

IVC filters—Trends in placement and indications, a study of 2 populations

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Abstract

Inferior vena cava filter (IVCF) placement appears to be expanding over time despite absence of clear directing evidence.

Two populations were studied. The first population included patients who received an IVCF between January 2005 and August 2013 at our community hospital center. Demographic information, indications for placement, and retrieval rate was recorded among other variables. The second population comprised of patients receiving an IVCF from 2005 to 2012 according to the Nationwide Inpatient Sample (NIS) using ICD-9CM coding. Patients were divided into 2 groups based on the year of admission for comparison, that is, first group from 2005 to 2008 and the second from 2009 to 2012. In addition, we analyzed annual trends in filter placement, acute venothromboembolic events (VTE) and several underlying comorbidities within this population.

At our center, 802 IVCFs were placed (55.2% retrievable); 34% for absolute, 61% for relative, and 5% for prophylactic indications. Major bleeding (27.5%), minor self-limited bleeding (13.7%), and fall history (11.2%) were the commonest indications. Periprocedural complication rate was 0.7%, and filter retrieval rate was 7%. The NIS population (811,487 filters) saw a decline in IVCF placement after year 2009, following an initial uptrend ($P_{\text{trend}} < 0.01$). IVCF use among patients with neither acute VTE nor bleeding among prior VTE saw a 3-fold absolute reduction from 2005 to 2012 (33,075–11,655; $P_{\text{trend}} < 0.01$). Patients from 2009 to 2012 were more likely to be male and had higher rates of acute VTE, thrombolytic use, cancer, bleeding, hypotension, acute cardiorespiratory failure, shock, prior falls, blood product transfusion, hospital mortality including higher Charlson comorbidity scores. The patients were younger, had shorter length of stay, and were less likely to be associated with strokes including hemorrhagic or require ventilator support. Prior falls (adjusted odds ratio—aOR 2.8), thrombolytic use (aOR 1.76), and shock (aOR 1.45) were most predictive of IVCF placement between 2009 and 2012 on regression analysis.

Recent trends suggest that a higher proportion of patients receive temporary IVCF, for predominantly relative indications. Nationally, the number of filters being placed is decreasing, especially among those who did not experience acute VTE or bleeding events. Prior falls, thrombolytic therapy, and shock were most predictive of IVCF placement in latter half of the study period.

Abbreviations: ACCP = American College of Chest Physicians, AHRQ = Agency for Healthcare Research and Quality, aOR = adjusted odds ratio, CI = confidence interval, DVT = deep vein thrombosis, FDA = Food and Drug Administration, HCUP = Healthcare Cost and Utilization Project, IVCF = inferior vena caval filter, NIS = Nationwide Inpatient Sample, PE = pulmonary embolism, PREPIC = Prevention of Recurrent Pulmonary Embolism by Vena Cava Interruption, VTE = venous thromboembolism.

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1. Introduction

Venous thromboembolism (VTE) is a significant cause of morbidity and mortality in the United States with an average annual incidence of 1 to 2 cases per 1000 person years.^[1] For patients with VTE, the mainstay of treatment is anticoagulation therapy. Inferior vena cava filters (IVCF), initially introduced in the 1960s have continued to evolve since, and may be considered when anticoagulation is contraindicated or fails. While all major guidelines agree on these indications, some indications are more controversial (i.e., patients with VTE and limited cardiopulmonary reserve, questionable compliance, or recurrent falls).^[2–4] Additionally, they are increasingly utilized for prophylaxis in the absence of VTE despite the lack of convincing evidence.^[5] Though filters are usually placed via minimally invasive procedures, there is clear evidence for filter-related complications even several years after placement.^[6] There is a great deal of inconsistency in the recommendations by different societies with relative liberalization of filter use by the Society of Interventional Radiology compared to the American College of Chest Physicians (ACCP).^[3,4,7]

IVCFs have been in use since their initial approval through the FDA's 501K clearance protocol despite the presence of minimal

human or animal data. According to a National Discharge Survey (1979–1999) and a Medicare survey (1999–2008) rates of IVCF placement have markedly increased in the last 2 decades.^[8,9] This is likely a combination of an increasing number of providers capable of IVCF insertion, an aging population with contraindication to anticoagulation, introduction of retrievable filters, and newer applications for filter placement.^[10]

The expanding indications and utility of IVCFs prompted us to examine IVCF use including that of retrievable filters during a 9-year period at our institution. In addition, we decided to assess national trends in IVCF placement using the Nationwide Inpatient Sample (NIS).

2. Subjects and methods

Two distinct populations who received IVCF were studied and were analyzed separately as below. The Institutional Review Board at Einstein Medical Center in Philadelphia approved the study.

