Curr Treat Options Cardio Med (2015) 17: 41
DOI 10.1007/s11936-015-0401-2

Inferior Vena Cava Filters: Indications, Outcomes, and Evidence

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Published online: 7 August 2015

This article is part of the Topical Collection on *Vascular Disease*

Keywords Inferior vena cava filter · Pulmonary embolism · Deep venous thrombosis · Venous thromboembolic disease

Opinion statement

Filter technology seems relatively stable, although absorbable devices are an area of investigational interest. The indications for filter placement remain controversial, with wide variations in adherence to guidelines, and relatively poor quality of data about the specific prophylactic indications of trauma or bariatric surgery. The outcomes of filters are not well-defined despite widespread clinical use, and good data remains difficult to obtain. Several larger database and institutional retrospective studies support the notions that while filters prevent pulmonary embolism, they may be associated with venous thrombotic complications. Some subsets of cancer patients may be at increased risk of these complications, but whether the filter or the underlying hypercoagulable state is the cause is not clear. Lastly, although the benefits of filter retrieval are widely assumed (but not proven), filter retrieval rates remain lower than expected. The single most influential factor in improving filter retrieval rates is dedicated follow-up with intent to retrieve the filter.

Introduction

Venous thromboembolic disease (VTE), encompassing deep venous thrombosis (DVT) and pulmonary embolism (PE), is a significant source of morbidity and mortality. Anticoagulation is the first-line therapy in treating VTE. Certain patients, however, have contraindications to anticoagulation or have progressive disease despite anticoagulation. Inferior vena cava filters (IVCFs) are often used in these situations. In the setting of acute VTE, all published guidelines agree that IVCFs are indicated to prevent PE for patients in which anticoagulation is contraindicated or has failed to prevent recurrent or progressive VTE [1•, 2•, 3•].

The evidence supporting the appropriate use of IVCFs is limited. The published literature is largely

comprised of controlled and uncontrolled observational studies. There are only a few randomized trials available for analysis. The original Prevention du Risque d'Embolie Pulmonaire par Interruption Cave (PREPIC) study was the first randomized controlled trial to examine outcomes of patients with IVCFs compared to medical therapy alone [4]. This study evaluated permanent IVCFs (pIVCF) as an adjunct to anticoagulation therapy in patients with acute DVT. After 8 years of follow-up, the study demonstrated a significantly reduced rate of PE in those patients with IVCF; however, this came at a cost of increased recurrent DVT [5]. Ultimately, no survival difference was found between groups.

The follow-up PREPIC-2 study has just been published [6••]. This randomized, controlled, prospective study sought to investigate the safety and efficacy of a retrievable IVCF as an adjunct to anticoagulation in the setting of acute PE. Inclusion criteria for the study required a documented acute, symptomatic PE, associated with acute lower-limb DVT or superficial vein thrombosis as well as at least one additional "severity" criteria. These criteria included age >75 years old, active cancer, chronic cardiac or respiratory insufficiency, ischemic stroke with leg paralysis within 6 months, iliocaval or bilateral DVT, or right ventricular dysfunction or myocardial injury (by echo criteria or biomarkers). Absolute indications for IVCF placement were exclusion criteria in this study. Results at the 3- and 6-month time points using an "intention to treat" analysis demonstrated recurrent PE rates of 3 % of patients in the IVCF group and 1.5 % of patients in the control group at 3 months and 3.5 vs. 2.0 % at 6 months, not significantly different at either time point. However, seven patients from the IVCF group never received filters and six patients in the control group received filters at a later time point. Had the authors analyzed patients by the treatment they actually received (excluding the six patients that crossed over from medical management to IVCF), there would have been a recurrent PE rate of 2.1 % for patients with IVCFs and 2.5 % for patients who never received a filter. Additional findings were that there was no difference all-cause mortality between the two groups; 4.2 % of patients had complications attributed to the filters and 96.3 % of filters were retrieved. An important limitation of this study were the power calculations based upon an expected recurrent PE rate of 8.0 % in the control group. This was much less than the actual observed incidence. Had the study been powered based on a recurrent PE incidence of 1.5 % (the observed rate in the control group at 3 months), 1,147 patients would have been needed in each group.

