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Patient and hospital characteristics predictive of inferior vena cava filter usage in venous thromboembolism patients

A study from the 2013 to 2014 Nationwide Readmissions Database

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Abstract

To examine the association between patient and hospital characteristics and inferior vena cava filter (IVCF) utilization in patients with venous thromboembolism (VTE).

The 2013 to 2014 Nationwide Readmissions Database was used to define a cohort of patients with VTE aged ≥18 after a primary VTE diagnosis. Comorbidities of interest were classified via diagnosis codes and IVCF placement was identified via procedure code. Chi square analysis tested differences between patient and hospital-level characteristics and whether or not IVCFs were placed. A hierarchical logistic regression model estimated the relationship between patient-level factors (demographics, socioeconomic status, comorbidities), hospital-level factors (bed size, teaching status, urbanity) and whether or not IVCFs were placed. Additional models were specified to examine goodness of fit across methodological alternatives.

There were 212,395 VTE hospitalizations, with 12.18% (n=25,877) receiving IVCF placement. There were significant differences between those who did and did not receive IVCF placement; notably, those receiving IVCFs were older ($P<.001$), had Medicare insurance more than private ($P<.001$), longer lengths of stay ($P<.001$), and were in privately owned hospitals ($P<.001$). IVCF placement remained significantly associated with patient and hospital-level characteristics following multivariate adjustment via hierarchical logistic regression; notably, age >80 (adjusted Odds Ratio [aOR]: 2.53, 95% confidence interval [CI]: 2.25–2.85), ≥13 comorbid conditions (aOR: 3.85, 95% CI: 3.25–4.27), and privately owned hospitals (aOR: 1.21, 95% CI: 1.08–1.36). Optimal goodness-of-fit was achieved with a combination of random effects and patient-level fixed effects.

These findings provide evidence that combinations of patient and hospital-level factors are related to whether patients with VTE receive IVCFs.

Abbreviations: ACCP = American College of Chest Physicians, AHRQ = Agency for Healthcare Research and Quality, AIC = Akaike information criterion, BIC = Bayesian information criterion, CI = confidence interval, DVT = deep vein thrombosis, ICC = intraclass correlation coefficient, ICD = International Classification of Disease, IVCF = inferior vena cava filter, NRD = Nationwide Readmissions Database, PE = pulmonary embolism, SIR = Society for Interventional Radiology, VTE = venous thromboembolism.

Keywords: claims data, inferior vena cava filters, venous thromboembolism

1. Introduction

Inferior vena cava filters (IVCFs) may be used as secondary prevention after venous thromboembolism (VTE), and are also used prophylactically for the prevention of pulmonary embolism (PE) in patients meeting certain high-risk criteria such as failed or contraindicated anticoagulation.[1] Despite the increased risk for VTE recurrence after IVCF placement,[2,3] device-related complications,[4] and recommendation that indications for IVCFs be "rare" in patients with deep vein thrombosis (DVT) and PE,[5] IVCFs continue to be employed prophylactically and therapeutically in patients with VTE.

In 2005, the PREPIC study conducted a randomized controlled trial of permanent IVCF placements in patients with DVT and followed up for 8 years; it was reported that IVCFs reduced PE risk but increased DVT, with overall no effect on survival rates.[3] A 2015 randomized controlled trial (the PREPIC2 study) of retrievable IVCFs reached similar conclusions: where patients with VTE were given either retrievable IVCFs and anticoagulation or anticoagulation alone there were no discernible differences in recurrent PE after 3 months.[6] Evidence on IVCF effectiveness from studies in particular subgroups remains mixed. One observational study in 2012 reported that in-hospital mortality rates were lower in stable patients who received IVCFs as well as in unstable patients receiving thrombolytic therapy.[7]

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A 2014 observational study also reported a decrease in in-hospital mortality in unstable adults with PE that received IVCFs.[8]

Recent studies of IVCF usage in cancer patients with VTE have demonstrated clinically poor outcomes. One 2017 population-based study of hospital discharge records found a higher 180-day risk of recurrent DVT in patients with cancer who received IVCFs, whereas these patients received no reduction of either 180-day PE risk or 30-day mortality.[9] Another 2017 retrospective cohort analysis of cancer and noncancer Canadian patients found that 21% of IVCF placements occurred in patients with no anticoagulation contraindication and that a greater proportion of these patients (31%) had active cancer(s) and a high short-term mortality rate, which suggests possible inappropriate IVCF placement in end-of-life care settings in this population.[10] In addition, a 2017 meta-analysis of IVCF placements from randomized controlled trials in cancer and noncancer PE patients concluded that there is no evidence for routine IVCF use in these populations as evidenced by a lack of reduction in both absolute and relative risk after IVCF placement.[11]

