ORIGINAL RESEARCH

Vena Cava Filter Retrieval Rates and Factors Associated With Retrieval in a Large US Cohort

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***Background*—**Retrieval of vena cava filters (VCFs) is important for safety as complications increase with longer dwell times. This study assessed VCF retrieval rates and factors associated with retrieval in a national cohort.

***Methods and Results*—**VCFs were identified by procedural codes from an administrative claims database. Patients were identified who had a VCF placement during a hospitalization from a national commercial administrative claims database. Indications for VCF placement were identified as pulmonary embolism with or without deep vein thrombosis, deep vein thrombosis only, or prophylactic. Patient demographic and clinical characteristics were included in proportional hazard regression models to find associations with early (90-day) and 1-year VCF retrieval. Initiation of anticoagulation and the correlation between time-to-retrieval and time-to-initiation of anticoagulation were observed. Of 54 766 patients receiving a VCF, 36.9% had pulmonary embolism, 43.9% had deep vein thrombosis only, and 19.2% had no apparent venous thromboembolism present. Over the 1 year of follow-up, the cumulative incidence of VCF retrieval was 18.4%. Retrieval increased over time from a low of 14.0% in 2010 up to ≈24% in 2014. In adjusted time-to-event models, increasing age, differing regions, and some comorbidities were associated with poorer retrieval rates. Initiation of anticoagulation was poorly correlated with retrieval, with anticoagulation preceding retrieval by a median of 51 days while those without retrieval had a median of 278 days of exposure to anticoagulation.

***Conclusions*—**VCF retrieval increased over the study period but remained suboptimal and was weakly correlated with anticoagulation initiation. **(*J Am Heart Assoc*. 2017;6:e006708. DOI: 10.1161/JAHA.117.006708.)**

Key Words: pulmonary embolism • retrieval device • vena cava • vena cava filter • venous thromboembolism

Vena cava filters (VCFs) are used to mechanically prevent thrombi from migrating to the pulmonary circulation. Generally, VCFs are reserved for patients who have absolute or relative contraindications to anticoagulation and who are at a high risk of recurrent venous thromboembolism (VTE).[1–3] With the advent of retrievable VCFs, there has been a marked increase in overall use.[4–6] Retrievable VCFs differ in that they can be removed once contraindications have subsided and patients can be initiated on anticoagulation.

In real-world settings, retrieval rates of VCFs have been dismal, with reports ranging from 10% to 50% and an estimated average near 30%.[7,8] Poor retrieval rates correspond to an increase in reported adverse events.[7] Complications associated with VCFs include increased risk of deep vein thrombosis (DVT), inferior vena cava thrombosis, inferior vena cava penetration, VCF fracture, and VCF embolization.[7,9–11] Given these trends, the US Food and Drug Administration has issued a safety communication highlighting the need to remove VCFs once the risk of pulmonary embolism (PE) has subsided based on modeling studies showing that VCFs are most clinically beneficial if retrieved within 90 days after implantation.[11,12]

Given the continued growth in VCF use and the variation that has been observed between institutions,[13–17] assessment of what factors drive retrieval rates and timing of anticoagulation on a national scale is needed to evaluate clinical practice.[18] This study sought to evaluate the trend in retrieval rates and patient factors associated with retrieval as well as the association between retrieval and anticoagulation. While retrieval rates were expected to increase over time, we hypothesized differential retrieval based on indication and patient characteristics. Furthermore, we hypothesized there would be a weak association between retrieval and anticoagulation, although treatment with anticoagulation generally indicates there would no longer be a continued need for an indwelling VCF.

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Clinical Perspective

What Is New?

- This is the first known study to examine retrieval rates for vena cava filters (VCFs) in a national cohort.
- The results are consistent with prior meta-analyses of single institution retrieval rates showing about a 25% to 30% retrieval rate of all placed.
- Despite safety warnings for indwelling VCFs, most remained in place and were poorly correlated with initiation of anticoagulation.
- Retrieval rates were strongly dependent on age, with older patients less likely to have retrieval, patient residence, prophylactic indication for VCF placement (no thrombosis present), and having VCF placement in more recent years.

What Are the Clinical Implications?

- The US Food and Drug Administration has suggested that VCFs be removed once clinically appropriate to avoid complications.
- These warnings were in response to many reports of VCF failures including device fractures and penetration of the vena cava that were associated with indwell time.
- In order to maximize the net clinical benefit of VCFs, patients should be initiated on anticoagulation once contraindications have abated and VCFs should be removed.
- Utilization of VCFs and subsequent retrieval rates vary widely by geography, suggesting that institutions and clinics should evaluate their practices to better ensure patient safety.

Methods

Data Source

This observational cohort study utilized the Truven Health Analytics MarketScan database, which are administrative healthcare claims data including medical diagnostic and procedural information and pharmacy fill records billed to an individual's health insurance. The data include information for ≈40 million unique individuals per year. The university's Institutional Review Board approved use of the data and waived the requirement for informed consent of participants given that the data are de-identified and collected for nonresearch purposes.

