complications, including readmission. Conversely, open repair is usually reserved for better surgical risk patients, but is associated with a greater surgical burden.

Readmission following vascular surgery has not been extensively studied in the literature, although it is a frequent event occurring in up to 24% of all Medicare beneficiaries.⁵ Readmission has been targeted by the Center for Medicare and Medicaid Services (CMS) as

an area for improvement,¹¹ and has been linked to reduced reimbursement to hospitals with a higher-than-expected readmission rates. Specific vascular procedures have been examined with respect to 30-day readmission, most of which have focused on single-center experiences with small patient populations^{11–13} and may not be representative of national trends in vascular surgery readmissions.

For patients who were readmitted, infection was importantly related to readmission following open AAA repair. After open AAA repair, surgical site infection was the most common infection associated with readmission. Other authors have demonstrated the importance of infectious complications for readmission. Gupta *et al.* report their findings using NSQIP data to examine four common vascular surgery procedures. In subgroup analysis of the open AAA repair, the authors describe infectious complications as having a strong association with unplanned readmissions,¹⁴ and conclude that measures to reduce these infectious complications could reduce readmission. Infectious complications in vascular surgery patients has also been studied in large health care databases.^{15,16} An analysis using Health Facts evaluated 3,586 patients undergoing lower extremity vascular procedures. Patients who were hyperglycemic post-operatively manifested a higher rate of infection, increased hospital utilization and in-hospital mortality.¹⁶ Xenos *et al.* described risks associated with readmission after seven common open and endovascular procedures using local NSQIP data.¹⁷ They identified preoperative open wounds, perioperative blood transfusion, operative duration and wound infections as factors associated with readmission, with wound complications the most common reason for readmission for both EVAR and open aortic repair.

In a similar manner to other large database studies in colorectal and gastrointestinal surgery, we found that post-operative complications during the index hospitalization were linked to increased utilization of healthcare resources and an increased readmission rate.^{18,19} As has been described in other large patient series, any complication during the index hospitalization predisposes to an increased risk of readmission. This has been demonstrated in an analysis of ACS NSQIP registry data that examined six representative operations ranging from bariatric procedures to lower extremity bypass.¹⁸ The authors single out gastrointestinal complications (e.g., obstruction and ileus) to be importantly associated with readmission for general surgical procedures, while surgical site infection were associated with readmission following lower extremity bypass. The findings were replicated in the vascular literature examining a single institution experience of 1,170 patients.²⁰ Wound complications in both supra- and infrainguinal revascularization procedures and cardiac events following EVAR were the predominant associated factors in readmission in the vascular population. In the presented study, any coded complication from the index procedure led to risk of readmission twice that of an uncomplicated hospital course with the overwhelming majority of readmissions being related to infection.

In our unadjusted analysis, women were more likely to be readmitted than men. There was a trend towards more frequent readmission in women following EVAR, which may be related to the anatomical challenges of endovascular repair in female patients – a well-described phenomenon, especially with older generation endograft repair.^{21–23} There is also mounting evidence of the sex difference, however, as a contributing factor to cardiovascular events.

^{24,25} The gender disparity in vascular surgery is apparent in many different vascular disorders, especially carotid stenosis,^{26–28} peripheral arterial disease,²⁹ and aneurysmal disorders.³⁰ Chung *et al.* review a single institution's experience with EVAR from 1992 to 2012 and describe outcomes from 214 repairs in female patients.³⁰ They describe a significant difference in the age and cardiac burden of women at the time of repair, and interestingly revealed a morphological difference in aneurysm characteristics of women, with shorter aneurysm necks and more angulated necks. Postoperatively, women required more arterial reconstructions, thrombolysis and thrombectomy, and had more perioperative complications and more in-hospital days than men. Long-term follow-up revealed a greater number of endoleaks in women than men, but no difference in arterial re-interventions or survival. The authors concluded that these factors should be taken into consideration when offering female patients aneurysm repair.

Regarding post-operative medication use and readmission, this present study found an association between statin use and a lower readmission rate. Previous studies have looked at the association between statins and perioperative and long-term mortality following AAA repair^{31–33} but there is scant data on the effect of statins upon readmission. Statins have been reported to reduce all-cause readmissions and length of stay following sepsis³⁴ or ischemic stroke with respect to mortality and readmissions,³⁵ although this has remained an under-investigated area.