2.1. Study population A

We reviewed the electronic medical records of all patients who had an IVCF placed at the institute from January 1, 2005 to August 31, 2013. All filters were placed by the interventional radiology team. Patients under the age of 18 years and pregnant patients were excluded. The requirement for permission was waived because of the retrospective nature of the study and the minimal risk posed to the patients. Information regarding the acuity of a VTE event (deep vein thrombosis—DVT and/or pulmonary embolism—PE) and anticoagulation use was collected. Demographic information (age, sex, gender) and clinical data (presence of hypertension, diabetes, hyperlipidemia, end-stage renal disease, end-stage liver disease, connective tissue disorders, and malignancy) was recorded.

Information regarding the indication for IVCF use, contraindications to use of anticoagulation, and complications arising due to filter placement during the index admission were reviewed. We defined the indications for IVCF use as follows:

1. *Absolute indication*: Acute VTE while therapeutic on anticoagulation or in the presence of absolute contraindication to anticoagulation (recent neurosurgical procedure, major active or recent bleeding, coagulopathy).
2. *Relative indication*: Patient with acute or prior VTE considered at higher risk for either bleeding complications from anticoagulation or hemodynamic instability (transient bleeding, recurrent falls, multiple comorbidities, extensive PE, questionable compliance, central nervous system neoplasms, perioperative DVT, active cancer with potential for bleeding, poor cardiovascular reserve, ileocaval DVT, DVT with free floating thrombus).
3. *Prophylactic*: IVCFs were placed in the absence of current or prior VTE.

This classification system is in concordance with published guidelines.^[2–4] Patients with more than one indication were categorized by the most clinically relevant indication. In-hospital mortality was recorded if it occurred during the same hospitalization as filter placement. Our institutional follow-up protocol includes written instructions upon discharge and an additional letter mailed to home within 30 days encouraging patients to follow up with their care providers and reassess need for filter including possible retrieval. The number of IVCF removal

procedures during study period was recorded. Informed consent was not obtained from patients due to the retrospective nature of data collection and analysis.

2.2. Study population B

Data from the 2005 to 2012 Agency for Healthcare Research and Quality (AHRQ) Health Care Utilization Project Nationwide Inpatient Sample (NIS) was used. Patients aged 16 years and older who received an IVCF (ICD-9CM coding, procedure code 38.7) were included. Those who were transferred out during stay to another hospital and had missing information were excluded. The NIS is part of the Healthcare Cost and Utilization Project (HCUP), sponsored by the AHRQ. The NIS is the largest publicly available all-payer inpatient care database in the United States. A comprehensive synopsis on NIS data is available at <http://www.hcup-us.ahrq.gov>. Death was defined in the NIS as in-hospital mortality. Different comorbidities were identified by using ICD-9-CM diagnoses and diagnosis-related group (see Appendix, <http://links.lww.com/MD/B615>). We defined severity of comorbid conditions using Deyo modification of Charlson comorbidity index. This index contains 17 comorbid conditions with differential weights. The score ranges from 0 to 33, with higher scores corresponding to greater burden of comorbid diseases. Trends were analyzed from 2005 to 2012 for the rates of filter placement, baseline demographics, acute VTE events, clinical characteristics, in-hospital mortality and associated comorbidities including calculated Charlson comorbidity index. Two groups (4 years each) based on year of IVC filter placement: 2005 to 2008 and 2009 to 2012 were created for the purpose of analysis and comparison of the study variables.

Demographic, procedure-related data and all relevant clinical information in the Study population A was summarized using descriptive statistics and percentages. Cases from the NIS were weighted in order to approximate national averages and trends. Continuous data were expressed as mean \pm 1 standard deviation and categorical data as frequencies or percentages. The Student *t* test was used for continuous variables, and Fisher exact or Chi-square test for categorical variables. Trend analyses were performed using the Mantel–Haenszel test of trend and analysis of variance test for categorical and continuous variables respectively. Levene test of homogeneity was performed following the analysis of variance test for continuous variables before to deciding appropriate test for significance. A multivariable hierarchical mixed effect logistic regression model was created to assess which variables among age, sex, Caucasian race, elective admission, length of stay, Charlson comorbidity index, hypotension, stroke or transient ischemic attack, acute cardiorespiratory failure, ventilator use, acute DVT, acute PE, coagulation disorder, bleeding event, cancer, blood product transfusion, prior falls and thrombolytic use were likely to predict placement of an IVCF between 2009 to 2012 compared to the first half of study. *P*-value <0.05 was considered significant. All analyses were performed using the IBM SPSS Statistics for Windows, Version 20.0 (Armonk, NY) statistics software.

3. Results

3.1. Study population A

3.1.1. Baseline characteristics. Between January 2005 and August 2013, a total of 802 IVCFs were placed in 802 patients. Table 1 represents the characteristics of patients who received an IVCF. Females comprised 57% of all filter recipients and more

Table 1
Baseline characteristics of the study population at our institute.