Cohort Identification

All patients during the years 2010 to 2014 who had a VCF placed were identified using *Current Procedural Terminology* (CPT: 37191, 37620, 35940) and *International Classification of Diseases, 9th revision* (ICD-9: 38.7) procedural codes. The indication for VCF was identified by ICD-9 diagnosis codes as PE (415.1x) with or without DVT, DVT only (451.xx or 453.xx), or no apparent VTE (prophylactic).[19,20] To increase the validity of these indication diagnoses, only the primary diagnosis field was used. For inclusion, patients were required to be 18 years old or older and have a minimum of 6 months of eligibility in the database before VCF placement.

Cohort Characteristics

Demographic variables included age, sex, geographic region, and residence status. Age was divided into 18 to 34, 35 to 44, 45 to 54, 55 to 64, 65 to 74, and 75 and older categories. Geographic region included US census regions (Northeast, North Central, South, West, and unknown) and residence status was divided into urban or rural. Insurance status was classified as commercial or Medicare, fully or partially capitated, and assignment to a primary care provider (PCP).

Conditions and procedures present during VCF implantation were recorded. Concurrent bleeding, unstable condition, sepsis or septic shock, infection, anemia, trauma, and pregnancy were all recorded using ICD-9 diagnosis codes.[13,20] Patients receiving thrombolytic therapy, embolectomy procedures, or major surgery were identified using a combination of procedural codes.[21] Patients who died during the hospitalization during which the VCF was placed were also noted. Comorbid conditions observed in the pre-index period consisted of Charlson comorbidities along with a Charlson Comorbidity Index, which represents the overall "comorbidity burden" widely used for risk adjustment.[22,23]

Outcome Events

The primary outcome was VCF retrieval identified by CPT (37 193, 37 203) and ICD-9 (38.7) procedure codes. Given that the ICD-9 procedure code for placement and retrieval is the same, retrievals for those patients only having the ICD-9 procedure code present had to be on separate days to record retrieval. However, since CPT codes and not ICD-9 codes are used for billing purposes, patients lacking the CPT codes were the exception, with >95% of all patients having CPT codes recorded. Patients were followed forward from the VCF placement until the VCF was retrieved, they died, they were lost to follow-up, or the end of the study period. The 30-, 60-, 90-, 180-day, and 1-year cumulative incidence of VCF retrieval was estimated using Fine and Gray's time-to-event, survival analysis methodology, accounting for death as a competing risk.[24] Time to VCF retrieval was also reported.

Time to Anticoagulation Initiation

Anticoagulation initiation was assessed as the first outpatient prescription for an injectable (dalteparin, enoxaparin,

tinzaparin, fondaparinux) or oral (warfarin, dabigatran, rivaroxaban, apixaban) anticoagulant. Those with prophylactic indications ("no VTE") were excluded as they might not have indications for anticoagulation on discharge. Furthermore, those who had VCF retrieval before discharge were excluded. Time to anticoagulation was compared with the time to retrieval and described for those who did not have retrieval during follow-up. Time for both events was calculated based on the date of discharge from a hospitalization since the filled prescriptions data would not be available until hospital discharge occurred.

Time-to-Event Analysis

To identify factors associated with VCF retrieval, we developed a Cox proportional hazards model including patient characteristics. The proportionality assumption for all variables was evaluated for using Schoenfeld residuals as well as using time as an interaction term for each variable. Both methods showed that this assumption held true. Because of collinearity with age, Medicare or commercial insurance status was excluded in the model. Two models were estimated predicting 90-day and 1-year retrieval. The 90-day time point was chosen to represent "early retrievals" and was consistent with a prior modeling study showing higher net clinical benefit if removed in <90 days.[11] Patients who had not had retrieval or had not died at the end of the 90-day or 365-day period were censored. Hazard ratios and their 95% confidence intervals were estimated. All analyses were conducted using SAS Enterprise Guide version 7.1 (Cary, NC) with significance level of α=0.05 for all statistical analyses.

Results

Patient Characteristics

During 2010 to 2014, 54 766 patients received a VCF and met the eligibility requirements to be included in the study. Of these, 36.9% presented with a PE, 43.9% with DVT alone, and 19.2% had no apparent VTE present (Table 1). The mean (SD) age of the cohort was 65 (16) years old, 51% were female, and they were geographically diverse with nearly 85% residing in urban areas. Insurance details included 13.9% of the cohort having a primary care provider and 8.6% having insurance with full or partial capitated payments. A total of 1628 (3.0%) of the cohort died during the initial hospitalization and were not included in subsequent analyses.

Overall, 14.3% (N=7619) of the cohort who survived the index hospitalization had the VCF retrieved within 1 year and 8% (N=4228) died (Table 2). For those who had retrieval, the mean (SD) time to retrieval was 93 (78) days, with a median of 71 days and interquartile range (IQR) of 35 to 130 days. Those with PE had the highest mean and median times to retrieval (101 and 81 days) compared with those with DVT only (91 and 68 days) and compared with those with no VTE (83 and 61 days, P<0.001 for all comparisons).

