ELSEVIER

Characterizing Reimbursements for Medicare Patients Receiving Endovascular Abdominal Aortic Aneurysm Repair at Vascular Quality Initiative Centers

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Background: Endovascular aortic aneurysm repair (EVR) has a major financial impact on health care systems. We characterized reimbursement for index EVR hospitalizations among Medicare beneficiaries having surgery at Vascular Quality Initiative (VQI) centers.

Methods: We linked Medicare claims to VQI clinical registry data for patients undergoing EVR from 2003 to 2015. Analysis was limited to patients fully covered by fee-for-service Medicare parts A and B in the year of their operation and assigned a corresponding diagnosis-related group for EVR. The primary outcome was Medicare's reimbursement for inpatient hospital and professional services, adjusted to 2015 dollars. We performed descriptive analysis of reimbursement over time and univariate analysis to evaluate patient demographics, clinical characteristics, procedural variables, and postoperative events associated with reimbursement. This informed a multilevel regression model used to identify factors independently associated with EVR reimbursement and quantify VQI center-level variation in reimbursement.

Results: We studied 9,403 Medicare patients who underwent EVR at VQI centers during the study period. Reimbursements declined from \$37,450 ± \$9,350 (mean ± standard deviation) in 2003 to \$27,723 ± \$10,613 in 2015 (test for trend, $P < 0.001$). For patients experiencing a complication ($n = 773$; 8.2%), mean reimbursement for EVR was \$44,858 ± \$23,825 versus \$28,857 ± \$9,258 for those without complications ($P < 0.001$). Intestinal ischemia, new dialysis requirement, and respiratory compromise each doubled Medicare's average reimbursement for EVR. After adjusting for diagnosis-related group, several patient-level factors were independently associated with higher Medicare reimbursement; these included ruptured abdominal aortic aneurysm (+\$2,372), additional day in length of stay (+\$1,275), and being unfit for open

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repair (+$501). Controlling for patient-level factors, 4-fold variation in average reimbursement was seen across VQI centers.
Conclusions: Reimbursement for EVR declined between 2003 and 2015. We identified preoperative clinical factors independently associated with reimbursement and quantified the impact of different postoperative complications on reimbursement. More work is needed to better understand the substantial variation observed in reimbursement at the center level.

INTRODUCTION

Endovascular aortic aneurysm repair (EVR) of abdominal aortic aneurysms (AAAs) was approved by the US Food and Drug Administration in 1999. Adoption and dissemination of this technology has been rapid, increasing from 5% to 75% of AAA repairs between 2000 and 2010.[1,2] Most EVR patients are older than 65 years, and more than 23,000 EVR procedures were performed in the Medicare population in 2013.[1,2] As increasing attention is given to controlling the rising cost of health care, a better understanding of spending on EVR procedures is needed.[3] Medicare data are well suited for studying this population.

Initially, studies examined the direct costs of EVR using hospital accounting systems and found that about half of EVR cost is tied to devices that approach $10,000 per graft.[4–6] More recently, population-based studies have described the epidemiology of EVR, noting a gradual decline in both cost and perioperative morbidity.[1,7] However, little is known about how patient factors might affect cost and subsequent reimbursement from insurers. The extent of variation in reimbursement for providers performing EVR is also poorly understood.

In this study, we examine Medicare patients who underwent EVR at Vascular Quality Initiative (VQI) centers between 2003 and 2015. We describe temporal trends in reimbursement for EVR and, leveraging VQI clinical registry data, explore demographic, clinical, procedural, and postoperative factors associated with reimbursement for EVR. We also characterize the extent of variation in reimbursement at the level of VQI centers. Our hypothesis is that clinically relevant patient factors are independently associated with reimbursement for EVR, but that these factors fail to explain why some centers receive far greater reimbursement than others do.

MATERIALS AND METHODS

Data Source

The VQI was launched by the Society for Vascular Surgery to improve the quality, safety, effectiveness, and cost of vascular health care.[8] More than 500 centers in the United States and Canada contribute validated data to this registry (https://www.vqi.org/). The VQI data set was used to identify patients receiving EVR between January 2003 and September 2015 and associated information on preoperative risk factors, procedural characteristics, and postoperative events.

These patients were linked to Medicare claims using an established social security number to beneficiary identifier crosswalk.[9] Medicare claims were used to identify age, gender, race, date of surgery, dual eligibility for Medicaid, diagnosis-related group (DRG) assignment, and reimbursement amount. Use of these claims was pursuant to a data use agreement with the Centers for Medicare and Medicaid Services (CMS), and institutional review board approval was obtained from the Dartmouth College Committee for Protection of Human Subjects with waiver of informed consent. Any data points generated from fewer than 11 beneficiaries were suppressed from data presentation per CMS requirements.