Characteristic	Study population (N = 802)
Age, years ± SD	66.6 ± 14
Patient location, no. (%)	
Inpatient	785 (97.8)
Outpatient or ED	17 (2.2)
Sex, no. (%)	
Male	344 (42.9)
Female	458 (57.1)
Race, no. (%)	
African American	623 (77.7)
Caucasian	130 (16.3)
Hispanic	34 (4.2)
Others	15 (1.8)
History, no. (%)	
Hypertension	210 (26.2)
Diabetes	230 (28.7)
End-stage renal disease	58 (7.2)
End-stage liver disease	27 (3.4)
Stroke/transient ischemic attack	174 (21.7)
Ischemic heart disease	165 (20.6)
Connective tissue disorder	25 (3.1)
Smoker	142 (17.7)
Active or past malignancy	281 (35)
Recent chemotherapy, <3 mo	60 (7.5)
Bleeding history – no. (%)	
Anticoagulation related bleed	52 (6.5)
Gastrointestinal bleed	82 (10.2)
Intracranial bleed	60 (6.5)
Hematuria	21 (2.6)
Venous thromboembolism related, no. (%)	
Prior history of DVT	138 (17.2)
Prior history of PE	89 (11.1)
Prior history of prior VTE (type undocumented)	97 (12.1)
New onset VTE (DVT and/or PE)	602 (75)
Anticoagulation (AC) treatment related, no. (%)	
On anticoagulation at admission	176 (21.9)
Subtherapeutic INR	52 (6.5)
Therapeutic INR	115 (14.3)
Supratherapeutic INR	9 (1.1)

DVT = deep venous thrombosis, ED = emergency department, INR = International Normalized Ratio, PE = pulmonary embolism, SD = standard deviation, VTE = venous thromboembolic event.

than a quarter of all patients had underlying hypertension or diabetes mellitus. An active or history of malignancy was present in 35% of patients. More than 25% of the filters were placed in patients with a bleeding history. A total of 176 patients (22%) were already on anticoagulation preceding hospital encounter with 70.4% of them being either therapeutic or supratherapeutic on anticoagulation. An acute thromboembolic event was diagnosed in 602 (75%) patients; whereas 160 (20%) patients had a prior VTE and 40 (5%) patients had no current or past VTE.

3.1.2. Filter type and complications. Among the 802 filters, 443 (55%) were temporary and the rest were permanent. Figure 1 illustrates the increasing trend in the utility of temporary filters over our study period ($P_{\text{trend}} < 0.05$). A total of 785 (97.8%) filters were placed in the inpatient setting while 17 (2.2%) were placed either as outpatients or in the emergency department. A discussion between the patient, care team, and interventional radiologist led to the choice of permanent versus temporary filter. The commonest filters placed were Option filters (23%) followed by TrapEase (21%), Vena-Tech (20%), and Bard G2 IVCFs (19%).

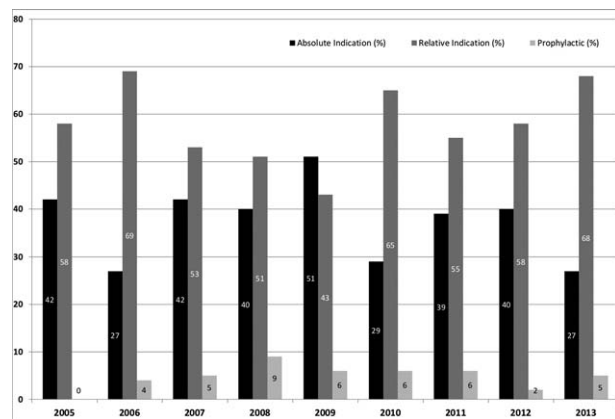


Figure 1. Trends in placement of temporary and permanent filters from 2005 to 2013.

The immediate complication rate for filter placement was 0.7% (6/802). All 6 complications were self-limited and included 1 case of contrast extravasation, 1 pneumothorax, 1 superficial access site hematoma, 2 retroperitoneal bleeds and an episode of transient hypotension requiring the administration of vaso-pressors. There were no procedure-related deaths, myocardial infarctions, or strokes. The in-hospital mortality for patients requiring IVCFs was high at 8.7%.

3.1.3. Indications for IVCF placement. Table 2 shows a breakdown of the listed indications for IVCF placement as

Table 2
Documented indications for IVC filter placement.

Indication, n (%)	Study total (N = 802)
Absolute indications	269 (34%)
• Absolute contraindication to anticoagulation	221
Major bleeding*	175
High risk neurosurgery involving brain or spinal cord	26
Coagulopathy (thrombocytopenia/HIT, DIC)	20
• Recurrent VTE despite anticoagulation	48
Relative indications	493 (61%)
• Transient/self-limiting bleeding	110
• History of recurrent falls	90
• Old age/dementia/multiple comorbidities/poor cardiopulmonary reserve†	73
• Massive PE by visual estimate on CT imaging	57
• Noncompliance	34
• CNS neoplasm/metastasis	31
• High risk surgical/perioperative with contraindication to anticoagulation	30
• Neoplasms with potential to bleed (e.g., GI or GU cancer)	29
• PE with poor cardiopulmonary reserve	21
• Ileocaval DVT	12
• DVT with free floating iliofemoral thrombus	6
Prophylactic indications	40 (5%)

CNS = central nervous system, CT = computed tomography, DIC = disseminated intravascular coagulation, DVT = deep venous thrombosis, GI = gastrointestinal, GU = genitourinary, HIT = heparin-induced thrombocytopenia, INR = International Normalized Ratio, IVC = inferior vena caval, PE = pulmonary embolism, VTE = venous thromboembolic event.

