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A comparison of reintervention rates after endovascular aneurysm repair between the Vascular Quality Initiative registry, Medicare claims, and chart review

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ABSTRACT

Objective: The accurate measurement of reintervention after endovascular aneurysm repair (EVAR) is critical during postoperative surveillance. The purpose of this study was to compare reintervention rates after EVAR from three different data sources: the Vascular Quality Initiative (VQI) alone, VQI linked to Medicare claims (VQI-Medicare), and a "gold standard" of clinical chart review supplemented with telephone interviews.

Methods: We reviewed the medical records of 729 patients who underwent EVAR at our institution between 2003 and 2013. We excluded patients without follow-up reported to the VQI (n = 68 [9%]) or without Medicare claims information (n = 114 [16%]). All patients in the final analytic cohort (n = 547) had follow-up information available from all three data sources (VQI alone, VQI linked to Medicare, and chart review). We then compared reintervention rates between the three data sources. Our primary end points were the agreement between the three data sources and the Kaplan-Meier estimated rate of reintervention at 1 year, 2 years, and 3 years after EVAR. For gold standard assessment, we supplemented chart review with telephone interview as necessary to assess reintervention.

Results: VQI data alone identified 12 reintervention events in the first year after EVAR. Chart review confirmed all 12 events and identified 18 additional events not captured by the VQI. VQI-Medicare data successfully identified all 30 of these events within the first year. VQI-Medicare also documented four reinterventions in this time period that did not occur on the basis of patient interview (4/547 [0.7%]). The agreement between chart review and VQI-Medicare data at 1 year was excellent ($\kappa = 0.93$). At 3 years, there were 81 (18%) reinterventions detected by VQI-Medicare and 70 (16%) detected by chart review for a sensitivity of 92%, specificity of 96%, and κ of 0.80. Kaplan-Meier survival analysis demonstrated similar reintervention rates after 3 years between VQI-Medicare and chart review (log-rank, $P = .59$).

Conclusions: Chart review after EVAR demonstrated a 6% 1-year and 16% 3-year reintervention rate, and almost all (92%) of these events were accurately captured using VQI-Medicare data. Linking VQI data with Medicare claims allows an accurate assessment of reintervention rates after EVAR without labor-intensive physician chart review. (J Vasc Surg 2018;■:1-6.)

Keywords: Reintervention; EVAR; Medicare claims; Event adjudication; ICD-9 codes for reintervention

More than 30,000 patients undergo elective endovascular aneurysm repair (EVAR) in the United States each year.[1] Late results from early randomized trials and Cochrane reviews suggest that 20% to 30% of patients need one or more additional interventions after their initial endovascular repair,[2-4] and this need for reintervention does not appear to plateau over time.[2,5] These findings indicate that the number of reinterventions after elective EVAR will likely continue to rise, highlighting the need for diligent postoperative surveillance. As such, it is

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imperative to develop reliable and scalable means of tracking patients who have undergone EVAR and to follow their long-term outcomes.

However, the current method of follow-up—relying on patients and surgeons to achieve this goal—has demonstrated limitations. Current reports suggest that nearly one in three patients undergoing EVAR is lost to follow-up within the first 3 years.[6-9] Combining data from vascular registries, such as the Vascular Quality Initiative (VQI),[10] with Medicare claims[11] may offer a solution to this challenging problem. The VQI registry was created to allow surgeons to follow procedure-specific outcomes and to provide clinically relevant information to patients and physicians about their vascular care. However, the VQI registry is designed to capture only 1-year outcomes—not long enough to provide adequate surveillance after EVAR—and follow-up continues to be challenging for many surgical practices.[9] Conversely, Medicare claims data offer the advantage of long-term follow-up for a large number of patients and can identify procedures performed at different institutions. However, it can be difficult to accurately identify patients and clinical events using the diagnostic and procedural codes implemented for billing. Furthermore, the number and type of billing codes used to identify events have an impact on the accuracy of event detection[12] and have major implications for the interpretation of study findings.

We hypothesized that VQI data linked to Medicare claims could provide an accurate means by which to assess outcomes in patients undergoing EVAR. To test this hypothesis, we compared the rate of reintervention found within a combined data set of VQI registry data linked to Medicare claims (VQI-Medicare) against the rate found on retrospective chart review at our institution.

ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective analysis of single-institution and Vascular Quality Initiative (VQI) and Medicare claims data
- **Take Home Message:** Reintervention rates after 547 endovascular aneurysm repairs demonstrated a high degree of agreement between individual chart review and VQI-linked Medicare data ($\kappa = 0.93$).
- **Recommendation:** This study suggests that linking VQI with Medicare claims data provides an accurate assessment of reintervention rates.

METHODS

Cohort creation. We identified all patients who underwent EVAR at our institution from January 2003 to December 2013 using the VQI registry.[10] This method has been shown on internal review to capture 98% to 100% of EVAR procedures performed at our institution (unpublished data). We then performed chart reviews of all patients to identify reintervention events. All reinterventions were adjudicated by two reviewers (J.A.C., P.P.G.).

We then obtained the corresponding Medicare claims information for patients who were Medicare eligible. Medicare follow-up data were available from January 2003 to December 2013. Patients identified by the VQI registry were then linked to their respective Medicare claims file. We linked patients using an indirect matching method described previously.[5] Briefly, patients in the VQI registry were identified in Medicare claims data using a series of nonunique identifiers (eg, procedure date, date of birth, ZIP code) to create unique patient-level matches between the registry and the Medicare claims file.

We then created a cohort of patients for whom follow-up information was available in all three data sources (VQI registry alone, VQI-Medicare, and chart review). This allowed us to capture the date and type of all procedures performed after the index procedure (EVAR). From this, we were able to assess the concordance of reintervention rates after EVAR between the three different data sources. When data sets were discordant, we conducted telephone interviews with patients to assess whether a reintervention had occurred.

Primary outcomes. Our primary outcome measure was reintervention after EVAR. We defined reintervention as any additional procedure performed after the index hospitalization to treat endoleaks, further aneurysmal degeneration, or any complications related to the original repair (eg, femoral artery repair for access site complication). Any subsequent procedures performed for pre-existing conditions (eg, for an endovascular repair of a popliteal artery aneurysm) were not included as reinterventions. We compared the rate of reintervention between VQI-Medicare and chart review at 1 year, 2 years, and 3 years using Kaplan-Meier estimation. We assessed the concordance of reintervention rates using Cohen's κ.

Medicare coding algorithm. We created a list of primary diagnosis and procedure codes using the *International Classification of Diseases, Ninth Revision* (ICD-9) to identify reintervention events. The initial list of codes compiled was based on prior work at our institution and others (Supplementary Table I, online only).[5,6,13] Medicare billing code events identified within the VQI-Medicare linked data set were then compared with the reintervention events identified on chart review to determine whether billing events represented true

Table I. Characteristics of the analytic cohort

Variable	(N = 547)
Age, years	75.5 (7.3)
Female	22.9
Body mass index, kg/m^2	27.7 (5.1)
Hypertension	84.0
Coronary artery disease	35.5
Congestive heart failure	14.6
Chronic obstructive pulmonary disease	42.6
History of smoking	83.8
Diabetes	22.1
Creatinine >1.7 mg/dL	8.8
Preoperative aspirin	74.3
Preoperative statin	65.4
Elective operation	90.7

Categorical variables are presented as percentage. Continuous variables are presented as mean (standard deviation).

reinterventions. If the occurrence of a reintervention was unclear, telephone interviews of the patients were conducted.

We then calculated the accuracy of each individual billing code by determining the percentage of billing events representing a true clinical event (eg, a specific billing code appearing 10 times but representing a true reintervention of only four times would have 40% accuracy). We determined the accuracy for all codes appearing in the first year after EVAR. If a billing code was associated with a true clinical event <50% of the time, it was considered for removal from our list of codes used to represent reintervention. Details of the revisions to the coding algorithm are described in the Supplementary Methods (online only) and Supplementary Table II (online only).