Study Population and Outcomes

The cohort selection process is outlined in Figure 1. We used a 100% sample of Medicare beneficiaries and Medicare Provider Analysis and Review claims for short-term inpatient hospital services to ensure there was a corresponding claim for EVR. EVR claims were identified using a previously validated list of *International Classification of Diseases, Ninth Edition* (*ICD-9*) procedure codes (*ICD-9-Clinical Modification*: 39.71–79, 39.90).[9] Patients were excluded if they had EVR previously or were not fully fee-for-service and eligible for Medicare parts A and B throughout the year of their operation. Given the fundamental role of DRG coding when examining Medicare reimbursement, we excluded patients who were not billed under the primary DRGs used for EVR, which in 2008 changed from 110 to 111 (major vessel operation except heart, with and without major comorbidity or complication [MCC], respectively) to 237 and 238 (major cardiovascular procedures, with and without MCC, respectively). A

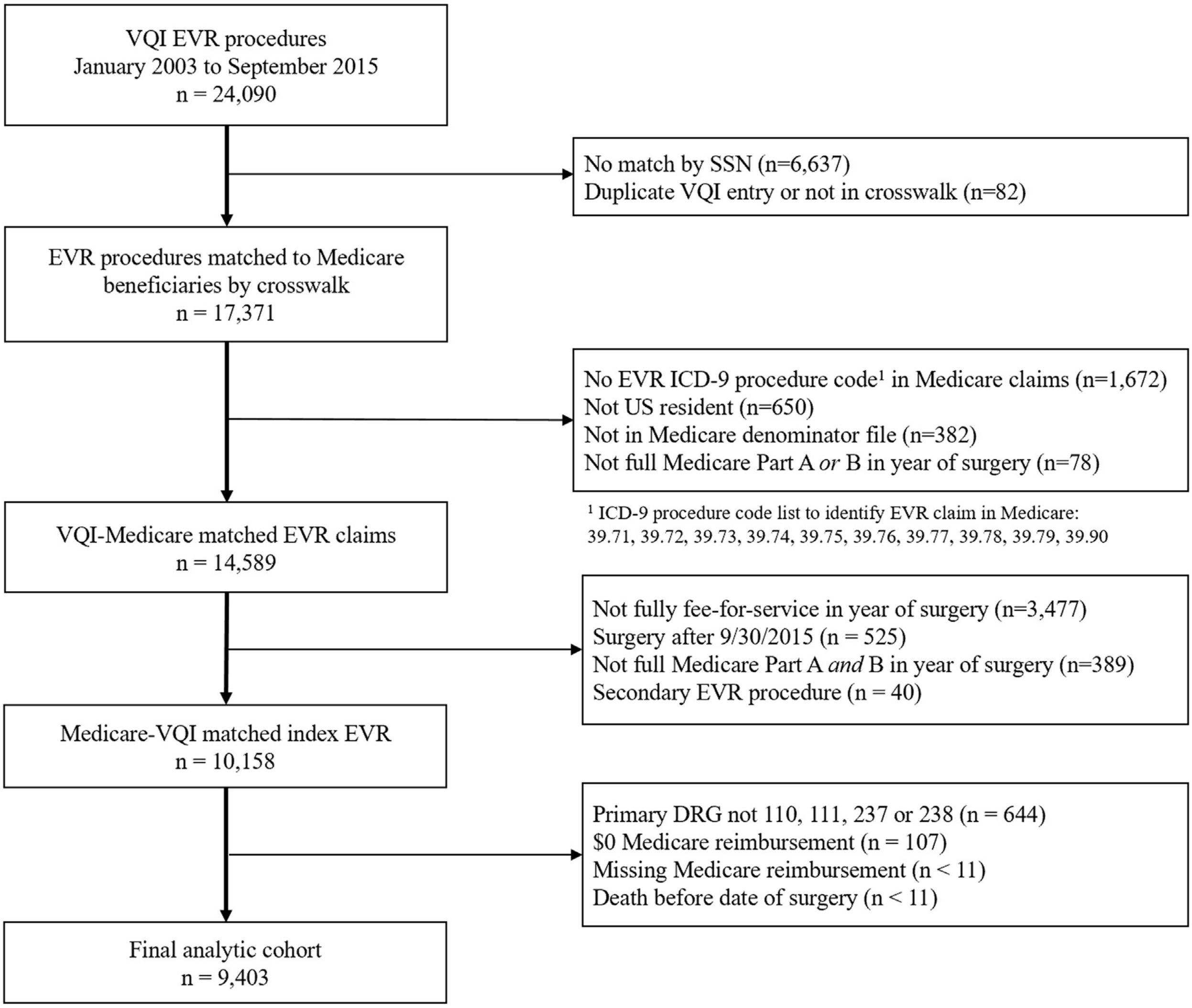


Fig. 1. Cohort selection flowchart. SSN, social security number.

small number of patients (n = 107) had no reimbursement associated with their index operation and were excluded.

