American College of Radiology
ACR Appropriateness Criteria®
Radiologic Management of Venous Thromboembolism-Inferior Vena Cava Filters

Variant 1: **Acute venous thromboembolism (proximal deep vein thrombosis of the leg or pulmonary embolism) with no contraindication to anticoagulation.**

Procedure	Appropriateness Category
Anticoagulation	Usually Appropriate
Retrievable IVC filter	May Be Appropriate
Permanent IVC filter	Usually Not Appropriate

Variant 2: **Acute venous thromboembolism (proximal deep vein thrombosis of the leg or pulmonary embolism) with contraindication to anticoagulation, major complication of anticoagulation, or failure of anticoagulation.**

Procedure	Appropriateness Category
Retrievable IVC filter	Usually Appropriate
Permanent IVC filter	May Be Appropriate
Observation	Usually Not Appropriate

Variant 3: **Isolated acute distal deep vein thrombosis of the leg.**

Procedure	Appropriateness Category
Observation with serial imaging	Usually Appropriate
Anticoagulation	May Be Appropriate
Retrievable IVC filter	Usually Not Appropriate
Permanent IVC filter	Usually Not Appropriate

Variant 4: **Chronic venous thromboembolism (eg, chronic thromboembolic pulmonary hypertension).**

Procedure	Appropriateness Category
Anticoagulation	Usually Appropriate
Pulmonary thromboendarterectomy	Usually Appropriate
Balloon pulmonary angioplasty	May Be Appropriate
Permanent IVC filter	May Be Appropriate
Retrievable IVC filter	May Be Appropriate

Variant 5: **Venous thromboembolism prophylaxis in high-risk patient (eg, major trauma, traumatic brain injury, etc).**

Procedure	Appropriateness Category
Intermittent pneumatic compression devices	Usually Appropriate
Prophylactic anticoagulation	Usually Appropriate
Retrievable IVC filter	May Be Appropriate
Surveillance US	May Be Appropriate
Permanent IVC filter	Usually Not Appropriate

Variant 6: **Proximal deep vein thrombosis of the leg undergoing catheter-directed thrombolysis.**

Procedure	Appropriateness Category
Anticoagulation	Usually Appropriate
Retrievable IVC filter	May Be Appropriate
Permanent IVC filter	Usually Not Appropriate

Variant 7: **Indwelling prophylactic retrievable inferior vena cava filter, resolution of risk factors for venous thromboembolism.**

Procedure	Appropriateness Category
Venography at time of retrieval procedure	Usually Appropriate
US duplex Doppler lower extremities prior to retrieval	May Be Appropriate
CT venography prior to retrieval	Usually Not Appropriate

Variant 8: **Indwelling retrievable inferior vena cava filter for venous thromboembolism, now tolerating or completed therapeutic anticoagulation.**

Procedure	Appropriateness Category
Venography at time of retrieval procedure	Usually Appropriate
US Duplex lower extremities prior to retrieval	May Be Appropriate (Disagreement)
CT venography prior to retrieval	Usually Not Appropriate

Variant 9: **Indwelling retrievable inferior vena cava filter with failed first retrieval attempt.**

Procedure	Appropriateness Category
Re-attempt retrieval with advanced techniques	Usually Appropriate
Convert to permanent device	May Be Appropriate
Refer for surgical evaluation for retrieval	Usually Not Appropriate

RADIOLOGIC MANAGEMENT OF VENOUS THROMBOEMBOLISM-INFERIOR VENA CAVA FILTERS

Expert Panel on Interventional Radiology: Jeet Minocha, MD[a]; Aaron M. Smith, MD[b]; Baljendra S. Kapoor, MD[c]; Nicholas Fidelman, MD[d]; Thomas R. Cain, MD[e]; Drew M. Caplin, MD[f]; Jens Eldrup-Jorgensen, MD[g]; Khashayar Farsad, MD, PhD[h]; Amit Gupta, MD[i]; Margaret H. Lee, MD[j]; Joseph J. McBride, MD[k]; Lisa K. Moores, MD[l]; Paul J. Rochon, MD[m]; Jonathan M. Lorenz, MD.[n]

Summary of Literature Review

Introduction/Background

Deep vein thrombosis (DVT) and pulmonary embolism (PE) represent the clinical spectrum of venous thromboembolism (VTE). VTE is a common cause of morbidity and mortality, affecting up to 5% of the population during their lifetimes [1]. VTE can be provoked by surgery, provoked by a nonsurgical transient risk factor (eg, estrogen therapy, pregnancy, leg injury, flight >8 hours), unprovoked, or associated with cancer ("cancer-associated thrombosis") [2]. These four subgroups of patients are distinguished by their different estimated risks of recurrent VTE [3].

The mainstay of VTE prophylaxis and therapy is anticoagulation [1,4]. In select patients with VTE, inferior vena cava (IVC) filters are used. Unlike anticoagulation, IVC filters do not prevent or treat DVT [5]. The sole function of IVC filters is to prevent PE by trapping emboli as they pass from the lower extremity venous system through the IVC, thereby precluding embolization into the pulmonary arterial circulation [6]. IVC filters are placed percutaneously with relatively low risk to even severely ill patients [7].

Devices

There are two general types of IVC filters currently available in the United States: permanent and optional (also referred to as retrievable or removable), including one brand of filter that can be converted to a venous stent (ie, convertible IVC filter). Newer filter designs are also under development (eg, absorbable filters). Permanent filters have been used since the 1970s and are placed in patients with a long-term need for mechanical prophylaxis against PE. There are more robust data on permanent filter designs, starting in 1973 and including over 9,500 filter placements. While retrievable filters are now preferred in many cases, certain patient parameters, including age, diagnosis of cancer, and previous failure of anticoagulation, may help predict whether a filter will become permanent and consequently guide whether a permanent or retrievable filter should be placed [8].

Optional or retrievable filters (ie, filters that have the "option" of being retrieved) have been available since the late 1990s and are designed to be retrieved or left in place after the temporary risk of PE or contraindication to anticoagulation has resolved. If retrieved, these devices offer the theoretical benefit of fewer long-term complications associated with permanent IVC filters, such as increased risk of subsequent DVT, filter migration/embolization, and IVC stenosis or occlusion.

Retrievable filters were developed based on the concept that the embolic risk is highest early after the onset of VTE, while complications, including recurrent DVT, filter-associated caval thrombosis, and strut fracture, appear later [9-11]. Multiple retrievable filter designs are available in the United States with no one design currently considered superior [12,13]. Retrievable filters continue to increase in popularity, and the vast majority of filters placed in the United States from 2009 to 2012 were retrievable filters [14]. A 2011 review of 37 trials that included 11 prospective clinical trials and consisted of 6,834 patients who received retrievable filters found a rate of PE following filter placement of only 1.7%, suggesting that retrievable filters are as effective in preventing PE as permanent filters [12].