*Major bleeding defined as all intracranial/retroperitoneal/pericardial bleeds and bleeds resulting in a drop in hemoglobin of at least 3 g/dL, hemodynamic compromise including mean arterial pressure <65 mm Hg or need for ≥2 units of packed red blood cell transfusion.

†Clinically determined by the primary physician.

described above. All patients within the absolute and relative indication groups had need for continued anticoagulation in the setting of either acute, acute on chronic, or chronic VTE. Absolute indications necessitated filter placement in 34% of the cases, most commonly for contraindications to anticoagulation (221/269). Among these patients, 175/221 (79.1%) had an acute VTE in addition to bleeding. Additionally, 48/269 (17.8%) of the patients received the IVC because of recurrent VTE on failed anticoagulation.

Figure 2 represents how relative indications outnumbered absolute indications for IVCF placement during study period. A total of 493 filters (61%) were placed for relative indications. Minor self-limited bleeding (110/493, 22%), history of falls (90/493, 18%), and dementia or multiple comorbidities (73/493, 15%) represented more than half of the relative indications for IVCF placement. Fifty-seven patients received an IVCF in the setting of a massive pulmonary embolus, while 21 received a filter in the setting of poor cardiorespiratory reserve. Forty filters (5%) were placed prophylactically in high risk patients in the absence of documented VTE. At the time of filter placement, 252 patients (31.4%) were receiving concomitant therapeutic anticoagulation and 210 (26.2%) patients were taking anticoagulants at the time of discharge. A total of 48 (5.9%) patients received thrombolysis and 38 (4.7%) underwent thrombectomy. Filter retrieval was attempted in 31 (3.8%) patients and was successful in 29 of them.

3.2. Study population B

3.2.1. Trends in IVCF placement and associated variables. A total of 811,487 IVCF placements were studied between 2005 and 2012. IVCF placement increased from 103,843 in the year 2005 to 131,843 by year 2009, following which it steadily declined to less than half of the peak by the year of 2012 (n = 63,445) as seen in Fig. 3 ($P_{trend} < 0.01$). Figure 3 represents a similar pattern in IVCF placement among patients with neither acute VTE nor prior VTE with bleeding during current hospitalization, showing a roughly 3-fold decline between 2005 and 2012 ($P_{trend} < 0.01$).

Figure 4 A–F represents the annual variations and trends in patient demographics, baseline characteristics, comorbidities including in-hospital mortality, cost of stay, and length of stay during the study period among patients who received an IVCF. It can be noted that there was an overall uptrend favoring IVCF placement with time in patients who were younger, male, Caucasian, and had an increasing association with clinical

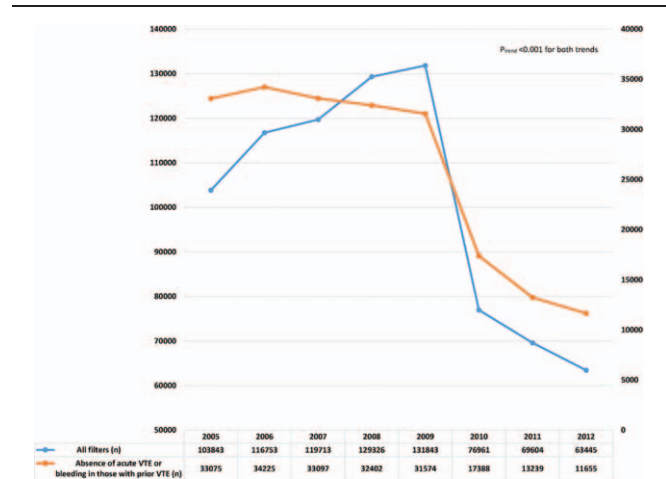


Figure 3. Trend in placement of IVC filters between 2005 and 2012 based on Nationwide Inpatient Sample.

variables such as acute VTE (both PE and DVT), prior VTE, bleeding events, cancer, hypotension, shock, thrombolytic use, and blood product transfusion. The in-hospital mortality showed a relative 23% increase by the year 2012 (9.6%) compared to the year 2005 (7.8%). On the other hand, proportion of patients with a stroke or transient ischemic attack, those needing ventilator support and length of hospital stay saw a downtrend during study period. P_{trend} for all represented variable trends was < 0.01 .

3.2.2. 2005–2008 versus 2009–2012. Patients were categorized into 2 groups, 4 years each and comparisons were made between the first and second half of the study duration to examine the changes in practice across several characteristics. The latter 4 years already saw a 27.5% decline in the total number of filters placed. Table 3 represents the differences between the 2 groups.