Figure 1 shows the cumulative incidence of VCF retrieval by the index indication and Table 3 shows the cumulative incidence for selected variables. At 1 year, retrieval was highest for those with no VTE on index, reaching nearly 25% (23.9–25.8%). Retrieval increased with each year of study, going from 14.0% (13.3–14.7%) in 2010 up to 38.2% (19.4–57.0%, skewed by low follow-up time) in 2014 (P<0.001 for trend excluding 2014 data). Data from 2014 allowed for smaller sample size for 1-year of follow-up. However, trends were consistent across smaller time frames for 2014 and showed a year-over-year increase in retrieval at all time points. Differences in retrieval between age groups were significant, with younger age groups having higher retrieval. For example, those aged 18 to 34 had 1-year retrieval of 42.8% (40.4–45.2%) while retrieval in those 75 years old and older was just 5.4% (5.0–5.8%, P<0.001).

Factors Related to Retrieval

In fully adjusted analyses (Table 4), age remained significantly associated with VCF retrieval at both 90 days and 365 days of follow-up, although the association was much stronger for the 1-year model. Patients with no VTE were more likely to have retrieval compared with those with DVT only, and there was no difference in retrieval between those with PE compared with those with DVT. Geographic region was also significant, with those residing in the North Central (90 days and 1 year) and West (1 year only) regions being more likely to have retrieval compared with those in the Northeast.

Year of filter placement was modeled both as a covariate as well as used to stratify the analysis. In stratified analysis, no differences were observed between the covariates and their association with VCF retrieval compared with the base model with year as a covariate. As a covariate, each year of VCF placement was associated with increased 90-day and 1-year retrieval compared with year 2010. For the final year 2014, this corresponded to nearly a 2-fold difference in retrieval rate compared with 2010 (hazard ratio=1.90, 95% confidence interval, 1.76–2.06).

Time to Anticoagulation

During follow-up, the data set had follow-up prescription information for 37 272 persons in the cohort with DVT/PE

Table 1. Demographic and Clinical Characteristics of Patients Receiving VCFs by Indication

	All		Pulmonary Embolism		Deep Vein Thrombosis		No PE/DVT	
	N	%	N	%	N	%	N	%
	54 766	100.0	20 202	36.9	24 060	43.9	10 504	19.2
Age group (y)								
Mean, SD	65 (16)		64 (15)		69 (16)		60 (17)	
18 to 34	2196	4.0	728	3.6	610	2.5	858	8.2
35 to 44	3551	6.5	1347	6.7	1183	4.9	1021	9.7
45 to 54	7888	14.4	3337	16.5	2757	11.5	1794	17.1
55 to 64	13 076	23.9	5530	27.4	4881	20.3	2665	25.4
65 to 74	9422	17.2	3452	17.1	4334	18.0	1636	15.6
75 and older	17 846	32.6	5492	27.2	10 038	41.7	2316	22.0
Sex of patient								
Male	26 839	49.0	10 217	50.6	11 542	48.0	5080	48.4
Female	27 927	51.0	9985	49.4	12 518	52.0	5424	51.6
Region								
Northeast	11 526	21.0	4154	20.6	5191	21.6	2181	20.8
North Central	15 678	28.6	5752	28.5	7142	29.7	2784	26.5
South	18 448	33.7	6666	33.0	7882	32.8	3900	37.1
West	7891	14.4	3158	15.6	3361	14.0	1372	13.1
Unknown	1223	2.2	472	2.3	484	2.0	267	2.5
Residence								
Rural	8496	15.5	3119	15.4	3381	14.1	1996	19.0
Urban	46 270	84.5	17 083	84.6	20 679	85.9	8508	81.0
Concurrent conditions during hospitalization								
Bleed	5004	9.1	1418	7.0	2779	11.6	807	7.7
Unstable condition	870	1.6	243	1.2	464	1.9	163	1.6
Sepsis	2351	4.3	619	3.1	1360	5.7	372	3.5
Infection	9202	16.8	3105	15.4	4680	19.5	1417	13.5
Anemia	10 195	18.6	3193	15.8	5433	22.6	1569	14.9
Trauma	5777	10.5	1600	7.9	3027	12.6	1150	10.9
Thrombolytic therapy	841	1.5	452	2.2	316	1.3	73	0.7
Embolectomy procedure	367	0.7	176	0.9	149	0.6	42	0.4
Major surgery	13 371	24.4	5249	26.0	5836	24.3	2286	21.8
Pregnant	441	0.8	148	0.7	221	0.9	72	0.7
Died during hospitalization	1628	3.0	720	3.6	461	1.9	447	4.3
Comorbid conditions								
CCI score, mean (SD)	3.1 (3.3)		2.9 (3.3)		3.5 (3.4)		2.9 (3.3)	
History of VTE	4864	8.9	1522	7.5	2149	8.9	1193	11.4
History of bleeding	8483	15.5	2587	12.8	4577	19.0	1319	12.6
MI	3254	5.9	1122	5.6	1623	6.7	509	4.8
CHF	8464	15.5	2620	13.0	4514	18.8	1330	12.7
PVD	7450	13.6	2147	10.6	4030	16.7	1273	12.1
Dementia	2366	4.3	621	3.1	1518	6.3	227	2.2

