Pulmonary embolism (PE) occurs with an incidence of approximately 600,000 cases annually and it has been estimated that it causes 150,000 to 200,000 deaths per year. Without treatment, PE carries a 30% mortality rate, which decreases to 8% after treatment with systemic anticoagulation. Although systemic anticoagulation remains the cornerstone of venous thromboembolism treatment, not all patients are candidates for this therapy, some fail the therapy, and some patients on anticoagulation suffer complications from the treatment. Fortunately, inferior vena cava (IVC) filtration is available for these selected patients as an adjunctive treatment for venous thromboembolism, or as an effective prophylactic measure in selected high-risk patients.

Indications for IVC Filtration

Classic Indications

- Presence of venous thromboembolic disease (pulmonary embolus or IVC, iliac, or femoropopliteal deep venous thrombosis (DVT)) combined with one of the following:
  - Contraindication to anticoagulation
    - Bleeding complication of anticoagulation
    - Known recent hemorrhage
    - Recent major trauma or surgery
    - Hemorrhagic stroke
    - Ataxia or increased risk for falls
    - Thrombocytopenia
    - Heparin-associated thrombocythemia thrombosis syndrome
    - Guaiac-positive stools
    - Known central nervous system neoplasm, aneurysm, or vascular malformation
  - Complication of anticoagulation
  - Failure of anticoagulation
    - Recurrent PE despite adequate anticoagulation
    - Inability to achieve therapeutic systemic anticoagulation

Other Well-Accepted Indications

- Massive pulmonary embolism with residual DVT in a patient at risk for further PE
- Free-floating iliofemoral or IVC thrombus
- Severe cardiopulmonary disease and DVT (e.g. cor pulmonale with pulmonary hypertension)
- Poor compliance with anticoagulant medications
“Extended” Indications

- Prophylactic IVC filter placement in selected, high-risk patients without documented PE or DVT:
  - Severe trauma victims with closed head injury, spinal cord injury, and/or multiple long bone or pelvic fractures
  - Patients who are immobilized or subjected to prolonged intensive care
  - Preoperatively in patients who have multiple risk factors for venous thromboembolism
- Protection during iliofemoral DVT thrombolysis

It must be emphasized that the prophylactic placement of IVC filters is for prevention of clinically significant PE, not for prophylaxis against the development of DVT.

Suprarenal Placement Indications

- Renal vein thrombosis
- IVC thrombosis extending up to or above the level of the renal veins
- Renal cell carcinoma with renal vein or IVC involvement
- Thrombus extending above a previously placed infrarenal filter
- PE after gonadal vein thrombosis
- Anatomic variants, such as a duplicated IVC and low insertion of the renal veins
- Pregnant women or women of childbearing age - this is controversial!!

Contraindications to IVC Filtration

Absolute Contraindications (rare)

- Complete, chronic thrombosis of the IVC
- Inability to gain central venous access

Relative Contraindications

- Severe, uncorrectable coagulopathy
- Bacteremia and/or sepsis
- Pediatric and young adult patients (long-term consequences of filters are not completely known)

Success and Efficacy of IVC Filtration

Technical Success

- IVC filter placement technical success should be at least 97% in experienced hands
- Rate below that should generate a quality assurance review to ascertain the cause(s) of the high failure rate

Filter Efficacy

- Primary indicator is the recurrent PE rate
- All available IVC filters have fairly comparable recurrent symptomatic PE rates, ranging between 2 and 5%
- True incidence of recurrent PE is probably higher, since most asymptomatic PE go undiagnosed

Since the introduction of the Mobin-Uddin umbrella in 1969 and the Greenfield filter in 1973, there have been innumerable observational and retrospective studies showing that IVC filters do reduce the PE rate compared to historical controls. A prospective, randomized trial of anticoagulated patients with proximal deep venous thrombosis by Decousus et al. compared IVC filters to a control group. This study showed a
significant benefit of filters at 12-day follow-up, with the control group experiencing a more than four fold increase in PE rate compared to the filter group (4.8% without filter vs. 1.1% with filter). This difference was even greater when only patients with PE at enrollment were considered (8.6% without filter vs. 1.1% with filter). However, there was no significant difference in mortality between these two groups. In addition, at 2-year follow-up, there was no significant difference between the two groups with respect to PE rate, but the filter group did experience more recurrent deep venous thrombosis than the control group (20.8% and 11.6%, respectively). These findings persisted in a subsequent paper reporting on 8-year follow-up of these patients. There was a significantly lower rate of symptomatic PE in the filter group compared with the control group (6.2% vs. 15.1%, p=0.008) while there was a slightly higher rate of DVT (35.7% vs. 27.5%, p=0.042).