Patients in the 2009- to 2012-year group were younger, more likely to be Caucasian or male with higher hospital mortality rates. The total cost of stay was higher despite shorter length of stay. These patients had higher Charlson comorbidity scores, prior falls and greater rates of shock and acute cardiorespiratory failure. Patients in the latter study half had higher rates of acute PE or DVT, thrombolytic use, hypotension, cancer, bleeding events, and transfusion of blood products. This group also had a higher proportion of patients with neither acute VTE nor bleeding in presence of prior VTE (21.6% vs 28.3%; $P < 0.001$). Patients in the first half of the study experienced relatively higher stroke rates including hemorrhagic strokes, and ventilator use.

A regression analysis revealed that prior falls (adjusted odds ratio (aOR) 2.8, 95% confidence interval (CI) 2.67–2.93; $P < 0.001$), thrombolytic use (aOR 1.76, 95% CI: 1.72–1.81; $P < 0.001$), bleeding event (aOR 1.38, 95% CI: 1.37–1.40; $P < 0.001$), shock (aOR 1.45, 95% CI: 1.42–1.48; $P < 0.001$), hypotension (aOR 1.39, 95% CI: 1.36–1.42; $P < 0.001$), Caucasian race (aOR 1.40, 95% CI: 1.38–1.41; $P < 0.001$), acute cardiorespiratory failure (aOR 1.36, 95% CI: 1.34–1.38; $P < 0.001$), acute DVT (aOR 1.22, 95% CI: 1.21–1.23; $P < 0.001$), and acute PE (aOR 1.19, 95% CI: 1.18–1.20; $P < 0.001$) were the most prominent independent predictors of a higher likelihood for IVCF placement between 2009 and 2012.

4. Discussion

Acute PE remains the most serious clinical presentation of VTE, and is a major cause of morbidity and mortality accounting for

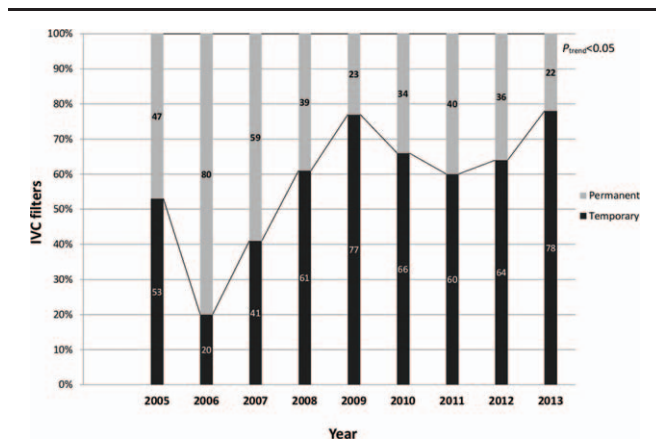


Figure 2. Annual trends in indications for IVC filter placement from 2005 to 2013.

