Frequency of 30-Day Readmission and Its Causes After Endovascular Aneurysm Intervention of Abdominal Aortic Aneurysm (from the Nationwide Readmission Database)

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Endovascular aneurysm intervention (EVAI) is one of the most commonly performed vascular interventions for abdominal aortic aneurysm (AAA). Data regarding 30-day readmission rates after EVAI are poorly reported in the literature. We used the United States Nationwide Readmission Database from 2010 to 2014 to identify all patients ≥18 years who were readmitted within 30 days after a hospital discharge for EVAI of the AAA. Incidence, etiologies, predictors of 30-day readmission, and trends of readmission rates were analyzed. In 138,014 patients who survived to discharge after an EVAI procedure for AAA, 14,146 (10.24%) were readmitted within 30 days. Median time to readmission was 11 days. Cardiac causes (16.34%) followed by infections (15.40%) and vascular complications (12.86%) were common etiologies of readmission. Greater patient age, female sex, coexisting co-morbidities such as heart failure, atrial fibrillation, peripheral vascular disease, lung disease, and chronic kidney disease were independent predictors of 30-day readmission. In-hospital complications during an index admission such as major bleeding or vascular complications were also predictive of 30-day readmission. Trend analysis showed a progressive decline in readmission rates from 11.3% in 2010 to 9.6% in 2014 (p_{trend} <0.0001), 20% lower odds in 2014 compared with 2010 (odds ratio 0.80, 95% confidence interval 0.72 to 0.87, p <0.0001). In this contemporary study of EVAI for AAA, nearly 1 in 10 patients was readmitted within 30 days of discharge after an index admission. Cardiac complications and infections were common causes of readmission within 30 days. **(Am J Cardiol 2019;123:986−994)**

One in 5 Medicare beneficiaries is readmitted within 30 days after hospital discharge, resulting in an annual financial burden of nearly US $26 billion on the United States (U.S.) economy.[1] The U.S. Center for Medicare and Medicaid Services adopted the hospital readmission reduction program to reduce readmissions in high-risk Medicare beneficiaries. The decrease in readmission rates after the implementation of hospital readmission reduction program may potentiate its expansion to other cardiovascular conditions such as vascular interventions which account for nearly 24% of readmissions in the Medicare beneficiaries.[2,3] A common vascular intervention in older patients is endovascular aneurysm intervention (EVAI) of the abdominal aortic aneurysm (AAA). Nearly 70% of the AAA repairs performed in the U.S. are covered through Medicare fee for service.[4] Although previous studies examined readmission rates after vascular interventions, data pertaining to EVAI of AAA at a national level are lacking. We sought to study the 30-day readmission rate in patients who underwent EVAI for AAA and to identify patients at high risk for readmission.

Methods

Data were obtained from the U.S. Healthcare Utilization Project's (HCUP) Nationwide Readmission Database (NRD), the largest publicly available all-payer inpatient database that collects information from 21 states in the U.S. with reliable and verified linkage numbers. The NRD represents nearly 50% of total U.S. hospitalizations. Patients were identified using the variable "NRD_visitlink" and