Limitations

This study has limitations secondary to using ICD-9 codes, as coding may vary between institutions. Because procedure type was not randomly assigned, selection bias could explain the differences between groups; we addressed this with a propensity score analysis. Residual confounding is still possible despite controlling for multiple covariates.³⁶ Cerner Corporations' Health Facts is a proprietary database comprised of electronic clinical records from hospitals and hospital systems that use Cerner's electronic health record, and the ethnicity and patient mix may not be representative of the wider US population. Proportions by ethnicity, however, are comparable to our previously published evaluation of carotid intervention using Medicare data, which is considered representative of the elderly US population.³⁷ Certain types of data (e.g., laboratory or medication data) might differ between hospitals that do and do not contribute these data. We could not detect readmissions to different hospital systems, thus we likely undercounted readmissions. Most Medicare patients (78%) who are readmitted, however, go to the same hospital as the index admission.³⁸

SUMMARY

Infections and procedural complications incurred during the index procedure were strongly associated with readmission following any AAA repair. Statins were associated with lower odds of readmission, and this warrants further research as to the generalizable effect in other cardiovascular disorders. We advocate strategies to identify high-risk patients and implement measures to lower readmission following AAA repair. Given the elective nature of most repairs, enhanced outpatient surveillance program; aggressive medical management

including the use of aspirin, statins and antihypertensive agents; and improved home outreach, such as telehealth and home-based case visits, should be actively pursued to potentially mitigate readmission.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1.

Patient and encounter characteristics for patients who underwent AAA procedures, by readmission status [Frequency (Column percentage)].

	Overall (n = 4723)		Not Readmitted (n = 4368)		Readmitted (n = 355)		p-value*
	N	%	N	%	N	%	
Age in years, mean (SD)	69.8	(10.3)	69.8	(10.2)	70.3	(11.2)	.40
21–59	751	(15.9)	688	(15.8)	63	(17.8)	
60–69	1419	(30.0)	1324	(30.3)	95	(26.8)	
70–79	1698	(36.0)	1582	(36.2)	116	(32.7)	
80 or older	855	(18.1)	774	(17.7)	81	(22.8)	
Gender							.004
Female	1254	(26.6)	1137	(26.0)	117	(33.0)	
Male	3469	(73.5)	3231	(74.0)	238	(67.0)	
Race							.03
Caucasian	4202	(89.0)	3894	(89.2)	308	(86.8)	
African American	303	(6.4)	269	(6.2)	34	(9.6)	
Other or unknown	218	(4.6)	205	(4.7)	13	(3.7)	
Hospital size (beds)							.14
<200	888	(18.8)	837	(19.2)	51	(14.4)	
200–299	693	(14.7)	642	(14.7)	51	(14.4)	
300–499	1371	(29.0)	1258	(28.8)	113	(31.8)	
500 or more	1771	(37.5)	1631	(37.3)	140	(39.4)	
Teaching facility	3231	(68.4)	2971	(68.0)	260	(73.2)	.11
Procedure type							.0005
Open	1622	(34.3)	1470	(33.7)	152	(42.8)	
EVAR	3101	(65.7)	2898	(66.4)	203	(57.2)	
Length of stay, mean (SD)	4.5	(6.2)	4.3	(5.9)	6.9	(9.9)	<.0001
Charlson Index, mean (SD)	2.1	(1.4)	2.1	(1.4)	2.4	(1.6)	<.0001

*p-value based on chi-square comparison (t-test for continuous variables) by readmission status.

AAA = abdominal aortic aneurysm. SD = standard deviation. EVAR = endovascular aneurysm repair

Table 2.