A single randomized controlled trial was conducted comparing two different permanent IVCFs, the Greenfield (Boston Scientific, Natick, MA) and the TrapEase (Cordis, Bridgewater, NJ) [7]. This study, however, was terminated prematurely due to the interim results demonstrating significantly increased rates of symptomatic inferior vena cava or iliac vein thrombosis in the TrapEase group.

On the forefront is a recently approved study, Predicting the Safety and Effectiveness of Inferior Vena Cava Filters (PRESERVE), just getting underway (ClinicalTrials.gov NCT02381509). This prospective, nonrandomized, multispecialty trial is seeking to evaluate the overall safety and efficacy of IVCFs with plans to enroll 2,100 IVCF subjects with 24 months of follow-up.

Despite the lack of level 1 evidence, there has been a marked increase in the use of IVCFs over time, including indications other than lack of ability to anticoagulate [8, 9]. However, indwelling IVCFs are not without risk. Reported complications are not only mostly common thrombotic, but also include filter fracture, migration, and penetration/perforation [10–12]. In fact, the U.S. Food and Drug Administration (FDA) issued a safety communication advising removal of retrievable filters when the protection from pulmonary embolism is no longer needed and the risk/benefit profile favors removal [13]. The FDA developed a quantitative decision analysis that suggested removal between 29 and 54 days if the patient's transient risk for PE had passed [14]. Removal of retrievable IVCFs (rIVCF) at the earliest possible time point possible may reduce the various complications seen with these devices. A review of the literature demonstrated that the vast majority of complications are associated with long-term use [10].

This article seeks to review recently published articles on IVCFs, highlighting topics with multiple publications, and therefore, felt to be of particular interest. This covers publications on the device itself, indications for IVCF placement, outcomes following IVCF placement and management, and retrieval of IVCFs.

Treatment

Research in devices

Since the U.S. Food and Drug Administration approval of the retrievable IVCF in 2003, several new devices have come to market in the USA, including the Celect filters (Cook Medical, Bloomington, IN), Option Filter (Argon, Plano, TX), Crux Filter (Volcano, San Diego, CA), ALN Filter (ALN Implants Chirurgicaux, Ghisonaccia, France), OptEase filter (Cordis, Fremont, CA), and multiple iterations of the Bard filters (Bard Peripheral Vascular, Tempe, AZ) [15–21]. The most recently published (2014) FDA-mandated clinical device trial described the results with the Denali Retrievable Vena Cava Filter (Bard Peripheral Vascular, Tempe, AZ) [22]. This prospective, multicenter, nonrandomized, single-arm study included 200 patients and 6 months of follow-up. The study had a high technical success of placement (94.5 %) with a 3 % incidence of recurrent PE and 1 % incidence of IVC occlusion. New or worsening DVT was reported at a rate of 12.8 %. There were no instances of filter fracture, migration or tilt greater that 15°. Filter leg penetration greater than 3 mm on venography occurred at a rate of 2.5 %. Filter retrieval was technically successful in 97.3 % of cases with a mean indwell time of 165 days±113.9 for those successfully retrieved. While the results of filter fracture and migration are encouraging, this was an interim report at 6 months with a planned 2-year follow-up duration. These results are similar to other recent clinical device trials [16, 17, 23].

The first convertible filter (VenaTech, B. Braun Medical, Bethlehem, PA) has recently been approved for clinical use in the USA, but the complete supporting clinical trial results are not yet published [24]. This device differs from retrievable filters in that the device is converted from a closed filter to open stent-like structure by snare removal of an apical cap. A different approach to a convertible filter, in which the conversion process occurs automatically as an absorbable component of the filter is dissolved, is being evaluated in clinical trial "A Prospective, Multi-Center Study of the Novate Sentry Bioconvertible Vena Cava Filter" (ClinicalTrials.gov NCT01975090). A true temporary filter coupled with a triple lumen central venous catheter, the Angel Catheter (BiO2Medical, San Antonio, TX), which must be removed within 30 days, is also in clinical trial in the USA (ClinicalTrials.gov NCT02186223). A pilot study of the Angel Catheter in eight patients demonstrated insertion and retrieval without complication [25].