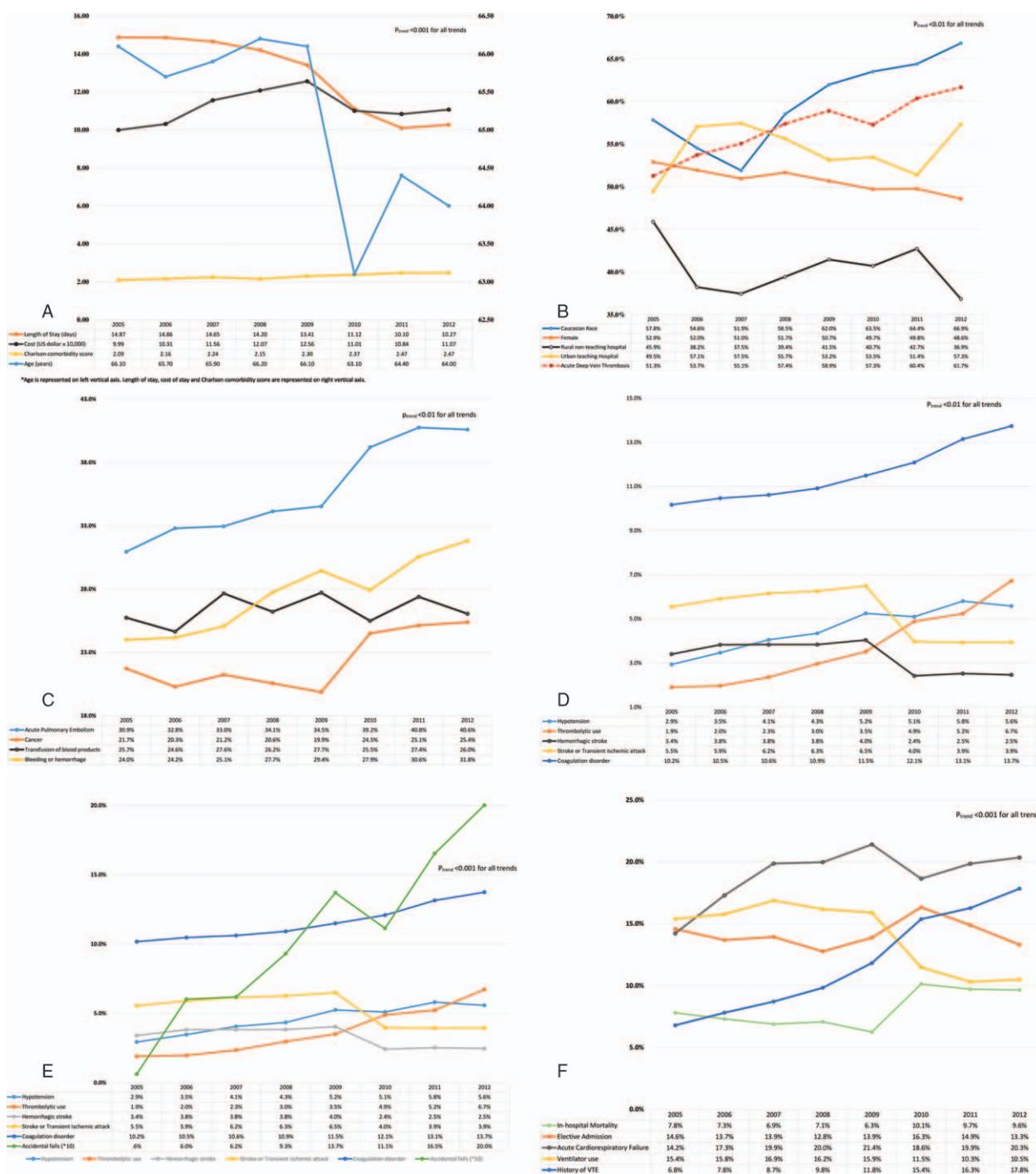


Figure 4. (A–F) Trends in patient characteristics, comorbidities, admission-related variables, and disease-associated complications including in-hospital mortality among patients who received an IVC filter between 2005 and 2012.

≥300,000 deaths each year in the United States. Prompt treatment is recommended in affected patients with the goal to halt progression of disease, and reduce risk for recurrent episodes of thromboembolism and/or death.^[3,11–14] The primary aim of filter insertion is prevention of fatal PE. There are currently no randomized trials to evaluate the benefit of IVCs over anticoagulation in patients with absolute or relative contraindications to anticoagulation as these patients were excluded from prior randomized trials.^[15,16]

Our study aimed to investigate indications for IVCF placement, and analyze the trends in type of filter use over a 9-year period at an urban academic medical center. We found that a majority of the filters were placed for relative indications, and there was a trend toward more temporary filter placement with time between years 2005 and 2013. There is overall agreement amongst societies for the insertion of IVCFs when it comes to patients with absolute contraindication to anticoagulation or complications of anticoagulation, the former

Table 3

Baseline characteristics between patients who received an IVC filter within the Nationwide Inpatient Sample, grouped according to year.

Characteristic	Years		P
	2005–2008 (n = 469,635)	2009–2012 (n = 341,852)	
Age in years (mean ± SD)	65.9 ± 17.6	64.7 ± 16.9	<0.001
Sex, female (%)	51.8	49.9	<0.001
Race (%)			<0.001
Caucasian	55.7	63.7	
African American	11.3	14.7	
Hispanic	5.8	7.2	
Other or missing	27.2	14.4	
Payer information (%)			<0.001
Medicare	58.5	54.3	
Medicaid	8.1	9.2	
Private	26.9	28.9	
Self-pay	3.0	4.3	
No charge	0.3	0.5	
Other	3.3	2.9	
Elective admission (%)	13.7	14.5	<0.001
Weekend admission (%)	20.8	20.4	<0.001
Hospital region (%)			<0.001
Northeast	24.9	21.8	
Midwest	22.1	21.4	
South	39.1	41.2	
West	13.9	15.5	
Hospital bed size (%)			<0.001
Small	7.4	7.8	
Medium	22.2	22.1	
Large	70.5	70.1	
Location/teaching status of hospital (%)			<0.001
Rural	4.8	5.7	
Urban nonteaching	40.1	40.7	
Urban teaching	55.1	53.7	
Length of stay in days (mean ± SD)	14.6 ± 17.6	11.6 ± 14.6	<0.001
Total charges, US dollar (mean)	110,417	115,857	<0.001
In-hospital mortality (%)	7.2	8.5	<0.001
Charlson comorbidity index (mean ± SD)	2.1 ± 2.3	2.3 ± 2.4	<0.001
History of VTE (%)	8.4	14.6	<0.001
All strokes including TIA (%)	6.0	4.9	<0.001
Hemorrhagic stroke (%)	3.7	3.1	<0.001
Acute DVT (%)	54.5	59.4	<0.001
Acute PE (%)	32.8	38.0	<0.001
Acute DVT or PE (%)	70.0	75.0	<0.001
Acute cardiorespiratory failure (%)	18.0	20.3	<0.001
Ventilator use (%)	16.1	12.8	<0.001
Thrombolytic use (%)	2.3	4.8	<0.001
Pressor use (%)	0.8	0.8	0.70
Transfusion of blood products (%)	26.1	26.8	<0.001
Hypotension (%)	3.7	5.4	<0.001
Shock (%)	4.9	6.1	<0.001
Coagulation disorder (%)	10.6	12.4	<0.001
History of fall (%)	0.6	1.5	<0.001
Bleeding (%)	25.3	29.8	<0.001
Cancer (%)	20.9	23.0	<0.001