Association of diagnoses and conditions during the index hospital admission with readmission within 30 days for all patients undergoing AAA procedure [Frequency (Column percentage)]

	Overall (n = 4723)		Not Readmitted (n = 4368)		Readmitted (n = 355)		Relative risk of readmission		
	N	%	N	%	N	%	RR	(95% CI)	p-value*
<i>Acute Conditions</i>									
Arterial embolism and thrombosis	504	(10.7)	458	(10.5)	46	(13.0)	1.25	(0.93 – 1.67)	.14
Cardiac/MI	114	(2.4)	105	(2.4)	9	(2.5)	1.05	(0.56 – 1.98)	.87
Fluid and electrolyte disorders	656	(13.9)	593	(13.6)	63	(17.7)	1.34	(1.03 – 1.73)	.02
Renal failure	376	(8.0)	325	(7.4)	51	(14.4)	1.94	(1.47 – 2.56)	<.0001
Respiratory Problems	564	(11.9)	504	(11.5)	60	(16.9)	1.50	(1.15 – 1.95)	.002
Other venous embolism or thrombosis	165	(3.5)	150	(3.4)	15	(4.2)	1.22	(0.74 – 2.00)	.43
<i>Chronic Conditions</i>									
Atrial fibrillation	541	(11.5)	492	(11.3)	49	(13.8)	1.24	(0.93 – 1.65)	.14
Anemia	473	(10.0)	424	(9.7)	49	(13.8)	1.44	(1.08 – 1.92)	.01
Chronic kidney disease	554	(11.7)	491	(11.2)	63	(17.7)	1.62	(1.26 – 2.10)	.0002
COPD	1149	(24.3)	1052	(24.1)	97	(27.3)	1.17	(0.94 – 1.46)	.17
Other conduction disorders	214	(4.5)	198	(4.5)	16	(4.5)	0.99	(0.61 – 1.61)	.98
Congestive heart failure	348	(7.4)	309	(7.1)	39	(11.0)	1.55	(1.13 – 2.12)	.006
Chronic heart disease	2043	(43.3)	1891	(43.3)	152	(42.8)	0.98	(0.80 – 1.20)	.86
Depressive disorders	253	(5.4)	233	(5.3)	20	(5.6)	1.05	(0.68 – 1.63)	.11
Diabetes	1095	(23.2)	1006	(23.0)	89	(25.1)	1.11	(0.88 – 1.40)	.38
Disorders of lipid metabolism	2351	(49.8)	2188	(50.1)	163	(45.9)	0.86	(0.70 – 1.05)	.13
Hypertension	3289	(69.6)	3039	(69.6)	250	(70.4)	1.04	(0.83 – 1.29)	.73
Osteoarthritis	317	(6.7)	292	(6.7)	25	(7.0)	1.05	(0.71 – 1.56)	.79
Other thyroid disorders	362	(7.7)	333	(7.6)	29	(8.2)	1.07	(0.74 – 1.54)	.71
Tobacco-related disorder	2589	(54.8)	2407	(55.1)	182	(51.3)	0.87	(0.71 – 1.06)	.16
<i>Infections</i>									
Any Infection	325	(6.9)	283	(6.5)	42	(11.8)	1.82	(1.34 – 2.46)	<.0001
Cellulitis or abscess of leg/foot	16	(0.3)	14	(0.3)	2	(0.6)	1.67	(0.45 – 6.12)	.44
Other infection	105	(2.2)	92	(2.1)	13	(3.7)	1.67	(1.00 – 2.81)	.05
Pneumonia	121	(2.6)	104	(2.4)	17	(4.8)	1.91	(1.22 – 3.01)	.005
Sepsis	70	(1.5)	57	(1.3)	13	(3.7)	2.53	(1.53 – 4.17)	<.001
Surgical site infection	35	(0.7)	26	(0.6)	9	(2.5)	3.48	(1.97 – 6.17)	<.0001
Urinary tract infection	98	(2.1)	90	(2.1)	8	(2.3)	1.09	(0.56 – 2.13)	.80
<i>Other Complications</i>									
Complications with procedure	348	(7.4)	313	(7.2)	35	(9.9)	1.38	(0.99 – 1.92)	.06
Hemorrhage or hematoma	145	(3.1)	125	(2.9)	20	(5.6)	1.88	(1.24 – 2.87)	.003
Posthemorrhagic anemia	546	(11.6)	492	(11.3)	54	(15.2)	1.37	(1.04 – 1.81)	.02

*p-value based on chi-square comparison by readmission status.