While retrievable filters have undergone redesign by various manufacturers, there have been limited reports rethinking the structure of the IVCF. Of note, there has been research into designing an absorbable IVCF [26, 27]. A recent article examined the effectiveness of infusing an absorbable IVCF with iodine-based contrast agents to produce a more radiopaque device [28]. The authors demonstrated that they could increase the radio-opacity of an absorbable IVCF to be visible on micro-CT imaging allowing for potentially improved deployment and monitoring of this technology.

Research in indications

While there is consensus that patients with acute VTE and a contraindication to anticoagulation or those who have failed appropriately dosed anticoagulation should receive a filter, other indications remain controversial (Table 1). Two

Table 1. Society guidelines for IVCF placement (adapted from Weinberg et al. [29])

ACCP [2•]	SIR [1•, 30]	AHA [3•]
Absolute indication, evidence level I or IIa		
Acute VTE and contraindication to anticoagulation	VTE and contraindication to anticoagulation Failure of anticoagulation in patients with VTE (recurrent VTE, complication of anticoagulation, inability to achieve or maintain therapeutic anticoagulation)	Adult VTE patients with contraindication to anticoagulation or active bleeding complication Recurrent acute PE despite therapeutic anticoagulation, it is reasonable to place an IVCF
Relative indication, evidence level IIb		
Unstable PE patients may benefit from IVCF in conjunction with anticoagulation	VTE with limited cardiopulmonary reserve Large, free-floating proximal DVT	Patients with acute PE and very poor cardiopulmonary reserve, including those with massive PE
Massive PE treated with thrombolysis/ thrombectomy or chronic PE treated with thromboendarterectomy	Massive PE treated with thrombolysis/ thrombectomy or chronic PE treated with thromboendarterectomy Thrombolysis for iliocaval DVT Iliocaval DVT Recurrent PE with IVCF in place Difficulty achieving anticoagulation or poor compliance to anticoagulation therapy High-risk of anticoagulation complications Prophylaxis for patients with severe trauma, closed head injury, spinal cord injury, multiple long bone injuries, and prolonged immobilization	
Not Indicated		
Prophylaxis	Patients with VTE who can be anticoagulated	Routine adjuvant to anticoagulation and systemic fibrinolysis in the treatment of acute PE

recent publications focused on compliance with the Society of Interventional Radiology (SIR) and American College of Chest Physician (ACCP) guidelines [1•, 2•, 30]. Both were retrospective studies examining the indications for placement of both permanent and retrievable IVCFs [31, 32]. As the SIR guidelines encompass more clinical scenarios in which a filter may be appropriate, it was not surprising that both studies found a higher rate of compliance with these guidelines as compared to the ACCP guidelines. Interestingly, Patel et al. still found 22.7 % of IVCFs, placed by multiple specialties, did not have a definite indication by the SIR guidelines published in 2006, even when including prophylactic indications. They did find that compliance to guidelines varied by operator specialty. Sader et al. demonstrated a very high compliance rate of 95.7 % with the 2011 SIR guidelines. When

analyzing placement indications based on the ACCP guidelines, Patel et al. found a compliance rate of 60 % while Sader et al. had a compliance rate of 41.3 %.