Statistical analysis. We report absolute numbers and percentages where appropriate. Continuous variables are represented as means with standard deviations, and categorical variables are listed as percentages. The final cohort for analysis represents the same group of patients, differing only by the data source from which reintervention events are identified; therefore, no comparative statistics on baseline characteristics were calculated. Rates of reintervention were calculated using Kaplan-Meier survival analysis with hazard function estimation. In addition, because the cohorts compared represent the same patients and differ only in which data source was used to assess the rate of reintervention, the at-risk number at each time point is the same for the data sets being compared. Concordance between the reintervention rates obtained from the three data sets was analyzed using Cohen's κ. We also calculated the sensitivity and specificity of VQI-Medicare linked data to identify a reintervention event compared with chart review. All statistical analyses were performed using Stata version 14 software (StataCorp LP, College Station, Tex).

Human subjects protection. Medical record review and patient interviews for this study were approved by the Committee for the Protection of Human Subjects at Dartmouth College. All patients' personal health information was protected, records and outcomes were deidentified, and no testing or procedures were required for this study. Thus, the need for specific consent was waived. VQI and Medicare information is collected under the auspices of an Agency for Healthcare Research and Quality-designated Patient Safety Organization. Therefore, this portion of the study was exempt from internal review.

RESULTS

Details of the analytic cohort. We identified 729 patients who underwent EVAR at our institution during the study period. We excluded 68 patients (9%) who did not have VQI follow-up available and 114 patients (16%) for whom Medicare claims data were not available (71 patients <65 years of age, 43 not matched to their respective Medicare claims file).

All (100%) of the remaining 547 patients had follow-up information available from each of the three data sources. This group of patients formed the final analytic cohort that was used to compare rates of reintervention and to examine concordance between our data sources. Cohort characteristics were typical for this population of patients (Table I), with a mean age of 75.5 years and 22.9% being female. Hypertension and smoking history were common, and most patients were receiving preoperative aspirin and statin therapy. More than 90% of EVARs were performed on an elective basis.

Rates of reintervention. The Kaplan-Meier estimated 1-year rate of reintervention after EVAR using the VQI registry alone was 3%, corresponding to a total of 12 events. As the VQI is designed to collect 1-year outcomes, we truncated survival estimates using the VQI registry alone at this time point. The estimated rate of reintervention found on chart review was twice that found using the VQI registry alone, showing a 1-year reintervention rate of 6% or 30 events. The chart review rate of reintervention maintained a nearly linear increase during the study period and was 16% at 3 years.

The rate of reintervention found using VQI-Medicare was 6% at 1 year and 18% at 3 years. This rate was calculated using a coding algorithm composed of the codes outlined in Table II.

Concordance between the data sets. Using the VQI registry alone, 12 reintervention events were identified within the first year after EVAR. Chart review confirmed these 12 events and identified an additional 18 events not captured by the VQI registry. The additional events found by chart review but not identified using the VQI registry consisted of EVAR limb thrombectomy or repair of a kinked EVAR limb (n = 4), femoral artery

Table II. List of *International Classification of Diseases, Ninth Revision* (ICD-9) codes used in the revised algorithm

3804	3846	3929	3971	4415	9966
3806	3864	3930	3972	4400	99660
3808	3866	3931	3974	4442	99661
3814	3868	3951	3975	44421	99662
3816	3884	3952	3976	4448	99669
3818	3886	3954	3977	44481	
3834	3888	3956	3978	44489	
3838	3891	3957	3979	99674	
3844	3925	3958	3990	9961	
3846	3926	3959	4413	99659	