DVT = deep vein thrombosis, IVC = inferior vena caval, PE = pulmonary embolism, SD = standard deviation, TIA = transient ischemic attack, VTE = venous thromboembolic disease.

encompassing active bleeding, recent surgery, coagulopathy and recent neurosurgical procedure or intracranial bleeding.^[2–4,14] In older studies, absolute indications guided IVCF placement in as much as 60% of the cases, compared to 30% at our institute.^[17,18] High rates of filter placement for prophylactic or relative indications have been reported in previous studies from the United States, in hospitals with busy trauma services.^[19]

Forty-eight patients received an IVCF because of recurrent VTE despite optimal anticoagulation, representing slightly more than 5% of our cohort. In a previous study, failure of anticoagulation was noted to be the indication for 3% to 5% of the filters placed.^[19] Although traditionally considered an indication for an IVCF, we like to emphasize that the recent Chest guidelines actually recommend modification of the anticoagulation regimen over IVCF placement in such individuals.^[20] We may see the prevalence of this indication reduce as more practitioners adapt the newest guidelines.

Relative indications were linked to the placement in almost 2nd/3rd of the filters at our institute, results that are in line with prior published data indicating a rise in placement of filters for relative indications.^[21] These patients were likely to be elderly, high fall risk, noncompliant, with active malignancies and considered at a high risk for bleeding complications with anticoagulation. Within the same category, we included patients with large PEs and poor cardiopulmonary reserve. Interestingly, according to another study patients that experienced a significant increase in filter placement were the elderly and those at risk for falls.^[17] According to our analysis, presence of old age with comorbidities and risk of falls contributed to more than 1 out of all 5 filters placed. It is an alarming statistic given the paucity of supportive data for use in this patient population.

Previously published national data suggest a possible survival benefit to using IVCFs in unstable patients and those receiving thrombolytic therapy.^[22,23] Fewer than 6% of the patients in both our study populations received thrombolytic therapy. With increasing discordance amongst societies on these relative indications, physician compliance in practice with the guidelines has been found to be expectedly poor.^[7]

Prior studies have demonstrated a significant increase in the number of IVCFs placed as prophylaxis, mostly in patients with major trauma.^[8,24] This trend was thought to have at least been partially driven by studies demonstrating a reduction in PE after IVCF placement in such patients.^[24] However, these results were not confirmed in other studies and consequently the 2012 ACCP guidelines recommend against the prophylactic use of IVCFs.^[3] In our study, only 5% of the IVCFs were placed prophylactically, most commonly in trauma patients or patients undergoing bariatric or neurosurgical procedures. Recent data questions the cost-effectiveness of prophylactic IVCFs compared to therapeutic filters.^[31] Meltzer et al.^[32] found a higher IVCF use in states with higher medico-legally litigious environments. In this era of cost-conscious care emphasis needs to be placed on appropriate patient stratification to eliminate unnecessary interventions.

According to our analysis, 443 of the filters were designed for retrieval but only 29 (7%) were successfully removed. Although temporary IVCFs are becoming increasingly popular, their timely removal remains a significant challenge. IVCF retrieval rates have traditionally been below 50%, even in large academic centers. For example, in a study of mostly trauma patients who received IVCF done by Sarosiek et al.,^[19] only 8.5% (58/679) of retrievable filters were actually removed. The highest retrieval rates have been reported in a study from the UK where an attempt to remove the IVCF was performed in 40% of patients and was successful in 32% of them.^[18] These numbers indicate that the majority of optional filters are not being actively removed, thereby increasing the risk of long-term complications such as DVT. In a recent analysis by Siracuse et al, factors associated with IVCF nonretrieval were age >80 years, current malignancy, postfilter anticoagulation and history of a DVT/PE.^[25] In our study, the low retrieval rate may also be attributed to the lack of a

standardized follow up protocol, socioeconomic barriers, and poor health literacy. This again highlights the utility of establishing IVCF clinics and possible allocation of resources to pursue a more aggressive approach when it comes to follow ups and ensuring timely removal. The Food and Drug Administration (FDA) issued a statement in 2010 urging physicians to consider removing IVCFs as soon as protection was no longer needed.^[26]