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time between 2 admissions was calculated by subtracting the variable "NRD_DaysToEvent." This has been recommended by HCUP.[5] The sampling weights provided by the sponsor allowed calculating national estimates. The design of NRD is available online at https://www.hcup-us.ahrq.gov/.[6] We queried the NRD years from 2010 to 2014 to create an index cohort of patients ≥18 years of age who had EVAI of an intact AAA using appropriate International classification of diseases, ninth revision, clinical modification (ICD-9 CM) codes. This was done by identifying cases with a diagnosis code for intact AAA (ICD-9 CM code 441.4) in any discharge diagnosis position and a procedure code for EVAI (ICD-9 CM code 39.71). To ensure that our study sample included only cases of intact AAA undergoing EVAI, we removed cases with concomitant diagnoses for AAA rupture (441.3), thoracic or thoracoabdominal aortic aneurysm (441.1, 441.2, 441.6, 441.7), aortic dissection (441.0), and procedure codes for open surgical aneurysm repair (38.44), aorto-iliac-femoral bypass (39.25), repair of the thoracic aorta (38.35, 38.45, 39.73), or visceral/renal bypass (38.46, 39.24, 39.26). Similar methods were used in previous studies.[7] We then excluded patients who did not survive the index hospitalization and those discharged after November to allow for a 30-day follow-up duration after discharge. The study design is presented in Figure 1. We used data in the NRD to identify patients' characteristics including age, sex, primary payer, admission type, admission day, discharge disposition, and hospital characteristics including bed size and teaching status.[8] Patients were categorized into 3 groups based on age: <75 years, 75 to 85 years, and >85 years. Clinically relevant co-morbidities were identified by ICD-9 CM codes and diagnosis-related groups on the day of discharge (Supplementary Table 1). These co-morbidities likely originated before hospital stay, but they are not directly related to the principal diagnosis or the main reason for admission. We defined the severity of co-morbid conditions by using the Deyo modification of the Charlson co-morbidity index (Supplementary Table 2).[9] The score ranges from 0 to 33, with higher scores corresponding to greater burden of co-morbid diseases. The bed size cut-off points were divided into small, medium, and large such that approximately one-third of the hospitals in each region, location, and teaching status combination would fall in each bed size category.[10] A hospital was considered a teaching facility if it was affiliated with an American Medical Association approved residency program or was a member of the council of teaching hospitals, or had a full-time equivalent resident to patient ratio of ≥0.25. We also evaluated length of stay provided by the NRD. Cost of hospitalization was calculated by merging cost to charge ratio provided by HCUP to main dataset and after adjusting for inflation.[11] The primary outcome was 30-day readmission. It was defined by any inpatient hospitalization within 30 days of discharge from an index hospitalization for

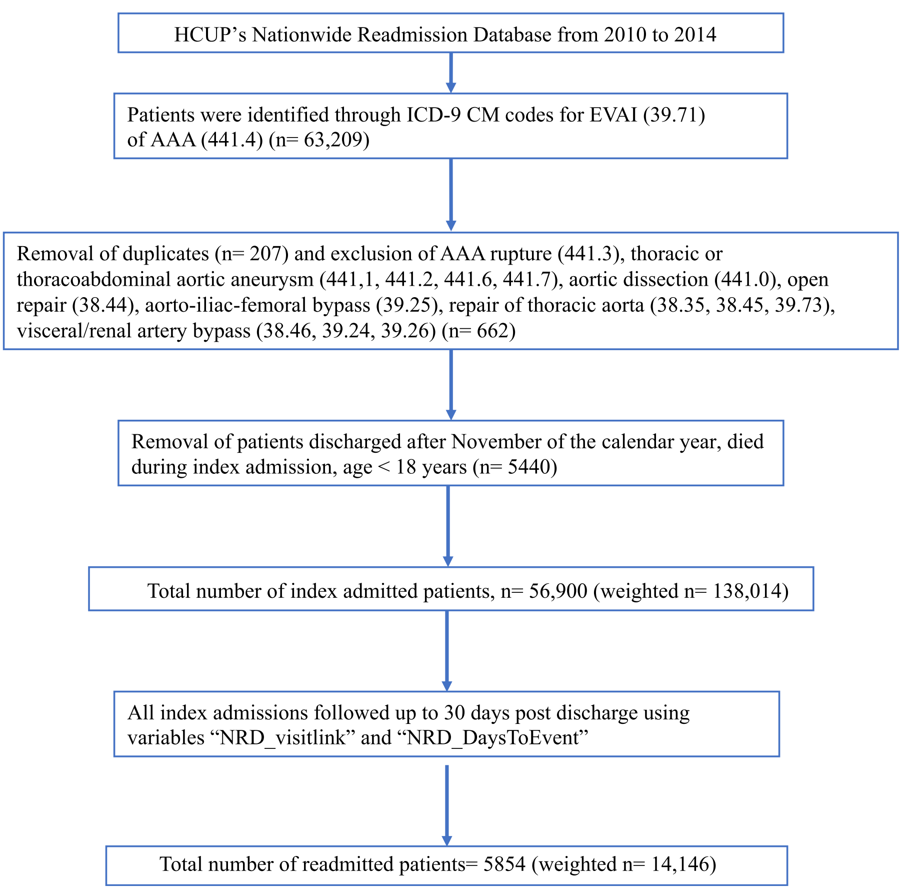

Figure 1. Study design and patient selection.