Continued

Table 1. Continued

	All		Pulmonary Embolism		Deep Vein Thrombosis		No PE/DVT	
	N	%	N	%	N	%	N	%
COPD	12 925	23.6	4872	24.1	5735	23.8	2318	22.1
Rheumatism	2286	4.2	801	4.0	1087	4.5	398	3.8
PUD	1593	2.9	503	2.5	829	3.4	261	2.5
Mild liver disease	4344	7.9	1586	7.9	1958	8.1	800	7.6
Severe liver disease	549	1.0	135	0.7	315	1.3	99	0.9
Diabetes mellitus	13 623	24.9	4483	22.2	6322	26.3	2818	26.8
Diabetes mellitus w/complications	3663	6.7	1040	5.1	1853	7.7	770	7.3
Paralysis	2244	4.1	672	3.3	1228	5.1	344	3.3
Renal disease	6684	12.2	1713	8.5	3836	15.9	1135	10.8
Cancer	16 672	30.4	6251	30.9	7856	32.7	2565	24.4
Metastatic cancer	7534	13.8	3013	14.9	3433	14.3	1088	10.4
Stroke	9744	17.8	2957	14.6	5240	21.8	1547	14.7
Hypertension	30 918	56.5	10 719	53.1	14 541	60.4	5658	53.9
CHD	11 125	20.3	3604	17.8	5597	23.3	1924	18.3
Hyperlipidemia	18 195	33.2	6676	33.0	8047	33.4	3472	33.1
Insurance source								
Commercial	26 350	48.1	10 821	53.6	9281	38.6	6248	59.5
Medicare	28 416	51.9	9381	46.4	14 779	61.4	4256	40.5
Insurance details								
Assigned care provider	7586	13.9	2910	14.4	3116	13.0	1560	14.9
Capitated payment	4718	8.6	1821	9.0	1969	8.2	928	8.8
Year VCF placed								
2010	11 784	21.5	4250	21.0	5239	21.8	2295	21.8
2011	12 750	23.3	4565	22.6	5672	23.6	2513	23.9
2012	12 210	22.3	4369	21.6	5393	22.4	2448	23.3
2013	9395	17.2	3596	17.8	4062	16.9	1737	16.5
2014	8627	15.8	3422	16.9	3694	15.4	1511	14.4

CCI indicates Charlson Comorbidity Index; CHD, coronary heart disease; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; DVT, deep vein thrombosis; IVC, inferior vena cava; MI, myocardial infarction; PE, pulmonary embolism; PUD, peptic ulcer disease; PVD, peripheral vascular disease; VCF, vena cava filter; VTE, venous thromboembolism

indications and who did not have retrieval before discharge. Among these, 23 510 (63.1%) initiated anticoagulation including 61% who never had retrieval, 79.2% among those with retrieval, and 47.8% among those who died, with median time to initiation of 17 (IQR 6–50) days. Initiation of anticoagulation differed significantly for those who eventually had retrieval (N=4729, median 11, IQR 5–-31 days) and those who did not have retrieval (N=17 628, median 17, IQR 6–50 days, $P<0.001$). Overall, time to anticoagulation and time to retrieval were poorly correlated, with anticoagulation preceding retrieval by a median of 51 (IQR 13–110) days and $R^2=0.06$ (Figure 2). For those who never had retrieval, there was a median of 278 (IQR 98–350) days of anticoagulation treatment during the 1-year follow-up period.

Discussion

In PREPIC2 (Prevention du Risque d'Embolie Pulmonaire par Interruption Cave 2), the only randomized trial for retrievable VCFs, the retrieval rate was >90% with a dedicated 3-month follow-up visit.[25] However, in real-world practice, estimates of the retrieval rates range much lower, with an average of about one third of all VCFs eventually being retrieved.[7] Patients are at risk for complications including inferior vena cava thrombosis, device fracture, device migration, and DVT so long as

Table 2. Outcomes of Patients Receiving VCFs At 1 Year of Follow-Up

	Overall		PE		DVT		No VTE	
Outcome								
VCF retrieval	7619	(14.3%)	2884	(14.8%)	2686	(11.4%)	2049	(20.4%)
Died	4228	(8.0%)	1627	(8.4%)	1950	(8.3%)	651	(6.5%)
Censored	41 291	(77.7%)	14 971	(76.8%)	18 963	(80.4%)	7357	(73.2%)
Follow-up time								
Mean, SD	202 (144)		202 (143)		202 (145)		200 (144)	
Median, IQR	186 (56–365)		188 (58–365)		187 (54–365)		176 (56–365)	
Time to retrieval								
Mean, SD	93 (78)		101 (81)		91 (79)		83 (73)	
Median, IQR	71 (35–130)		81 (38–143)		68 (33–132)		61 (32–113)	
Time to death								
Mean, SD	96 (91)		94 (91)		97 (91)		100 (90)	
Median, IQR	63 (26–142)		58 (24–140)		66 (26–144)		67 (32–141)	

