The concept of interrupting flow in the inferior vena cava (IVC) to prevent pulmonary embolism (PE) has been around since the nineteenth century. Bilateral common femoral vein ligation was suggested as a specific treatment for prevention of recurrent PE in the 1930s and 1940s; however, an unacceptably high incidence of recurrent PE as well as significant lower extremity venous stasis sequelae resulted in abandonment of the procedure. The next approach was ligation of the inferior vena cava. This provided theoretical control of the final common path to the pulmonary circulation for most emboli, and was commonly performed until the late 1960s. The sudden reduction in cardiac output resulted in a high postoperative mortality [1]. In addition, recurrent PE from dilated collateral veins and the venous stasis sequelae were unacceptable outcomes that prompted alternative methods to reduce the risk of PE without causing complete venous occlusion. A variety of surgical methods involving either suture and staple plication or external clips were developed to compartmentalize the vena cava. These techniques provided partial IVC interruption, allowing flow of liquid blood but trapping large emboli. Despite promising early patency rates, high rates of IVC occlusion were noted after brief follow-up [2]. In addition, these techniques required general anesthesia and laparotomy.
The next logical step was the development of transvenous approaches with the use of local anesthesia. The first true intravascular device was the Mobin-Uddin umbrella, introduced in 1967 [3]. It was a silicone membrane with small holes allowing for blood flow. It was associated with a high rate of vena caval thrombosis and was subsequently discontinued in 1986. Since then a new generation of devices have been developed that provide the ideal properties for a filter: ease of deployment, clot-trapping effectiveness, and preservation of IVC flow.

**Vena cava filters available**

Currently, there are two classes of vena cava filters (VCF) in use: permanent and retrievable. Retrievable IVC filters presumably offer the same protection from PE as permanent filters, whereas subsequent retrieval potentially eliminates the long-term complications. For this reason a large number of filters placed today are retrievable. In a multicenter trial coordinated through the American Association for the Surgery of Trauma (AAST), 79% of all filters placed at 21 participating institutions were retrievable [4]. **Box 1** lists the current filters approved by the United States Food and Drug Administration. Although each filter design has its device-specific advantages and disadvantages, all filters appear to have roughly comparable effectiveness and overall complication rates.

**Indications for vena cava filter placement**

The indications and patient selection criteria for VCF placement remain the most controversial and widely debated topics surrounding this

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**Box 1. Currently available vena cava filters**

*Permanent*

- Stainless steel Greenfield filter (BostonScientific/Meditech, Boston, Massachusetts)
- Titanium Greenfield filter (BostonScientific/Meditech)
- Bird’s Nest (Cook, Bloomington, Indiana)
- Nitinol (Bard, Covington, Georgia)
- Vena Tech (B. Braun, Boulogne, France)
- TrapEase (Cordis, Europa N.V., L.J. Roden, the Netherlands)
- Bard nonrecovery (Bard Peripheral Vascular, Tempe, Arizona)

*Retrievable*

- Günter Tulip (Cook)
- Recovery (Bard Peripheral Vascular)
- OptEase (Cordis Endovascular, Miami Lakes, Florida)
technology [5–10]. The paucity of prospective controlled trials available for analysis has resulted in the promulgation of a variety of guidelines based on individual interpretation of uncontrolled prospective and retrospective series, literature reviews, consensus panel guidelines, and expert opinion. Without solid data to support a strong evidence-based approach to filter use, the decision to place a VCF is often driven more by individual practice patterns and preferences than actual patient disease and clinical factors.

The one available prospective randomized trial analyzed the utility of VCF in patients who had documented lower extremity deep vein thrombosis (DVT) and no contraindication to anticoagulation [11]. There was a statistically significant decrease in early PE (within 12 days) in the filter group (1.1%) compared with the no filter group (4.8%), but the filter group demonstrated a significant increase in DVT (odds ratio 1.87) that persisted at long-term follow-up [12] and no mortality benefit. From this trial it appears that VCF placement has little value in the average patient who has DVT and who can be safely anticoagulated. There currently exist no other prospective randomized trials to evaluate the multiple other suggested indications for VCF placement.

Current indications for VCF placement can be divided into two broad categories based on the clinical situation: preventive and prophylactic. Preventive indications include medical or surgical patients who have proven venous thromboembolic disease who are now at risk for pulmonary embolism or who have had a documented pulmonary embolism. These have become the most widely accepted and used indications for VCF placement in the United States and worldwide. The goal of VCF placement in this cohort is prevention of an initial clot embolization (known DVT) or additional clot embolizations (known PE). Prophylactic indications involve VCF placement in patients who have no documented DVT or PE, but who are assumed to be at increased risk for the development of venous thromboembolic disease. This scenario is almost universally encountered and reported with surgical and trauma patients, and rarely described or analyzed in medical patients. The creation of these indications has revolved around identifying a set of criteria that reliably predict which patients are at “high risk” of developing a DVT and PE despite standard preventive measures. The utility of VCF placement in this population will thus be highly dependent on the sensitivity and specificity of the criteria used as indications. Other factors that must be taken into consideration when developing indications for VCF placement are the patient population, presence of any contraindications to standard preventive measures (anticoagulation, compressive devices), the degree and expected duration of disease and immobility, and the ability of the patient to tolerate any adverse pulmonary events (“pulmonary reserve function”).