Complications of IVC Filtration

- Vary among the specific filters (given occurrence rates are approximate)
- Most complications are minor, but occasionally can be very serious
- Thromboembolic Events
  - Recurrent PE – 0.5-6%
  - IVC thrombosis – 2-30%
    - Most partial IVC thromboses are diagnosed incidentally, remain asymptomatic, and might be better interpreted as evidence of efficient embolus trapping by the filter
    - Complete IVC thrombosis can result in phlegmasia cerulea dolens, and can sometimes be treated with venous thrombolysis.
  - Recurrent DVT – 20.8%
  - Access site thrombosis – 2-28%
- Filter Movement
  - Migration – 0-18%
  - Embolization to the right heart or pulmonary arteries – 2-5%
  - May be precipitated by entrapped guidewires
  - May be treated using Interventional Radiology transcatheter techniques
- IVC Penetration
  - Rate may be as high as 41%
  - Clinically significant penetration is probably a rare event
  - May cause retroperitoneal hematoma or perforation into the aorta or gastrointestinal tract
- Filter Fracture – 2-10%
  - Usually a late occurring event
  - Detected on plain radiographs

Special Circumstances

Superior Vena Caval Filtration

- Experience with filters in the superior vena cava (SVC) is limited
- Appears to be a rare, but definite, risk of PE from upper extremity venous thromboembolism
- Larger studies of SVC filters suggest that they are safe, feasible, and efficacious
- Is an off-label use for all devices
- Shorter devices generally fit better
- Must be cautious of caval penetration of hooks as pericardial reflection may come up high and hemopericardium with tamponade is a risk
- Must remember to use jugular insertion kit when placing via a femoral approach and vice versa to have filter apex correctly oriented
Bed-side Vena Caval Filter Placement

- Numerous reports have been published demonstrating the feasibility, safety, and efficacy
- Major advantage is that filter may be placed without moving critically-ill patients out of the intensive care setting
- Imaging modalities described for this technique include portable fluoroscopy and digital subtraction angiography, transabdominal ultrasonography, and intravascular ultrasound (IVUS)

Optional Filters

- Temporary or retrievable filters are better classified as “optional” filters, since they have the option to be permanent or temporary devices
- Avoid long-term complications of IVC filtration
- Attractive alternative for patients with a time-limited need for IVC filtration, for example:
  - Severely injured trauma patients at high risk for pulmonary thromboembolism
  - Patients with venous thromboembolism and a temporary contraindication to anticoagulation, who subsequently may be able to undergo anticoagulation
- Currently available devices FDA-approved for retrievability:
  - G2 and G2 Express Filters (Bard Peripheral Vascular)
  - Günther Tulip and Celect Filters (Cook Medical)
  - OptEase Filter (Cordis Endovascular)
- All of these devices are designed for retrieval from a jugular vein approach except the OptEase, which must be retrieved from the femoral approach
- Günther Tulip and Recovery (predecessor of the G2) filters have both been retrieved after prolonged implantation times without repositioning

Alternative Retrieval Techniques

Failed filter retrieval is most commonly due to an inability to grasp the hook or apex with a retrieval device. Authors have published many different methods to help free tilted or incorporated devices.

Tip-Deflecting Wire Technique

- A tip-deflecting wire is used through the central lumen of a recovery Cone device and used to displace the apex of the filter away from the vena cava wall in order to allow capture of the apex with the cone itself.

Guidewire Shearing of Neointima

- Snare guidewire to form a loop between filter apex and caval wall and apply traction to shear the embedded tip off the caval wall, allowing access to the hook

Balloon Displacement Technique

- An angioplasty balloon is passed below the filter, inflated, and pulled up into the cone of the filter to displace the apex from the vena cava wall to allow grasping with a snare.

Curved Sheath Technique

- A curved sheath is used, via a femoral approach, to push the vena cava wall opposite an inaccessible hook in order to move the hook away from the wall, which is then snared from above.
Loop Through Filter Techniques
- A wire and/or angiographic catheter is passed between the legs of the filter, forming a loop around the filter apex.

Bronchoscopic Forceps Technique
- Large sheath and rigid bronchoscopic forceps are used to dissect the embedded apex free which is then grasped.

Retrieval Cone for Gunther Tulip and OptEase Filters
- The Recovery Cone device may be used to grasp and retrieve other IVC filters.

Internal Jugular Vein Occlusion
- Snare initially placed via a femoral route up past filter apex, opened to encircle entire filter, closed to collapse the legs, and pull filter down into the ipsilateral iliac vein; the hook is then grasped with a second snare via the contralateral femoral approach and the device removed.