EVAI for AAA. The etiologies for 30-day readmission were identified using primary diagnosis categories and the corresponding HCUP clinical classification software. Independent predictors of readmission were analyzed as secondary outcomes. We followed survey-design-based methods suggested by the HCUP for statistical analyses. For descriptive analyses, chi-square and student *t* tests were used for categorical and continuous variables, respectively. To identify independent predictors of readmission events, we used hierarchical 2-level logistic regression models with each hospital as a random effect. These hierarchical or multilevel models take the effect of nesting of outcomes within hospitals into account. This method has been recommended by the HCUP and has been utilized in previous studies.[5,12] The multivariable model for readmission included hospital-level variables such as bed size and teaching status; patient-level variables such as age groups, gender, Charslon co-morbidity index (<3, ≥3), admission type (elective versus nonelective), admission day (weekend versus weekdays), and primary payer (private insurance and self-pay versus Medicaid/Medicare); clinical co-morbidities such as obesity, diabetes, peripheral vascular disease, chronic lung disease, renal failure, anemia or coagulation defects, depression or psychosis, or substance abuse; and disposition after index admission (long- or short-term facility versus home). The year was entered as a categorical variable in the multivariable logistic regression model to evaluate adjusted trends in 30-day readmission risk. SAS 9.4 (SAS Institute Inc, Cary, North Carolina) was used for all analyses. All p values are 2-sided with a significance threshold of $p < 0.05$. Categorical variables are expressed as percentages and continuous variables as mean (standard error [SE]). Results of logistic regression are reported as odds ratios and 95% confidence intervals.

Results

Our study included 138,014 adult patients who had an index hospitalization for an EVAI for AAA between 2010 and 2014, Table 1. Of them, 10.24% (14,146) were readmitted within 30 days after discharge. The population was predominantly male and most were <75 years of age, Table 1. Most were covered through Medicare/Medicaid. Readmitted patients had a higher burden of severe co-morbidities (Charlson co-morbidity index ≥3) compared with those who were not readmitted. Hypertension was the most common comorbidity in the readmitted patient population, and other co-morbidities included diabetes mellitus, heart failure, atrial fibrillation, and chronic renal failure. Patients discharged to facility after an index admission had higher risk of 30-day readmission. The in-hospital complications during index admission were higher in the readmitted population compared with those without readmission. The mean (SD) cost of index hospitalization for those with 30-day readmission was $35,779 ($21,518) compared with $29,858 ($15,619) for those without readmission ($p < 0.0001$). Cardiac conditions were the most common cause (16.34%) of readmission. In cardiac causes, heart failure was the most common (6.41%) followed by ischemic heart disease (3.80%) and arrhythmias (2.76%). The common noncardiac causes for readmission included infections (15.40%), vascular complications (12.86%), and renal complications (10.91%), Figure 2, Supplementary Table 3. Median time to 30-day readmission was 11 days, Figure 3. Trend analysis showed a progressive decrease in readmission rate from 11.3% in 2010 to 9.6% in 2014 ($p_{trend} < 0.0001$). In readmitted patients, 0.23% had repeat intervention and in-hospital mortality was 4.45%.

The results of multivariable hierarchical logistic regression analysis for predictors of 30-day readmission are presented in Table 2. The results showed that greater patient age, female gender, coexisting co-morbid conditions such as heart failure, atrial fibrillation, peripheral vascular disease, anemia, chronic obstructive pulmonary disease, and chronic kidney disease were predictive of readmission within 30 days. Patients discharged to home were less likely to be readmitted. Other factors such as the development of in-hospital complications including major bleeding, vascular complications, and acute kidney injury requiring dialysis were associated with a higher risk of readmission. After adjustment, the 30-day readmission rate in 2014 was 20% lower compared with 2010 (odds ratios 0.80, 95% CI: 0.72 to 0.87; $p < 0.0001$).