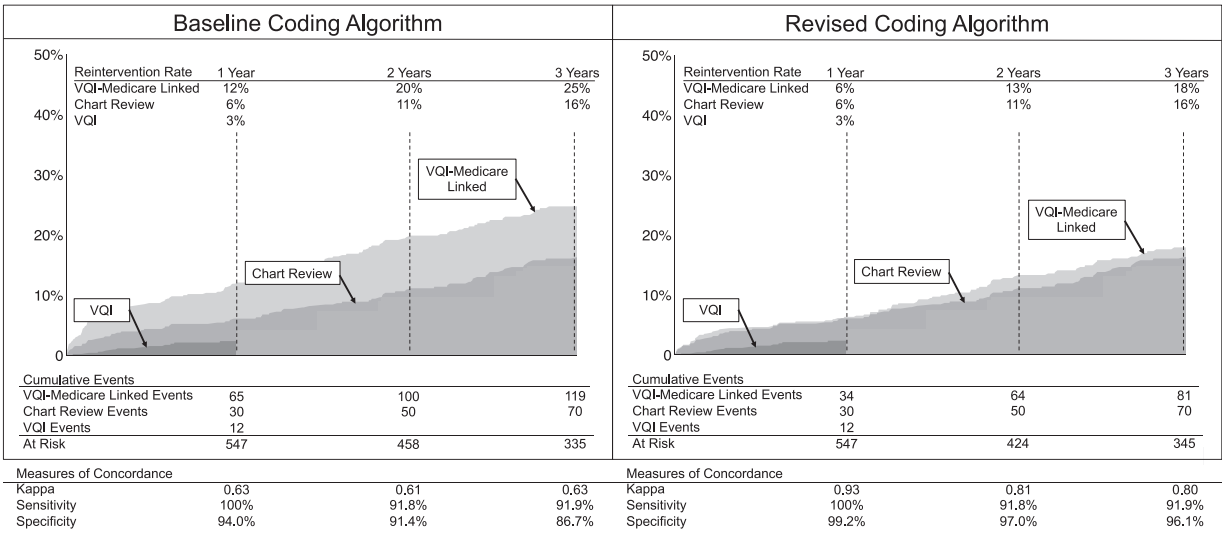

Fig. Reintervention rates and concordance between chart review and Vascular Quality Initiative (*VQI*)-Medicare: baseline and revised coding algorithms. *VQI-Medicare*, VQI data linked to Medicare claims. Standard error <10% for all reported statistics.

reconstruction or femoral-femoral bypass for an occluded EVAR limb (n = 4), unsuccessful reintervention procedures (n = 3), proximal aortic cuff placement (n = 3), coiling for type II endoleak (n = 1), and patients who died at another hospital and were thought to have suffered an aneurysm-related mortality event (n = 3). Full details of the reintervention procedures are described in Supplementary Table III (online only).

Both the baseline and revised coding algorithms of VQI-Medicare linked data captured all 30 of the events found on chart review during the first year. However, the baseline coding algorithm identified 35 additional events within the first year that did not represent a true reintervention. Changes were made in the coding algorithm to generate our revised coding algorithm as detailed in the Methods and Supplementary Methods (online only). These changes improved the concordance between chart review and VQI-Medicare significantly, with the revised coding algorithm now identifying only four events within the first year that did not represent a true reintervention based on chart review and telephone interview of the patients. The statistical agreement between chart review and VQI-Medicare before the coding changes was 0.63 at both 1 year and 3 years, as determined by Cohen's κ. However, after changes to the coding algorithm, this improved to 0.93 and 0.80 at 1 year and 3 years, respectively, indicating excellent agreement. Using chart review as the "gold standard," the sensitivity of VQI-Medicare to identify a reintervention event remained stable at 91.9% and specificity improved from 86.7% to 96.1% at 3 years (Fig).

DISCUSSION

Our review of a single-center series using multiple data sources to evaluate reintervention after EVAR demonstrated two important findings. First, nearly one in five patients whose abdominal aortic aneurysm is treated by endovascular means can expect to undergo reintervention, and this need for reintervention does not plateau over time. Second, our study suggests that a

linked clinical claims registry may offer a scalable, reliable, accurate, and cost-effective way to provide long-term surveillance for reintervention after EVAR.

Whereas our long-term rate of reintervention after EVAR was nearly identical to the rate reported in the EVAR 1 trial,[2] we also found that the rate of reintervention in our cohort was highly dependent on the codes chosen to represent events from the Medicare claims data. Initially, our coding algorithm was highly sensitive but had poor specificity, greatly overestimating the true reintervention event rate. For example, our initial list of codes used for event detection in Medicare included ICD-9 code 3893, "venous catheterization not elsewhere classified." We included this code because we hypothesized that it would be associated with transcaval coil embolization, a common method of treating type II endoleaks at our institution. This billing code appeared 21 times in our institution's Medicare data. However, it was associated with a reintervention found on chart review in only 1 of 21 cases, and in this case, it was also associated with another ICD-9 code used for event detection. We therefore removed ICD-9 code 3893 from our list of codes used to represent reintervention events. By performing adjudications of billing codes such as this, we were able to modify our coding algorithm such that the specificity of reintervention events found using the VQI-Medicare database improved from 86.7% to 96.1% at 3 years while maintaining high sensitivity (91.9% at 3 years). Similarly, the concordance of reintervention rates found using chart review vs the VQI-Medicare database was high (0.93 and 0.80 at 1 year and 3 years, respectively) after coding algorithm revision.