[a]University of California San Diego, San Diego, California. [b]Research Author, University of California San Diego, San Diego, California. [c]Panel Chair, Cleveland Clinic, Cleveland, Ohio. [d]Panel Vice-Chair, University of California San Francisco, San Francisco, California. [e]Desert Regional Medical Center, Palm Springs, California. [f]Zucker School of Medicine at Hofstra Northwell, Hempstead, New York. [g]Tufts University School of Medicine, Boston, Massachusetts; Society for Vascular Surgery. [h]Charles T. Dotter Department of Interventional Radiology, Portland, Oregon. [i]Stony Brook University School of Medicine, Stony Brook, New York. [j]David Geffen School of Medicine at UCLA, Los Angeles, California. [k]University of Nebraska Medical Center, Omaha, Nebraska. [l]Uniformed Services University of the Health Sciences, Bethesda, Maryland; American College of Chest Physicians. [m]University of Colorado Denver Anschutz Medical Campus, Aurora, Colorado. [n]Specialty Chair, University of Chicago Hospital, Chicago, Illinois.

Reprint requests to: publications@acr.org

There remain very few prospective, randomized trials evaluating the use of IVC filters. As a result, there is lack of consensus between current guidelines for filter placement. Furthermore, these guidelines are often not rigorously followed, with filter placement indications varying widely between institutions [15-17]. Filters were initially intended for use in patients with VTE and either a contraindication to anticoagulation, a complication of anticoagulation, or a failure of anticoagulation, so-called absolute or "classic" indications [1,18]. With relaxation in thresholds for IVC filter placement following the introduction of retrievable devices, the proposed indications for filter placement have continued to expand, including in addition to anticoagulation in certain subsets of patients with VTE ("extended" indications). Finally, IVC filters have been proposed for PE prophylaxis in certain patients at high risk for VTE but without evidence of current disease, such as those with major trauma [19-21].

Discussion of Procedures by Variant

Variant 1: Acute venous thromboembolism (proximal deep vein thrombosis of the leg or pulmonary embolism) with no contraindication to anticoagulation.

Anticoagulation

Pharmacologic anticoagulation, including intravenous heparin, oral warfarin, subcutaneous low-dose heparin, and low-molecular-weight heparin, remains the standard of care for patients with VTE [1,4]. Newer nonvitamin K oral anticoagulants (eg, dabigatran, rivaroxaban, apixaban, or edoxaban) are also gaining popularity [22]. The 10th edition of the American College of Chest Physicians (ACCP) Antithrombotic Guidelines now suggests the use of nonvitamin K oral anticoagulants over vitamin K antagonists (eg, warfarin) in patients with VTE and no evidence of cancer [3]. In patients with cancer-associated thrombosis, these guidelines still recommend low-molecular-weight heparin over vitamin K antagonists and nonvitamin K oral anticoagulants.

Permanent IVC Filters

In patients with acute DVT or PE who are treated with anticoagulants, the ACCP recommends against the use of an IVC filter [3]. This recommendation is primarily based on findings of the Prevention du Risque d'Embolie Pulmonaire par Interruption Cave (PREPIC) randomized trial, which showed that placement of a permanent IVC filter increased DVT, decreased PE, and did not influence mortality [23]. Additional meta-analyses have supported these results [24]. In circumstances when an IVC filter is placed in addition to anticoagulation for acute DVT or PE, retrievable IVC filters may be preferable to permanent IVC filters because of their ability to be removed when filtration is no longer desired, as detailed below.

Retrievable IVC Filter

Recent evidence suggests that filter placement may reduce in-hospital mortality when used as an adjuvant to anticoagulation in patients with PE. A comparative study consisting of 13,125 eligible patients demonstrated that in-hospital mortality decreased to 2.6% from 4.7% when IVC filters were placed in patients with PE, regardless of anticoagulation status, suggesting that adjuvant filter placement may result in decreased mortality for patients with acute PE [25]. In patients with PE status after total joint arthroplasty, adjuvant IVC filter placement is associated with fewer complications and overall hospital costs [26].

Certain subgroups of patients with VTE and without a contraindication to anticoagulation merit special consideration:

- History of PE and poor cardiopulmonary reserve: Patients with severe pulmonary hypertension and a history of PE are at high risk for death or severe morbidity from recurrent PE. Therefore, filters may be considered in patients who have had multiple prior episodes of VTE, or in whom any additional embolization event might result in severe morbidity or mortality [27]. Similarly, filters have been shown to decrease mortality in unstable patients who have undergone pulmonary thrombolysis/embolectomy [26,28,29].
- Free-floating iliofemoral or IVC thrombus: There has been much speculation about the risk of PE that is due to free-floating iliofemoral or IVC thrombus. One prospective study demonstrated no increased risk of PE in cases of free-floating thrombus [30]. Although no study has demonstrated improved outcomes with IVC filters in addition to or in place of anticoagulation, free-floating iliofemoral or IVC thrombus is still considered a relative indication in many consensus statements [18,31].
- Cancer: Cancer is a prethrombotic state and can provoke VTE. Some authors consider cancer a contraindication to filter placement, although recent studies have suggested that certain subsets of cancer patients with PE may benefit from filter placement [32,33]. One 2014 study found that an active diagnosis of cancer did not lead to an increase in filter-related complications but did result in decreased rates of filter retrieval [34]. The authors hypothesized that the decreased retrieval rate may be due to the perception that the

shorter life expectancy of patients with cancer may not make retrieval worthwhile, among other reasons. Currently, pharmacologic anticoagulation is preferred in cancer patients, with indications for filter placement the same as in the general population [35,36].

- Chronic obstructive pulmonary disease patients: Patients with a diagnosis of chronic obstructive pulmonary disease and PE have been proposed as a group that may benefit from IVC filter placement. One retrospective study by Stein et al [37] demonstrated reduced in-house hospital mortality for patients with chronic obstructive pulmonary disease and PE who were >50 years of age, with the largest mortality benefit in patients >80 years of age.
- Pregnancy: Pregnancy produces a hypercoagulable state, and VTE complicates 0.5% to 1% of pregnancies. Anticoagulation with heparin products is the mainstay of treatment for VTE in pregnancy, while warfarin is contraindicated because of its teratogenicity. Indications for filter placement are the same as in nonpregnant patients and include contraindication to anticoagulation, progression of VTE while anticoagulated, and inability to tolerate a subsequent PE [38,39].
- Septic emboli: The proposed use of IVC filters in patients with septic emboli is based on a single animal study and, given the risks of filter infection, is not currently recommended [40]. Retrievable filters may be removed if infected.