Discussion

Our study highlights several noteworthy findings related to 30-day readmission rate after EVAI of AAA in the U.S. First, approximately 1 in 10 patients was readmitted within 30 days of discharge and nearly 50% of these readmissions occurred by day 11 post discharge after the index hospitalization for EVAI of AAA. There was progressive decline in readmission rate from 2010 to 2014. Second, cardiac conditions, followed by infections, and vascular complications were common causes of readmission. Third, greater patient age, female gender, and co-morbidities such as heart failure, atrial fibrillation, peripheral vascular disease, anemia, and lung disease were predictive of readmission within 30 days.

AAAs are relatively common in the U.S. adults with an estimated prevalence of 9% in persons above the age of 65 years.[13] EVAI emerged as an alternative treatment for AAA after randomized controlled trials showed a lower risk of perioperative mortality when compared with open repair.[14-16] There has been a progressive increase in the utilization of EVAI with the expansion of its role for the treatment of ruptured AAA.[17] Readmission rates have been a topic of great interest over the last decade. The Medicare payment advisory commission identified vascular procedures as one of the seven categories accounting for nearly one-third of preventable readmissions.[18] Prior studies examined readmission rates after EVAI of AAA. However, they were either restricted to a specific patient population, used state-level databases, or studied readmission rates over a shorter duration of time.[19-21] Our study adds to the current literature by including national-level estimates over a 5-year period, making it the largest report to date.

The readmission rate in our study is comparable with the rates reported in the existing literature. In a recent study, Aridi et al reported a 30-day readmission rate of 10.4%

Table 1
Baseline characteristics of patients admitted for endovascular aneurysm intervention of abdominal aortic aneurysm

Variable	Readmitted within 30 days		Overall	p value
	No	Yes		
Index population	123,868	14,146	138,014	
Age (years)				<0.0001
<75	53.20%	44.99%	52.36%	
75-85	38.80%	44.10%	39.34%	
>85	8.00%	10.91%	8.30%	
Sex				<0.0001
Male	81.37%	74.07%	80.62%	
Female	18.63%	25.93%	19.38%	
Primary payer				<0.0001
Medicare/Medicaid	82.65%	86.99%	83.10%	
Private including HMO**	14.59%	10.85%	14.20%	
Self-pay/No charge/Other	2.39%	1.93%	2.34%	
Missing	0.37%	0.23%	0.36%	
Deyo/Charlson score‡				<0.0001
<3	77.97%	55.77%	75.79%	
≥3	22.03%	44.23%	24.21%	
Hypertension†	75.77%	76.74%	75.87%	0.01
Diabetes mellitus†	19.38%	21.63%	19.61%	<0.0001
Heart failure††	7.26%	14.60%	8.01%	<0.0001
Previous MI††	14.54%	15.95%	14.68%	<0.0001
Previous CABG††	16.89%	18.45%	17.05%	<0.0001
Previous stroke††	1.66%	2.20%	1.72%	<0.0001
Atrial fibrillation††	12.66%	19.77%	13.39%	<0.0001
Peripheral vascular diseases†	39.55%	47.81%	40.39%	<0.0001
Anemias†	8.11%	16.70%	8.99%	<0.0001
Coagulopathy†	3.89%	6.97%	4.21%	<0.0001
Chronic lung diseases†	30.44%	38.35%	31.25%	<0.0001
Chronic renal failure†	12.29%	22.74%	13.36%	<0.0001
Fluid and electrolyte disturbances†	7.44%	15.90%	8.31%	<0.0001
Neurological disorder or paralysis†	4.25%	6.20%	4.45%	<0.0001
Hospital characteristics				
Hospital bed size§				0.03
Small	7.69%	7.13%	7.63%	
Medium	19.53%	19.28%	19.50%	
Large	72.78%	73.59%	72.87%	
Hospital teaching status¶				0.03
Non-teaching	40.06%	39.15%	39.97%	
Teaching	59.94%	60.85%	60.03%	
Admission type				<0.0001
Non-elective	15.14%	23.54%	16.00%	
Elective	84.86%	76.46%	84.00%	
Admission day				<0.0001
Weekdays	97.37%	95.10%	97.14%	
Weekends	2.63%	4.90%	2.86%	
In hospital outcomes				
Major bleeding††	3.07%	6.61%	3.43%	<0.0001
Vascular complications††	7.14%	9.77%	7.41%	<0.0001
Stroke/TIA††	0.23%	0.56%	0.26%	<0.0001
Respiratory complications††	2.15%	5.13%	2.45%	<0.0001
Sepsis††	0.40%	1.39%	0.50%	<0.0001
AKI requiring dialysis††	0.19%	1.09%	0.29%	<0.0001
Disposition				<0.0001
Home	94.09%	85.20%	93.18%	
Facility/Others	5.81%	14.59%	6.71%	