Available FDA-Approved Filters (see Table)

Permanent Filters

Stainless Steel Greenfield Filter and Titanium Greenfield Filter – Boston Scientific Corporation
- Descendents of the original Kimray-Greenfield Filter introduced over 30 years ago
- Cone-shaped design allows for 70 to 80% of the volume of the device to be filled with clot without significant reduction in caval blood flow
- Titanium version is MRI-compatible
- Stainless version has an alternating hook arrangement and is an over-the-wire device, which facilitates insertion up the left iliac venous system and improved centering within the IVC

Gianturco-Roehm Bird’s Nest Filter – Cook Medical
- Unique design unlike most other filters with two V-shaped struts supporting a random tangle of very fine stainless steel wire filaments, introduced in 1984
- Ability to be placed into large diameter IVCs, up to 40 mm
- Severe magnetic susceptibility artifacts on MRI
- Placement is more technically complex than other filters

Simon-Nitinol Filter – Bard Peripheral Vascular
- First filter made of nitinol (alloy of nickel and titanium which has a thermo-mechanical memory), available since 1990
- Very flexible at room temperature, but conforms to its original design at body temperature
- Allowed for first low-profile insertion sheath (9 Fr outer diameter)
- Was first filter approved for antecubital insertion
- Provides for two levels of filtration, but insertion technique requires a two-stage deployment
- Causes only minimal MRI artifact
VenaTech LGM Filter and VenaTech LP – B. Braun Medical
- Conical designs with longitudinal anchoring side rails designed to better center the device to decrease tilting
- Eight-metal proprietary alloy with low ferromagnetism that does not cause significant artifact on MRI
- Same device can be placed from jugular or femoral vein approach
- LP version has a lower profile insertion system and has eight wires formed in a conventional conical configuration with additional side-rail wires
- LP version approved for IVC diameters up to 35 mm

TrapEase Filter – Cordis Endovascular
- Newest non-retrievable design with a symmetric trapezoidal shape, providing dual-level filtration
- Nitinol alloy is MRI-compatible
- Same device can be placed from jugular femoral or arm vein approach
- Approved for IVC diameters up to 30 mm

Optional Filters

Günther Tulip Filter and Celect Filter – Cook Medical
- First of the currently available retrievable designs, Günther Tulip used in Europe since 1992
- Made from conichrome, a non-ferromagnetic, MRI-compatible alloy
- Deployment is distinctly different for jugular and femoral approaches
- Approved for retrieval via a jugular approach using a hook at the apex
- Celect filter is a revised version, substituting 8 arms for the original upper looped wires to allow better centering and longer implantation intervals

OptEase Filter – Cordis Endovascular
- Very similar to TrapEase Filter, but retrievable due to only one set of securing barbs and a caudal hook
- Approved for retrieval up to 23 days post placement
- Only filter that must be retrieved from a femoral approach

Recovery Filter, G2 Filter, G2 Express Filter – Bard Peripheral Vascular
- Original Recovery Filter no longer available
- Two levels of filtration similar to Simon-Nitinol Filter
- Nitinol alloy is MRI-compatible
- G2 Filter is redesigned version with longer arms with hands articulated inward, rounder angle of the arms adjacent to apex, resting diameter increased to 40 mm, and more robust hooks at the ends of the six legs
- All versions can be retrieved via jugular approach with a Retrieval Cone, which consists of nine metal claws covered with urethane material
- G2 Express adds a hook on the filter’s head to also allow retrieval with a conventional snare
- Extended implantations have occurred, with filters successfully removed up to four years post insertion
### Current and Upcoming IVC Filters