Consensus guidelines

A variety of expert opinion and consensus conference guidelines are available to aid in the decision of whether or not to proceed with VCF
placement, although very few of these have focused specifically on surgical and trauma patients [13–20]. Table 1 shows current recommendations from a variety of expert groups and consensus committees. Although the recommendations and supporting evidence vary widely among groups, a common theme is the cited lack of adequate prospective and controlled data to make evidence-based decisions regarding placement of a vena caval filter in all situations. The only Level I recommendation identified is that VCF is not indicated in the patient who has venous thromboembolic disease and who can be anticoagulated [13]. The majority of groups agree that venous thromboembolic disease in the patient who cannot be anticoagulated, has a significant anticoagulation-related complication, or fails anticoagulation are acceptable reasons to consider VCF placement (all Level III recommendations). In the two guidelines focusing solely on trauma patients, no firm conclusions could be drawn, but they advised that VCF should be “considered” only in high-risk trauma patients, especially those who have a contraindication to standard prophylactic dose anticoagulation [17,19,20]. Again, these were noted to be Level III recommendations that are not supported by strong scientific data. Only one guideline addressed cancer patients who have DVT or PE and recommended against routine use of VCF unless another indication was present [13].

Table 2 provides a list of the most commonly cited indications for vena cava filter placement, divided into a small list of widely accepted indications and a longer list of indications that are considered relative or controversial. The remainder of this article focuses on the particular scenarios that are most likely to be encountered by the practicing surgeon.

Trauma

Multiple series have examined the role of prophylactic vena caval filter placement in the “high-risk” trauma patient [4,10,21–31]. These series vary widely in their definitions of “high-risk criteria,” as well as patient demographics, indications for placement, type of filter, length of follow up, and methods for determining rates of complications, DVT, and PE. Trauma patients remain one of the highest risk groups for development of venous thromboembolism (VTE), with a reported incidence of DVT as high as 50% and of PE as high as 32% [17,20]. Prolonged immobility, venous stasis and injury, a proinflammatory hypercoagulable state, and the high risk of bleeding all contribute to the increased risk of VTE and the overall poor results with standard thromboprophylaxis seen in severely injured trauma patients [32–36]. This lack of effective VTE prophylaxis options was emphasized in the 2002 Eastern Association for the Surgery of Trauma (EAST) guidelines, with no Level I recommendations for preventing DVT or PE in trauma patients identified [17].

Multiple independent risk factors for VTE in trauma patients have been described, including advanced age, high Injury Severity Score, head injury,
Table 1
Consensus and expert panel reports and recommendations for vena caval filter use

<table>
<thead>
<tr>
<th>Group</th>
<th>Indications</th>
<th>Recommendations</th>
<th>Level or grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>American College of Physicians &amp; American Academy of Family Physicians</td>
<td>DVT or PE</td>
<td>Insufficient evidence to make recommendations</td>
<td>N/A</td>
</tr>
<tr>
<td>British Committee for Standards in Haematology</td>
<td>VTE + contraindication to anticoagulation</td>
<td>VCF indicated</td>
<td>III (Grade B)</td>
</tr>
<tr>
<td></td>
<td>VTE + anticoagulated</td>
<td>VCF not indicated</td>
<td>IB (Grade A)</td>
</tr>
<tr>
<td></td>
<td>PE + anticoagulant failure</td>
<td>Consider VCF only if other options not available</td>
<td>IV (Grade C)</td>
</tr>
<tr>
<td></td>
<td>Free floating thrombus</td>
<td>VCF not indicated</td>
<td>III (Grade B)</td>
</tr>
<tr>
<td></td>
<td>DVT or PE in cancer patients</td>
<td>VCF not indicated unless contraindication to anticoagulation</td>
<td>III</td>
</tr>
<tr>
<td>American College of Chest Physicians, Consensus Committee on Pulmonary Embolism</td>
<td>DVT + anticoagulation</td>
<td>VCF not indicated</td>
<td>IA</td>
</tr>
<tr>
<td></td>
<td>DVT + contraindication to anticoagulation</td>
<td>VCF indicated</td>
<td>2C</td>
</tr>
<tr>
<td>American College of Chest Physicians, Consensus Conference on Antithrombotic and Thrombolytic Therapy</td>
<td>Recurrent VTE + anticoagulation</td>
<td>VCF indicated</td>
<td>2C</td>
</tr>
<tr>
<td></td>
<td>PE + contraindication to anticoagulation</td>
<td>VCF indicated</td>
<td>2C</td>
</tr>
<tr>
<td>International Consensus Conference on Thrombosis</td>
<td>Identical to ACCP</td>
<td>See above</td>
<td>See above</td>
</tr>
<tr>
<td></td>
<td>Consensus Conference recommendations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eastern Association for the Surgery of Trauma, Practice Management Guidelines for the Prevention of VTE in Trauma Patients</td>
<td>High-risk trauma patients: contraindication to anticoagulation + injury pattern including: severe head injury spinal cord injury pelvic + long bone multiple long bone</td>
<td>Consider VCF placement</td>
<td>III</td>
</tr>
<tr>
<td>Southern California Evidence-Based Practice Center Meta-analysis</td>
<td>Trauma patients (excluding burn, pregnant, and low mechanism elderly)</td>
<td>No firm conclusions drawn about VCF</td>
<td>III</td>
</tr>
<tr>
<td></td>
<td>Consider in high-risk group (elderly, spine fractures, spinal cord injury)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Abbreviations:* ACCP, American College of Chest Physicians; VTE, venous thromboembolism.
spinal cord or vertebral injury, pelvic and long bone fractures, venous injury, and multiple transfusions [22,37–40]; however, on careful meta-analysis of available data it appears that only spinal cord and vertebral column injuries are strong independent predictors (Level I recommendation) of VTE, whereas other described risk factors are of marginal or questionable value for reliably identifying a truly high-risk patient who could benefit from VCF placement [17,19,20].