Challenges with coding accuracy at both the billing code entry[14] and research use levels[12,15,16] have been described by many investigators across specialties. Even within vascular surgery, coding algorithms to define clinical events such as stroke can be difficult to define[15,17] and may have a profound impact on study results. These findings in concert with ours highlight the need for researchers to carefully select codes to represent true events when using Medicare data and to perform chart-level adjudication of billing codes to ensure accuracy.

We noted a substantial difference in the number of events detected by the VQI data set alone and those found on chart review. These events most often represented complications related to EVAR, such as EVAR limb thrombectomy or femoral artery reconstruction for access site complications. These procedures may have been errors in data entry (EVAR limb thrombectomy) or have been overlooked as related to the index EVAR (femoral artery reconstruction). These events represent opportunities for improvement for data entry into VQI in considering postoperative surveillance for EVAR.

Our findings have important implications. First, the cumulative incidence of reintervention after EVAR demonstrates a linear increase over time. This finding is consistent with long-term results from randomized trials[2] and may account for the inferior outcomes associated with patients who are lost to follow-up.[8] Furthermore, this indicates that patients who undergo EVAR must have long-term surveillance as the rate of reintervention does not appear to plateau. The method described in our report, which leverages registry data and Medicare claims, may be a cost-effective approach for a distributed surveillance network to evaluate EVAR performance over time. This linked registry-claims surveillance system is both sensitive and specific. It also offers a scalable mechanism that can identify reintervention events occurring at either the index or outside institutions for Medicare patients. Finally, it offers a reliable method to monitor mortality from rupture, even after EVAR, across the United States. These attributes of the linked registry represent an important advance over VQI data taken in isolation.

Our study has limitations. It is an experience from a single center, and as such, Medicare coding trends from our institution may not be representative of those at other hospitals. This limitation highlights the need for a multicenter validation project, which we are currently undertaking. Medicare coding events were compared with retrospective chart review. The optimal comparison would be prospectively collected data with blinded evaluation of reintervention events. However, no such source is available for use with the VQI registry. Therefore, we thought that our two-reviewer retrospective method of event adjudication provided the most reliable information possible. Our cohort was limited to patients who were found in all three data sources, and because of this, we cannot comment on coding trends for patients who are not Medicare eligible. We adjudicated chart review events against billing codes during the first year, using our findings to revise our coding algorithm. We then applied these changes to the 3 years of data. We did not think that it was necessary to adjudicate all 3 years of events for a series of reasons. First, our κ concordance remained excellent (>0.8) for all years analyzed. Second, the sensitivity and specificity of VQI-Medicare compared with chart review were 92% and 96%, respectively. Finally, our findings closely resembled those of randomized clinical trials. Although our sensitivity and specificity remained excellent (92% and 96%, respectively), we were not able to obtain perfect 100% agreement. However, given the known limitations of claims data, perfect agreement is likely not possible.

CONCLUSIONS

VQI data linked to Medicare claims closely mirrored chart review in evaluating reintervention after EVAR, and the rates of reintervention we found were similar to those published in randomized clinical trials.

Furthermore, VQI-Medicare was 92% sensitive and 96% specific in identifying a true reintervention event. The rate of events found in Medicare claims was highly dependent on the billing codes chosen to represent those events. Only after close adjudication and iterative revisions of our coding algorithm did rates become similar, highlighting the care that must be taken in using Medicare data for clinical research. Nevertheless, VQI-Medicare represents a validated and accurate assessment of reintervention after EVAR, without the need for labor-intensive chart review.