AAA = abdominal aortic aneurysm. MI = myocardial infarction. COPD = chronic obstructive pulmonary disease

Table 3.

Association of diagnoses and conditions during the index hospital admission with readmission within 30 days for all patients undergoing EVAR [Frequency (Column percentage)]

	Overall (n = 3101)		Not Readmitted (n = 2898)		Readmitted (n = 203)		Relative risk of readmission		
	N	%	N	%	N	%	RR	(95% CI)	p-value*
<i>Acute Conditions</i>									
Arterial embolism and thrombosis	114	(3.7)	100	(3.5)	14	(6.9)	1.94	(1.17 – 3.23)	.01
Cardiac/MI	36	(1.2)	32	(1.1)	4	(2.0)	1.71	(0.67 – 4.35)	.26
Fluid/electrolyte disorders	212	(6.8)	194	(6.7)	18	(8.9)	1.33	(0.83 – 2.11)	.23
Renal failure	123	(4.0)	103	(3.6)	20	(9.9)	2.65	(1.73 – 4.05)	<.0001
Respiratory problems	183	(5.9)	166	(5.7)	17	(8.4)	1.46	(0.91 – 2.34)	.12
Other venous embolism/thrombosis	103	(3.3)	95	(3.3)	8	(3.9)	1.19	(0.61 – 2.36)	.61
<i>Chronic Conditions</i>									
Atrial fibrillation	373	(12.0)	341	(11.8)	32	(15.8)	1.37	(0.95 – 1.97)	.09
Anemia	253	(8.2)	228	(7.9)	25	(12.3)	1.58	(1.06 – 2.35)	.02
Chronic kidney disease	366	(11.8)	325	(11.2)	41	(20.2)	1.89	(1.37 – 2.62)	<.0001
COPD	724	(23.4)	669	(23.1)	55	(27.1)	1.22	(0.91 – 1.64)	.19
Other conduction disorders	173	(5.6)	159	(5.5)	14	(6.9)	1.25	(0.74 – 2.11)	.39
Congestive heart failure	224	(7.2)	206	(7.1)	18	(8.9)	1.25	(0.79 – 1.99)	.34
Chronic heart disease	1425	(46.0)	1338	(46.2)	87	(42.9)	0.88	(0.67 – 1.15)	.35
Depressive disorders	131	(4.2)	122	(4.2)	9	(4.4)	1.05	(0.55 – 2.00)	.87
Diabetes	678	(21.9)	633	(21.8)	45	(22.2)	1.02	(0.74 – 1.40)	.91
Disorders of lipid metabolism	1535	(49.5)	1447	(49.9)	88	(43.4)	0.78	(0.60 – 1.02)	.07
Hypertension	2178	(70.2)	2031	(70.1)	147	(72.4)	1.11	(0.83 – 1.50)	.48
Osteoarthritis	201	(6.5)	183	(6.3)	18	(8.9)	1.40	(0.88 – 2.23)	.15
Other thyroid disorders	254	(8.2)	236	(8.1)	18	(8.9)	1.09	(0.68 – 1.74)	.71
Tobacco-related disorder	1583	(51.1)	1490	(51.4)	93	(45.8)	0.81	(0.62 – 1.06)	.12
<i>Infections</i>									
Any Infection	94	(3.0)	85	(2.9)	9	(4.4)	1.48	(0.79 – 2.80)	.22
Cellulitis or abscess of leg/foot	1	(0.0)	1	(0.0)	0	(0.0)	--	--	--
Other infection	35	(1.1)	31	(1.1)	4	(2.0)	1.76	(0.69 – 4.47)	.24
Pneumonia	27	(0.9)	23	(0.8)	4	(2.0)	2.29	(0.92 – 5.71)	.08
Sepsis	14	(0.5)	12	(0.4)	2	(1.0)	2.19	(0.60 – 7.97)	.24
Surgical site infection	6	(0.2)	4	(0.1)	2	(1.0)	5.13	(1.64 – 16.0)	.007
Urinary tract infection	43	(1.4)	40	(1.4)	3	(1.5)	1.07	(0.36 – 3.20)	.90
<i>Other Complications</i>									
Complications with procedure	197	(6.4)	183	(6.3)	14	(6.9)	1.09	(0.65 – 1.84)	.74
Hemorrhage or hematoma	85	(2.7)	75	(2.6)	10	(4.9)	1.84	(1.01 – 3.34)	.04
Posthemorrhagic anemia	164	(5.3)	152	(5.2)	12	(5.9)	1.13	(0.64 – 1.97)	.68

*p-value based on chi-square comparison by readmission status.