Variable Definitions

Our primary outcome was the actual reimbursement amount from Medicare for the EVR surgery and associated hospitalization. This amount was calculated by summing the Medicare facility payment (part A), pass-through amount (temporary add-on fees for innovative technologies) and professional services payment (part B). Reimbursements were adjusted to 2015 US dollars using the Bureau of Labor Statistics Consumer Price Index for Medical Care Services.[10] Patient demographics, preoperative clinical characteristics, as well as procedural and postoperative variables that were included in the analysis are shown in Tables I and II.

Statistical Analyses

We first performed descriptive analyses of mean reimbursement for EVR over time and variation in reimbursement at the level of VQI center, stratified by DRG assignment. Temporal trends were assessed using a nonparametric test of trend. We then evaluated for univariate differences in Medicare reimbursements across demographic, preoperative, procedural, and postoperative factors using Student's t-test for dichotomous covariates and one-way analysis of variance for categorical covariates. All variables that demonstrated a significant difference in mean reimbursement on univariate analysis ($P < 0.05$) were included in a multilevel linear

Table I. Medicare reimbursement for EVR by demographic and preoperative clinical factors

Variable	n = 9,403 (%)	Mean reimbursement ($)	Standard deviation ($)	P
Demographics				
Age (years)				<0.0001
Younger than 65	349 (3.7)	30,167	12,044	
65–74	3,785 (40.3)	29,218	12,680	
75–84	4,008 (42.6)	30,420	11,150	
85 and older	1,261 (13.4)	32,251	12,386	
Gender				0.0001
Male	7,477 (79.5)	29,932	12,085	
Female	1,926 (20.5)	31,104	11,744	
Race				0.0003
White	8,673 (92.2)	30,033	11,897	
Black	358 (3.8)	32,255	14,612	
Hispanic	160 (1.7)	30,814	12,185	
Other	174 (1.9)	32,723	12,278	
Unknown	38 (0.4)	28,006	9021	
Dual eligible				<0.0001
No	8,721 (92.7)	29,883	11,560	
Yes	682 (7.3)	33,867	16,441	
Clinical factors				
Smoking				0.0001
Never	1,521 (16.2)	31,255	13,326	
Prior	5,348 (56.9)	29,788	10,821	
Current	2,483 (26.4)	30,247	13,528	
BMI, kg/m^2				0.492
<18.5	240 (2.6)	30,768	11,185	
18.5–30	6,379 (67.8)	30,103	11,823	
>30	2,621 (27.9)	29,893	12,525	
Diabetes				0.626
No	7,943 (84.5)	30,174	11,872	
Yes	1,408 (15.0)	30,004	12,908	
Prior CAD				0.484
No MI history	6,543 (69.6)	30,065	12,299	
MI history, asymptomatic	2,110 (22.4)	30,264	11,349	
Angina (stable or unstable)	696 (7.4)	30,590	11,450	
COPD				0.007
No	7,286 (77.5)	29,959	12,249	
Yes	2,060 (21.9)	30,773	11,128	
CHF				<0.0001
No	8,201 (87.2)	29,772	11,803	
Asymptomatic history	660 (7.0)	31,800	12,605	
Mild to severe	489 (5.2)	34,246	13,954	
Dialysis				<0.0001
No	9,231 (98.2)	29,964	11,853	
Yes	128 (1.4)	44,281	16,115	
Iliac aneurysm				0.0002
No	7,081 (75.3)	29,922	11,983	
Yes	2,125 (22.6)	31,043	12,212	
Unfit for open repair				<0.0001
No	7,537 (80.2)	29,310	11,284	
Yes	1,738 (18.5)	34,042	14,300	

BMI, body mass index; CAD, coronary artery disease; MI, myocardial infarction.

regression model with clustering at the center level to identify factors independently associated with reimbursement for EVR.

The benefit of a multilevel model for this analysis was the ability to isolate the extent of variation in reimbursements occurring at the center level from

Table II. Medicare reimbursement for EVR by procedural and postoperative characteristics