Prophylactic IVCF placement remains highly controversial and a common topic in the IVCF literature. Trauma patients are one of the subsets of patients that some feel are indicated for prophylactic filter placement. Trauma is known to be a strong risk factor for VTE and current guidelines recommend prophylaxis with low molecular weight heparin [33, 34]. Select trauma patients, however, are at increased risk of bleeding owing to severe injuries. As such, there is an ongoing debate about the appropriateness of prophylactic IVCF placement in these high-risk patients. A recent review and meta-analysis found a decreased incidence of PE with prophylactic IVCF placement, although this was with low strength of evidence [35]. This meta-analysis included six studies to examine PE rates and only four studies to examine fatal PE. Results for fatal PE were less robust with some statistical analysis suggesting lower rates of fatal PE with IVCFs but other statistical analyses finding no significant difference. Only two of the papers included in the meta-analysis were published after 2000 and the older papers tended to favor IVCF placement more so than the two newer papers. There was insufficient evidence to draw any associations with prophylactic IVCF placement and DVT incidence or all-cause mortality. Additionally, the studies analyzed were inconsistent in reporting filter-related complications. Both the 2002 Eastern Association for the Surgery of Trauma (EAST) guidelines and the SIR guidelines support the use of prophylactic IVCF in high-risk trauma patients while the ACCP guidelines recommend against the use of prophylactic ICVF (Grade 2C) [1•, 33, 34]. Despite conflicting recommendations and low-level evidence, a recently published survey of members of EAST found that 93.2 % of responders would consider the use of prophylactic IVCF in certain clinical scenarios [36]. This survey had a 27 % response rate with the majority of responders from level 1 trauma centers. Nearly all (96.8 %) used pharmacologic prophylaxis with IVCFs when feasible. Only 28 % of responders stated that they had a standard IVCF placement protocol, 38 % tracked the IVCFs, 25.5 % had institutional protocols for retrieval, and 53 % felt that the proceduralist should be among those determining the appropriateness of retrieval. Unfortunately, follow-up of trauma patients is notoriously challenging and concerns about the rate of filter retrieval and potential long-term complications for those left in place remain. A recent retrospective study of IVCFs placed in trauma patients found the risk of mechanical complications including adherence to the IVC wall, filter thrombus, and displaced or tilted filter increased substantially when filters were in place >50 days [37]. This single center study included 223 patients in whom 10 % of IVCFs were placed due to acute VTE and a contraindication to anticoagulation while the remaining 90 % were placed prophylactically. They found a 16 % incidence of VTE subsequent to IVCF placement. In multivariate analysis, the time to anticoagulation, injury severity score and tibia and/or fibula fractures were independently associated with VTE incidence. There was a progressive risk of VTE following IVCF placement with increased time to anticoagulation and authors raised the concern that the delay to anticoagulation may in part be due to the misconception that an IVCF alone is sufficient treatment.

Another group of patients that are considered by some for prophylactic IVCF placement are those undergoing bariatric surgery. VTE has historically been a

significant cause of morbidity and mortality in bariatric surgery patients [38]. Bariatric surgery is now more commonly being performed by laparoscopic techniques and symptomatic VTE rates are reported to be lower when compared to open surgery (less than 1 % compared with 2 %) [39, 40]. Typically, patients receive perioperative pharmacologic thromboprophylaxis and sequential calf compression devices; however, some question whether this is adequate. Two papers were published recently in an attempt to address this issue. One was a meta-analysis that examined 6 papers culled from 701 abstracts [41]. The papers analyzed were a mix of prospective and retrospective cohorts and involved mostly open bariatric surgery. IVCFs were used in 1.8 % of patients and indications were not always clear although commonly reported risk factors included prior VTE, hypercoagulable state, impaired functional status, lower extremity edema, and "extreme" obesity (however, papers did not define this consistently). The meta-analysis found an increased DVT incidence in patients with IVCFs and no difference in PE incidence. The authors also reported a trend toward increased mortality in patients with IVCFs, whether this was caused by the filters or the filters were a marker for high-risk patients is unclear. The other paper, a systematic review of the literature, examined 18 papers (including all those in the above mentioned meta-analysis) that were a combination of controlled cohort studies and case series with many studies involving open surgery [42]. The controlled cohort studies suggested an increased risk of VTE in patients who received IVCFs. Based on the available data, however, the authors suggested that IVCFs may reduce PE-related mortality in a subset of patients with multiple risk factors. Patients identified as highest risk included those with prior VTE, pulmonary hypertension, a personal or family history of coagulopathy, chronic immobility, preoperative lower extremity venous stasis, and those with the "highest" BMI. However, as with the meta-analysis by Kaw [41], a specific BMI value could not be provided due to the lack of uniformity of definitions used in the papers that were analyzed .