Variant 2: Acute venous thromboembolism (proximal deep vein thrombosis of the leg or pulmonary embolism) with contraindication to anticoagulation, major complication of anticoagulation, or failure of anticoagulation.

The "classic" indications for IVC filter placement are VTE (DVT and/or PE) with a contraindication to anticoagulation, a major complication of anticoagulation, or a failure or inability to adequately anticoagulate [41].

Anticoagulation

Contraindication to Anticoagulation

Absolute contraindications to anticoagulation include active bleeding; recent intracranial hemorrhage; recent, planned, or emergent surgery or procedure with high bleeding risk; platelet count <50,000/uL; or severe bleeding diathesis. Relative contraindications to anticoagulation include recurrent but inactive gastrointestinal bleeding; intracranial or spinal tumor; recent, planned, or emergent surgery or procedure with intermediate bleeding risk; major trauma including cardiopulmonary resuscitation; aortic dissection; and platelet count <150,000/uL.

Certain clinical situations lack data to support withholding anticoagulation. Peptic ulcer disease without a history of bleeding is not an absolute contraindication to anticoagulation nor is a history of guaiac-positive stools. Anticoagulation is safe in most trauma and neurosurgical patients after the first or second postoperative week and in most stroke patients without intracranial hemorrhage. Patients with spinal cord injuries but without hematomyelia also may be considered for anticoagulation.

Certain patients do not meet strict contraindications to anticoagulation but have relative contraindications or are considered "too risky" to anticoagulate. Elderly patients, patients who are unable to reliably comply with pharmacologic anticoagulation regimens, and patients with a history of falls are at increased risk of bleeding and complications stemming from anticoagulation [42]. Discomfort from frequent blood draws or self-injections may also result in poor patient compliance and the inability to use pharmacologic anticoagulation. Certain medications and vitamin K–rich diets may affect the ability to anticoagulate with warfarin, although newer medications are making this problem obsolete.

Major Complication of Anticoagulation

Major bleeding is the most common and most significant major complication of anticoagulation. Major bleeding as a complication of anticoagulation is defined as intracranial bleeding, retroperitoneal bleeding, or bleeding that requires hospitalization or transfusion while a patient is therapeutically anticoagulated. IVC filter placement should be considered when anticoagulation for VTE is discontinued because of major bleeding [43]. Heparin-induced thrombocytopenia—defined as platelet count <50,000/uL, with or without arterial thrombosis—is considered a complication of heparin therapy, and placement of an IVC filter should be considered after heparin therapy is discontinued if alternate means of anticoagulation cannot be initiated.

Failure of Anticoagulation

It is unusual for VTE to progress while a patient is on therapeutic anticoagulation; however, certain patients will develop recurrent or progressive disease despite reaching target pharmacologic levels. These patients are

considered to have failed anticoagulation. In any case of perceived failure of anticoagulation, it is critical to ascertain if therapeutic medication levels have been achieved. Raising the target international normalized ratio may be preferable to filter placement in the setting of inadequate anticoagulation with warfarin. If a filter is to be placed, hypercoagulable states, such as antiphospholipid antibody or Trousseau syndrome, must be excluded prior to placement in order to avoid significant morbidity [31].

Permanent IVC Filter

There have been two randomized clinical trials on caval filters. In the PREPIC study, 400 patients with iliofemoral DVT at high risk for PE were anticoagulated and randomized to either receive a permanent filter or not [23,44]. Patients receiving filters had fewer PE initially and at follow-up but experienced more frequent DVT and no decrease in mortality.

Growing evidence suggests that filters reduce the risk of recurrent PE to approximately 1% to 3%, while increasing the risk of lower extremity DVT [12,43-46]. In a 26-year single-institution study of 1,765 filters, major complications associated with filter placement occurred at a rate of 0.3% and included postinsertion migration, filter fracture, and caval perforation. Another significant risk was caval thrombosis, which occurred at a rate of 2.7% [47]. Some authors cite a long-term caval thrombosis rate of up to 30% [48,49]. Several complications, such as maldeployment, malpositioning, tilt, migration, perforation, fragmentation, caval thrombosis, and recurrent PE, can be seen on cross-sectional imaging [50].

Retrievable IVC Filter

In the recent PREPIC2 study, 399 patients with PE were anticoagulated and randomized to receive a retrievable filter or not [51]. There was no significant difference in recurrent PE between the two groups. It is important to note that in both the PREPIC and PREPIC2 studies all patients were anticoagulated and therefore not representative of typical patients who receive filters. Still, no study has shown a survival benefit for patients who receive IVC filters.

Retrievable IVC filters were specifically designed to have a less secure implantation to facilitate retrieval. Despite this, retrievable and permanent filters may have similar safety profiles [52]. A 2-year follow-up study of one type of retrievable filter found a similar rate of complications to that found in permanent filters [53]; however, multiple reports have also demonstrated significant filter-related complications that were most commonly related to duration of implantation. Andreoli et al [14] found significantly higher complication rates for retrievable filters than for permanent ones; however, this was potentially attributed to a higher self-reported complication rate. Certain factors may increase the complication rate and decrease the rate of successful filter retrieval. Longer dwell times are associated with higher rates of mechanical complications and recurrent VTE [9,54]. Thrombus in a retrievable filter may prevent removal until the thrombus resolves [55]. Likewise, factors that decrease the rate of successful retrieval include longer dwell time, increased transverse tilt, and the presence of an embedded hook in the caval wall [56].

One influential 2010 retrospective study by Nicholson et al [57] found high rates of strut fractures and complications in retrievable filters. The Nicholson study prompted an FDA warning in 2010, updated in 2014, which recommended that "implanting physicians and clinicians responsible for the ongoing care of patients with retrievable IVC filters consider removing the filter as soon as protection from PE is no longer needed," but did not make any direct recommendations against use of filters or comment on filter indications [58]. The complications seen in the Nicholson study did not apply to all models of retrievable filters and may be remedied by improved filter design.

Variant 3: Isolated acute distal deep vein thrombosis of the leg.

The management of distal DVT of the leg, defined as thrombosis within the deep veins of the calf, distal to the popliteal vein, is more controversial than is the management for proximal DVT because of the lower risk of extension or embolization [3].