Emerging evidence in the literature suggests that patients with VTE with either DVT or PE are more likely to receive an IVCF placement if they have certain types of cancers, if they have characteristics deemed high risk for bleeding from anticoagulation therapies, or if they are treated in hospitals that have certain characteristics.[12] The purpose of this study is to expand on previous work to examine the association between patient and hospital characteristics and IVCF utilization in patients with VTE using a large sample retrospective cohort design.

2. Materials and methods

The Agency for Healthcare Research and Quality (AHRQ) 2013 and 2014 Nationwide Readmissions Database (NRD) were used in this retrospective cohort study. The NRD database includes all-payer administrative hospital discharge claims from 21 states in 2013 and 22 states in 2014 with unique patient identifiers to facilitate follow-up within each calendar year, which accounts for 85% of the discharges from all the State Inpatient Database. In addition to patient demographic information (eg, age, sex, race, and zip-code income), and diagnostic and procedural information from the NRD Core File, information on severity of illness and comorbidities were also identified by linkages via patient identification number in the NRD Severity File. Hospital characteristics (eg, bed size, ownership, teaching status, rural, or urban) were included from the NRD Hospital File and linked via hospital identifiers to patient data within each calendar year. NRD data are deidentified and publicly available; hence, this study was deemed exempt from institutional review board review.

2.1. Study population: cohort definition

The study cohort was defined as all VTE cases in patients aged 18 years and older, based on *International Classification of Disease Codes version 9* (*ICD-9*), with primary diagnoses of either DVT (*ICD-9* Codes 451.xx and 453.xx) or PE (*ICD-9* Codes 415.1x). Index hospitalization for patients with VTE was identified as the first hospitalization within each calendar year. Elective index hospitalizations were excluded. IVCF placements were identified by *ICD-9* procedural code 38.7 at any point in the 2013 to 2014 data following initial PE or DVT diagnosis. Hospitals that did not have the capacity to conduct IVCF placement, defined as performing zero IVCF procedures within the study period, were excluded to avoid bias of hospital-level characteristics. Hospitals were also required to have a minimum of 55 VTE hospitalizations during the study period to calculate reliable point estimates and 95% confidence intervals (CIs).

2.2. Variable definitions

Patients with VTE were categorized as DVT or PE according to blood clot location. Patients with DVT were further classified by location of DVT to lower (*ICD-9* Codes 451.0x, 451.1x, 451.2x, 451.81, 453.4, 453.5, 453.6), deep (*ICD-9* Codes 451.1x, cc451.81, 453.4, 453.5, 453.72, 453.82), proximal (*ICD-9* Codes 451.81, 453.41, 453.51), and migrant DVT (*ICD-9* Codes 453.1). Patient demographic, admission-related, and socioeconomic variables were also included. Age was categorized by 10-year intervals, (eg, 18–29, 30–39, 39–40, etc). Admission day was categorized as on the weekend or on a weekday. Patient health insurance was classified as Medicare, Medicaid, private insurance, self-pay, no charge, or other type of health insurance. Median household income was reported as a quartile classification of the patient's zip code of residence. Patient location was classified into 3 levels: the large metropolitan areas, small metropolitan areas, and the micropolitan with other areas (rural). Count of chronic conditions were aggregated into the following categories: 0 conditions, 1 to 3 conditions, 4 to 6, 7 to 9, 10 to 12, and ≥13.

Comorbidity measures included 28 AHRQs comorbidities and other comorbidities of interest. AHRQ comorbidities and other comorbidities of interest were identified from the NRD severity data file, and were selected based on previously published coding algorithms.[13] Comorbidities of interest included hyperlipidemia, chronic obstructive pulmonary disorder, stroke, sepsis, infection, trauma, bleeding, thrombolysis, embolectomy, and the "unstable," which refers to patients with shock or ventilator use.