AUTHOR CONTRIBUTIONS

Conception and design: JC, AS, PG
Analysis and interpretation: JC, RK, AW, JK, KL, KT, RH, NR, AS, PG
Data collection: JC, KL, KT, RH
Writing the article: JC, RK, PG
Critical revision of the article: JC, RK, AW, JK, KL, KT, RH, NR, AS, PG
Final approval of the article: JC, RK, AW, JK, KL, KT, RH, NR, AS, PG
Statistical analysis: JC, NR
Obtained funding: AS, PG
Overall responsibility: PG

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SUPPLEMENTARY METHODS (online only)

Coding algorithm. Our initial coding algorithm to define reintervention events after endovascular aneurysm repair included 42 *International Classification of Diseases, Ninth Revision* (ICD-9) diagnosis codes and 24 ICD-9 procedure codes (Supplementary Table I, online only). We defined a reintervention event in Medicare claims as any patient having one of these billing codes appear in their Medicare claims file after their index procedure. We allowed either an ICD-9 diagnosis code (which was the primary diagnosis code for the admission) or an ICD-9 procedure code to represent a reintervention event. These were not considered mutually exclusive, so that an ICD-9 primary diagnosis code also found with an ICD-9 procedure code during the same admission was considered a single reintervention event. Although it included subcodes that were not specific to vascular procedures, we thought it important to initially include procedure code 9966.x to capture potentially miscoded events. Code 9957 was included for a similar reason.

Using the original coding algorithm, the Vascular Quality Initiative (VQI)-Medicare linked data identified 65 events during the first year after endovascular aneurysm repair (Supplementary Table III, online only). We then compared the VQI-Medicare identified events with the reintervention events found on chart review. We conducted telephone interviews if the clinical outcome could not be adequately determined on chart review. If a patient died during a hospital admission at another institution and that admission was connected with one of the billing codes in our algorithm, we assumed that the death was aneurysm related and associated with an attempted reintervention. This was done to provide the most conservative estimate of events. Although we considered records from all hospitals that had been entered into the patient's available medical record, we did not visit outside institutions to perform additional chart reviews. We did not attempt telephone interviews to assess for reintervention events in deceased patients.

Billing codes with an accuracy lower than 50% were considered for removal from the coding algorithm (Supplementary Table II, online only). For example, procedure code 3893 was associated with a true clinical reintervention event in 1 of 21 cases; this code was therefore removed from our list of codes chosen to represent a reintervention event. If a code appeared only once, however, we did not think that this provided adequate information to remove it from the algorithm. Therefore, codes appearing only once, even if not associated with a clinical event, were kept in the algorithm. We also removed codes with 50% accuracy that were associated with another code that consistently performed well. For example, diagnosis code 44422 was associated with a true reintervention event in one of two cases. However, that reintervention event was also associated with procedure code 3929, a code that was associated with a true event in five of five cases. We therefore removed diagnosis code 44422 from the coding algorithm. The rate of reintervention using the VQI-Medicare data was then recalculated using the revised list of billing codes.

Supplementary Table I (online only). Codes used to identify reintervention after endovascular aneurysm repair (EVAR): Baseline coding algorithm