<table>
<thead>
<tr>
<th>Name</th>
<th>Manufacturer</th>
<th>FDA Approved</th>
<th>Insertion Routes</th>
<th>Delivery Size</th>
<th>Composition</th>
<th>Max Caval Diameter</th>
<th>Filter Height</th>
<th>MRI Compatible</th>
<th>Retrievable Design, Route</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>G2</td>
<td>Bard Peripheral</td>
<td>Yes (2005/2008)</td>
<td>Fem, Jug/Subcl, Antecub</td>
<td>10 Fr ID / 12 Fr OD (J/S); 7 Fr ID / 9 Fr OD (Fem)</td>
<td>Nitinol</td>
<td>28 mm</td>
<td>41 mm</td>
<td>Yes</td>
<td>Yes, Jugular</td>
<td>10 Fr ID Recovery Cone</td>
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<tr>
<td>G2 Express</td>
<td>Bard Peripheral</td>
<td>Yes (2008/2008)</td>
<td>Fem, Jug/Subcl, Antecub</td>
<td>10 Fr ID / 12 Fr OD (J/S); 7 Fr ID / 9 Fr OD (Fem)</td>
<td>Nitinol</td>
<td>28 mm</td>
<td>41 mm</td>
<td>Yes</td>
<td>Yes, Jugular</td>
<td>10 Fr ID Recovery Cone or conventional snare</td>
</tr>
<tr>
<td>Simon Nitinol</td>
<td>Bard Peripheral</td>
<td>Yes (1990)</td>
<td>Fem, Jug/Subcl, Antecub</td>
<td>7 Fr ID / 9 Fr OD</td>
<td>Nitinol</td>
<td>28 mm</td>
<td>38 mm</td>
<td>Yes</td>
<td>No</td>
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<td>Titanium Greenfield</td>
<td>Boston Scientific</td>
<td>Yes (1989)</td>
<td>Fem, Jug</td>
<td>12 Fr ID / 15 Fr OD</td>
<td>Beta III Titanium</td>
<td>28 mm</td>
<td>49 mm</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Over-the-Wire Greenfield</td>
<td>Boston Scientific</td>
<td>Yes (1995)</td>
<td>Fem, Jug</td>
<td>12 Fr ID / 15 Fr OD</td>
<td>316L Stainless Steel</td>
<td>28 mm</td>
<td>49 mm</td>
<td>Yes (artifacts)</td>
<td>No</td>
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<tr>
<td>Vena Tech LGM</td>
<td>B. Braun</td>
<td>Yes (1989)</td>
<td>Fem, Jug</td>
<td>10 Fr ID / 13 Fr OD</td>
<td>Phynox</td>
<td>28 mm</td>
<td>38 mm</td>
<td>Yes</td>
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<tr>
<td>Vena Tech LP</td>
<td>B. Braun</td>
<td>Yes (2001)</td>
<td>Fem, Jug</td>
<td>7 Fr ID / 9 Fr OD</td>
<td>Phynox</td>
<td>28 mm</td>
<td>43 mm</td>
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<td>Gianturco-Roehm Bird’s Nest</td>
<td>Cook Medical</td>
<td>Yes (1982)</td>
<td>Fem, Jug</td>
<td>12 Fr ID / 14 Fr OD</td>
<td>304L Stainless Steel</td>
<td>40 mm</td>
<td>50-80 mm</td>
<td>Yes (artifacts)</td>
<td>No</td>
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<td>Gunther Tulip</td>
<td>Cook Medical</td>
<td>Yes (2000/2003)</td>
<td>Fem, Jug</td>
<td>7 Fr ID / 9 Fr OD (Jug); 8.5 Fr ID / 10 Fr OD (Fem)</td>
<td>Conichrome</td>
<td>30 mm</td>
<td>50 mm</td>
<td>Yes</td>
<td>Yes, Jugular</td>
<td>11 Fr Retrieval Set</td>
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<td>Celect</td>
<td>Cook Medical</td>
<td>Yes (2007/2008)</td>
<td>Fem, Jug</td>
<td>7 Fr ID / 9 Fr OD (Jug); 8.5 Fr ID / 10 Fr OD (Fem)</td>
<td>Conichrome</td>
<td>30 mm</td>
<td>48 mm</td>
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<td>Yes, Jugular</td>
<td>11 Fr Retrieval Set</td>
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<td>TrapEase</td>
<td>Cordis</td>
<td>Yes (2000)</td>
<td>Fem, Jug, Antecub</td>
<td>6 Fr ID / 8 Fr OD</td>
<td>Nitinol</td>
<td>30 mm</td>
<td>50 mm</td>
<td>Yes</td>
<td>No</td>
<td></td>
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<tr>
<td>OptEase</td>
<td>Cordis</td>
<td>Yes (2002/2004)</td>
<td>Fem, Jug, Antecub</td>
<td>6 Fr ID / 8 Fr OD</td>
<td>Nitinol</td>
<td>30 mm</td>
<td>54 mm</td>
<td>Yes</td>
<td>Yes, Femoral</td>
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<tr>
<td>SafeFlo</td>
<td>Rafael Medical Technologies</td>
<td>No*</td>
<td>Fem, Jug</td>
<td>6 Fr ID / 8 Fr OD</td>
<td>Nitinol</td>
<td>16-19mm 19-22mm 22-25mm</td>
<td>Yes</td>
<td>Yes*</td>
<td>Same site as placement</td>
<td>* CE market approval, not available in US</td>
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<tr>
<td>Option</td>
<td>Rex Medical</td>
<td>No**</td>
<td>Fem, Jug</td>
<td>5 Fr ID / 6 Fr OD</td>
<td>Nitinol</td>
<td>32 mm</td>
<td>51 mm</td>
<td>Yes</td>
<td>Yes**, Jugular</td>
<td>** Currently under IDE investigation</td>
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REFERENCES