Hospital characteristics included hospital ownership (eg, Government, non-Federal; privately owned non-profit; private, investment-owned), bed size, teaching status, and urban-rural designation. Bed size classifications of "Small" "Medium," and "Large," are operationalized by NRD according to a combination of hospital location and teaching status (ie, a "Small" bed size in a rural northeast United States area may have 49 beds, but 49 beds is classified as "Medium" bed size in the rural Midwestern United States).[14] Urban and rural classification were based on population thresholds of residents in the hospital county, where categories were grouped into large metropolitan areas (≥1 million residents), small metropolitan areas (metropolitan area with <1 million residents), and micropolitan and other rural areas.

2.3. Statistical analysis

Bivariate analysis via chi square analysis was performed to compare patient and hospital characteristics between IVCF users and nonusers after DVT or PE diagnosis at hospitalization. Bivariate testing for any patient characteristic or condition with <30 patients was conducted via Fisher exact test. A hierarchical logistic regression model was constructed to analyze variance in the binary outcome IVCF use, due to patient demographic and clinical characteristics and hospital characteristics being at hierarchical levels. Adjusted odds ratios and 95% CIs were calculated after controlling for these factors, with a priori significance set at 0.05.

Four hierarchical models with hospital as random effects and potential risk factors at the patient level and/or at the hospital level as fixed effects were specified to test assumptions of the original model and to explore goodness of fit across methodological alternatives. The intraclass correlation coefficient (ICC) was calculated to quantify the variance of IVCF use between hospitals and within hospitals. To account for variation of IVCF use by hospitals, a random effects only model was built as Model 1. Model 2 only included level-1 (patient level) fixed effects, that is, the patient characteristics potentially associated with IVCF use as fixed effects. Model 3 was restricted to level-2 (hospital-level) fixed effects. A full model including both level-1 and level-2 was subsequently performed as model 4. C-statistics were used as a measure of discrimination ability between IVCF use and no IVCF use. Akaike information criterion (AIC) and Bayesian information criterion (BIC) were calculated to assess the model fit across the 5 specified hierarchical models. All analysis was conducted using SAS version 9.4 (SAS Institute, Cary, NC).

3. Results

There were 212,395 patients with VTE in the NRD database with a primary diagnosis of either DVT (n=89,482) or PE (n=122,913). Approximately 12.18% (n=25,877) of these underwent IVCF placement during the study period and n=186,518 did not receive an IVCF. There were 1524 hospitals that performed at least 55 IVCF procedures, with a range of 0.60% of patients with VTE receiving IVCF to 47.10% of patients with VTE receiving IVCF in these hospitals. Table 1 provides a summary of patient and hospital characteristics, by patients who

Table 1

Patient and hospital characteristics by inferior vena cava filter use in all deep vein thrombosis and pulmonary embolism patients, from the 2013 to 2014 Nationwide Readmissions Database.

Characteristics Patient characteristics (level 1)	VTE patients receiving VCFs (N=25,877) n (%)	VTE patients who did not receive VCFs (N=186,518) n (%)	*P*	% Receiving VCF %
Age				
18–29	444 (1.72)	7876 (4.22)	<.0001	5.34
30–39	848 (3.28)	13,200 (7.08)		6.04
40–49	2061 (7.96)	22,784 (12.22)		8.30
50–59	3770 (14.57)	32,800 (17.59)		10.31
60–69	5432 (20.99)	37,907 (20.32)		12.53
70–79	5832 (22.54)	36,582 (19.61)		13.75
80+	7490 (28.94)	35,369 (18.96)		17.48
Sex				
Male	12,282 (47.46)	89,095 (47.77)	.3581	12.12
Female	13,595 (52.54)	97,423 (52.23)		12.25
Admission day				
Workdays	20,445 (79.01)	145,720 (78.13)	.0013	12.30
Weekends	5432 (20.99)	40,798 (21.87)		11.75
Insurance				
Medicare	16,515 (63.82)	98,027 (52.56)	<.0001	14.42
Medicaid	1982 (7.66)	20,119 (10.79)		8.97
Private insurance	5788 (22.37)	51,888 (27.82)		10.04
Self-pay	729 (2.82)	8614 (4.62)		7.80
No charge	136 (0.53)	1515 (0.81)		8.24
Other	727 (2.81)	6355 (3.41)		10.27
Median household income				
0–25th percentile	7022 (27.14)	50,616 (27.14)	.0688	12.18
26th–50th percentile	6651 (25.70)	48,547 (26.03)		12.05
51st–75th percentile	6106 (23.60)	44,707 (23.97)		12.02
76th–100th percentile	6098 (23.57)	42,648 (22.87)		12.51
Patient location (urban/rural status)				
Large metropolitan	15,581 (60.21)	109,404 (58.66)	<.0001	12.47
Small metropolitan	7684 (29.69)	59,097 (31.68)		11.51
Micropolitan/others	2612 (10.09)	18,017 (9.66)		12.66
Number of chronic conditions				
0	353 (1.36)	7049 (3.78)	<.0001	4.77
1–3	5282 (20.41)	56,207 (30.13)		8.59
4–6	9888 (38.21)	68,439 (36.69)		12.62
7–9	6956 (26.88)	38,188 (20.47)		15.41
10–12	2672 (10.33)	13,161 (7.06)		16.88
13+	726 (2.81)	3474 (1.86)		17.29
DVT type				
Lower DVT	21,052 (81.35)	97,409 (52.22)	<.0001	17.77
Deep DVT	20,850 (80.57)	98241 (52.67)	<.0001	17.51
Proximal DVT	13,286 (51.34)	55,161 (29.57)	<.0001	19.41
Migrans DVT	32 (0.12)	90 (0.05)	<.0001	26.23