ICD-9 code	Definition
Procedure codes	
3804	Incision of vessel, aorta
3806	Incision of vessel, abdominal artery
3808	Incision of vessel, lower limb artery
3814	Endarterectomy of aorta
3816	Endarterectomy of abdominal arteries
3818	Endarterectomy of lower limb arteries
3834	Resection of vessel with anastomosis
3838	Resection of lower limb arteries w/anastomosis
3844	Resection of abdominal aorta w/replacement
3846	Resection of abdominal arteries w/replacement
3848	Resection of lower limb arteries w/replacement
3864	Other excision of vessels, aorta, abdominal
3866	Other excision of abdominal arteries
3868	Other excision of lower limb arteries
3884	Other surgical occlusion of abdominal aorta
3886	Other surgical occlusion of abdominal arteries
3888	Other surgical occlusion of lower limb arteries
3891	Arterial catheterization
3893	Venous catheterization not elsewhere classified
3925	Aorta-iliac-femoral bypass
3926	Other intra-abdominal vascular shunt or bypass
3929	Other (peripheral) vascular shunt or bypass
3930	Suture of unspecified blood vessel
3931	Suture of artery
3950	Angioplasty/atherectomy of other noncoronary vessel(s)
3951	Clipping of aneurysm
3952	Other repair of aneurysm
3954	Re-entry operation (aorta)
3956	Repair of blood vessel w/tissue patch graft
3957	Repair of blood vessel w/synthetic patch graft
3958	Repair blood vessel w/unspecified type patch graft
3959	Other repair of vessel
3971	Endovascular implantation graft abdominal aorta
3972	Endovascular repair/occlusion head and neck vessels
3973	Endovascular implantation graft thoracic aorta
3974	Endovascular removal obstruction head and neck vessels
3975	Endovascular embolization or occlusion
3976	Endovascular embolization or occlusion
3977	Temporary treatment endovascular occlusion vessel
3978	Endovascular implant aortic branch graft
3979	Other endovascular repair of other vessels
3990	Insertion nondrug-eluting peripheral vessel stents
Diagnosis codes	
4413	Abdominal aortic aneurysm, ruptured
4415	Aortic aneurysm of unspecified site, ruptured
4400	Atherosclerosis of aorta
4442	Embolism and thrombosis arteries of the extremities
44421	Embolism and thrombosis arteries upper extremity
44422	Embolism and thrombosis arteries lower extremity
4448	Embolism and thrombosis of other specified artery
44481	Embolism and thrombosis of iliac artery
44489	Embolism and thrombosis of other specified artery
9957	Other adverse food reactions, other
9961	Mechanical complications other vascular device implant and graft
99659	Mechanical complication due to other implant and internal device, not elsewhere classified
9966	Infection and inflammatory reaction due to internal prosthetic device implant and graft
99660	Infection and inflammatory reaction due to unspecified device implant and graft
99661	Infection and inflammatory reaction due to cardiac device implant and graft

Supplementary Table I (online only). Continued.

ICD-9 code	Definition
99662	Infection and inflammatory reaction due to other vascular device implant and graft
99663	Infection and inflammatory reaction due to nervous system device implant and graft
99664	Infection and inflammatory reaction due to indwelling urinary catheter
99665	Infection and inflammatory reaction due to other genitourinary device implant and graft
99666	Infection and inflammatory reaction due to internal joint prosthesis
99667	Infection and inflammatory reaction due to other internal orthopedic device implant and graft
99668	Infection and inflammatory reaction due to peritoneal dialysis catheter
99669	Infection and inflammatory reaction due to other internal prosthetic device implant and graft
99674	Other complications due to other vascular device implant and graft

ICD-9, International Classification of Diseases, Ninth Revision.

Supplementary Table II (online only). Changes to the coding algorithm based on chart review

Code	Definition	Chart review events	Times appearing	Decision	Justification
Diagnosis codes					
4400	Atherosclerosis of aorta	0	1	Keep	Appeared once
4413	Abdominal aortic aneurysm, ruptured	1	3	Keep	Add modifier, drop if days to event <1
9961	Mechanical complications due to other vascular device implant and graft	17	17	Keep	Correct all times
44422	Embolism and thrombosis arteries, lower extremity	1	2	Drop	Correct only when found with 3929
99669	Infection and inflammation reaction due to other internal prosthetic device implant and graft	1	1	Keep	Appeared once
99674	Other complications due to other vascular device implant and graft	7	7	Keep	Correct all times
Procedure codes					
3806	Incision of vessel, abdominal artery	1	1	Keep	Appeared once
3818	Endarterectomy of lower limb arteries	1	1	Keep	Appeared once
3834	Resection of vessel with anastomosis	0	1	Keep	Appeared once
3848	Resection of lower limb arteries w/replacement	0	2	Drop	Incorrect both times
3893	Venous catheterization not elsewhere classified	1	21	Drop	Correct once when found with 99612
3929	Other (peripheral) vascular shunt or bypass	5	5	Keep	Correct all times
3950	Angioplasty/atherectomy noncoronary vessel(s)	3	8	Drop	Correct when found with 9961, 99674 in two of the cases
3952	Other repair of aneurysm	0	1	Keep	Appeared once
3971	Endovascular implantation of graft abdominal aorta	7	8	Keep	Correct in most cases
3973	Endovascular implantation of graft thoracic aorta	0	2	Drop	Incorrect both times
3979	Other endovascular repair of other vessels	6	6	Keep	Correct all times

Supplementary Table III (online only). Reintervention events occurring within the first year in Medicare: Baseline coding algorithm