Variable	*n* = 9,403 (%)	Mean reimbursement ($)	Standard deviation ($)	*P*
Procedural				
Quintile of VQI center volume[a]				<0.0001
Bottom quintile	149 (1.6)	30,532	13,378	
Middle 60%	3715 (39.5)	28,374	11,700	
Top quintile	5539 (58.9)	31,369	12,053	
Urgency				<0.0001
Elective	8300 (88.3)	29,185	10,462	
Symptomatic	668 (7.1)	33,533	13,878	
Ruptured	384 (4.1)	45,310	23,522	
Procedure time (min)				<0.0001
<180	7198 (76.6)	28,537	10,182	
≥180	2113 (22.5)	35,659	15,730	
Intraoperative RBC transfusion				<0.0001
No	8407 (89.4)	28,992	9,775	
Yes	834 (8.9)	42,250	22,182	
Graft manufacturer				0.0012
Graft A	1834 (19.5)	31,065	11,474	
Graft B	5450 (58.0)	29,886	12,503	
Graft D	1566 (16.7)	30,413	11,436	
Graft E	260 (2.8)	28,046	9,936	
Graft F	21 (0.2)	30,926	13,249	
Graft G	92 (1.0)	28,870	10,714	
Other	19 (0.2)	32,617	8,023	
Postoperative				
Length of stay (days)				<0.0001
<4	7416 (78.9)	27,692	7,735	
≥4	1987 (21.1)	39,440	18,772	
Complication				<0.0001
Any	773 (8.2)	44,858	23,825	
None	8630 (91.8)	28,857	9,258	

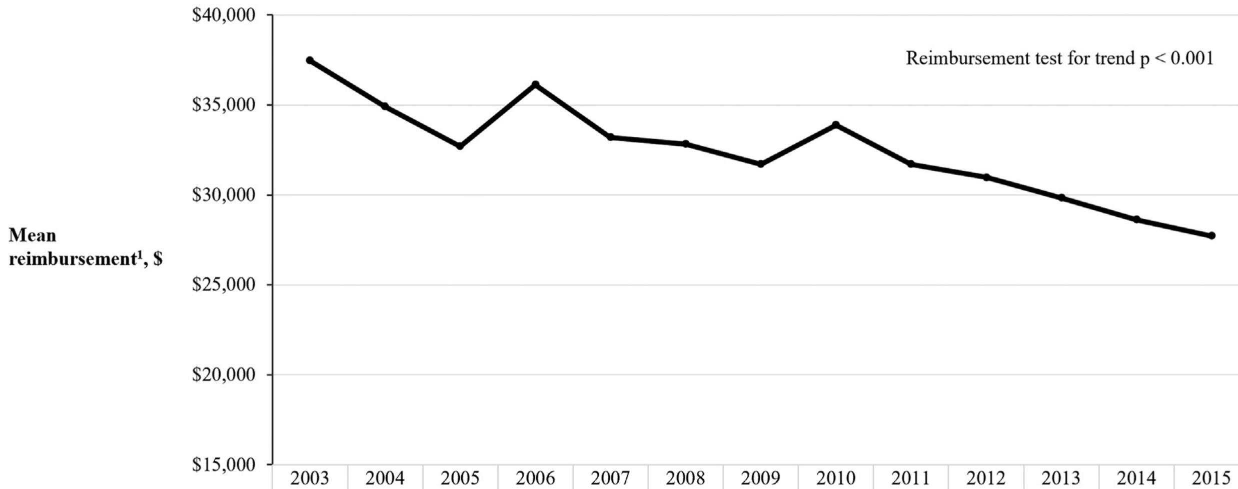
RBC, red blood cell.
[a]Mean volume = 56 ± 76 EVR per center. Bottom quintile = 6 ± 2 EVR and top quintile = 234 ± 151 EVR.

those attributable to patient-level characteristics.[11] Furthermore, we constructed the model in stepwise fashion (demographic, preoperative, procedural, and postoperative factors) to estimate the relative explanatory power from each set of variables with respect to eventual reimbursement. Finally, we performed 2 sensitivity analyses for the final model by excluding DRG code and excluding outliers in the bottom (<$3,675) or top (>$72,911) 1% of reimbursements. All statistical analyses were performed using Stata, version 15.1 (StataCorp 2017; StataCorp LP, College Station, TX).

RESULTS

Cohort Demographics

The analytic cohort consisted of 9,403 patients undergoing index EVR. Mean age at surgery was 76.4 ± 7.4 years, 79.5% were male, 92.2% white, and 7.3% dual eligible for Medicaid. In terms of preoperative clinical factors, average body mass index was 27.6 ± 5.5 kg/m^2, most patients (56.9%) were prior smokers, 30.4% had coronary artery disease, 21.9% were being treated for chronic obstructive pulmonary disease (COPD), 15.0% were receiving therapy for diabetes, 5.2% had symptomatic congestive heart failure (CHF), and 1.4% were on dialysis. Concomitant iliac aneurysm was present in 22.6%, and 18.5% of patients were deemed unfit for open AAA repair. The vast majority of EVR operations were elective (88.3%), with 7.1% performed on symptomatic patients and 4.1% in the setting of rupture. Three graft manufacturers accounted for almost 95% of cases (58% graft B, 20% graft A, and 17% graft D). Mean procedure time was 142 ± 72 min with 8.9% requiring intraoperative blood transfusion. Mean length of stay was



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
n (N=9,403)	101	84	103	148	176	163	198	440	947	1461	1884	2101	1597
Mean reimbursement, $	$37,450	$34,895	$32,704	$36,128	$33,194	$32,830	$31,701	$33,887	$31,700	$30,979	$29,838	$28,620	$27,723

[1] Adjusted to 2015 dollars

Fig. 2. Temporal trend in reimbursement over study period.