In a 1997 practice pattern survey of 210 United States trauma surgeons (87% from Level I trauma centers) there was overwhelming agreement for vena caval filter placement only in the setting of the traditional indications such as PE while therapeutically anticoagulated (93% agreed) and DVT with a contraindication to anticoagulation (89% agreed) [41]. For all other indications, including standard high-risk trauma criteria, agreement was 50% or less; however, there was a statistically significant trend toward increased filter use for 9 out of 10 relative indications when given the option of choosing a removable VCF. This study also revealed the wide range of VCF use, with 61% of centers inserting 0 to one filters per month, and 13% inserting more than four filters per month. In a subsequent analysis of the National Trauma Data Bank and a survey of 131 participating trauma centers, 86% of VCF appeared to have been placed for prophylactic

<table>
<thead>
<tr>
<th>Accepted indications</th>
<th>Relative and controversial indications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Known VTE with contraindication to anticoagulation</td>
<td>Known VTE without contraindication to anticoagulation</td>
</tr>
<tr>
<td>Known VTE with severe complication of anticoagulation</td>
<td>High-risk trauma: severe head injury</td>
</tr>
<tr>
<td>Recurrent PE while on therapeutic anticoagulation</td>
<td>spinal cord injury</td>
</tr>
<tr>
<td>Progression of DVT while on therapeutic anticoagulation</td>
<td>vertebral fracture</td>
</tr>
<tr>
<td>Recent VTE and operative procedure requiring prolonged withholding of anticoagulation</td>
<td>pelvic and long bone fractures</td>
</tr>
<tr>
<td></td>
<td>prolonged immobility</td>
</tr>
<tr>
<td></td>
<td>venous repair</td>
</tr>
<tr>
<td></td>
<td>High risk bariatric patient: BMI &gt;50 (superobese)</td>
</tr>
<tr>
<td></td>
<td>elderly venous stasis disease</td>
</tr>
<tr>
<td></td>
<td>obesity hypoventilation/sleep apnea pulmonary hypertension</td>
</tr>
<tr>
<td></td>
<td>Malignancy</td>
</tr>
<tr>
<td></td>
<td>Free-floating thrombus</td>
</tr>
<tr>
<td></td>
<td>Thrombolysis of DVT</td>
</tr>
<tr>
<td></td>
<td>Known VTE with poor cardiopulmonary reserve</td>
</tr>
<tr>
<td></td>
<td>Chronic thromboembolic pulmonary hypertension</td>
</tr>
<tr>
<td></td>
<td>Hypercoagulable state</td>
</tr>
</tbody>
</table>

Abbreviation: BMI, body mass index.
indications, and 12% were placed in patients who had no identifiable VTE risk factors [37]. Among survey respondents, only 16% stated they would place a VCF for prophylactic indications, with the majority using mechanical compression devices only.

**Surgical oncology**

Patients who have active malignant disease have long been recognized as a high-risk population for developing venous thromboembolic disease and complications [42–45]. This increased risk can be attributed to various combinations of the prothrombotic state induced by malignant disease, venous stasis caused by mass effect of solid tumors, and the frequent presence of other risk factors (ie, age, immobility) seen in this patient population [46–48]. Aggressive mechanical and chemical prophylaxis is warranted in hospitalized cancer patients, particularly in those who have the added risk of undergoing a surgical procedure. The surgeon must consider not only the factors described for other patient populations, but also must take into account the nature and severity of the malignant process, quality of life, and the estimated duration of survival.