(*continued*)

Table 1 (***Continued***)

Variable	Readmitted within 30 days		Overall	p value
	No	Yes		
Length of stay (Mean ± Std err)	2.8 ± 0.02	5.0 ± 0.09	3.1 ± 0.02	<0.0001
Cost (Mean ± SD)[¶]	29858 ± 15619	35779 ± 21518	30471 ± 16429	<0.0001

AKI = acute kidney injury; CABG = coronary artery bypass grafting; MI = myocardial infarction; SD = standard deviation; Stderr = standard error; TIA = transient ischemic attack.

[†] Variables are AHRQ co-morbidity measures.

[‡] Charlson/Deyo co-morbidity index (CCI) was calculated as per Deyo classification.

[§] The bed size cut-off points divided into small, medium, and large have been done so that approximately one-third of the hospitals in a given region, location, and teaching status combination would fall within each bed size category. https://www.hcup-us.ahrq.gov/db/vars/hosp_bedsize/nrdnote.jsp

[¶] A hospital is considered to be a teaching hospital if it has an AMA-approved residency program, is a member of the Council of Teaching Hospitals (COTH) or has a ratio of full-time equivalent interns and residents to beds of 0.25 or higher. https://www.hcup-us.ahrq.gov/db/vars/hosp_ur_teach/nrdnote.jsp

** HMO = Health maintenance organization

[††] Other primary diagnosis: derived from appropriate ICD 9CM code mentioned in Supplementary Table 3.

utilizing the Premier healthcare database.[20] Greenblatt et al utilized a 5% random sample from the Medicare beneficiaries and reported readmission rate of 13.3%.[19] Vogel et al reported a 30-day readmission rate of 11.6% utilizing the Washington State administrative discharge database.[21] In another study, Jackson et al reported a very low 30-day readmission rate of 4.9%.[22] Although EVAI is an alternative therapeutic option for AAA in patients deemed to be at high risk for surgery, subsequent re-interventions are more likely due to complications related to the vascular access site.[23] This finding was also evident in our study with complications related to vascular device/implant being one of the most common causes for readmission. In the study by Greenblatt et al, wound complications were the most common causes for readmission.[19] Infections were the most common causes for readmission in the study by Aridi et al.[20] In contrast, cardiac conditions were the most common causes of readmission in our study. The association between AAA and cardiac co-morbidities has been recognized and appreciated for years.[7,24,25] The fact that these two conditions share so many common risk factors likely explains their frequent coexistence. In cardiac co-morbidities, heart failure was the most common cause of readmission in our study. Due to inherent limitations in the dataset, we were unable to distinguish whether any patients admitted with heart failure following EVAI had carried the diagnosis prior to the treatment. Other studies demonstrated that patients with a preexisting diagnosis of heart failure were more likely to require readmission with the same diagnosis.[26,27] These findings are of importance as the current readmission reduction program counts any readmission irrespective of the cause to penalize hospitals.[3,28] Given the