Research in outcomes

The results of the PREPIC 2 are discussed above in the "Introduction" section. The recent IVCF literature also includes multiple non-randomized studies examining the survival benefits of IVCFs. While it is widely accepted that IVCFs trap thromboemboli, there is no level 1 evidence that this translates to a survival benefit. Muriel et al. looked at patients with acute VTE and known significant bleeding risk in the international multicenter RIETE (Computerized Registry of Patients With Venous Thromboembolism) [43•]. Using a matched cohort design, investigators found a significantly lower 30-day PE-related mortality rate for those patients with an IVCF compared to those without (1.7 vs. 4.9 %, p=0.03). Patients with an IVCF also had a significantly increased rate of recurrent VTE (6.1 vs. 0.6 %, p<0.001). Of patients without an IVCF, 95 % were anticoagulated, compared to 68 % of patients with an IVCF. Critics of this publication point out that a time bias may have been introduced by calculating survival from the time of anticoagulation in patients without an IVCF and from the time of IVCF placement in those with an IVCF, thereby including more critically ill patients in the first group who may have died prior to the possible insertion of a filter [44]. In a response to this critique, the authors reanalyzed the data after propensity score matching and being alive on the day of filter

placement thus eliminating 8 patients from the control group [45]. Results of this reanalysis still supported a significantly lower risk of PE-related mortality in patients with an IVCF (0.9 vs. 3.3 %, p=0.04).

Another group sought to examine survival in unstable PE patients (those with shock or ventilator dependence) with and without IVCF placement [46]. This retrospective study analyzed patients over a 10-year span identified from the United States National Inpatient Sample. Their analysis found decreased all-cause in-hospital mortality rates for patients who received an IVCF and underwent thrombolysis as well as those who did not undergo thrombolysis compared to patients without an IVCF with or without lysis. Elderly patients had the greatest reduction in mortality rates. Critics of this analysis site the lack of information on comorbidities, cause of death, and timing of PE diagnosis and IVCF placement as possible sources of selection bias [47]. In response, the authors reanalyzed the data on patients with no Charlson Index co-morbidities for PE-related mortality and found that data still supported decreased in-hospital mortality for patients who received an IVCF [48]. This reanalysis, however, did not comment on accounting for the timing of PE diagnosis and IVCF placement therefore potentially still including patients who may have died prior to IVCF placement in the control group.

A Japanese group examined outcomes of PE patients with and without IVCF placement who were additionally receiving anticoagulation or thrombolysis [49]. They identified 3,474 matched pairs from a national database and found significantly lower in-hospital mortality for the cohort with IVCF placement (2.6 vs. 4.7 %, p<0.001). In an attempt to eliminate selection bias, the authors used propensity score analysis and eliminated patients that required cardiopulmonary resuscitation or extracorporeal membrane oxygenation on the day of admission as well as those discharged the day of admission, as many of those were deceased. Patients in this study received thrombolytic therapy if there was evidence of right ventricular dysfunction even if hemodynamically stable.

Several recently published articles have focused on the outcomes of cancer patients who receive IVCFs. Patients with cancer have a fourfold to sevenfold increased risk of VTE compared to those without [50, 51]. A retrospective, single-center study examined the outcomes of patients who received IVCFs, comparing those with solid tumors (carcinomas and sarcomas) to those without cancer [52]. Indications for IVCF placement varied and approximately one-third of patients in the study had a malignancy. The authors found a trend toward increased PE (i.e., filter failure) in patients with cancer compared to those without and a significant increase in those with carcinomas compared to those without cancer (7.3 vs. 2.9 %, p=0.018). Additionally, patients with metastatic cancer and filters were more likely to develop PE compared to those with nonmetastatic cancer (10.4 vs. 3.2 %, p=0.022). Of note, cancer patients were significantly less likely to be anticoagulated after IVCF placement and multivariate analysis determined the absence of anticoagulation to be the sole covariate independently associated with filter-related complications. Additionally, cancer patients were less likely to have their filters retrieved, even after adjusting for patients who died within 90 days and those who developed a permanent indication.