Among cancer patients who have diagnosed VTE, treatment failures and VTE recurrence can be seen in 10% to 20% of cases despite standard anticoagulation therapy, and appear to be significantly higher with oral therapy (warfarin) compared with low molecular weight heparins [49,50]. This has resulted in some authors including malignancy as an indication for VCF placement in patients undergoing major surgical procedures [51–54]. Several series have questioned the validity of malignancy as an indication for VCF placement [49,55–57], however, with one series demonstrating a doubling of the mortality among cancer patients undergoing VCF placement [58]. There remains no consensus opinion or prospective validation data on the use of malignancy as an independent indication for VCF placement.

**Bariatrics**

With the rapidly spreading “obesity epidemic” and explosion in bariatric surgical procedures worldwide, there has been increasing awareness and debate concerning prevention and management of VTE in the obese surgical patient [40,59–62]. Multiple studies have found obesity to be a strong independent risk factor for the development of DVT, as well as fatal and nonfatal PE. In a prospective study of over 100,000 females, obesity (BMI > 29 kg/m²) was found to be one of the strongest independent risk factors for PE, with an adjusted relative risk of 2.9 [63]. This risk, combined with the added risk of surgery and difficulties in proper dosing of chemoprophylaxis in obese patients, makes them particularly susceptible to VTE-related morbidity and mortality [64–67].
Efforts to combat the high rate of DVT and PE in this patient population have led some authors to recommend routine preoperative prophylactic IVC filter placement for select patients undergoing bariatric surgery [68]. In one retrospective review of 3861 bariatric procedures there was a low overall incidence of PE identified (0.85%), but mortality in this group was 27%. A prophylactic VCF was used in 145 of these patients, with three postoperative PEs identified (2.1%) in the filter group. Despite this, the study authors’ conclusions recommend VCF use in patients who are super obese and who have limited mobility. Ferrell and colleagues [62] retrospectively analyzed 586 patients undergoing gastric bypass and identified 12 who had a VCF placed; 6 of these were prophylactic and 6 were placed for postoperative complications. Despite the identified “technical challenges” of VCF placement in these patients, there were no long-term complications identified, and the study authors recommend VCF placement for patients who have elevated VTE risk factors or patients who have prolonged immobility and ICU stay caused by complications. In another study of 5554 bariatric operations, risk factors for postoperative VTE were identified and recommended as indications for VCF [61]. These included venous stasis disease, body mass index of 60 or greater, truncal obesity, and obesity hyperventilation syndrome. Several recent retrospective studies using similar “high-risk” criteria for patients undergoing bariatric surgery have demonstrated a high technical success rate and a significantly decreased incidence of PE with VCF placement [69,70], with one series demonstrating a 0% rate of PE in patients who received a prophylactic VCF [70].

Contraindication to anticoagulation

One of the most frequently cited reasons for considering or placing a VCF in the surgical patient population is a contraindication to anticoagulation [4,37,41]. In the trauma population this is most commonly secondary to injuries that are high risk for bleeding, such as intracranial hemorrhage, solid organ injuries, or severe pelvic and extremity fractures [71]. In other surgical populations there is often fear of an increased risk of bleeding complications with anticoagulants or the anticipated need to hold anticoagulation for prolonged periods around the time of operation. Although these are certainly valid concerns in many patients, it is the authors’ experience that these decisions are often made based on an exaggerated estimate of the bleeding risk associated with pharmacologic anticoagulants, especially when considering prophylactic dose regimens. Prophylactic dose unfractionated heparin and low molecular weight heparins have both been demonstrated to be safe and effective in patients undergoing surgery for cancer, orthopedic surgery, polytrauma, and neurosurgery/neurotrauma, and can usually be started within 24 to 48 hours of injury or surgery [72–77]. Even among patients who have intracranial hemorrhage or solid organ injury being managed nonoperatively, prophylactic dose anticoagulation can
usually be safely started after an initial observation period and with no signs of ongoing hemorrhage [72,74,76,78]. In these patients the authors recommend consideration of chemical prophylaxis rather than proceeding directly to prophylactic vena cava filter placement.

Vena cava filter placement techniques

With the increasing use and expanded indications for vena cava filter placement in many centers, the techniques of filter placement and the personnel placing them have undergone significant evolution. Once purely the purview of interventional radiologists or vascular specialists, vena cava filters are now being placed by a variety of other specialists, including general surgeons and surgical subspecialists, medical internists, and critical care physicians [37,41]. The requirement for specialized personnel and equipment had previously required transfer of the patient to another area of the hospital, which consumes valuable hospital resources and can be hazardous with a critically ill patient. More recently, many series have reported excellent results and significant cost savings with bedside placement of vena cava filters [79–87].