(*continued*)

Table 1

(continued).

Characteristics Patient characteristics (level 1)	VTE patients receiving VCFs (N=25,877) n (%)	VTE patients who did not receive VCFs (N=186,518) n (%)	*P*	% Receiving VCF %
AHRQ comorbidity				
Acquired immune deficiency syndrome	67 (0.26)	546 (0.29)	.342	10.93
Alcohol abuse	963 (3.72)	5899 (3.16)	<.0001	14.03
Deficiency anemia	7283 (28.14)	38,158 (20.46)	<.0001	16.03
Rheumatoid arthritis/collagen vascular diseases	971 (3.75)	7013 (3.76)	.952	12.16
Chronic blood loss anemia	756 (2.92)	1557 (0.83)	<.0001	32.68
Congestive heart failure	2466 (9.53)	21,307 (11.42)	<.0001	10.37
Chronic pulmonary disease	5600 (21.64)	40,308 (21.61)	.9123	12.20
Coagulopathy	3134 (12.11)	12,226 (6.55)	<.0001	20.40
Depression	2848 (11.01)	21,515 (11.54)	.0123	11.69
Diabetes, uncomplicated	5501 (21.26)	35,799 (19.19)	<.0001	13.32
Diabetes with chronic complications	922 (3.56)	7078 (3.79)	.0665	11.53
Drug abuse	475 (1.84)	6078 (3.26)	<.0001	7.25
Hypertension, uncomplicated and complicated	16,224 (62.7)	109,133 (58.51)	<.0001	12.94
Hypothyroidism	3514 (13.58)	23,114 (12.39)	<.0001	13.20
Liver disease	850 (3.28)	4802 (2.57)	<.0001	15.04
Lymphoma	477 (1.84)	2833 (1.52)	<.0001	14.41
Fluid and electrolyte disorders	7576 (29.28)	37,457 (20.08)	<.0001	16.82
Metastatic cancer	3006 (11.62)	12,482 (6.69)	<.0001	19.41
Other neurological disorders	3062 (11.83)	15,210 (8.15)	<.0001	16.76
Obesity	4591 (17.74)	36,827 (19.74)	<.0001	11.08
Paralysis	1042 (4.03)	3993 (2.14)	<.0001	20.70
Peripheral vascular disorders	2013 (7.78)	7246 (3.88)	<.0001	21.74
Psychoses	1056 (4.08)	8595 (4.61)	.0001	10.94
Pulmonary circulation disorders	2429 (9.39)	25,516 (13.68)	<.0001	8.69
Renal failure	3795 (14.67)	24,326 (13.04)	<.0001	13.50
Solid tumor without metastasis	2171 (8.39)	9720 (5.21)	<.0001	18.26
Peptic ulcer disease excluding bleeding	15 (0.06)	45 (0.02)	.0030	25.00
Valvular disease	1139 (4.4)	9835 (5.27)	<.0001	10.38
Weight loss	2110 (8.15)	8138 (4.36)	<.0001	20.59
Other comorbidities				
Hyperlipidemia	9115 (35.22)	63,043 (33.8)	<.0001	12.63
COPD	7425 (28.69)	48,292 (25.89)	<.0001	13.33
Stroke	1485 (5.74)	6189 (3.32)	<.0001	19.35
Sepsis	666 (2.57)	1835 (0.98)	<.0001	26.63
Infection/pneumonia	5201 (20.1)	28,650 (15.36)	<.0001	15.36
Trauma	852 (3.29)	2924 (1.57)	<.0001	22.56
Bleeding	2020 (7.81)	3432 (1.84)	<.0001	37.05
Thrombolysis	2456 (9.49)	4793 (2.57)	<.0001	33.88
Embolectomy	332 (1.28)	321 (0.17)	<.0001	50.84
Unstable	1054 (4.07)	2388 (1.28)	<.0001	30.62
Hospital characteristics (level 2)				
Bed size				
Small	1807 (6.98)	15,613 (8.37)	<.0001	10.37
Medium	6765 (26.14)	50,992 (27.34)		11.71
Large	17,305 (66.87)	119,913 (64.29)		12.61
Ownership				
Government, nonfederal	2851 (11.02)	21,291 (11.41)	<.0001	11.81
Private, notprofit	18,483 (71.43)	135,931 (72.88)		11.97
Private, invest-own	4543 (17.56)	29,296 (15.71)		13.43
Urban-rural designation				
Large metropolitan areas	16,277 (62.9)	112,746 (60.45)	<.0001	12.62
Small metropolitan areas	8835 (34.14)	66,493 (35.65)		11.73
Nonmetropolitan areas	765 (2.96)	7279 (3.9)		9.51
Teaching status				
Nonteaching	11,134 (43.03)	78,359 (42.01)	.0019	12.44
Teaching	14,743 (56.97)	108,159 (57.99)		12.00