EVAR = endovascular aneurysm repair. MI = myocardial infarction. COPD = chronic obstructive pulmonary disease

Table 4.

Association of diagnoses and conditions during the index hospital admission with readmission within 30 days for all patients undergoing open AAA repair [Frequency (Column percentage)]

	Overall (n = 1622)		Not Readmitted (n = 1470)		Readmitted (n = 152)		Relative risk of readmission		
	N	%	N	%	N	%	RR	(95% CI)	p-value*
<i>Acute Conditions</i>									
Arterial embolism and thrombosis	390	(24.0)	358	(24.3)	32	(21.0)	0.84	(0.58 – 1.22)	.36
Cardiac/MI	78	(4.8)	73	(4.9)	5	(3.2)	0.67	(0.28 – 1.59)	.35
Fluid and electrolyte disorders	444	(27.3)	399	(27.1)	45	(29.6)	1.12	(0.80 – 1.55)	.51
Renal failure	253	(15.6)	222	(15.1)	31	(20.3)	1.39	(0.96 – 2.01)	.08
Respiratory problems	381	(23.4)	338	(22.9)	43	(28.2)	1.29	(0.92 – 1.79)	.14
Other venous embolism/thrombosis	62	(3.8)	55	(3.7)	7	(4.6)	1.21	(0.59 – 2.48)	.59
<i>Chronic Conditions</i>									
Atrial fibrillation	168	(10.3)	151	(10.2)	17	(11.1)	1.09	(0.68 – 1.76)	.72
Anemia	220	(13.5)	196	(13.3)	24	(15.7)	1.19	(0.79 – 1.80)	.32
Chronic kidney disease	188	(11.5)	166	(11.2)	22	(14.4)	1.29	(0.84 – 1.98)	.24
COPD	425	(26.2)	383	(26.0)	42	(27.6)	1.08	(0.77 – 1.51)	.67
Other conduction disorders	41	(2.5)	39	(2.6)	2	(1.3)	0.51	(0.13 – 2.00)	.31
Congestive heart failure	124	(7.6)	103	(7.0)	21	(13.8)	1.94	(1.27 – 2.96)	.002
Chronic heart disease	618	(38.1)	553	(37.6)	65	(42.7)	1.21	(0.89 – 1.65)	.21
Depressive disorders	122	(7.5)	111	(7.5)	11	(7.2)	0.96	(0.53 – 1.72)	.88
Diabetes	417	(25.7)	373	(25.3)	44	(28.9)	1.18	(0.84 – 1.64)	.33
Disorders of lipid metabolism	816	(50.3)	741	(50.4)	75	(49.3)	0.96	(0.71 – 1.30)	.80
Hypertension	1111	(68.5)	1008	(68.5)	103	(67.7)	0.97	(0.70 – 1.34)	.83
Osteoarthritis	116	(7.1)	109	(7.4)	7	(4.6)	0.63	(0.30 – 1.31)	.20
Other thyroid disorders	108	(6.6)	97	(6.6)	11	(7.2)	1.09	(0.61 – 1.96)	.76
Tobacco-related disorder	1006	(62.0)	917	(62.3)	89	(58.5)	0.87	(0.64 – 1.18)	.35
<i>Infections</i>									
Any Infection	231	(14.2)	198	(13.4)	33	(21.7)	1.67	(1.17 – 2.39)	.005
Cellulitis or abscess of leg/foot	15	(0.9)	13	(0.8)	2	(1.3)	1.43	(0.39 – 5.24)	.59
Other infection	70	(4.3)	61	(4.1)	9	(5.9)	1.40	(0.74 – 2.62)	.30
Pneumonia	94	(5.8)	81	(5.5)	13	(8.5)	1.52	(0.90 – 2.58)	.12
Sepsis	56	(3.4)	45	(3.0)	11	(7.2)	2.18	(1.26 – 3.79)	.007
Surgical site infection	29	(1.7)	22	(1.5)	7	(4.6)	2.65	(1.37 – 5.15)	.005
Urinary tract infection	55	(3.3)	50	(3.4)	5	(3.2)	0.97	(0.41 – 2.27)	.94
<i>Other Complications</i>									
Complications with procedure	151	(9.3)	130	(8.8)	21	(13.8)	1.56	(1.02 – 2.40)	.04
Hemorrhage or hematoma	60	(3.7)	50	(3.4)	10	(6.5)	1.83	(1.02 – 3.30)	.04
Posthemorrhagic anemia	382	(23.5)	340	(23.1)	42	(27.6)	1.24	(0.89 – 1.74)	.21