Peripheral venous access and insertion is most commonly obtained via the femoral or internal jugular vein, although antecubital insertion is an option for several filter types [48]. Imaging of the vena cava must then be performed to assess the size and patency of the vena cava, as well as to identify the proper site for filter placement (most commonly below the renal veins) and rule out any anatomic abnormalities such as a duplicated vena cava. This is most commonly done with standard intravenous contrast venography and fluoroscopy. An alternative technique using carbon dioxide as a contrast agent has been described, and may be a promising approach in patients who have contrast allergy or are at risk for contrast induced nephropathy [88–90]. Other recent series have described the use of both transabdominal and intravascular ultrasound (IVUS) to size the vena cava, guide placement, and confirm proper filter positioning [79,80,82,91,92]. One study demonstrated that IVUS was significantly more accurate than contrast venography for the critical steps of sizing the vena cava and determining the optimal site for filter placement, with contrast venography resulting in inaccurate placement and significant overestimation of IVC diameter [93].

Although the ideal and preferred position for VCF placement is in the infrarenal IVC, in cases of anatomic abnormality or proximal thrombus extension, alternative sites must be considered. Placement in the suprarenal vena cava has been analyzed in several series, with outcome measures and rates of migration and caval thrombosis that compare with those with infrarenal positioning [94–96]; however, one should carefully observe these patients for the severe and potentially fatal complication of renal vein thrombosis [97]. Several series have also described placement of VCF in the superior vena cava, typically in the setting of acute upper extremity
venous thrombosis and either contraindication to anticoagulation or other high-risk criteria [98–102]. These studies are limited by study quality and relatively small numbers, but generally report low complication rates with high technical success. Complications such as erosion into adjacent structures, superior vena caval thrombosis, migration, and guide wire entrapment are well-described, however, and should be appreciated when considering this option [102–105].

Retrievable filters

Concerns about the permanent nature and long-term complication profile noted with standard vena cava filter designs has led to alterations in filter design that allow for filter removal at a variable time period after placement. Several filter designs are currently available that allow for removal via either the jugular or femoral vein, with technical success rates of 78% to 100% [48,106]. Although initially designed for removal within several weeks of placement, successful delayed removal of many of these filters have been described at time periods of up to 1 year or greater postimplantation [106–108]. These filters may represent a particularly attractive option in the patient who is expected to have only a temporary period of high risk or contraindication to anticoagulation, or for protection during thrombolytic therapy for an established DVT.

Results of vena cava filter placement

Clinical outcomes and results following VCF placement will be highly dependent on multiple factors, such as the patient population, indication for placement, technique of placement, filter type and location, use of concurrent anticoagulation, and the nature and intensity of surveillance and follow-up. Although it is a commonly held misconception that vena cava filters are completely protective for PE, this has not been borne out by clinical experience. There is no question that patients who have vena cava filters remain at risk for PE [5,14,15,109]; the only debate is whether there is a significant benefit in terms of PE reduction with filters, and whether this benefit outweighs the risks of placement. The main outcomes that should be assessed to determine if there exist any benefits of VCF are mortality and the incidence of initial or recurrent pulmonary embolism after filter placement.

Table 3 shows the incidence of recurrent symptomatic PE and several defined complications for a variety of vena cava filters. The majority of studies demonstrate an incidence of symptomatic PE in 2% to 4% of VCF patients, whereas the incidence of asymptomatic PE remains unknown but is undoubtedly higher. The prospective randomized trial by Decousus and colleagues [11] demonstrated a recurrent PE rate of 3.4% and 21.6%
mortality in the filter group compared with 6.3% and 20.1% in the no filter group ($P = .16$ and 0.65); however, this was for patients who had known DVT who were able to receive anticoagulation, and has limited application to the typical surgical patient in whom a VCF is being considered.

**Trauma patients**

Analysis of results for VCF placement in trauma patients is mainly limited by the lack of adequate control groups for comparison, with most series using unmatched cohorts or historical data for comparison. A meta-analysis of older series demonstrated a PE incidence of 0.2% with VCF, compared with 1.5% among controls without a VCF and 5.8% for historic controls [19]. Rodriguez and colleagues [110] compared 40 critically injured patients who received a prophylactic VCF with 80 matched historic controls. Only 1 patient (3%) who had a VCF developed PE, compared with 14 (18%) in the control group, four of these being fatal PE. Similar reductions in the incidence of PE with filter use compared with control populations or historical data have been reported in other series [26,111,112]. Rogers and colleagues [28] reported on 132 trauma patients receiving prophylactic VCF with 5-year follow-up data. They found a 2.3% incidence of PE after