AHRQ = Agency for Healthcare Research and Quality, COPD = chronic obstructive pulmonary disorder, DVT = deep vein thrombosis, VCF = inferior vena cava filter, VTE = venous thromboembolism.

Table 2

The association between inferior vena cava filter utilization and patient and hospital characteristics in patients with deep vein thrombosis or pulmonary embolism, hierarchical logistic regression (n=212,395).

Characteristics	Adjusted odds ratio	95% CI
Patient characteristics (level 1)		
Age		
18–29	Ref.	Ref.
30–39	1.06	0.93–1.20
40–49	1.3	1.16–1.46
50–59	1.49	1.34–1.67
60–69	1.75	1.56–1.95
70–79	1.91	1.70–2.15
80+	2.53	2.25–2.85
Sex		
Male	Ref.	Ref.
Female	1	0.97–1.03
Admission day		
Workdays	Ref.	Ref.
Weekends	0.99	0.96–1.03
Insurance		
Medicare	Ref.	Ref.
Medicaid	0.93	0.88–0.99
Private insurance	1.07	1.02–1.12
Self-pay	0.89	0.81–0.98
No charge	0.9	0.74–1.10
Other	1.02	0.93–1.11
Median household income		
0–25th percentile	Ref.	Ref.
26th–50th percentile	1	0.96–1.05
51st–75th percentile	1.06	1.02–1.11
76th–100th percentile	1.06	1.00–1.11
Patient location (urban/rural status)		
Micropolitan/other rural	Ref.	Ref.
Small metropolitan	0.81	0.76–0.87
Large metropolitan	0.76	0.70–0.82
Number of chronic conditions		
0	Ref.	Ref.
1–3	1.57	1.40–1.77
4–6	2.21	1.96–2.49
7–9	2.79	2.45–3.17
10–12	3.34	2.90–3.85
13+	3.85	3.25–4.57
DVT Type		
Lower DVT	3.32	3.04–3.63
Deep DVT	1.16	1.06–1.26
Proximal DVT	1.22	1.18–1.26
Migrans DVT	1.63	1.02–2.59
AHRQ comorbidity		
Acquired immune deficiency syndrome	0.87	0.66–1.14
Alcohol abuse	1.18	1.09–1.28
Deficiency anemias	1.15	1.11–1.19
Rheumatoid arthritis/collagen vascular diseases	0.89	0.82–0.96
Chronic blood loss anemia	2.59	2.33–2.88
Congestive heart failure	0.68	0.64–0.71
Chronic pulmonary disease	0.21	0.19–0.22
Coagulopathy	1.33	1.26–1.39
Depression	0.87	0.83–0.91
Diabetes, uncomplicated	0.95	0.92–0.99
Diabetes with chronic complications	0.73	0.67–0.79
Drug abuse	0.72	0.65–0.80
Hypertension, uncomplicated and complicated	0.88	0.85–0.91
Hypothyroidism	0.92	0.88–0.96
Liver disease	1.08	0.99–1.17
Lymphoma	1.03	0.93–1.15

(continued)

Table 2

(continued).