Anticoagulation

The ACCP recommends anticoagulation in patients with acute isolated distal DVT of the leg with severe symptoms or risk factors for extension (eg, positive d-dimer, thrombosis close to proximal veins, active cancer, inpatient status) [3]. In the absence of severe symptoms or risk factors, serial imaging is recommended. Patients at high risk for bleeding are more likely to benefit from serial imaging. Patients who place a high value on avoiding

the inconvenience of repeat imaging and a low value on the inconvenience of treatment and on the potential for bleeding are likely to choose initial anticoagulation over serial imaging.

Permanent IVC Filter
The role of IVC filter placement in patients with distal DVT is unclear; however, as in proximal DVT, filter placement is likely not indicated unless a patient cannot be anticoagulated or fails anticoagulation.

Retrievable IVC Filter
The role of IVC filter placement in patients with distal DVT is unclear; however, as in proximal DVT, filter placement is likely not indicated unless a patient cannot be anticoagulated or fails anticoagulation. The decision to insert a filter in patients with distal DVT of the leg should be individualized.

Observation/Conservative Management
In patients with acute isolated distal DVT of the leg without severe symptoms or risk factors for extension (eg, positive d-dimer, thrombosis close to proximal veins, active cancer, inpatient status), observation with serial imaging of the deep veins for 2 weeks is recommended over anticoagulation [3]. If serial imaging is used, no anticoagulation is needed if the thrombus does not extend. On the other hand, anticoagulation is suggested if there is evidence of thrombus extension on follow-up imaging. The muscular veins of the calf (soleus, gastrocnemius) have a lower risk of extension of thrombosis than the true deep (peroneal and tibial) veins.

Variant 4: Chronic venous thromboembolism (eg, chronic thromboembolic pulmonary hypertension).

Anticoagulation
The ACCP recommends extended (ie, indefinite) anticoagulation in patients with chronic thromboembolic pulmonary hypertension (CTEPH) [3]. In addition to anticoagulation, pulmonary vasodilators may also be of benefit. For example, in patients with inoperable CTEPH or persistent pulmonary hypertension after pulmonary thromboendarterectomy, pulmonary vasodilator therapy may significantly improve exercise capacity and pulmonary vascular resistance [59].

Pulmonary Thromboendarterectomy
A small percentage of patients who experience acute PE will eventually develop CTEPH [60]. In selected patients with CTEPH who are identified by an experienced thromboendarterectomy team, pulmonary thromboendarterectomy is an established, effective surgical treatment [61].

Permanent IVC Filter
Permanent filters have been placed in patients prior to pulmonary thromboendarterectomy as an adjuvant to lifelong pharmacologic anticoagulation, although there are currently no robust data to support their efficacy [62]. In patients who cannot be safely anticoagulated, IVC filter placement can be considered.

Retrievable IVC Filter
Because of more robust data on their efficacy, permanent filters have historically been preferred over retrievable filters in patients undergoing pulmonary thromboendarterectomy [62].

Balloon Pulmonary Angioplasty
Balloon pulmonary angioplasty is a developing treatment for select patients with inoperable CTEPH. This technique is designed to target lesions in patients not amenable to surgery. Although balloon pulmonary angioplasty may improve hemodynamics, functional capacity, and biomarkers, longer-term outcomes are still under evaluation [63]. This procedure may be useful in select patients at centers with expertise in balloon pulmonary angioplasty.

Variant 5: Venous thromboembolism prophylaxis in high-risk patient (eg, major trauma, traumatic brain injury, etc).

Prophylactic Anticoagulation
Prophylactic anticoagulation is common practice for hospitalized patients, particularly in high-risk patients such as those suffering from major trauma. Prophylactic anticoagulation has been shown to be safe in many of these patients [64].

Permanent IVC Filter
In general, retrievable filters are preferred for prophylaxis as they can be removed when risk factors for VTE have resolved. Certain patients, such as spinal cord injury patients and stroke patients, remain at high risk of VTE that is due to immobility, and permanent IVC filters may therefore be considered in these patients. IVC filters have

been found to be safe in patients with nonhemorrhagic stroke, and certain authors have advocated for prophylactic filter placement in stroke patients; however, no guidelines currently advocate for prophylactic filter placement in stroke [65].

Retrievable IVC Filter

Prophylactic retrievable IVC filter placement has grown in popularity in recent years for certain subgroups of patients, particularly in trauma patients. The following subgroups of patients deserve special consideration:

- Prophylactic IVC filter in major trauma patients: Patients recovering from trauma, especially spinal cord injury, have one of the highest risks of VTE of all hospitalized patients [66]. Independent risk factors for VTE in trauma patients include lower limb injuries and central venous catheterization [15]. The use of IVC filters in trauma patients remains controversial. However, an increasing number of authors advocate for filter placement in patients that cannot be anticoagulated [19,20,67]. Other authors have argued that filters confer no benefit to these patients and that as soon as hemostasis is achieved (within 36 hours in most patients), pharmacologic prophylaxis should begin [68-71]. Prospective randomized trials are lacking in this area, although such a study is considered feasible [72]. A recent meta-analysis of 8 studies suggested a reduction in PE and fatal PE when filters are placed prophylactically in trauma patients, but no reduction in DVT or overall mortality [73].
- Prophylactic IVC filter in high-risk surgery patients: Patients undergoing orthopedic procedures, such as total knee and total hip arthroplasty, are at high risk for VTE. Although retrievable filters are sometimes used in the perioperative period for patients undergoing high-risk surgical procedures but without evidence of VTE, pharmacologic therapies are safe and effective once the immediate risk of hemorrhage is past and are preferred to prophylactic filter placement [67].
- Prophylactic IVC filter in burn patients: Burn patients are at high risk for VTE. Filter use in burn patients was found to be safe in one small series, but burn injury is not considered an established indication for prophylactic filter placement [74].
- Prophylactic IVC filter in bariatric surgery patients: PE is a leading cause of perioperative death in bariatric patients; however, there is little evidence to support routine use of filters in place of pharmacologic anticoagulation [75]. One study found a higher mortality rate (0.31% versus 0.03%) and increased hospital stay length when prophylactic IVC filters were placed in patients undergoing bariatric surgery [76]. Currently, prophylactic IVC filters are not generally recommended in bariatric surgery patients [21,77].

Intermittent Pneumatic Compression Devices

Intermittent pneumatic compression devices have been proposed as a reasonable alternative to prophylactic anticoagulation in high-risk patients because of their low rate of thromboembolic complications [78].

Surveillance US

Surveillance ultrasound (US) can be performed in high-risk patients. Surveillance US increases the detection rate of DVT but not of PE, raising the possibility that surveillance US detects primarily clinically insignificant DVTs and may in fact be unnecessary [79]. Given limited data guiding its use, the use of surveillance US varies across institutions.

Variant 6: Proximal deep vein thrombosis of the leg undergoing catheter-directed thrombolysis.