Another retrospective, single-center study also found an increased risk of thrombotic complications in cancer patients with IVCFs compared to noncancer patients [53]. Indications for IVCF placement were varied with the majority of cancer patients having a contraindication to (68 %) or failure of anticoagulation (13 %) while the majority of cancer-free patients had a contraindication to anticoagulation (58 %) or a prophylactic indication (17 %). Rates of anticoagulation were similar in the two groups. While cancer patients had a twofold increased risk of VTE following filter placement compared to noncancer patients, the authors point out that this is less than the fourfold to sevenfold historical risk associated with malignancy. As such, the authors concluded that IVCFs do not confer an additional risk of VTE in cancer patients over that found in cancer-free patients with IVCFs.

A retrospective, single-center study analyzed the outcomes of patients with advanced cancer and IVCF placement for VTE [54]. Of the patients analyzed, 96.2 % had a contraindication to or complication from anticoagulation, 94.2 % had tumor, node, and metastasis (TNM) stage III or IV disease, 30.8 % were receiving hospice or palliative care and 16.8 % were "do not resuscitate." There was an incidence of 9.3 % recurrent DVT and 2.8 % recurrent PE. Only one third of patients survived beyond 3 months, and authors raise concerns about the limited survival benefit for those with advanced stage disease.

Research in patient management and filter retrieval

A large portion of the recent IVCF literature is focused on the retrieval of IVCFs. Multiple studies have demonstrated that filter retrieval is highly successful using both routine and advanced techniques. One such study from the Mayo Clinic reviewed their results over a 3-year period [55]. The authors reported that retrieval was attempted in 223 of 460 patients with rIVCFs (48.5 %). Initial attempts were successful in 87.9 %. Of those that were initially unsuccessful, 85.2 % were due to the presence of filter thrombus, while 14.8 % were due to filter tilt or perforation. Of the filters that had significant filter thrombus, 39.1 % were eventually retrieved following anticoagulation. Another study examining the success of different retrieval techniques also demonstrated a high degree of success for both routine and advanced techniques [56]. This study was a retrospective review of attempted retrieval in 217 patients over a 10-year period with a mean filter dwell time of 134 days. Routine retrieval techniques were successful 73.2 % of the time. Of those that failed routine retrieval, 92 % had subsequent attempted retrieval with advanced techniques with a success rate of 94.7 %. Failure of routine techniques was linked to increased filter dwell time, increased filter tilt, and embedded retrieval hook. Overall complication rates of retrieval were low (1.7 %), but with a significantly increased rate of complications found with advanced techniques compared to routine (5.3 vs. 0.4 %, $p<0.05$). Another report evaluated one institution's results with advanced retrieval using endobronchial forceps [57]. This study included 114 patients over a 10-year period that had tip-embedded IVCFs as

identified on rotational venography. Rigid endobronchial forceps were used to dissect the hook of the filter and then remove it through the sheath. Filters had a mean dwell time of 465 days (31–2,976 days). This technique was successful in 96 % of cases with the majority of failures occurring early in the author's experience. Four complications were reported including two cases of embolized filter fragments (one occurring in a filter fractured before presentation and both cases with successful retrieval of fragments) and two cases of small IVC pseudoaneurysms. No patients had permanent sequelae of these complications.

Despite evidence that IVCF retrieval is highly successful with few complications, concerns remain that many IVCFs remain in place after the patient's risk of PE has passed, prompting the recent FDA warnings [13, 14]. Multiple publications have sought to identify the factors that influence retrieval rates and how these can be improved. A recent retrospective study examined 688 patients who received rIVCFs over 3 years [58•]. The authors found a 17.7 % incidence of filter-related complications, the majority of which were thrombotic. Complications were associated with older age and a lack of anticoagulation. Two thirds of patients had appropriately dosed anticoagulation within 3 days of filter placement and one third of patients had dedicated IVCF follow-up. Filter retrieval was attempted in 36.6 % of all patients; however, excluding those patients who were lost to follow-up, died, or developed permanent indications, the attempted retrieval rate was 51.7 %. Despite the initiation of early anticoagulation in many patients, the median time to retrieval was 134 days. Those patients who had dedicated filter follow-up had a retrieval rate of 71.8 % compared to 9.9 % for patients without dedicated follow-up. Retrieval had an initial success rate of 87.9 %. Multivariate analysis found the most significant association between filter retrieval attempt and dedicated follow-up (odds ratio 52.09).