Of patients with VTE's who had filters placed, 252 patient were receiving anticoagulation at the same time and eventually 210 were discharged on anticoagulant medication. This was similar to the rates reported in an analysis from Boston Medical Center.^[19] Once the risk of bleeding is assessed to be low, such that conventional anticoagulation can be started, the general recommendation is that the filter be removed.^[3] Hence, we can infer that many of the patients may have qualified for filter removal even prior to hospital discharge. We agree that the tendency to discharge patients with IVCFs on anticoagulation could be influenced by the number of permanent IVCFs being placed. However, we hypothesize that among the most likely contributors are an increased reimbursement rates when filters are retrieved in an outpatient setting and an under appreciation of the potential harms of leaving filters in place for extended periods.^[19] We acknowledge that this practice exposes the patients to unnecessary risk while providing no benefit in terms of PE recurrence prevention, as clearly demonstrated in the PREPIC 2 trial.^[27]

Complications of IVCF placement include access site hematoma, IVC thrombosis, air embolism, pneumothorax, filter migration or fracture and IVC perforation.^[28] Some of these complications may be evident early; others are asymptomatic or can be seen as a late event. Hadjuk et al, demonstrated filter thrombosis in up to 30% of patients receiving this device, however, the vast majority of these events were completely asymptomatic.^[29] The nature of our study allowed only for the detection of immediate symptomatic complications. In our cohort, their incidence was 0.7%, which is significantly lower than the prior reported rates between 4 to 15.^[30] Nationally, the in-hospital mortality rates were significantly high (8.7%) among patients receiving IVCFs. This probably reflects the underlying severity of illness and high prevalence of comorbidities among these patients.

Kuy et al^[33] analyzed the NIS data from 2000 to 2009 and found a 234% increase in IVCF placement over the decade. They also found that roughly 84.7% of the patients had a PE or DVT. These findings were similar to a 21-year study on IVCF trends reported by Stein et al.^[8] In another analysis of the NIS, on one hand IVCF cases between increased from 2001 to 2008, the mortality rate saw a decline during the same study period. Our study analyzed patients from 2005 to 2012 and found that the number of IVCF placements experienced a downward trend following the year 2009 after the initial uptrend, whereas the in-hospital mortality saw an increase over the entire study period, that was most marked from 2009 to 2010. The rate of IVCF placement although lower toward the latter half of the study, was more likely in patients with acute or prior VTE, bleeding events, hypotension, shock, cardiorespiratory system compromise and among those requiring thrombolytic use. These patients had higher rates of in-hospital mortality rates and higher Charlson comorbidity scores reflecting a higher risk category of patients compared to former years. These recent changes in practice may be attributable to increasing awareness among caretakers on the lack of evidence for IVCF placement in most cases and also the

FDA advisory warning of 2010. In addition, IVC filter-related late complications and litigation surrounding inappropriate placement, lack of retrieval, filter-related complications, lower reimbursement for inpatient filter placement may have all contributed to changing practice. The PREPIC 2 randomized study published in 2015 showed no benefit of IVCF placement over anticoagulation in high risk PE patients, however other observational studies since 2012 continue to show variable findings suggesting benefit in some.^[22,23,27] Hence, it may be challenging to predict future trends in IVCF placement but in our assessment, are unlikely to trend up significantly.

Being retrospective in nature, the study suffers from the limitations inherent to such a study design and presence of confounding and unmeasured variables. The study is also subject to biases related to such data as accuracy of the documented records and ICD coding for procedure and diagnosis in the case of the NIS database. The use of multiple different types of filter over 9 years at our institute makes generalization of these findings challenging with regards to efficacy and complication rates, since these properties may be affected by the device type. In addition, the NIS sample includes only inpatients and hence is not representative of outpatient practice.

Our findings mainly suggest that a majority of filters were placed for relative indications with an increasing proportion of the filters over time being temporary. IVCFs for DVT/PE prophylaxis were uncommon at our institute. Periprocedural complications around filter placement were low with an overall low retrieval rate at our center. There was a high use of concomitant anticoagulation among patients. The national trends in IVCF placement have declined following 2009 and a relatively sicker proportion of patients with higher mortality rate and comorbidities were more likely to receive them as time progressed. In addition, the number of filters being placed among patients with neither acute VTE nor bleeding during current hospitalization in patient with prior VTE has seen a significant decline.

There is a need for dedicated prospective studies particularly in the groups of patients who require filters for relative or prophylactic indications. We also acknowledge that such an endeavor can be challenging due to the vast array of indications, ethical challenges and significant heterogeneity among the patients who receive filters. In the meantime, a relatively stringent approach for patient selection, filter placement, and prompt retrieval must be advocated.

5. Conclusions

The recent trend is toward more temporary IVCF placement for relative indications. Nationally, the number of filters being placed is decreasing, most pronounced among those without acute VTE or bleeding. Recent trends indicate that prior falls, thrombolytic use and bleeding complications were most predictive for IVCF placement among patients.

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