2.8 ± 3.9 days, 8.2% experienced any complication in the VQI database, and in-hospital mortality was 1.6%.

Temporal Trends in Reimbursement and DRG Coding

Average reimbursement for EVR during the study period was $30,172 ± $12,025 (mean ± standard deviation) and declined from $37,450 in 2003 to $27,723 in 2015 (test for trend, $P < 0.001$; Fig. 2). The mean reimbursement for hospital services through Medicare part A was $26,975 ± $10,735, for professional services through Medicare part B was $2835 ± $1463, and for pass-through payments was $424 ± $1,008. Reimbursement for both hospital and professional services declined at similar rates during the study period, whereas pass-through payments remained stable. DRG codes for EVR changed in 2008 from 110/111 to 237/238. Before 2008, most procedures (56−71%) were coded as having MCC, whereas only 10−14% of procedures were assigned a DRG with MCC after the change. Mean reimbursement for each DRG is provided in Table III.

VQI Center-Level Reimbursement

Average reimbursements were calculated for each VQI center and stratified based on DRG assignment. Center-level reimbursement ranged from $20,123 to $46,211 for EVR without MCC and from $31,156 to $62,202 for EVR with MCC. This did not include outlier centers with fewer than 11 patients, in which case we saw 4-fold crude variation in reimbursement for procedures assigned a DRG with MCC. Center-level variation in reimbursement was similar for both hospital and professional services. For example, among EVR without MCC, the range of hospital services reimbursement was $17,340 to $42,313 and for professional services was $1,661 to $4,345. However, 1 in 4 centers secured no additional pass-through payment for performing EVR, whereas 10% of centers received between $900 and $2,400 in average pass-through reimbursement. Similarly, among EVR patients with MCC, 1 in 5 centers received no additional pass-through payment, whereas 25% of centers received between $1,500 and $4,000 in additional pass-through reimbursement.

Univariate Analysis of Clinical Factors

Patient demographics and comorbidity profile align with previous studies of EVR patients in Medicare (Table I). Demographic groups with the highest mean reimbursement were those aged 85 years and older ($32,251 ± $12,386), female gender ($31,104 ± $12,386), black or other race ($32,255 ± $14,612 and $32,723 ± $12,278, respectively), and dual-eligible patients ($33,867 ± $16,411). Preoperative clinical characteristics with the largest differences in reimbursement were patients on dialysis ($44,281 vs.

Table III. Medicare reimbursement by DRG code

DRG	n = 9,403 (%)	Mean reimbursement ($)	Standard deviation ($)
Without MCC			
111 (2003–2007)	197 (2.1)	24,428	4,036
238 (2008–2013)	7859 (83.6)	27,436	7,272
With MCC			
110 (2003–2007)	378 (4.0)	40,121	7,900
237 (2008–2013)	969 (10.3)	49,652	21,483