Characteristics	Adjusted odds ratio	95% CI
Fluid and electrolyte disorders	1.24	1.20–1.28
Metastatic cancer	1.63	1.55–1.72
Other neurological disorders	1.18	1.13–1.24
Obesity	1.01	0.97–1.06
Paralysis	1.35	1.24–1.48
Peripheral vascular disorders	1.91	1.80–2.04
Psychoses	0.9	0.84–0.97
Pulmonary circulation disorders	0.28	0.26–0.30
Renal failure	0.76	0.73–0.80
Solid tumor without metastasis	1.66	1.57–1.75
Peptic ulcer disease excluding bleeding	0.61	0.32–1.16
Valvular disease	0.72	0.67–0.77
Weight loss	1.19	1.12–1.26
Other comorbidities		
Hyperlipidemia	0.87	0.84–0.90
COPD	5.1	4.69–5.55
Stroke	1.17	1.09–1.27
Sepsis	1.24	1.11–1.40
Infection/pneumonia	1.19	1.14–1.24
Trauma	2.03	1.86–2.22
Bleeding	3.53	3.30–3.77
Thrombolysis	3.15	2.97–3.34
Embolectomy	4.45	3.72–5.33
Unstable	1.96	1.78–2.15
Hospital characteristics (level 2)		
Bed size		
Small	Ref.	Ref.
Medium	1.1	0.99–1.22
Large	1.22	1.10–1.35
Hospital ownership		
Government, nonfederal	Ref.	Ref.
Private, notprofit	0.96	0.87–1.06
Private, invest-own	1.21	1.08–1.36
Urban-rural designation		
Nonmetropolitan areas	Ref.	Ref.
Small metropolitan areas	1.48	1.26–1.72
Large metropolitan areas	1.69	1.44–1.99
Teaching status		
Nonteaching	Ref.	Ref.
Teaching	0.98	0.91–1.04

AHRQ = Agency for Healthcare Research and Quality, CI = confidence interval, COPD = chronic obstructive pulmonary disorder, DVT = deep vein thrombosis.

underwent the IVCF procedure and patients who did not. In bivariate analysis, patients who received IVCF were older ($P<.001$), were admitted on a weekday more frequently than on the weekend ($P=.013$), had Medicare more often than private insurance (63.82% IVCF Medicare vs 52.56% no IVCF Medicare; $P<.001$), and had a greater number of chronic conditions ($P<.001$). Patients with DVT and PE receiving IVCF also were more likely to be treated in large metropolitan hospitals ($P<.001$), nonteaching hospitals ($P<.001$), and private, investment-owned hospitals ($P<.001$), than patients who did not receive IVCF.

Table 2 details results from the hierarchical logistic regression results estimating the relationship between patient and hospital characteristics associated with IVCF utilization. Following multivariate adjustment, several patient and hospital-level characteristics that were associated with IVCF placement remained statistically significant. Patients with DVT and PE with private insurance were 1.07 times more likely to receive

Table 3

Comparison of fit statistics for hierarchical regression modeling in the association of inferior vena cava filter utilization and patient and hospital characteristics.

	Model 1	Model 2	Model 3	Model 4
	Random effects only	Model 1 + level 1* fixed effects	Model 1 + level 2† fixed effects	Model 1 + level 1 and level 2 fixed effects
Intercept (SE)	−2.10 (0.015)	5.47 (0.480)	−1.82 (0.046)	5.72 (0.481)
Hospital random effects (SE)	0.28 (0.014)	0.28 (0.015)	0.26 (0.013)	0.27 (0.014)
ICC (%)‡	7.82	7.93	7.41	7.51
C-statistic	0.66	0.80	0.65	0.80
AIC§	154,280.70	132,038.50	154,210.00	131,962.70
BIC§	154,291.50	132,406.80	154,258.80	132,369.00

AIC = Akaike information criterion, BIC = Bayesian information criterion, ICC = intraclass correlation coefficient, SE = standard error.
* Level 1: patient-level characteristics.
† Level 2: hospital-level characteristics.
‡ The ICC accounts for the variance of VCF use between hospitals and within hospitals.
§ AIC and BIC assess the model fit by penalizing the addition of parameters (eg, smaller values indicate better fit).