DVT indicates deep vein thrombosis; IQR, interquartile range; PE, pulmonary embolism; VCF, vena cava filter; VTE, venous thromboembolism.

the VCF remains in place.[7,26] One study found that there is an optimal net clinical benefit if a VCF is retrieved within 29 to 54 days after placement in prophylactic indications, which remained in favor of VCFs up to 180 days postimplantation.[11] That article was referenced by a US Food and Drug Administration safety communication, which responded to multiple reports of complications with VCFs and increasing publicity through litigation and media.[12]

The current analysis is consistent with other reports regarding VCF retrieval.[7,8] The retrieval rate increased over time, from roughly every 1-out-7 VCFs being retrieved in 2010 up to 1-out-4 retrieved in 2014. This effect may be explained by the increased attention VCFs received over this time period including US Food and Drug Administration safety alerts, as well as guideline updates (American College of Chest Physicians),[1] which called for more conservative use of VCFs

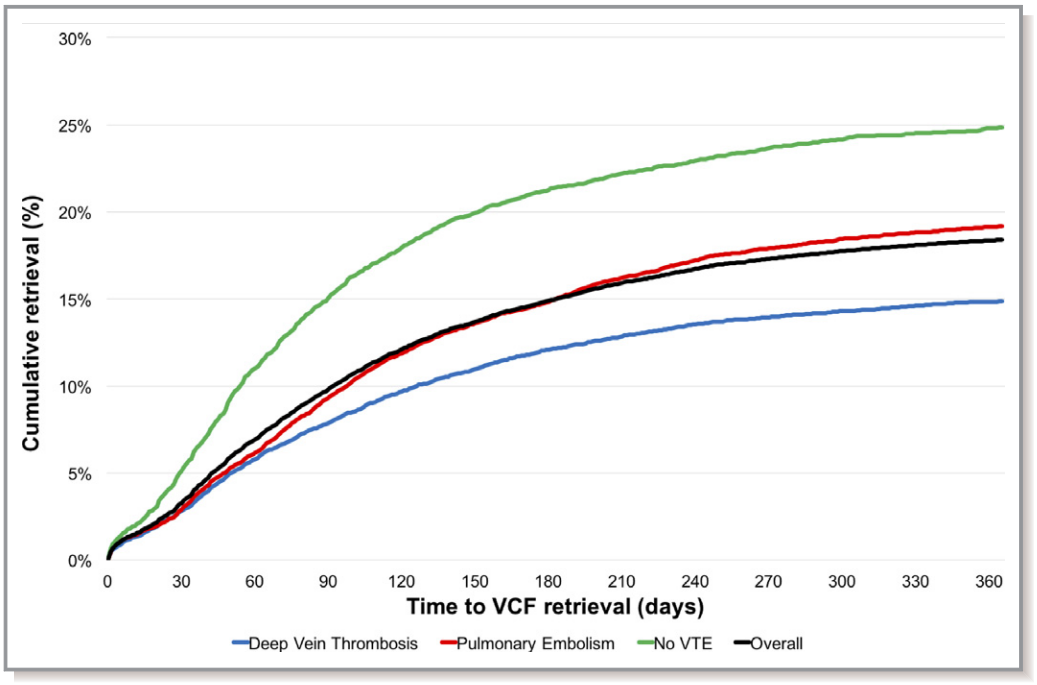

Figure 1. Cumulative incidence of vena cava filter (VCF) retrieval by indication over 1-y of follow-up accounting for death as a competing risk. VTE indicates venous thromboembolism.

Table 3. Cumulative Incidence and 95% Confidence Interval of Inferior VCF Retrieval at Time Intervals by Key Demographic and Clinical Factors