Anticoagulation

Indications and contraindications for anticoagulation in patients undergoing catheter-based interventions for DVT are the same as in patients not undergoing intervention.

Permanent IVC Filter

Percutaneous endovascular intervention (PEVI) has grown in popularity for the treatment of proximal DVT. IVC filter placement has been recommended by some authors to protect from embolization of thrombolysis products. The randomized FILTER-PEVI trial demonstrated an 8-fold decreased risk of PE in patients undergoing PEVI for DVT who received filters, but no decrease in mortality [31,80].

Retrievable IVC Filter

As in other indications for IVC filter placement, permanent filters have more robust data supporting their use but have fallen out of favor because of the flexibility afforded by retrievable IVC filters. As noted above, the randomized FILTER-PEVI trial demonstrated an 8-fold decreased risk of PE in patients undergoing PEVI for DVT who received filters but no decrease in mortality [31,80]. All of the filters placed in this trial were

retrievable, although only 34% were retrieved [80]. IVC filter placement during PEVI remains operator-preference and patient dependent.

Variant 7: Indwelling prophylactic retrievable inferior vena cava filter, resolution of risk factors for venous thromboembolism.

Although the number of retrievable IVC filters placed has dramatically increased in the past decade, until recently, many of these filters were never retrieved. Successful filter retrieval requires diligent patient follow-up and interdepartmental cooperation [52,81]. Historically, the rate of filter retrieval has been low, even in patients with good follow-up, such as military populations [82]. Recently published studies, however, have described reproducible methods to improve filter retrieval rates. Minocha et al [83] demonstrated that a dedicated IVC filter clinic improved retrieval rates from 29% preclinic to 60% postclinic. Similarly, Ko et al [84] reported that filter retrieval rates improved from 42% to 95% following the implementation of a dedicated retrieval algorithm, with the help of the trauma service in their institution. Multiple institutions have reported improved retrieval rates following the establishment of a dedicated filter registry or rigorous follow-up [85,86].

In patients with retrievable IVC filters placed prophylactically (ie, with no documented VTE at time of placement), every effort should be made to remove these devices when the risk factors for VTE have resolved and/or the patients can tolerate chemoprophylaxis [18].

US duplex Doppler Lower Extremities Prior to Retrieval

Patients who are not anticoagulated and who do not have a known diagnosis of VTE may undergo lower-extremity imaging prior to filter retrieval to ensure that a DVT has not developed if clinically indicated [18]. If a DVT is identified prior to filter retrieval, patients should be managed as any patient with a new diagnosis of VTE. Although the use of US prior to retrieval of prophylactic filters is not routine, it may be indicated in certain patients.

CT Venogram Prior to Retrieval

Prior to filter retrieval, the IVC can be imaged with CT venogram, MR venography, or US [18]. However, in most centers, imaging of the IVC is usually performed with venography at the time of the retrieval procedure unless other patient factors favor noninvasive imaging prior to the procedure.

Venography at Time of Retrieval Procedure

Venography is typically performed at the time of IVC filter retrieval, both to assess for filter-associated thrombus preretrieval and to assess for caval injury postretrieval. If a patient undergoes a particularly prolonged or difficult filter retrieval or reports significant pain during the procedure, venography is strongly recommended following retrieval [18].

Variant 8: Indwelling retrievable inferior vena cava filter for venous thromboembolism, now tolerating or completed therapeutic anticoagulation.

For patients with VTE and retrievable IVC filters, the decision on when to retrieve the filter can be challenging. The Society of Interventional Radiology guidelines propose an algorithm for removal of retrievable IVC filters [18]. When these patients can tolerate anticoagulation or when their VTE or risk for VTE has resolved, IVC filter removal should be considered. A retrospective study of 115 patients failed to show any benefit to reversing anticoagulation prior to IVC filter retrieval [87]. Consequently, anticoagulation reversal is generally not recommended prior to a retrieval attempt.

US Duplex Lower Extremities Prior to Retrieval

Patients with VTE who are on adequate anticoagulation, are in stable condition, and who do not have new, recurrent, or progressive symptoms or clinical findings of VTE, likely do not require imaging of the extremities prior to filter retrieval [18].

CT Venogram Prior to Retrieval

Prior to filter retrieval, the IVC can be imaged with CT venogram, MR venography, or US [18]. However, in most centers, imaging of the IVC is usually performed with venography at the time of the retrieval procedure unless other patient factors favor noninvasive imaging prior to the procedure.

Venography at Time of Retrieval Procedure

Venography is typically performed at the time of IVC filter retrieval, both to assess for filter-associated thrombus preretrieval and to assess for caval injury postretrieval. If a patient undergoes a particularly prolonged or difficult

filter retrieval or reports significant pain during the procedure, venography is strongly recommended following retrieval [18].

Variant 9: Indwelling retrievable inferior vena cava filter with failed first retrieval attempt.

Convert to Permanent Device

Because of the high success rate of advanced filter removal techniques, it is rarely necessary to "convert" (ie, intentionally not retrieve) a retrievable filter to a permanent device when caval filtration is no longer clinically indicated [56]. In certain scenarios, it may be reasonable to convert the filter into a permanent device in lieu of using advanced techniques, which carry a slightly higher complication rate.

Reattempt Retrieval with Advanced Techniques

Once the decision to retrieve a filter has been made, technical success of retrieval is high. Retrieval techniques have evolved in recent years. Advanced techniques using snares, guidewires, and angioplasty balloons have been used when routine techniques fail. Lasers may be used to retrieve embedded filters [88,89]. While advanced retrieval techniques enjoy high success and somewhat low complication rates (98.2% and 1.7%, respectively, in one study), complication rates are nevertheless higher when advanced techniques are required [56]. If a first retrieval attempt is unsuccessful, referral to a center that specializes in advanced retrieval techniques will often result in successful removal.

Refer for Surgical Evaluation for Retrieval

A dreaded complication of IVC filters is pulmonary or cardiac migration. Migration to the heart or lungs can lead to cardiac tamponade, chamber perforation, myopericarditis, tricuspid valve damage, or death. In these cases, surgical management may be necessary and preferred over endovascular management [90,91].