IVCFs when compared with patients with Medicare (95% CI: 1.02–1.12), whereas patients with Medicaid insurance were 7% less likely to receive IVCFs when compared with patients with Medicare (95% CI: 0.88–0.99). Older patients, specifically those older than 80 years, were 2.53 times more likely to receive IVCFs than younger patients aged 18 to 29 years (95% CI: 2.25–2.85). Patients who had many chronic conditions were also more likely to receive IVCFs; those with 13 or greater conditions were 3.85 times more likely to receive IVCF (95% CI: 3.25–4.57) compared to patients without chronic conditions. A solid tumor without metastasis diagnosis resulted in 1.66 times greater likelihood of receiving IVCF placement (95% CI: 1.57–1.75).

At the hospital level, teaching status was not a significant predictor of whether or not a DVT or PE patient received IVCF. Private, investment ownership of a hospital, however, was associated with a 1.21 times greater likelihood of IVCF placement (95% CI: 1.08–1.36). Large metropolitan hospitals also placed IVCFs 1.69 times more often than micropolitan/rural hospitals (95% CI: 1.44–1.99), as did small metropolitan hospitals (adjusted Odds Ratio [aOR]: 1.48; 95% CI: 1.26–1.72), and hospitals with large bed sizes (aOR: 1.22; 95% CI: 1.10–1.35).

Table 3 includes a comparison of the fit statistic results for 4 model fitting methodologies. Complete regression results for each model fitting are available from the authors. Taken in combination, AIC and BIC results (lower scores are better) also suggest that the full Model 4, which included fixed effects for hospital and patient characteristics and the random effects intercept for between hospital variation, was optimal. Model 4 also fit the data well with a c-statistics of 0.80. In this final model, the ICC showed that 7.51% of the model variation was explained by the between hospital variation, that is, the random effects intercept.

4. Discussion

A previous study employing this design was limited to discharge data in a single state (Kentucky).[13] Overall, the findings using this larger cohort and nationwide data suggest that patients with DVT and PE who are treated at large, investment-owned private hospitals may be more likely to receive an IVCF placement than similar patients treated at smaller, nonprofit, and/or Government hospitals. Patient characteristics such as having many comorbidities are also associated with whether or not they receive IVCF placement and this supports findings from the Kentucky study. This study did not include as many cancer-related comorbidities as in previous work, however, which were found to be significant patient-level factors related to IVCF utilization and so should be explored in future analyses using the larger, nationwide cohort.

In addition, it should be noted that the overall hospital-level factors, as gauged by hospital-level random effects, were found to be a smaller contributor to variation in IVCF utilization when compared with patient-level factors in this study. These findings support evidence from the previous Kentucky study that reached similar conclusions using a single-state analysis of hospital variation in IVCF utilization, where residual variation between hospital IVCF utilization rates was reported to be low after controlling for patient case mix and hospital characteristics.[15] The present study and the previous Kentucky study showed smaller variation than a California-based study in which the between-hospital variation was approximately 12% and the range in IVCF use was more dispersed.[12] Although the NRD data did not permit a state-based analysis, comparing the results imply not only hospital level variation, but state-based variation in IVCF use as well.

Although anticoagulation is the mainstay of VTE treatment, IVCF placement is indicated for patients when anticoagulation is contraindicated, for example, concurrent intracranial hemorrhage, massive gastrointestinal bleed, or imminent planned surgery, or when patient has failed anticoagulation therapy, for example, development of PE while on anticoagulation therapy.[1] In other words, the decision for IVCF placement is largely clinical, and the type of patient cohort at each institution or practice is likely to dictate the percentage of patients with VTE receiving IVCFs, leading to much variation in IVCF usage across different institutions. Furthermore, the current guideline encourages the usage of temporary instead of permanent IVCF and filter retrieval as soon as clinically appropriate;[16] although, emerging evidence suggests that the initiation of anticoagulation therapy is only weakly associated with temporary IVCF retrieval, which would indicate that there are other barriers to the timely retrieval of IVCFs after placement.[17]

In the United States, there are 2 major guideline statements that address IVCF implantation practices in patients with VTE: the American College of Chest Physicians (ACCP) guidelines on the management of VTE and the Society for Interventional Radiology (SIR) guidelines for the management of PE. ACCP guidelines do not call for prophylactic use and only recommend