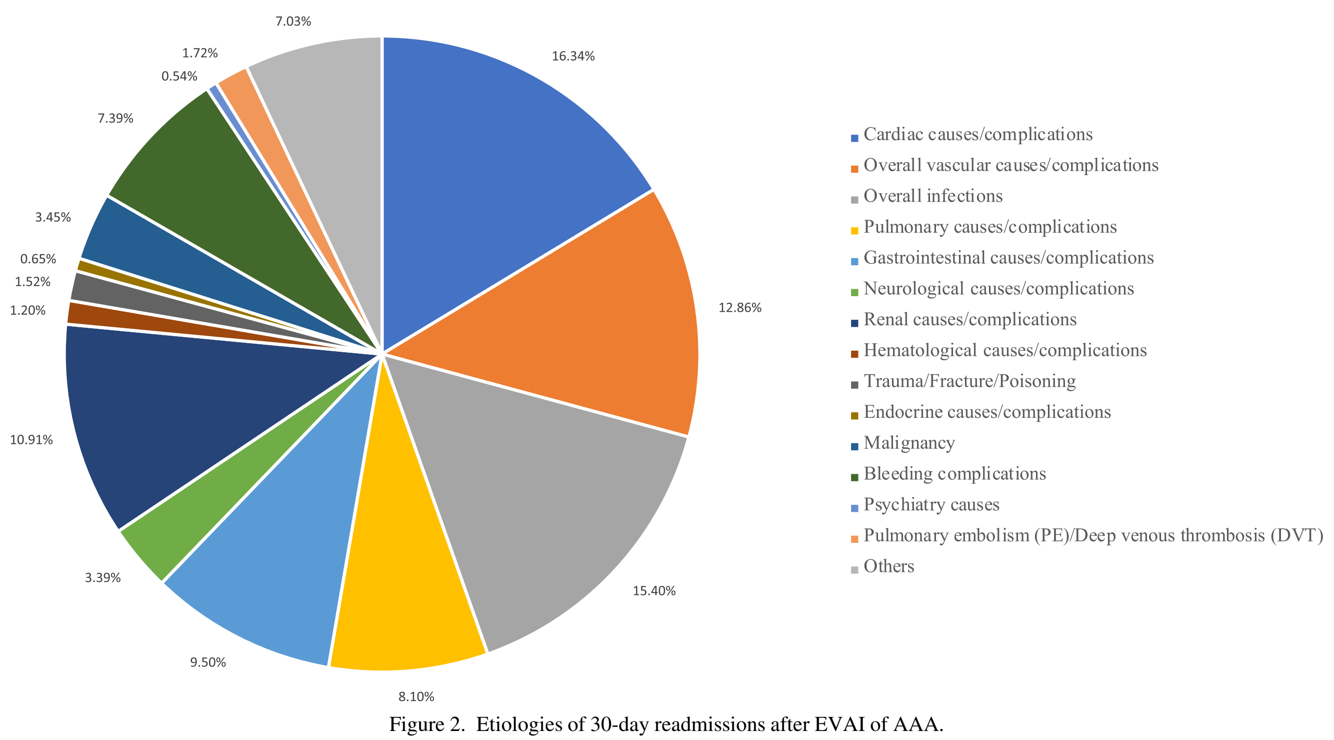

Figure 2. Etiologies of 30-day readmissions after EVAI of AAA.