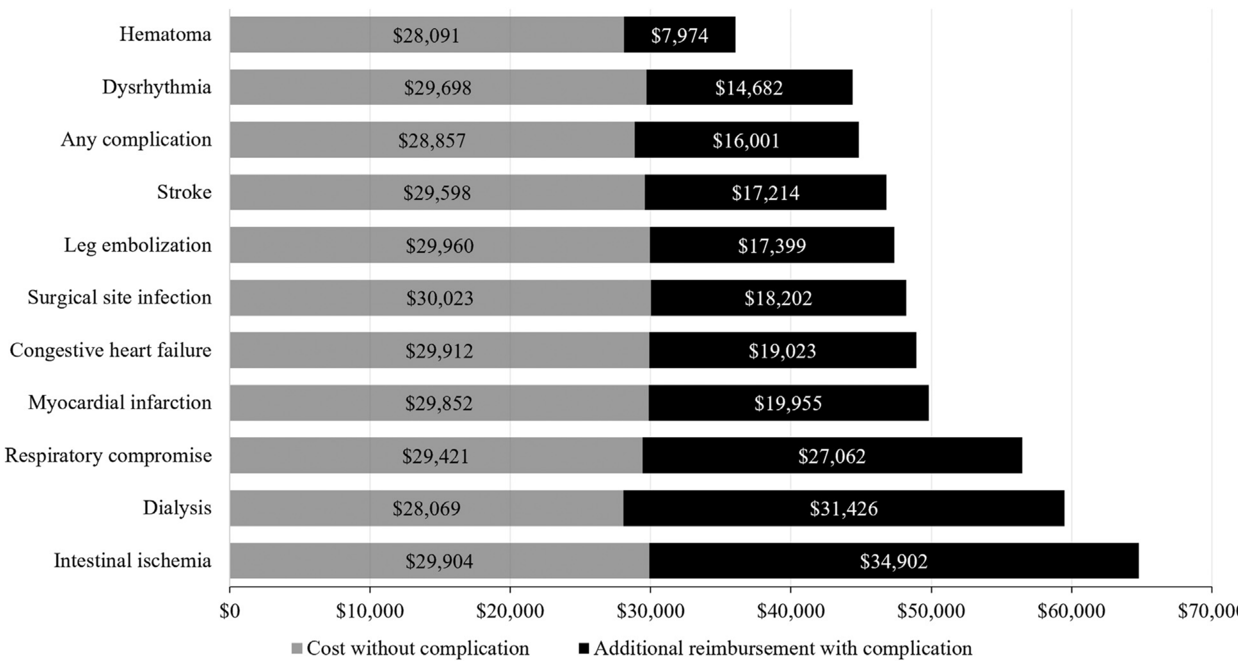


Fig. 3. Univariate analysis describing the additional mean reimbursement for specific complications captured in the VQI.

$29.964 for nondialysis patients), those unfit for open AAA repair ($34,042 vs. $29,310), and those with symptomatic CHF ($34,246 vs. $29,772 with no CHF).

Reimbursement varied significantly based on urgency of operation ranging from $29,185 ± $10,462 for elective EVR to $33,533 ± $13,878 for symptomatic patients and $45,310 ± $23,522 for patients with AAA rupture ($P < 0.0001$) (Table II). Both high-volume and low-volume centers received higher reimbursement for EVR on average. Significant differences in reimbursement were also noted for postoperative factors, including procedures more than 180 min ($35,659 vs. $28,537 for shorter procedures), need for intraoperative blood transfusion ($42,250 vs. $28,992 with no transfusion requirement), and length of stay 4 days or more ($39,440 vs. $27,692 for shorter hospitalizations).

The contribution of different types of complications to average reimbursement is shown in Figure 3. The occurrence of any complication captured in the VQI entailed additional Medicare reimbursement of $16,001 ($44,858 with any complication vs. $28,857 with no complication, $P < 0.0001$). Complications associated with the greatest additional reimbursement were intestinal ischemia ($64,806 with vs. $29,904 without, $P < 0.0001$), dialysis requirement ($59,495 with vs. $28,069 without, $P < 0.0001$), and respiratory compromise ($56,483 with vs. $29,421 without, $P < 0.0001$).

Multilevel Regression Modeling

All significant variables on univariate analysis were introduced into a multilevel linear regression model

Table IV. Factors significantly associated with reimbursement in multilevel regression model

	Baseline reimbursement[a]	
	$23,237	
	Change in reimbursement	*P*
Increased reimbursement		
DRG with MCC	$12,733	<0.001
Ruptured AAA	$2,372	<0.001
Blood transfusion	$2,024	<0.001
Any complication in VQI	$1,921	<0.001
Procedure >180 min	$1,447	<0.001
Length of stay, additional day	$1,275	<0.001
Iliac aneurysm	$557	0.001
Unfit for open repair	$501	0.014
Decreased reimbursement		
Surgery 2003−2007 (vs. 2012−2015)	−$3,870	<0.001
Age 85 years and older (vs. 65−74)	−$852	<0.001
Graft A (vs. graft B)	−$767	<0.001
Female gender	−$530	0.003
COPD[b]	−$507	0.004

Other significant covariates in sensitivity analyses:

1. Excluding outliers
   - Symptomatic AAA (+$1,086); CHF on therapy (+$482)
   - Other graft devices (−$2,599); graft E ($−542) versus graft B
2. Excluding DRG code
   - Preoperative dialysis (+$10,453)

[a] *Y*-intercept from the final regression model.
[b] Not statistically significant in sensitivity analysis excluding outlier payments.

with adjustment for clustering by the center. Factors significantly associated with reimbursement in the final model and sensitivity analyses are summarized in Table IV. DRG assignment was associated with the biggest difference in reimbursement, with the more complex DRG entailing additional reimbursement of $12,733. Other factors positively associated with reimbursement were all procedural or postoperative: ruptured AAA, comorbid iliac aneurysm, being unfit for open surgery, longer procedures, intraoperative blood transfusion, suffering a postoperative complication, and longer length of stay. Alternatively, demographic features, including, surgery from 2003 to 2007, age 85 years and older, female gender, and COPD, were associated with lower reimbursements. Sensitivity analyses reinforced these findings. When excluding DRG from the model, the only variable that changed in significance was preoperative dialysis requirement, which became associated with an additional $10,453 in reimbursement. In the sensitivity model excluding outlier reimbursements, COPD was no longer associated with reimbursement.