<table>
<thead>
<tr>
<th>Filter</th>
<th>N</th>
<th>F/U (months)</th>
<th>Recurrent PE</th>
<th>DVT (0%–18%)</th>
<th>IVC thromboses (0%–18%)</th>
<th>Postphlebitic syndrome (0%–47%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless-steel Greenfield</td>
<td>3184</td>
<td>(1–60)</td>
<td>2.6%</td>
<td>5.9%</td>
<td>3.6%</td>
<td>19%</td>
</tr>
<tr>
<td>Titanium-Greenfield</td>
<td>511</td>
<td>(0–81)</td>
<td>3.1%</td>
<td>22.7%</td>
<td>6.5%</td>
<td>14.4%</td>
</tr>
<tr>
<td>Bird’s Nest</td>
<td>1426</td>
<td>(0–60)</td>
<td>2.9%</td>
<td>6%</td>
<td>3.9%</td>
<td>14%</td>
</tr>
<tr>
<td>Simon Nitinol</td>
<td>319</td>
<td>(0–62)</td>
<td>3.8%</td>
<td>8.9%</td>
<td>7.7%</td>
<td>12.9%</td>
</tr>
<tr>
<td>Vena-Tech</td>
<td>1050</td>
<td>(0–81)</td>
<td>3.4%</td>
<td>32%</td>
<td>11.2%</td>
<td>41%</td>
</tr>
<tr>
<td>Stainless-steel over-the-wire Greenfield</td>
<td>599</td>
<td>26</td>
<td>2.6%</td>
<td>7.3%</td>
<td>1.7%</td>
<td>2% (ulceration)</td>
</tr>
<tr>
<td>TrapEase</td>
<td>65</td>
<td>6</td>
<td>0%</td>
<td>45.7%</td>
<td>2.8%</td>
<td>NR</td>
</tr>
<tr>
<td>Vena-Tech low-profile</td>
<td>30</td>
<td>2.3</td>
<td>0%</td>
<td>10.3%</td>
<td>0%</td>
<td>NR</td>
</tr>
<tr>
<td>Günther Tulip</td>
<td>83</td>
<td>4.5</td>
<td>3.6%</td>
<td>NR</td>
<td>9.6%</td>
<td>NR</td>
</tr>
</tbody>
</table>

Values are given as numbers or percentages as indicated; values in parentheses indicate ranges of reported values.

**Abbreviations:** F/U, follow-up; NR, not reported.

filter placement and a mortality of 4.4%, with one fatal PE. Carlin and colleagues [113] compared a group of 122 trauma patients who received a therapeutic VCF with 78 patients receiving prophylactic filters. They found a mortality rate of 11% for therapeutic VCF and 3% for prophylactic, and an incidence of recurrent PE of 18% in the therapeutic group versus 0% in the prophylactic group. In addition, they associated a 50% reduction in their overall incidence of PE over a 10-year period with a significant increase in use of VCF. In summary, the majority of series report a decreased incidence of all PE and fatal PE with the use of VCF in appropriately selected patients, but there remains a lack of rigorous control groups for comparison.

Results with retrievable filters in trauma patients

The large majority of experience with retrievable VCF in surgical patients has been in the setting of major trauma. As stated previously, trauma surgeons are more likely to place a VCF if given the option of a retrievable filter [41], and retrievable filters are being increasingly used in many trauma centers [37,114]. Meier and colleagues [115] analyzed the results of prophylactic retrievable VCF placement in 35 trauma patients. Filters were retrieved in 86% of patients, and 36% demonstrated trapped clot or thrombus within the device. The incidence of PE was 3%, which occurred in 1 patient 5 days after VCF removal, and mortality was 3%. Several other series have reported a high technical success rate and low incidence of PE among high-risk trauma patients who received a retrievable VCF [116–118].

In a recently published multicenter study by the AAST, 446 patients received a retrievable VCF, with the majority (76%) placed prophylactically [4]. In this large series, the retrieval rate was only 22%, and only half of patients had postdischarge follow-up reported. The reported rate of “breakthrough” PE in these patients was low at 0.5%, but should be interpreted with caution because of the poor follow-up. Although these filters seem to represent an attractive option for the high-risk trauma patient, they create additional difficult decisions, such as the timing of removal and ensuring adequate follow-up and surveillance. The highest risk for PE is in the early postinjury period, but there remains a significant risk for late PE occurring weeks after injury, which must be considered when timing the removal of a VCF [116,119]. With the expanding use of retrievable filters at many trauma centers, there remains significant debate about their utility, the optimal timing of removal, and the amount and duration of follow-up. These questions will require further prospective data to answer [4,114,116].