*p-value based on chi-square comparison by readmission status.

AAA = abdominal aortic aneurysm. MI = myocardial infarction. COPD = chronic obstructive pulmonary disease

Table 5.

Association of diagnoses and conditions present at readmission for patients undergoing AAA procedure, by procedure type, open repair vs. EVAR [Frequency (column percentage)]

	Overall (n = 355)		Open (n = 152)		EVAR (n = 203)		Relative risk associated with EVAR during index stay		
	N	%	N	%	N	%	RR	95% CI	p-value
<i>Acute Conditions</i>									
Arterial embolism and thrombosis	17	(4.8)	3	(2.0)	14	(6.9)	1.47	(1.16 – 1.87)	.03
Cardiac/MI	21	(5.9)	4	(2.6)	17	(8.4)	1.45	(1.16 – 1.83)	.02
Fluid and electrolyte disorders	68	(19.2)	22	(14.5)	46	(22.7)	1.24	(1.02 – 1.50)	.05
Renal failure	50	(14.1)	16	(10.5)	34	(16.8)	1.23	(0.99 – 1.52)	.09
Respiratory problems	50	(14.1)	22	(14.5)	28	(13.8)	0.98	(0.75 – 1.27)	.85
Other venous embolism/thrombosis	21	(5.9)	8	(5.3)	13	(6.4)	1.08	(0.76 – 1.54)	.65
<i>Chronic Conditions</i>									
Atrial fibrillation	47	(13.2)	15	(9.9)	32	(15.8)	1.23	(0.98 – 1.53)	.10
Anemia	91	(25.6)	31	(20.4)	60	(29.6)	1.22	(1.01 – 1.46)	.05
Chronic kidney disease	72	(20.3)	22	(14.5)	50	(24.6)	1.28	(1.07 – 1.55)	.01
COPD	92	(25.9)	44	(29.0)	48	(23.7)	0.89	(0.71 – 1.10)	.25
Other conduction disorders	17	(4.8)	3	(2.0)	14	(6.9)	1.47	(1.16 – 1.87)	.03
Congestive heart failure	59	(16.6)	22	(14.5)	37	(18.2)	1.12	(0.90 – 1.39)	.34
Chronic heart disease	148	(41.7)	57	(37.5)	91	(44.8)	1.14	(0.95 – 1.36)	.16
Depressive disorders	25	(7.0)	14	(9.2)	11	(5.4)	0.76	(0.48 – 1.19)	.16
Diabetes	78	(22.0)	28	(18.4)	50	(24.6)	1.16	(0.95 – 1.41)	.16
Disorders of lipid metabolism	144	(40.6)	56	(36.8)	88	(43.4)	1.12	(0.94 – 1.34)	.21
Hypertension	225	(63.4)	89	(58.6)	136	(67.0)	1.17	(0.96 – 1.43)	.10
Osteoarthritis	27	(7.6)	11	(7.2)	16	(7.9)	1.04	(0.75 – 1.44)	.82
Other thyroid disorders	28	(7.9)	11	(7.2)	17	(8.4)	1.07	(0.78 – 1.46)	.69
Tobacco-related disorder	143	(40.3)	56	(36.8)	87	(42.9)	1.11	(0.93 – 1.33)	.25
<i>Infections</i>									
Any Infection	94	(26.5)	45	(29.6)	49	(24.1)	0.88	(0.71 – 1.10)	.24
Cellulitis/abscess of leg/foot	6	(1.7)	3	(2.0)	3	(1.5)	0.87	(0.39 – 1.95)	.71
Other infection	49	(13.8)	25	(16.5)	24	(11.8)	0.84	(0.62 – 1.13)	.21
Pneumonia	18	(5.1)	8	(5.3)	10	(4.9)	0.97	(0.64 – 1.48)	.88
Sepsis	26	(7.3)	9	(5.9)	17	(8.4)	1.16	(0.86 – 1.55)	.38
Surgical site infection	39	(11.0)	25	(16.5)	14	(6.9)	0.60	(0.39 – 0.92)	.004
Urinary tract infection	19	(5.4)	4	(2.6)	15	(7.4)	1.41	(1.10 – 1.81)	.04
<i>Other Complications</i>									
Complications with procedure	27	(7.6)	7	(4.6)	20	(9.9)	1.33	(1.04 – 1.69)	.06
Hemorrhage or hematoma	33	(9.3)	8	(5.3)	25	(12.3)	1.37	(1.10 – 1.70)	.02
Acute posthemorrhagic anemia	26	(7.3)	10	(6.6)	16	(7.9)	1.08	(0.79 – 1.49)	.64