	30 Days	60 Days	90 Days	180 Days	365 days
Overall, %	3.3 (3.1–3.5)	6.9 (6.7–7.2)	9.8 (9.5–10.1)	14.9 (14.6–15.2)	18.4 (18.0–18.8)
Indication					
No VTE, %	5.2 (4.7–5.6)	11.0 (10.4–11.7)	15.0 (14.3–15.8)	21.3 (20.4–22.2)	24.8 (23.9–25.8)
DVT, %	2.8 (2.6–3.0)	5.8 (5.5–6.1)	7.9 (7.5–8.2)	12.1 (11.6–12.6)	14.9 (14.3–15.4)
PE, %	2.9 (2.7–3.1)	6.1 (5.8–6.5)	9.3 (8.9–9.8)	14.8 (14.3–15.4)	19.2 (18.5–19.8)
Year VCF placed					
2010, %	3.1 (2.8–3.5)	6.0 (5.6–6.5)	8.0 (7.5–8.6)	11.3 (10.7–11.9)	14.0 (13.3–14.7)
2011, %	3.0 (2.7–3.3)	6.3 (5.9–6.8)	8.8 (8.3–9.3)	13.2 (12.6–13.9)	16.1 (15.4–16.8)
2012, %	3.4 (3.1–3.8)	7.5 (7.0–8.0)	9.9 (9.4–10.5)	15.6 (14.9–16.3)	19.2 (18.4–20.0)
2013, %	3.3 (3.0–3.7)	7.5 (7.0–8.1)	11.2 (10.5–11.9)	17.1 (16.3–18.0)	21.6 (20.7–22.6)
2014, %	3.7 (3.3–4.2)	7.7 (7.1–8.3)	12.4 (11.6–13.3)	20.5 (19.4–21.6)	38.2 (19.4–57.0)*
Age group (y)					
18 to 34, %	6.8 (5.8–7.9)	15.2 (13.7–16.8)	22.8 (21.0–24.7)	34.9 (32.7–37.1)	42.8 (40.4–45.2)
35 to 44, %	6.1 (5.3–6.9)	13.9 (12.7–15.1)	18.9 (17.6–20.3)	28.4 (26.8–30.0)	35.5 (33.7–37.2)
45 to 54, %	4.9 (4.5–5.5)	11.4 (10.7–12.2)	15.9 (15.0–16.8)	23.7 (22.6–24.7)	29.3 (28.1–30.4)
55 to 64, %	3.9 (3.5–4.2)	8.0 (7.5–8.5)	11.5 (10.9–12.1)	17.8 (17.0–18.5)	21.8 (21.0–22.7)
65 to 74, %	2.7 (2.4–3.1)	5.3 (4.8–5.8)	7.4 (6.9–8.0)	11.4 (10.7–12.1)	14.1 (13.3–15.0)
75 and older, %	1.4 (1.2–1.6)	2.4 (2.1–2.6)	3.1 (2.8–3.3)	4.5 (4.1–4.8)	5.4 (5.0–5.8)
Cancer					
Yes, %	2.6 (2.3–2.8)	4.5 (4.2–4.9)	6.3 (5.9–6.7)	9.1 (8.6–9.7)	11.7 (11.1–12.4)
No, %	3.6 (3.4–3.8)	7.9 (7.6–8.2)	11.1 (10.8–11.5)	17.0 (16.6–17.5)	20.8 (20.4–21.3)
Insurance source					
Commercial, %	4.8 (4.5–5.0)	10.5 (10.1–10.9)	14.9 (14.5–15.4)	22.6 (22.1–23.2)	28.0 (27.4–28.6)
Medicare, %	1.9 (1.7–2.0)	3.4 (3.2–3.6)	4.6 (4.3–4.9)	7.0 (6.6–7.3)	8.6 (8.2–8.9)

DVT indicates deep vein thrombosis; VCF, vena cava filter; PE, pulmonary embolism; VTE, venous thromboembolism.
*Estimates for long-term follow-up in 2014 are unstable because of smaller sample sizes. Extrapolation of 2014 6-month estimates with the overall trend in retrieval rates across 2010 to 2014 produce a retrieval estimate of 23% to 25%.

compared with guidelines presented by other physician societies in interventional radiology and trauma.[27,28] For those who did have their VCF retrieved in our study, time to retrieval was within mean and median times of 93 and 71 days postimplantation. However, retrieval was poorly correlated with anticoagulation initiation.

Several patient-related factors were also associated with retrieval, including demographic and clinical characteristics. Increasing age of the patient was associated with lower retrieval, which likely contributed to perceived ongoing risk of PE or a desire to not treat older individuals with anticoagulation. Region of residence was also strongly associated with retrieval, which may indicate regional practice differences as well as differences in patient demography. Patients living in an urban setting were more likely to have their filter retrieved as well, suggesting that patients being referred to a distant medical center for VCF placement may have limited follow-up for retrieval. Among patient comorbidities, those considered prothrombotic (eg, cancer, stroke, hyperlipidemia, myocardial infarction) and related to bleeding (eg, liver disease) were associated with lower retrieval.

Other studies investigating factors associated with retrieval rates have focused on poor patient follow-up as the primary reason VCFs are not removed.[29–33] Patient follow-up is generally left to the referring or primary physician, with some studies showing improved retrieval if the responsibility of follow-up is placed on the implanting physician instead.[32–34] In institutions where the implanting physicians are made responsible for patient follow-up, retrieval rates have increased from 24% to 59% and 29% to 60%.[32,33]

While there is inherent concern for patient safety associated with these low retrieval rates, clinical practices are also financially incentivized to increase retrieval of VCFs. One study showed that because of the increased cost between

Table 4. Regression Results Showing Patient Factors Associated With 90-D (Early) Retrieval and 1-Year Retrieval