Surgical oncology

The prevention and management of VTE in the cancer patient remains problematic, particularly in the perioperative period. In response to concerns about the safety and effectiveness of standard anticoagulant therapy in the cancer patient [49,50,120], many have recommended the consideration
of VCF placement in this population [52,55,121,122]. Ghanim and colleagues [123] found no significant difference in overall or in-hospital mortality among 175 patients who had brain tumors and VTE managed with VCF or anticoagulation only, with median survival of 21 weeks and 11 weeks respectively. A study of 166 cancer patients undergoing VCF placement for therapeutic or prophylactic indications demonstrated a median survival time of only 10 months, confirming the overall poor outcomes in this patient population [53]. A series of 116 patients undergoing active treatment of malignant disease found a low procedural complication rate and a low recurrent PE rate of 3% following VCF placement [55]; however, only 14% of patients were alive at 1 year, leading the study authors to conclude that VCF in these patients may be of little clinical benefit. In a retrospective case-control study Schunn and colleagues [56] demonstrated that VCF in cancer patients appeared to be effective at preventing PE, but there was no survival benefit when compared with a matched control population. Similar results have been reported in several other series [58,124,125]. Chau and colleagues [126] used a Markov model of cost effectiveness in comparing VCF or anticoagulation in patients who had malignant brain tumors and DVT. They demonstrated that VCF was not cost-effective in this patient population, but when the model was adjusted to reflect the anticipated 5-year survival for a breast cancer population, VCF appeared to be more effective and less expensive than anticoagulation alone. From the available data it appears that VCF placement will be most effective in cancer patients who have proven VTE and who have good functional status and longer predicted survival times, and should be discouraged in patients who have advanced disease.

Bariatric patients

There are relatively few studies detailing the outcomes from VCF use in the bariatric population, and these are limited to case reports and case series. Piano and colleagues [70] analyzed outcomes from a protocolized approach using a retrievable VCF in 59 patients undergoing bariatric surgery who met high-risk criteria. All filters were placed immediately before surgery, and removal was attempted at 4 weeks postoperatively. There was one postoperative PE (1.7%) in a patient who was not receiving chemical anticoagulation, and no fatal PE or deaths. In another series of patients undergoing open gastric bypass there were 58 prophylactic VCF placed with 100% technical success rate, and no postoperative PE in patients who had VCF, compared with a historic control PE rate of 13% [69]. These results have been similar to those reported in several other smaller series [68,127]; however, interpretation of these results is significantly limited by the lack of prospective data, adequate control populations, standardized approach to chemoprophylaxis, and the small numbers available for analysis. Given the relative infrequency of all PE and fatal PE after bariatric surgery
[128], much larger trials will be required to provide any meaningful data regarding the indications and efficacy of VCF in this patient population.

**The argument against vena cava filter efficacy**

Although the majority of series cited above have concluded that VCF placement offers a benefit in terms of reduction in PE and PE-related morbidity and mortality, there remains a significant amount of skepticism and ongoing debate. The only prospective randomized trial of VCF demonstrated a reduction in early (within 12 days) PE but no long-term benefit in terms of PE or mortality, and a significantly increased risk of DVT [11]. A large population-based study using discharge data from California hospitals found that there was no reduction in rehospitalization for PE among patients who received a VCF compared with those who had no filter, but that the VCF group had a significantly higher hospital readmission rate for DVT [129]. Spain and colleagues [130] found a low rate of DVT and PE among 2868 trauma patients, 280 of whom were deemed “high-risk” for VTE, despite the use of only one prophylactic VCF over the 2-year study period. There were no diagnosed PE in the low-risk group and no deaths attributable to PE in the high-risk group, leading the study authors to conclude that routine VCF use is a waste of resources with little benefit. The high costs and lack of proven benefit for routine prophylactic VCF use compared with standard prophylactic measures has also been questioned in the population of patients who have acute spinal cord injury [131]. Antevil and colleagues [24] demonstrated a threefold increase in VCF use after introduction of a retrievable filter at their institution, but no significant differences were seen in the incidence of PE or filter-related complications. In addition, only 21% of retrievable filters were successfully removed, which is in agreement with data from a multicenter trial of retrievable VCF [4].