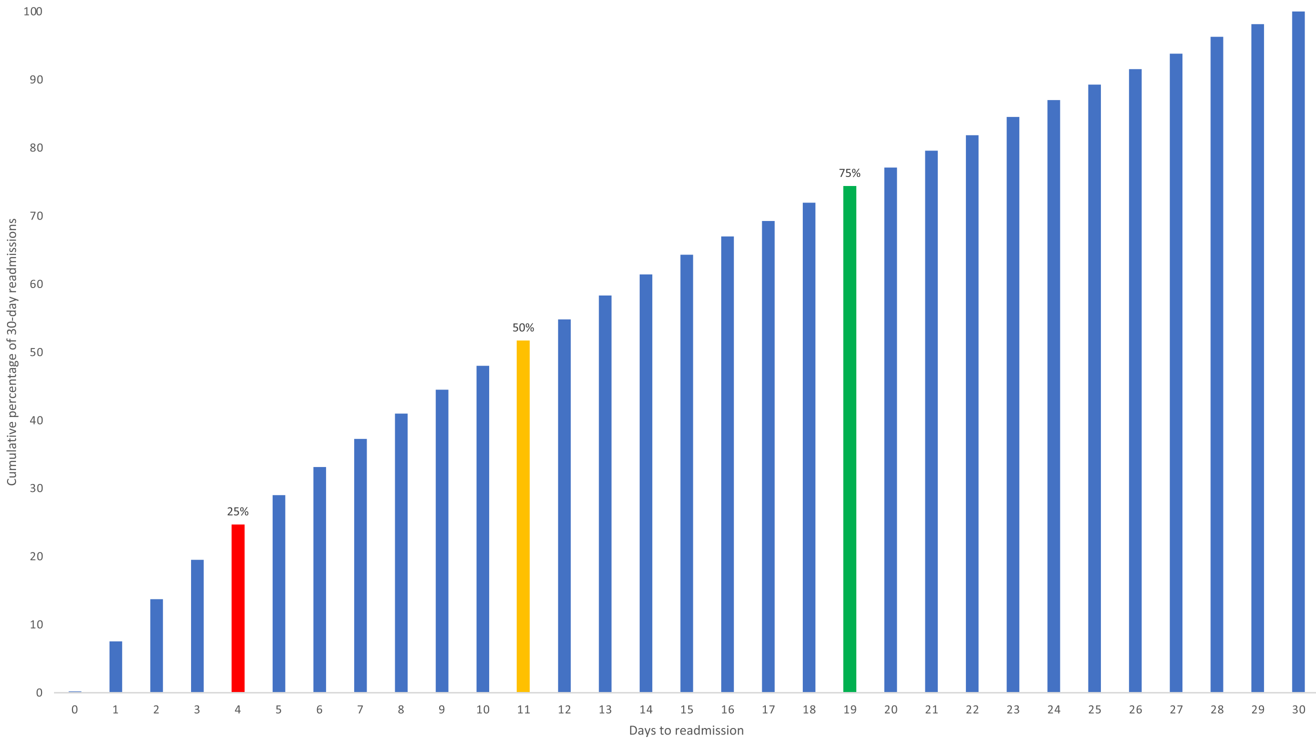

Figure 3. Trends of 30-day readmissions after EVAI.

findings of our study, the question remains whether hospitals should be penalized for patients readmitted following major surgical procedures such as EVAI, if the patients have pre-existing co-morbidities that may predispose them to readmission, perhaps even irrespective of surgery.

We were able to confirm the association between the presence of diabetes, advanced age, and subsequent readmission reported in prior studies.[22,29] A complicated in-hospital course during the time of EVAI such as major bleeding, vascular complications, and acute kidney injury requiring dialysis significantly predicted a higher risk of readmission after discharge. Another finding in our study is the progressive decrease in 30-day readmission rate from 2010 to 2014. The advancement of operator experience, evolution of EVAI procedural technique and technology, better patient selection, and increased awareness of financial penalties may have contributed to the observed decline in 30-day readmission rate during our study period. Finally, our results support the need for future, prospective studies to investigate the preventability of 30-day readmissions after EVAI and also the development of readmission risk prediction models that can identify patients at increased risk.

The findings of our study should be interpreted in the context of the following limitations. NRD is an administrative database that relies heavily on the ICD-9 CM codes; thus, there is a possibility of risk of errors in data due to variations in coding practices. Only data related to readmission within 30 days after index hospitalizations are available. Information related to longitudinal follow-up of these patients is not available. NRD does not include deaths out of the hospital or in the emergency room. Data related to race and ethnicity are not reported in the NRD. Individual operator and procedure level data are not available. Other factors which can affect a patient's prognosis such as drugs and imaging studies are not included in the database as well. Data related to severity of co-morbidities which could affect a patient's prognosis are not included. Also, the indications for nonelective/emergent admissions are not available. Although NRD collects discharge information from 21 states across the U.S. with sample weights that allows calculation of national estimates, the generalizability of our results may be somewhat limited. The large sample size included in our study can partially offset some of these limitations and the real-world clinical experience can add to the current existing literature.

In this large real-world study, 1 in 10 patients who underwent EVAI for AAA was readmitted within 30 days after the index hospitalization. Cardiac conditions, infections, and vascular complications were the most common causes for readmission, highlighting the importance of procedural optimization and appropriate periprocedural care. Other predisposing factors included female sex, complicated hospital course, and discharge to an extended care facility. There has been a progressive decrease in 30-day readmission rates during our study period.