	90-D Retrieval			1-Y Retrieval		
	HR	95% CI		HR	95% CI	
Age group (y)						
18 to 34	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
35 to 44	0.97	0.94	1.00	0.88	0.80	0.97
45 to 54	0.95	0.92	0.98	0.79	0.72	0.86
55 to 64	0.91	0.88	0.93	0.62	0.57	0.68
65 to 74	0.87	0.84	0.89	0.41	0.37	0.45
75 and older	0.82	0.80	0.84	0.17	0.15	0.19
Sex						
Male	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Female	1.01	1.01	1.02	1.04	0.99	1.09
Region						
Northeast	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
North Central	1.03	1.02	1.04	1.29	1.20	1.38
South	0.99	0.98	1.00	0.89	0.83	0.95
West	1.10	1.09	1.12	1.89	1.76	2.04
Unknown	1.01	0.98	1.04	1.24	1.05	1.46
Residence						
Rural	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Urban	1.01	1.00	1.02	1.13	1.06	1.21
Index VTE						
DVT only	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
No VTE	1.05	1.03	1.06	1.24	1.17	1.32
PE	0.99	0.98	1.00	0.99	0.93	1.04
Concurrent conditions during hospitalization						
Bleed	1.00	0.99	1.02	1.10	0.93	1.29
Unstable condition	0.98	0.96	1.00	0.80	0.60	1.06
Sepsis	1.00	0.98	1.01	0.92	0.76	1.12
Infection	0.98	0.97	0.99	0.84	0.76	0.91
Anemia	0.99	0.98	0.99	0.91	0.84	0.98
Trauma	0.99	0.98	1.00	1.00	0.92	1.09
Thrombolytic therapy	1.06	1.02	1.09	1.29	1.11	1.49
Embolectomy procedure	1.00	0.96	1.04	0.89	0.68	1.17
Major surgery	0.98	0.97	0.99	0.92	0.87	0.97
Pregnant	1.05	0.99	1.11	1.36	1.15	1.60
Comorbid conditions during pre-index look back						
CCI score (per 1 unit)	1.00	0.99	1.01	0.97	0.90	1.05
History of VTE	1.03	1.02	1.04	1.17	1.08	1.26
History of bleeding	0.98	0.97	0.99	0.77	0.67	0.87
Myocardial infarction	0.99	0.98	1.00	0.82	0.71	0.96
Heart failure	0.98	0.97	0.99	0.67	0.60	0.74
Peripheral vascular disease	0.99	0.98	1.00	0.85	0.77	0.94

Continued

Table 4. Continued

	90-D Retrieval			1-Y Retrieval		
	HR	95% CI		HR	95% CI	
Dementia	0.97	0.96	0.98	0.31	0.22	0.43
COPD	0.99	0.98	1.00	0.88	0.83	0.94
Rheumatism	1.00	0.98	1.01	0.96	0.84	1.08
Peptic ulcer disease	1.02	1.00	1.04	1.16	0.95	1.41
Mild liver disease	1.00	0.98	1.01	1.00	0.91	1.11
Severe liver disease	0.99	0.98	1.00	0.86	0.81	0.92
Diabetes mellitus	0.99	0.98	1.00	0.96	0.85	1.09
Diabetes mellitus w/complications	0.98	0.97	1.00	0.76	0.65	0.89
Paralysis	0.98	0.97	0.99	0.81	0.73	0.90
Renal disease	0.99	0.98	1.00	0.94	0.87	1.00
Cancer	0.91	0.89	0.94	0.28	0.17	0.46
Metastatic cancer	0.92	0.90	0.93	0.43	0.38	0.49
Stroke	0.98	0.98	0.99	0.80	0.73	0.88
Hypertension	1.00	0.99	1.00	0.95	0.90	0.99
Coronary heart disease	1.00	0.99	1.00	0.87	0.80	0.94
Hyperlipidemia	1.02	1.01	1.03	1.23	1.17	1.30
Insurance details						
Assigned care provider	1.00	0.99	1.02	1.03	0.94	1.12
Capitated payment	0.99	0.97	1.00	0.84	0.75	0.94
Year VCF placed						
2010	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
2011	1.01	1.00	1.02	1.19	1.11	1.28
2012	1.03	1.02	1.04	1.41	1.32	1.52
2013	1.04	1.03	1.05	1.63	1.51	1.75
2014	1.05	1.04	1.07	1.90	1.76	2.06

C-index for models: 90-d retrieval (0.695), 1-y retrieval (0.720). CCI indicates Charlson Comorbidity Index; CI, confidence interval; COPD, chronic obstructive pulmonary disease; DVT, deep vein thrombosis; HR, hazard ratio; PE, pulmonary embolism; VTE, venous thromboembolism.

retrievable and permanent devices, retrievable devices are only cost-effective in interventional radiology clinics if at least 40% are eventually retrieved, driven by separate billable procedure codes for implantation and retrieval.[34] Even without the cost differential between permanent and retrievable devices, it is inherent that clinic revenue will be increased with improved patient follow-up, management, and retrieval. At least 1 study at a single institution evaluated the financial feasibility of implementing a quality improvement initiative within their clinical practice.[35] They compared baseline retrieval rates with those achieved by issuing letters to patients and then with those achieved with prospective follow-up of patients. Overall, their retrieval rates increased from 8% to 40% with mailed letters to retrospective patients, and increased further up to 52% with prospective follow-up of new patients. Although improving VCF retrieval requires a shift in patient management, retrieval will improve patient outcomes and provides financial incentive to the clinic.