*p-value based on chi-square comparison by procedure type. AAA = abdominal aortic aneurysm. MI = myocardial infarction. COPD = chronic obstructive pulmonary disease

Table 6.

Multivariable logistic regression of risk factors for 30-day readmission, overall and by AAA procedure type

	Overall (N = 355)		EVAR (n = 203)		Open (n = 152)	
	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Propensity score	2.97 (0.97 – 9.10)	.06				
Procedure type - EVAR	0.71 (0.54 – 0.92)	.009				
Age in years	1.03 (1.01 – 1.05)	.005	1.02 (1.01 – 1.04)	.01	1.00 (0.99 – 1.02)	.61
Race (reference = Caucasian)						
African American	1.45 (0.98 – 2.13)	.06	1.30 (0.74 – 2.29)	.36	1.47 (0.85 – 2.54)	.17
Other or unknown	0.73 (0.41 – 1.31)	.28	0.98 (0.50 – 1.93)	.96	0.44 (0.13 – 1.45)	.17
Male gender	0.84 (0.66 – 1.07)	.14	0.75 (0.54 – 1.05)	.09	0.91 (0.64 – 1.30)	.60
Charlson Index	1.12 (1.04 – 1.21)	.002	1.20 (1.09 – 1.33)	.001	0.97 (0.85 – 1.11)	.69
<i>Acute/Chronic Problems</i>						
Renal failure			1.64 (0.92 – 2.93)	.09		
Lipid metabolism			0.77 (0.56 – 1.04)	.09		
Chronic heart failure					2.18 (1.22 – 3.89)	.008
Tobacco-related disorder	0.80 (0.64 – 1.00)	.05				
<i>Other Complications</i>						
Surgical site infection	2.79 (1.25 – 6.22)	.01	5.62 (0.89 – 35.6)	.07	2.91 (1.17 – 7.28)	.02
Complications with procedure					1.66 (0.99 – 2.79)	.05
<i>Post-Operative Medications</i>						
Bronchodilators	1.34 (1.06 – 1.70)	.01	1.39 (1.03 – 1.88)	.03		
Statins	0.65 (0.52 – 0.82)	<.001	0.71 (0.53 – 0.96)	.02	0.55 (0.38 – 0.79)	.001
H2 blockers	0.76 (0.60 – 0.96)	.02				
Steroids	1.45 (1.04 – 2.02)	.03			1.92 (1.24 – 2.96)	.003
Vasodilators	0.78 (0.61 – 1.00)	.04	0.68 (0.48 – 0.95)	.02		
<i>Post-Operative Lab Results</i>						
Serum potassium (ref = normal)						
High (> 5.2)	1.89 (1.16 – 3.06)	.01	2.19 (1.01 – 4.74)	.05		
Low (< 3.7)	0.97 (0.76 – 1.25)	.83	1.01 (0.74 – 1.40)	.93		

OR = odds ratio; CI = confidence interval; EVAR = endovascular aneurysm repair