Three other recently published retrospective studies sought to determine the factors that may contribute to low retrieval rates. In the first, 406 of 629 rIVCFs placed over a 2-year period were deemed eligible for retrieval and included in analysis [59]. Indications for placement based on 2006 SIR guidelines were absolute indications (75 %), relative indications (6 %), and prophylactic indications (20 %). Authors reported a 23 % retrieval rate overall. Independent risk factors that had a negative correlation with filter retrieval included increased age, increased distance to the medical center, and Medicare insurance. The second study included 605 rIVCFs placed over a 2-year period [60]. Indications for placement were absolute (45 %), relative (9 %), and prophylactic (46 %). Authors reported attempted retrieval in 25 % of patients with 93 % success rate after an average dwell time of 111 days (8–688 days). Multivariate analysis identified age >80, acute bleed, and malignancy as risk factors for nonretrieval. Post-filter anticoagulation and a history of VTE were associated with an increased likelihood of retrieval. While filters had been placed by three specialties, there was no impact of

operator service on retrieval rate. Based on their data, the authors suggested that permanent filters should be considered in patients with a higher likelihood of short-term mortality or who are less likely to follow-up. The third study was conducted at a Canadian institution, retrospectively analyzing 275 patients who received rIVCFs over a 3-year period [61]. Filters were placed for absolute indications (65.4 %), relative indications (28.6 %), and prophylactic indications (13.8 %). The authors reported a filter-related complication rate of 22.5 %, the majority of which were thrombotic, including three patients with fatal PE following filter placement. Retrieval was attempted in 60 % of patients and successful in 88.5 %. Fourteen patients required multiple retrieval attempts due to the presence of filter thrombus. In multivariate analysis, predictors of retrieval included a documented filter management plan (odds ratio 16.7), a surgery related indication, age <70, and hematology service involvement. Metastatic cancer was associated with a risk of nonretrieval. There was a documented filter management plan for 73.8 % of patients and 77.3 % of those patients had an attempted retrieval (compared to 11.1 % attempted retrieval in patients without a documented plan).

One institution published their results using the "Define, Measure, Analyze, Improve, and Control" methodology to improve IVCF retrieval rates [62]. The authors improved retrieval rates from a baseline of 8 to 40 % by mailing follow-up letters to patients after filter placement and had a further increase to 52 % with prospective scheduling of follow-up clinic visits. All of these studies illustrate the importance of patient follow-up and highlight that more aggressive follow-up translates into a higher likelihood of retrieval.

Conclusion

Inferior vena cava filters remain an important clinical tool in the treatment of VTE. The bulk of recent clinical research has been focused on retrievable filters. However, defining which patients will derive the most benefit from the placement of an IVCF remains surprisingly difficult. In the absence of high level data, it is important that the decision to place a filter be based upon careful assessment of patient's risk of PE, with close follow-up to determine when filtration can or should be discontinued.

Acknowledgments

John A. Kaufman reports other from Bio2 Medical, grants from Cook Medical, during the conduct of the study, grants from NIH, grants from WL Gore, grants and personal fees from Guerbet, personal fees from Covidien, personal fees from Delcath, personal fees from MarrowStim, while the others are from Elsevier, ARRS/AJR, Hatch Medical, Vu Medi, Endoshape, Veniti, Javelin Medical, and AV Medical.

Compliance with Ethics Guidelines

Conflict of Interest
Jennifer P. Montgomery declares no potential conflicts of interest.

Human and Animal Rights and Informed Consent
This article does not contain any studies with human or animal subjects performed by any of the authors.

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