Ethical Approval

The manuscript has not been submitted or is under consideration elsewhere in any other journal.

No data have been fabricated or manipulated. Consent to submit has been received explicitly from all coauthors.

Table 2
Multivariable predictors of readmission within 30 days after endovascular aneurysm intervention of abdominal aortic aneurysm

	Odds ratio	LL	UL	p value
Variable				
Year				
2010	Referent	Referent	Referent	
2011	0.97	0.89	1.06	0.5
2012	0.86	0.78	0.94	0.002
2013	0.76	0.70	0.84	<0.0001
2014	0.80	0.72	0.87	<0.0001
Age (years)				
<75	Referent	Referent	Referent	
75-85	1.11	1.05	1.19	0.001
>85	1.19	1.07	1.31	0.001
Sex				
Male	Referent	Referent	Referent	
Female	1.31	1.22	1.40	<0.0001
Primary payer				
Medicare/Medicaid	Referent	Referent	Referent	
Private including HMO**	0.91	0.83	1.00	0.05
Self-pay/No charge/Other	0.99	0.81	1.20	0.8
Deyo/Charlson score[‡]				
<3	Referent	Referent	Referent	
≥3	1.32	1.21	1.45	<0.0001
Hypertension[†]	0.97	0.91	1.04	0.3
Diabetes mellitus[†]	1.03	0.96	1.11	0.3
Heart failure[††]	1.31	1.20	1.44	<0.0001
Previous MI[††]	1.02	0.94	1.10	0.6
Previous CABG[††]	1.06	0.98	1.14	0.1
Previous stroke[††]	0.96	0.78	1.16	0.6
Atrial fibrillation[††]	1.25	1.16	1.35	<0.0001
Peripheral vascular diseases[†]	1.16	1.10	1.23	<0.0001
Anemias[†]	1.41	1.29	1.53	<.0001
Coagulopathy[†]	1.11	0.99	1.25	0.08
Chronic lung diseases[†]	1.17	1.10	1.25	<0.0001
Chronic renal failure[†]	1.21	1.10	1.33	<0.0001
Fluid and electrolyte disturbances[†]	1.33	1.21	1.45	<0.0001
Neurological disorder or paralysis[†]	1.07	0.94	1.22	0.2
Hospital characteristics				
Hospital bed size[§]				
Small	Referent	Referent	Referent	
Medium	1.05	0.92	1.20	0.4
Large	1.05	0.93	1.19	0.4
Hospital teaching status[¶]				
Nonteaching	Referent	Referent	Referent	
Teaching	1.02	0.96	1.08	0.5
Admission type				
Nonelective	Referent	Referent	Referent	
Elective	0.74	0.69	0.80	<0.0001
Admission day				
Weekdays	Referent	Referent	Referent	
Weekends	1.11	0.96	1.28	0.1
In hospital outcomes				
Major bleeding[††]	1.17	1.03	1.32	0.01
Vascular complications[††]	1.16	1.05	1.28	0.004
Stroke/TIA[††]	0.93	0.61	1.42	0.7
Respiratory complications[††]	1.10	0.95	1.28	0.2
Sepsis[††]	1.24	0.95	1.64	0.1
AKI requiring dialysis[††]	2.09	1.51	2.88	<0.0001

(continued)

Table 2 (***Continued***)

	Odds ratio	LL	UL	p value
Disposition				
Home	Referent	Referent	Referent	
Facility/Others	1.63	1.49	1.79	<0.0001

AKI = acute kidney injury; CABG = coronary artery bypass grafting; MI = Myocardial infarction; SD = standard deviation, Stderr = standard error; TIA = transient ischemic attack.

† Variables are AHRQ co-morbidity measures.

‡ Charlson/Deyo co-morbidity index (CCI) was calculated as per Deyo classification.

§ The bed size cut-off points divided into small, medium, and large have been done so that approximately one-third of the hospitals in a given region, location, and teaching status combination would fall within each bed size category. https://www.hcup-us.ahrq.gov/db/vars/hosp_bedsize/nrdnote.jsp

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†† Other primary diagnosis: derived from appropriate ICD 9CM code mentioned in Supplementary Table 3.

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Supplementary materials

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