Summary of Recommendations

- **Variant 1:** In the absence of a contraindication, anticoagulation is usually appropriate for acute VTE, including proximal DVT of the leg or PE.
- **Variant 2:** Retrievable IVC filter placement is usually appropriate for acute VTE, including proximal DVT of the leg or PE with contraindication to anticoagulation, or a major complication of anticoagulation, or a failure of anticoagulation.
- **Variant 3:** Observation with serial imaging is usually appropriate for the management of isolated acute distal DVT of the leg.
- **Variant 4:** Anticoagulation and pulmonary thromboendarterectomy are usually appropriate for the management of chronic VTE, including CTEPH. These are complementary procedures (ie, more than one may be ordered).
- **Variant 5:** Prophylactic anticoagulation or intermittent pneumatic compression devices are usually appropriate for prophylaxis of VTE in high-risk patients including those experiencing major trauma, or traumatic brain injury, etc. These procedures are equivalent alternatives.
- **Variant 6:** Anticoagulation is usually appropriate in patients undergoing catheter-directed thrombolysis for proximal DVT of the leg.
- **Variant 7:** Venography is usually appropriate at the time of indwelling prophylactic IVC filter retrieval when the risk factors for VTE have resolved.
- **Variant 8:** Venography is usually appropriate at the time of indwelling retrievable IVC filter retrieval for patients who have completed or are now tolerating therapeutic anticoagulation.
- **Variant 9:** When the first attempt to retrieve an indwelling retrievable IVC filter fails, it is usually appropriate to re-attempt retrieval with advanced techniques.

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

References

1. Wells PS, Forgie MA, Rodger MA. Treatment of venous thromboembolism. JAMA 2014;311:717-28.
2. Cohen AT, Tapson VF, Bergmann JF, et al. Venous thromboembolism risk and prophylaxis in the acute hospital care setting (ENDORSE study): a multinational cross-sectional study. Lancet 2008;371:387-94.
3. Kearon C, Akl EA, Ornelas J, et al. Antithrombotic Therapy for VTE Disease: CHEST Guideline and Expert Panel Report. Chest 2016;149:315-52.
4. Tapson VF. Acute pulmonary embolism. N Engl J Med 2008;358:1037-52.
5. Wang SL, Lloyd AJ. Clinical review: inferior vena cava filters in the age of patient-centered outcomes. Ann Med 2013;45:474-81.
6. Young T, Tang H, Hughes R. Vena caval filters for the prevention of pulmonary embolism. Cochrane Database Syst Rev 2010:CD006212.
7. Uberoi R, Tapping CR, Chalmers N, Allgar V. British Society of Interventional Radiology (BSIR) Inferior Vena Cava (IVC) Filter Registry. Cardiovasc Intervent Radiol 2013;36:1548-61.
8. Eifler AC, Lewandowski RJ, Gupta R, et al. Optional or permanent: clinical factors that optimize inferior vena cava filter utilization. J Vasc Interv Radiol 2013;24:35-40.
9. Vijay K, Hughes JA, Burdette AS, et al. Fractured Bard Recovery, G2, and G2 express inferior vena cava filters: incidence, clinical consequences, and outcomes of removal attempts. J Vasc Interv Radiol 2012;23:188-94.
10. Weinberg I, Abtahian F, Debiasi R, et al. Effect of delayed inferior vena cava filter retrieval after early initiation of anticoagulation. Am J Cardiol 2014;113:389-94.
11. Morales JP, Li X, Irony TZ, Ibrahim NG, Moynahan M, Cavanaugh KJ, Jr. Decision analysis of retrievable inferior vena cava filters in patients without pulmonary embolism. J Vasc Surg Venous Lymphat Disord 2013;1:376-84.
12. Angel LF, Tapson V, Galgon RE, Restrepo MI, Kaufman J. Systematic review of the use of retrievable inferior vena cava filters. J Vasc Interv Radiol 2011;22:1522-30 e3.
13. Montgomery JP, Kaufman JA. A Critical Review of Available Retrievable Inferior Vena Cava Filters and Future Directions. Semin Intervent Radiol 2016;33:79-87.
14. Andreoli JM, Lewandowski RJ, Vogelzang RL, Ryu RK. Comparison of complication rates associated with permanent and retrievable inferior vena cava filters: a review of the MAUDE database. J Vasc Interv Radiol 2014;25:1181-5.

15. Baadh AS, Zikria JF, Rivoli S, Graham RE, Javit D, Ansell JE. Indications for inferior vena cava filter placement: do physicians comply with guidelines? J Vasc Interv Radiol 2012;23:989-95.
16. Sader RB, Friedman A, Berkowitz E, Martin E. Inferior vena cava filters and their varying compliance with the ACCP and the SIR guidelines. South Med J 2014;107:585-90.
17. White RH, Geraghty EM, Brunson A, et al. High variation between hospitals in vena cava filter use for venous thromboembolism. JAMA Intern Med 2013;173:506-12.
18. Kaufman JA, Kinney TB, Streiff MB, et al. Guidelines for the use of retrievable and convertible vena cava filters: report from the Society of Interventional Radiology multidisciplinary consensus conference. J Vasc Interv Radiol 2006;17:449-59.
19. Giannoudis PV, Pountos I, Pape HC, Patel JV. Safety and efficacy of vena cava filters in trauma patients. Injury 2007;38:7-18.
20. Malinoski D, Ewing T, Patel MS, et al. Risk factors for venous thromboembolism in critically ill trauma patients who cannot receive chemical prophylaxis. Injury 2013;44:80-5.
21. Rajasekhar A, Crowther M. Inferior vena caval filter insertion prior to bariatric surgery: a systematic review of the literature. J Thromb Haemost 2010;8:1266-70.
22. Connolly SJ, Ezekowitz MD, Yusuf S, et al. Dabigatran versus warfarin in patients with atrial fibrillation. N Engl J Med 2009;361:1139-51.
23. Decousus H, Leizorovicz A, Parent F, et al. A clinical trial of vena caval filters in the prevention of pulmonary embolism in patients with proximal deep-vein thrombosis. Prevention du Risque d'Embolie Pulmonaire par Interruption Cave Study Group. N Engl J Med 1998;338:409-15.
24. Bikdeli B, Chatterjee S, Desai NR, et al. Inferior Vena Cava Filters to Prevent Pulmonary Embolism: Systematic Review and Meta-Analysis. J Am Coll Cardiol 2017;70:1587-97.
25. Isogai T, Yasunaga H, Matsui H, Tanaka H, Horiguchi H, Fushimi K. Effectiveness of inferior vena cava filters on mortality as an adjuvant to antithrombotic therapy. Am J Med 2015;128:312 e23-31.
26. Raphael IJ, McKenzie JC, Zmistowski B, Brown DB, Parvizi J, Austin MS. Pulmonary embolism after total joint arthroplasty: cost and effectiveness of four treatment modalities. J Arthroplasty 2014;29:933-7.
27. Stein PD, Matta F, Keyes DC, Willyerd GL. Impact of vena cava filters on in-hospital case fatality rate from pulmonary embolism. Am J Med 2012;125:478-84.
28. Stein PD, Matta F. Vena cava filters in unstable elderly patients with acute pulmonary embolism. Am J Med 2014;127:222-5.
29. Carlbom DJ, Davidson BL. Pulmonary embolism in the critically ill. Chest 2007;132:313-24.
30. Pacouret G, Alison D, Pottier JM, Bertrand P, Charbonnier B. Free-floating thrombus and embolic risk in patients with angiographically confirmed proximal deep venous thrombosis. A prospective study. Arch Intern Med 1997;157:305-8.
31. Hann CL, Streiff MB. The role of vena caval filters in the management of venous thromboembolism. Blood Rev 2005;19:179-202.
32. Matsuo K, Carter CM, Ahn EH, et al. Inferior vena cava filter placement and risk of hematogenous distant metastasis in ovarian cancer. Am J Clin Oncol 2013;36:362-7.
33. Stein PD, Matta F, Sabra MJ. Case fatality rate with vena cava filters in hospitalized stable patients with cancer and pulmonary embolism. Am J Med 2013;126:819-24.
34. Abtahian F, Hawkins BM, Ryan DP, et al. Inferior vena cava filter usage, complications, and retrieval rate in cancer patients. Am J Med 2014;127:1111-7.
35. Barginear MF, Gralla RJ, Bradley TP, et al. Investigating the benefit of adding a vena cava filter to anticoagulation with fondaparinux sodium in patients with cancer and venous thromboembolism in a prospective randomized clinical trial. Support Care Cancer 2012;20:2865-72.
36. Segal JB, Streiff MB, Hofmann LV, Thornton K, Bass EB. Management of venous thromboembolism: a systematic review for a practice guideline. Ann Intern Med 2007;146:211-22.
37. Stein PD, Matta F. Vena cava filters in hospitalised patients with chronic obstructive pulmonary disease and pulmonary embolism. Thromb Haemost 2013;109:897-900.
38. Krivak TC, Zorn KK. Venous thromboembolism in obstetrics and gynecology. Obstet Gynecol 2007;109:761-77.
39. Stone SE, Morris TA. Pulmonary embolism during and after pregnancy. Crit Care Med 2005;33:S294-300.
40. Timsit JF, Farkas JC, Boyer JM, et al. Central vein catheter-related thrombosis in intensive care patients: incidence, risks factors, and relationship with catheter-related sepsis. Chest 1998;114:207-13.