Diagnosis code	Procedure code	Clinical event	Chart review event	Found in VQI
9961	3979	EVAR limb extension	Yes	Yes
9961		Proximal aortic cuff	Yes	Yes
9961	3971	Proximal aortic cuff	Yes	Yes
99674	3929	Femoral-femoral bypass for EVAR limb occlusion	Yes	Yes
	3971	Proximal aortic cuff and renal stent implantation	Yes	Yes
9961	3979	Translumbar coiling of endoleak	Yes	Yes
9961		EVAR limb thrombectomy	Yes	Yes
	3950	EVAR limb distal extension	Yes	Yes
9961	3971	Proximal aortic cuff	Yes	Yes
99674	3929	Femoral-femoral bypass for EVAR limb occlusion	Yes	Yes
9961	3971	Proximal aortic cuff and renal stent	Yes	Yes
9961	3979	Transcaval coiling of endoleak	Yes	Yes
99674	3979	EVAR limb thrombectomy and complete relining of EVAR	Yes	No
9961	3971	Proximal aortic cuff	Yes	No
9961	3971	Proximal aortic cuff	Yes	No
9961	3979	Transfemoral coiling of endoleak	Yes	No
9961	3893	Attempted transcaval coiling of endoleak	Yes	No
99674	3979	EVAR limb thrombectomy	Yes	No
99674	3929	Femoral-femoral bypass for EVAR limb occlusion	Yes	No
9961		Attempted recanalization of renal chimney	Yes	No
9961	3971	Proximal aortic cuff	Yes	No
99674	3806	EVAR limb thrombectomy	Yes	No
9961		Attempted coiling of endoleak	Yes	No
9961	3950	Repair of kinked EVAR	Yes	No
99674	3950	Reconstruction for exposed AUI and femoral-femoral bypass	Yes	No
44422	3929	Femoral-femoral bypass for EVAR limb occlusion	Yes	No
	3818	Femoral reconstruction for new short-distance claudication after percutaneous EVAR	Yes	No
9961		Deceased at outside hospital, unknown cause	Yes	No
	3929	Deceased at outside hospital, unknown cause	Yes	No
4413		Deceased at outside hospital, unknown cause	Yes	No
4413	3834	No reintervention, no rupture	No	No
44422	3848	Popliteal aneurysm repair	No	No
	3848	Popliteal aneurysm repair	No	No
	3893	Tunneled dialysis catheter placement	No	No
	3893	PICC line placement	No	No
	3893	PICC line placement	No	No

(Continued on next page)

Supplementary Table III (online only). Continued.

Diagnosis code	Procedure code	Clinical event	Chart review event	Found in VQI
	3893	PICC line placement	No	No
	3893	LTF	No	No
	3893	No reintervention, no rupture	No	No
	3893	PICC line placement	No	No
	3893	LTF	No	No
	3893	No reintervention, no rupture	No	No
	3893	ICD and pacemaker placement	No	No
	3893	LTF	No	No
	3893	LTF	No	No
	3893	Central line placement	No	No
	3893	No reintervention, no rupture	No	No
	3893	No reintervention, no rupture	No	No
	3893	Central line placement	No	No
	3893	No reintervention, no rupture	No	No
	3893	Temporary pacer wire placement	No	No
	3893	Central line placement	No	No
	3893	Groin lymphocele, nonoperative management	No	No
	3950	No reintervention, no rupture	No	No
	3950	Renal artery stent	No	No
	3950	No reintervention, no rupture	No	No
	3950	No reintervention, no rupture	No	No
	3950	Revisions to a peripheral bypass graft	No	No
	3952	No reintervention, no rupture	No	No
	3971	No reintervention, no rupture	No	No
	3973	Ruptured thoracic aortic aneurysm	No	No
	3973	TEVAR	No	No
4400		Coronary stent	No	No
4413		No reintervention, index repair for rupture	No	No
99669		No reintervention, no rupture	No	No

AUI, Aortouni-iliac; *EVAR,* endovascular aneurysm repair; *ICD,* implantable cardioverter-defibrillator; *PICC,* peripherally inserted central catheter; *LTF,* lost to follow-up; *TEVAR,* thoracic endovascular aortic repair; *VQI,* Vascular Quality Initiative.