**Complications**

Surgeons contemplating VCF placement or managing patients who have a VCF should be aware of the potential complications associated with their use. Thrombotic complications associated with VCF include vena caval thrombosis, access site thrombosis, and DVT. Multiple series have confirmed that vena cava filters significantly increase the risk of both initial DVT formation and DVT recurrence [11,12,129], and have prompted recommendations for chemical anticoagulation when possible in patients who have filters [132–134]. In addition to representing a risk for PE, these thrombotic complications can result in renal compromise and extremity postphlebitic symptoms of varying severity [28,97,135–137]. Table 3 lists the incidence of thrombotic complications from a variety of filter types, with DVT and postphlebitic syndromes as high as 46% and 41%
respectively, and vena caval thrombosis demonstrated in up to 11% of patients. Several series in surgical patients have presented significantly lower incidences of these complications, but are generally limited by the duration and intensity of follow-up \[4,21,138,139\]. Although retrievable filters have been proposed to theoretically avoid some of these long-term thrombotic complications, a large review of retrievable filters published in 1996 found reported complication rates of 6% to 30% for caval thrombosis, 3% to 69% for filter migration, and 5% to 70% for postphlebitic syndrome \[106\]. Lower complication rates were reported in the AAST multicenter trial of trauma patients receiving retrievable filters \[4\], but these results are significantly limited by the poor overall follow-up. Filter removal itself is associated with several potential complications that should be considered, including technical failure, bleeding, and access site thrombosis \[106,140,141\]. In addition, it appears that on average only 25% to 50% of “retrievable” vena cava filters are actually ever removed, which may reflect a conscious decision based on continued VTE risk, or in many cases may represent inadequate planning and follow-up \[4,141,142\].

Additional rare but potentially serious complications of VCF are filter malposition or migration, filter perforation with hemorrhage or erosion into surrounding structures, and entrapment of guide wires during procedures such as central venous catheter placement \[143–152\]. Although many of these complications occur at the time of insertion or early in the postprocedure period, the patient who has a VCF does remain at risk for thrombotic and other filter-related complications for the duration of filter placement, and should be evaluated and managed appropriately. In all patients it is critical to incorporate the nature and degree of these potential risks into the decision-making process for VCF placement, particularly when done for prophylactic indications.

**Future directions**

IVC filters are relatively safe and appear to be effective (at least transiently) in reducing the incidence of PE; however, complications continue to occur and no ideal filter exists that can completely trap all clot and maintain IVC patency. Because venous thromboembolism continues to pose significant problems in all patient populations, other treatment modalities continue to be entertained. Newer anticoagulant agents are continuously developed and studied in an attempt to find the ideal therapy. Although low molecular weight heparin agents are the preferred pharmacological prophylaxis for VTE in trauma patients and other high-risk populations, a number of newer agents are in various stages of development and evaluation. These new anticoagulants can be classified into three groups: (1) inhibitors of activation of coagulation (nematode anticoagulant peptide c2 [NAPc2], derived from the nematode Ancylostoma caninum); (2) inhibitors of propagation of coagulation (fondaparinux, idraparinux), and (3)
inhibitors of thrombin formation (hirudin, bivalirudin, ximelagatran, melagatran) [153,154].

An emerging concept in VTE disease is the role of clot burden. There is evidence that anticoagulant therapy changes clot burden, and that this change influences the long-term frequency of recurrent VTE [155]. Catheter-directed thrombolysis for lower extremity DVT with and without IVC filters has been shown to be safe and effective in treating acute DVT and may actually prevent PE [156]. The actual role of catheter-directed thrombolysis deserves further evaluation, however promising it may be.

Summary and recommendations

Prevention and management of VTE in surgical patients remains a critical area that has significant implications for patient morbidity and mortality and the health care system as a whole. Although there is a considerable pool of data available for medical preventive and management options, there remains a complete lack of well-controlled data on which to base decisions regarding when and how to use vena cava filters [157]. Despite this lack of an evidence-based rationale, the use of vena cava filters, and particularly retrievable vena cava filters placed for prophylactic indications, is rapidly increasing. The increasing use of an unproven technology that is invasive and has a well-defined complication profile should prompt further questioning and analysis.

Based on the available evidence the authors continue to recommend placement of vena cava filters in patients who have established VTE and an absolute contraindication to or significant complication of anticoagulation. It should also be considered in patients who have “free-floating” venous thrombus and in patients undergoing thrombolysis, although these are not absolute indications. In the “high-risk” trauma population (severe head injury, pelvic and long bone fractures, spinal cord injury, prolonged immobilization, venous injury) there is little to no evidence to support a practice of routine prophylactic VCF placement, and decisions should be made on an individual basis. The authors believe that most of these patients can be managed with appropriately dosed chemoprophylaxis, and we would consider VCF only in the patient who has a true contraindication to anticoagulation that is expected to persist. Similarly, there are very few data suggesting a benefit of routine prophylactic VCF placement in the bariatric surgical population or patients who have active malignancy, and these patients may be at higher risk for VCF associated complications; however, in patients who have multiple risk factors and other considerations, such as poor cardiopulmonary reserve or relative contraindications to anticoagulation, an individual risk-to-benefit analysis should be performed when deciding on VCF placement. If a decision is made to place a retrievable VCF, then particular attention should be paid to ensuring the filter is left in place for the duration of the period of increased risk, and appropriate follow-up
should be arranged and ensured for subsequent filter removal. Large, well-controlled trials using the currently available devices as well as alternative methods of VTE treatment and prophylaxis are critically needed to determine if there is any true benefit of vena cava filter placement over standard management, and which patient populations would maximally benefit.

References