41. Ray CE, Jr., Prochazka A. The need for anticoagulation following inferior vena cava filter placement: systematic review. Cardiovasc Intervent Radiol 2008;31:316-24.
42. Shaw CM, Scorza LB, Waybill PN, Singh H, Lynch FC. Optional vena cava filter use in the elderly population. J Vasc Interv Radiol 2011;22:824-8.
43. Muriel A, Jimenez D, Aujesky D, et al. Survival effects of inferior vena cava filter in patients with acute symptomatic venous thromboembolism and a significant bleeding risk. J Am Coll Cardiol 2014;63:1675-83.
44. Eight-year follow-up of patients with permanent vena cava filters in the prevention of pulmonary embolism: the PREPIC (Prevention du Risque d'Embolie Pulmonaire par Interruption Cave) randomized study. Circulation 2005;112:416-22.
45. Ren W, Li Z, Fu Z, Fu Q. Analysis of risk factors for recurrence of deep venous thrombosis in lower extremities. Med Sci Monit 2014;20:199-204.
46. Smouse HB, Mendes R, Bosiers M, Van Ha TG, Crabtree T. The RETRIEVE trial: safety and effectiveness of the retrievable crux vena cava filter. J Vasc Interv Radiol 2013;24:609-21.
47. Athanasoulis CA, Kaufman JA, Halpern EF, Waltman AC, Geller SC, Fan CM. Inferior vena caval filters: review of a 26-year single-center clinical experience. Radiology 2000;216:54-66.
48. Joels CS, Sing RF, Heniford BT. Complications of inferior vena cava filters. Am Surg 2003;69:654-9.
49. Stavropoulos SW. Inferior vena cava filters. Tech Vasc Interv Radiol 2004;7:91-5.
50. Cina A, Masselli G, Di Stasi C, et al. Computed tomography imaging of vena cava filter complications: a pictorial review. Acta Radiol 2006;47:135-44.
51. Mismetti P, Laporte S, Pellerin O, et al. Effect of a retrievable inferior vena cava filter plus anticoagulation vs anticoagulation alone on risk of recurrent pulmonary embolism: a randomized clinical trial. JAMA 2015;313:1627-35.
52. Seshadri T, Tran H, Lau KK, Tan B, Gan TE. Ins and outs of inferior vena cava filters in patients with venous thromboembolism: the experience at Monash Medical Centre and review of the published reports. Intern Med J 2008;38:38-43.
53. Hoffer EK, Mueller RJ, Luciano MR, Lee NN, Michaels AT, Gemery JM. Safety and efficacy of the Gunther Tulip retrievable vena cava filter: midterm outcomes. Cardiovasc Intervent Radiol 2013;36:998-1005.
54. Ho KM, Tan JA, Burrell M, Rao S, Misur P. Venous thrombotic, thromboembolic, and mechanical complications after retrievable inferior vena cava filters for major trauma. Br J Anaesth 2015;114:63-9.
55. Lorch H, Welger D, Wagner V, et al. Current practice of temporary vena cava filter insertion: a multicenter registry. J Vasc Interv Radiol 2000;11:83-8.
56. Al-Hakim R, Kee ST, Olinger K, Lee EW, Moriarty JM, McWilliams JP. Inferior vena cava filter retrieval: effectiveness and complications of routine and advanced techniques. J Vasc Interv Radiol 2014;25:933-9; quiz 40.
57. Nicholson W, Nicholson WJ, Tolerico P, et al. Prevalence of fracture and fragment embolization of Bard retrievable vena cava filters and clinical implications including cardiac perforation and tamponade. Arch Intern Med 2010;170:1827-31.
58. U.S. Food & Drug Administration. Removing Retrievable Inferior Vena Cava Filters: FDA Safety Communication. Available at: https://www.fda.gov/MedicalDevices/Safety/AlertsandNotices/ucm396377.htm. Accessed November 30, 2018.
59. Ghofrani HA, D'Armini AM, Grimminger F, et al. Riociguat for the treatment of chronic thromboembolic pulmonary hypertension. N Engl J Med 2013;369:319-29.
60. Pengo V, Lensing AW, Prins MH, et al. Incidence of chronic thromboembolic pulmonary hypertension after pulmonary embolism. N Engl J Med 2004;350:2257-64.
61. Madani M, Mayer E, Fadel E, Jenkins DP. Pulmonary Endarterectomy. Patient Selection, Technical Challenges, and Outcomes. Ann Am Thorac Soc 2016;13 Suppl 3:S240-7.
62. Fedullo P, Kerr KM, Kim NH, Auger WR. Chronic thromboembolic pulmonary hypertension. Am J Respir Crit Care Med 2011;183:1605-13.
63. Jenkins D. New interventions to treat chronic thromboembolic pulmonary hypertension. Heart 2018.
64. Geerts WH, Jay RM, Code KI, et al. A comparison of low-dose heparin with low-molecular-weight heparin as prophylaxis against venous thromboembolism after major trauma. N Engl J Med 1996;335:701-7.
65. Somarouthu B, Yeddula K, Wicky S, Hirsch JA, Kalva SP. Long-term safety and effectiveness of inferior vena cava filters in patients with stroke. J Neurointerv Surg 2011;3:141-6.