We estimated the explanatory power of different sets of variables by building the model in a stepwise fashion. Patient demographics and preoperative clinical factors explained only 2.4% and 3.3% of the variation seen in reimbursements, respectively. The addition of procedural and postoperative factors explained an additional 13.2% and 25.2% of this variation, whereas the final addition of DRG code explained another 7.0%. Altogether these patient-level factors explained half of the observed variation in reimbursement for EVR. Of the remaining unexplained variation, 40% was at the center level (67% when excluding outliers).

To better characterize this center-level variation, we estimated the average difference in reimbursement for each center, controlling for DRG assignment and all the other factors included in our multilevel model. Most centers received lower reimbursements on average, whereas a number of outlier centers received substantially higher reimbursements. This differential reimbursement varied 4-fold from −$7,338 at the lowest reimbursed center to $21,659 at the highest reimbursed center (Fig. 4).

DISCUSSION

This study characterized reimbursements for Medicare patients receiving EVR at VQI centers over a 13-year period. Reimbursement for index surgery hospitalizations was substantial at roughly $30,000 per patient. During the study duration, inflation-adjusted reimbursement declined more than 25% as the volume of procedures increased. We identified specific postoperative complications associated with the greatest incremental reimbursement: respiratory failure, new dialysis requirement, and intestinal ischemia each effectively doubled the reimbursement for EVR. Patient demographics, preoperative, procedural, and postoperative factors together accounted for half of the variation observed in reimbursements. After adjusting for these patient-level factors and DRG assignment, reimbursement at the level of VQI center varied 4-fold.

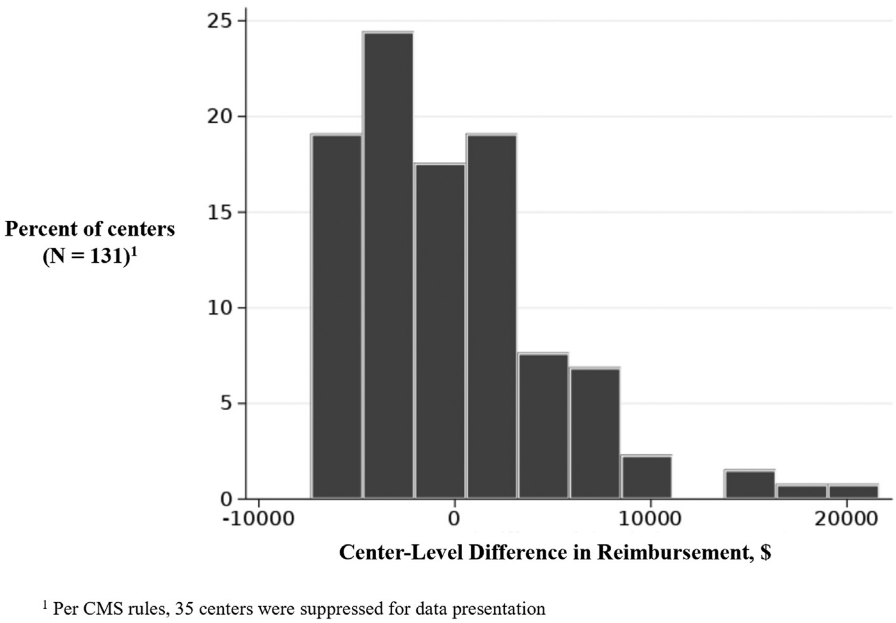


Fig. 4. Mean difference in reimbursement for each VQI center, controlling for DRG assignment and all other factors included in multilevel modeling.

Given the rapid adoption and dissemination of EVR, prior studies have sought to characterize the costs and reimbursement associated with this procedure. Clair et al.[4] described the direct hospital costs of EVR for 45 patients at their institution in 1998, noting that device costs of nearly $9,000 led this procedure to be more expensive than open repair, despite much shorter lengths of stay. Bertges et al.[6] expanded this approach to 221 EVR patients from 7 institutions and reported average Medicare reimbursements of $20,837 (in 2000–2001 dollars). They also described significant variation in mean reimbursements across centers ranging from $14,818 to $30,343.[6] More recently, Salzler et al.[7] performed an epidemiologic description of EVR via the National Inpatient Sample, an all-payer database, and used cost-to-charge ratios to estimate costs of EVR. They noted that although the volume of EVR procedures increased 13-fold between 2000 and 2011, the adjusted mean cost of these procedures declined from $28,174 in 2000–20,002 to $22,811 in 2009–2011. This occurred alongside simultaneous reductions in perioperative mortality and complications such as myocardial infarction, bleeding, and infection, which were attributed to the provider learning curve and advances in perioperative care.