Limitations

This study has limitations inherent to all studies utilizing administrative claims data.[36,37] Most notably, detailed clinical data are not available, which may have impacted the study results. Procedural codes were utilized to identify VCF placement; however, these codes are not specific to permanent or retrievable devices. As of 2006, retrievable devices made up about 85% of the VCF market in the United States, which likely increased to >90% since then.[38–41] Therefore, the retrieval estimates presented here are underestimated. Assuming that 10% to 20% of all VCFs used are permanent and thus cannot be retrieved, this would make

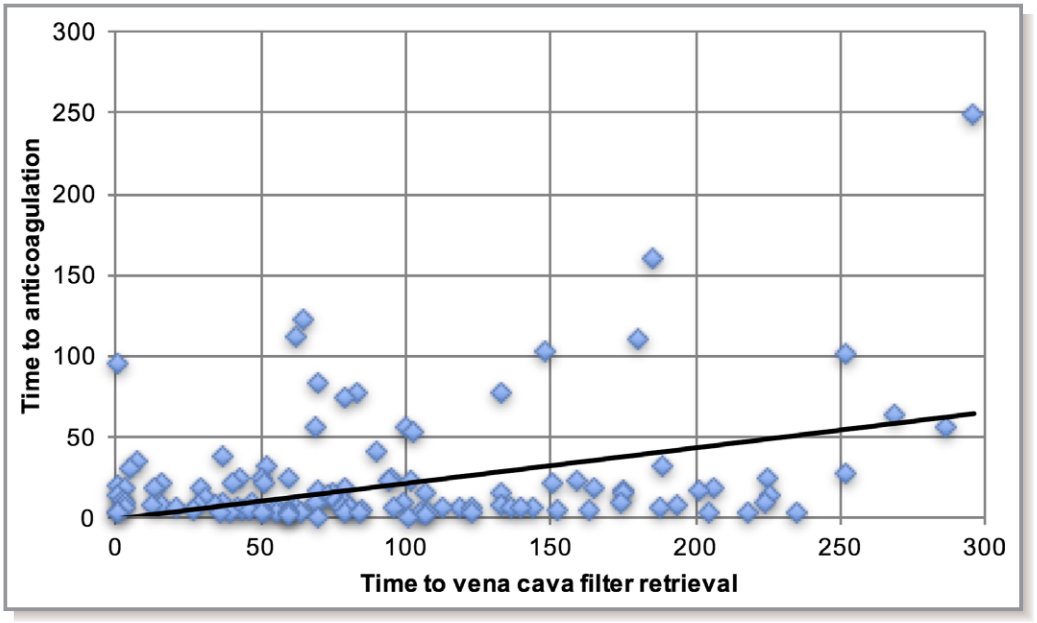

Figure 2. Plot of times to outpatient anticoagulation and vena cava filter retrieval. Black line represents the fit of the data. Time is based on follow-up after the discharge date from the hospitalization where the VCF was placed. Those with prophylactic indications and those with retrieval before discharge are excluded. R^2=0.06. VCF indicates vena cava filter.

our estimated retrieval ≈26% to 30%, making this corrected estimate near previous estimates of national retrieval rates of ≈30%.[6,7]

We allowed enrollment of patients in 2014, but those enrolled later in 2014 would have limited follow-up, which skewed the estimates of cumulative retrieval at 365 days. However, the increasing trend in retrieval rates is stable across estimates at earlier time points (30, 60, 90, and 180 days) in 2014. Extrapolating these stable estimates from 180 days to 365 days across all years shows a trend increasing year-to-year of +2% to 4%. Therefore, we have estimated that with perfect follow-up for those enrolled in 2014, the retrieval estimate would be nearer 23% to 25%.

It is unclear how selection of retrievable versus permanent devices would differ between, for example, older versus younger patients or in cancer patients with poor prognosis, adding some uncertainty to the comparison of retrieval between certain relevant groups. However, in contemporary patients, use of retrievable VCFs (also referred to as "optional" VCFs because they can be left permanently or retrieved when clinically indicated) may be a more preferred therapeutic option allowing for flexibility in care versus nonretrievable alternatives. Thus, while there may be a differential influence of this limitation, the results are still interpretable to identify patient subgroups that are less likely to receive, as well as to not have retrieval of, retrievable VCFs. Therefore, the trend showing an increase in retrieval rates likely indicates both a trend in uptake of retrievable VCFs as well as increased retrieval rates. More work will be needed with detailed clinical data to determine differences in selection of permanent versus retrievable treatment options. Lastly, routine medications administered during a hospital stay are often omitted from billing records because of capitated payment systems. Thus, we did not attempt to observe use of anticoagulation during the hospital stay because it would be unreliably reported or unreported.

Conclusion

In this national study of VCF retrieval, less than 1 of every 4 filters was retrieved within 1 year. Retrieval rates differ based on patient characteristics but increased over the study time period (2010–2014), while retrieval and initiation of anticoagulation were poorly correlated. Physicians should consider ongoing indications for indwelling VCFs and timing of retrieval with anticoagulation initiation throughout follow-up to optimize patient care.

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Disclosures

None.

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