IVCF placement in cases of contraindication for anticoagulation.[1] SIR guidelines, however, recommend prophylactic use in patients with VTE at high risk for bleeding and/or are contraindicated for anticoagulation therapy.[18] The inconsistencies between these intersocietal guidelines, along with loose adherence to these societal guidelines and the increase in availability of retrievable IVCF, all have been blamed for significant overuse in IVCF.[19] Although the aforementioned factors may play a significant role in the variation of IVCF placement across the United States, several other factors may have been largely overlooked.[20] IVCF use varies from country to country, among the states within the United States and even at the county level despite adjusting for clinical and socioeconomic status.[12,21,22] Given that the efficacy of IVCF filters and its impact on patient's outcome remain a highly debated topic[23] our study was designed to shed some light on potential underlying hospital- and patient population–related factors that may be contributing to whether patients receive or not receive IVCFs as suggested by several articles.[13,24]

In our study 12.18% of patients with DVT and PE received an IVCF placement during the study period, which is on the higher side of the IVCF placement rates reported on the literature. This is a more frequent occurrence than the currently recommended "rare" usage of IVCFs.[5] Our results are suggestive of the fact that certain financial factors may have some level of influence on the rates of IVCFs placed. Patients with VTE with private insurance are more likely to receive IVCFs, and patients admitted to investment-owned private hospitals are also more likely to have an IVCF placed. These findings may also explain the fact that Medicare (more generous reimbursement than Medicaid) patients also have a higher IVCF placement rate than their Medicaid counterparts; however, this could be limited by selection bias given the fact that the Medicare population is generally older with overall higher comorbidities and increased rates of absolute or relative contraindications for anticoagulation therapy, leading to more IVCF candidates in this population.[25] For a similar reason, such demographic factors, such as older age or Medicaid insurance, can also decrease the IVCF retrieval rate.[26]

Beyond financial factors, expertise availably may also have an impact on IVCF placement rates as suggested by the higher placement rates in urban settings and during weekdays as compared with weekends. Several nonteaching hospitals have limited access to IVCF implanting specialists, and the same is true for nonurban hospitals. Many of these patients end up transferred to another facility for filter placement, or simply await regular working hours during the weekdays. These practice patterns could explain some of the dynamics of IVCF placement across the country. Also, therapeutic IVCF placement is not usually considered a weekend emergency and the implanting physician may defer placement to the first weekday in many clinical circumstances. As expected, the presence of more comorbidities did show a statistically significant correlation with increased IVCF placement rate; a "sicker cohort" would likely have overall clustering of underling VTE risk factors such as cancer and also higher likelihood of having anticoagulation contraindications.

There are several limitations with the analysis and study design. First, follow-up after the initial DVT or PE diagnosis was limited to the 2013 to 2014 study period, which means that patients with VTE may have received an IVCF placement at some point after the study period and these patients would not be labeled in our analysis as receiving IVCF. Longitudinal tracking was not available for individual patients across calendar years due to a lack of patient identification linkage variable, so individual patients can only be analyzed within a year. No medication use data were available; hence, we could not compare patients who are contraindicated to anticoagulation, or patients with anticoagulation failure. In addition, patients who received a DVT or PE diagnosis at an NRD participating hospital may have received IVCF at a hospital that does not report readmission statistics to NRD, which would render our estimates of IVCF usage as conservative. There are also limitations with underreporting and misclassification inherent to the use of administrative data and diagnosis/procedure codes, so it is possible that IVCF usage is conservatively recorded in this data. Also, information on race was not included in NRD so race cannot be examined using this data. The retrospective cohort study design allows for the construction of a highly powered statistical analysis with large sample sizes, but does present limitations to the generalizability of these results due to the possibility of selection bias. Last, the data used from this study were entirely collected in the United States, so generalization to IVCF usage in other countries is limited.

5. Conclusion

This study was undertaken to assess whether a combination of patient and hospital-level factors correlates with the rate of IVCF placement in patients with VTE. The findings in this study contribute to the growing body of evidence that IVCFs may be inappropriately employed in certain populations and that hospitals should evaluate their dissemination of the most recent clinical guidelines for treatment of "high-risk" DVT and PE patients. This study indicated the need for additional research to investigate whether the utilization of IVCFs could be explained by hospital variation and patient characteristics at a national level.

Author contributions

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