66. Johns JS, Nguyen C, Sing RF. Vena cava filters in spinal cord injuries: evolving technology. J Spinal Cord Med 2006;29:183-90.
67. Sarani B, Chun A, Venbrux A. Role of optional (retrievable) IVC filters in surgical patients at risk for venous thromboembolic disease. J Am Coll Surg 2005;201:957-64.
68. Geerts WH. Prevention of venous thromboembolism in high-risk patients. Hematology Am Soc Hematol Educ Program 2006:462-6.
69. Girard TD, Philbrick JT, Fritz Angle J, Becker DM. Prophylactic vena cava filters for trauma patients: a systematic review of the literature. Thromb Res 2003;112:261-7.
70. Hemmila MR, Osborne NH, Henke PK, et al. Prophylactic Inferior Vena Cava Filter Placement Does Not Result in a Survival Benefit for Trauma Patients. Ann Surg 2015;262:577-85.
71. Sarosiek S, Rybin D, Weinberg J, Burke PA, Kasotakis G, Sloan JM. Association Between Inferior Vena Cava Filter Insertion in Trauma Patients and In-Hospital and Overall Mortality. JAMA Surg 2017;152:75-81.
72. Rajasekhar A, Lottenberg L, Lottenberg R, et al. A pilot study on the randomization of inferior vena cava filter placement for venous thromboembolism prophylaxis in high-risk trauma patients. J Trauma 2011;71:323-8; discussion 28-9.
73. Haut ER, Garcia LJ, Shihab HM, et al. The effectiveness of prophylactic inferior vena cava filters in trauma patients: a systematic review and meta-analysis. JAMA Surg 2014;149:194-202.
74. Still J, Friedman B, Furman S, et al. Experience with the insertion of vena caval filters in acutely burned patients. Am Surg 2000;66:277-9.
75. Brotman DJ, Shihab HM, Prakasa KR, et al. Pharmacologic and mechanical strategies for preventing venous thromboembolism after bariatric surgery: a systematic review and meta-analysis. JAMA Surg 2013;148:675-86.
76. Li W, Gorecki P, Semaan E, Briggs W, Tortolani AJ, D'Ayala M. Concurrent prophylactic placement of inferior vena cava filter in gastric bypass and adjustable banding operations in the Bariatric Outcomes Longitudinal Database. J Vasc Surg 2012;55:1690-5.
77. Rowland SP, Dharmarajah B, Moore HM, et al. Inferior vena cava filters for prevention of venous thromboembolism in obese patients undergoing bariatric surgery: a systematic review. Ann Surg 2015;261:35-45.
78. Ginzburg E, Cohn SM, Lopez J, Jackowski J, Brown M, Hameed SM. Randomized clinical trial of intermittent pneumatic compression and low molecular weight heparin in trauma. Br J Surg 2003;90:1338-44.
79. Dietch ZC, Edwards BL, Thames M, Shah PM, Williams MD, Sawyer RG. Rate of lower-extremity ultrasonography in trauma patients is associated with rate of deep venous thrombosis but not pulmonary embolism. Surgery 2015;158:379-85.
80. Sharifi M, Bay C, Skrocki L, Lawson D, Mazdeh S. Role of IVC filters in endovenous therapy for deep venous thrombosis: the FILTER-PEVI (filter implantation to lower thromboembolic risk in percutaneous endovenous intervention) trial. Cardiovasc Intervent Radiol 2012;35:1408-13.
81. Gyang E, Zayed M, Harris EJ, Lee JT, Dalman RL, Mell MW. Factors impacting follow-up care after placement of temporary inferior vena cava filters. J Vasc Surg 2013;58:440-5.
82. Johnson ON, 3rd, Gillespie DL, Aidinian G, White PW, Adams E, Fox CJ. The use of retrievable inferior vena cava filters in severely injured military trauma patients. J Vasc Surg 2009;49:410-6; discussion 16.
83. Minocha J, Idakoji I, Riaz A, et al. Improving inferior vena cava filter retrieval rates: impact of a dedicated inferior vena cava filter clinic. J Vasc Interv Radiol 2010;21:1847-51.
84. Ko SH, Reynolds BR, Nicholas DH, et al. Institutional protocol improves retrievable inferior vena cava filter recovery rate. Surgery 2009;146:809-14; discussion 14-6.
85. Kalina M, Bartley M, Cipolle M, Tinkoff G, Stevenson S, Fulda G. Improved removal rates for retrievable inferior vena cava filters with the use of a 'filter registry'. Am Surg 2012;78:94-7.
86. Lynch FC. A method for following patients with retrievable inferior vena cava filters: results and lessons learned from the first 1,100 patients. J Vasc Interv Radiol 2011;22:1507-12.
87. Hoppe H, Kaufman JA, Barton RE, et al. Safety of inferior vena cava filter retrieval in anticoagulated patients. Chest 2007;132:31-6.
88. Kuo WT, Odegaard JI, Louie JD, et al. Photothermal ablation with the excimer laser sheath technique for embedded inferior vena cava filter removal: initial results from a prospective study. J Vasc Interv Radiol 2011;22:813-23.
89. Kuo WT, Cupp JS. The excimer laser sheath technique for embedded inferior vena cava filter removal. J Vasc Interv Radiol 2010;21:1896-9.

90. Iliescu B, Haskal ZJ. Advanced techniques for removal of retrievable inferior vena cava filters. Cardiovasc Intervent Radiol 2012;35:741-50.
91. Rana MA, Gloviczki P, Kalra M, Bjarnason H, Huang Y, Fleming MD. Open surgical removal of retained and dislodged inferior vena cava filters. J Vasc Surg Venous Lymphat Disord 2015;3:201-6.