Our study provides a clearer picture of reimbursement for EVR. It is not surprising that postoperative course, and the resulting assignment to a standard versus complicated DRG, is the major determinant of reimbursement among Medicare patients. EVR is performed on a high-risk population, and many postoperative complications are unavoidable. Yet strategies exist to mitigate certain complications too, from intraoperative technical aspects to postoperative protocols. Perioperative optimization of renal and respiratory status, for example, must remain a focus for clinicians seeking to minimize the human and financial toll of these procedures.

We controlled for DRG assignment, acknowledging a mediating role, to identify other factors associated with different levels of reimbursement. Independent of DRG assignment, individuals with ruptured AAA, comorbid iliac aneurysm, who were unfit for open surgery, had longer procedures, required intraoperative blood transfusion, suffered a postoperative complication, or had longer lengths of stay were each associated with higher reimbursement from Medicare. These may reflect clinical factors predictive of higher cost patients, which are not fully captured in the current application of DRG-based reimbursement. CMS recently modified procedural codes for ruptured aortic repairs to reflect the increased complexity of these patients, and similar development of more granular DRG buckets may be warranted.[12]

The overall rate of complications was 8.2% in this study. Rates of individual complications like acute myocardial infarction and respiratory failure were slightly lower in our analysis than were reported for EVR patients using the National Inpatient Sample.[7] One study that also used the VQI to examine

EVR patients in 2014 reported a 15% complication rate, although complications were defined somewhat differently.[13] In addition, some complications such as stroke were not reliably gathered in the VQI before 2010, whereas new dialysis requirement, postoperative hematoma, and site occlusion were only collected starting in 2014. Nevertheless, 42% of patients with a VQI complication in our study were not assigned to the more complex DRG. In the multicenter VQI study from Lemmon et al.,[13] only 9% of procedures with complications were assigned to the more complex DRG, and efforts to model expected versus observed coding practices suggested that both undercoding and overcoding are endemic sources of variation in reimbursement. Not all complications will meet CMS criteria for a more complex DRG, but accurate DRG assignment is of great financial importance to provider organizations.[14]

DRG assignment relies on comorbidities and complications recorded using administrative *ICD-9/10* codes. This lacks some of the disease-specific granularity provided by variables in the VQI. Preoperative dialysis requirement offers an example of a clinical factor that is well captured by current DRG coding. Preoperative dialysis was associated with an additional $10,453 in reimbursement before controlling for DRG code but was not significant once doing so. Coding specialists assigning DRG codes based on clinician documentation are unlikely to miss a dialysis comorbidity, and more than 94% of these patients in our cohort were assigned the more complex DRG.

We also observed significant variation in the degree to which centers secured pass-through payments for performing EVR, which are provided by CMS as supplemental fees for using new technologies. Although some of this variation is a function of the year in which a claim was submitted, there is also likely variability in the degree to which centers applied the appropriate codes needed to receive pass-through payments. Our results should prompt hospital administrators to examine institutional coding practices for EVR.

This analysis is subject to limitations. For most Medicare fee-for-service providers, DRG rates are the basis on which our primary outcome was determined (providers in Maryland are exempt from DRG-based reimbursement).[15] CMS performs a series of adjustments to DRG base payment rates, which therefore confound our analysis.[16] DRG-based reimbursement is intended to reflect cost.[17] Base rates are a function of labor and nonlabor components, the former of which is adjusted for price using a wage index. Although our analysis did not adjust for regional differences in price, prior research has found that this only explains a fraction of the variation generally seen in Medicare spending.[18,19] Additional add-on payments to DRG rates are performed for approved teaching hospitals, hospitals that see a disproportionate share of low-income patients, or in the event of an outlier case that is unusually costly. We included Medicaid dual eligibility in our model to provide some degree of socioeconomic adjustment and performed a sensitivity analysis excluding outlier reimbursements. Nevertheless, the combination of these adjustments to DRG rates undoubtedly explains some of the residual variation we observed in center-level reimbursement.

We considered Medicare's reimbursement for index EVR hospitalization, not the direct costs of these procedures. Prior studies have often found that costs tend to exceed reimbursement,[6,13,20] and CMS' ongoing modification of DRG codes and reimbursement levels for EVR will require further examination.[21] Finally, although the cost of index EVR procedures is substantial, this is a snapshot in the continuum of care for these patients. Guidelines recommend annual surveillance imaging after EVR, and readmission or reintervention, such as for endoleak, entail significant expense as well.[22,23] These downstream costs, and clinical factors associated with them, would benefit from further characterization building on the methods used for this study.

CONCLUSION

EVR represents a significant source of health care expenditure. It is difficult to anticipate reimbursement for EVR using preoperative demographic and clinical characteristics. Perioperative factors that do impact reimbursement may be unaccounted for in current DRG coding schemes or subject to inaccurate coding at the center level. Controlling for patient-level variables, VQI center reimbursement varies more than four-fold. Further research is needed to explore how coding practices or other process of care measures contribute to this center-level variation.

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