Techniques for Retrieval of Permanent Inferior Vena Cava Filters

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The use of inferior vena cava filters (IVCFs) has increased significantly since their introduction in the early 1970s, largely due to expansion of relative and absolute indications for placement, lowering thresholds for utilization. In the short term, they have demonstrated a reduction in both the incidence of pulmonary embolism (PE) and PE-related mortality.^{1,2} However, studies suggest that these benefits may be counterbalanced by an increase in the rate of lower extremity deep vein thrombosis (DVT),¹ as well as several other device-related complications including device fracture^{3–5} and component perforation^{6,7} with subsequent penetration into nearby abdominal and retroperitoneal structures such as the pancreas,⁸ duodenum,^{9,10} and aorta.¹¹ Though numerous advanced techniques have been described for the removal of embedded retrievable IVCFs,^{12–14} there is a paucity of literature on the retrieval of permanent devices. In this article, we will present our approach to the retrieval of Greenfield (Boston Scientific, Natick, MA), TrapEase (Cordis, Miami Lakes, FL), and Simon Nitinol (Bard Peripheral Vascular, Tempe, AZ) filters. For each device, we will provide a brief history of the device's development and implementation into clinical practice; this will be followed by a description of our procedural approach, which we will illustrate with a case and images from our practice. We will also discuss techniques described in the literature for the retrieval of VenaTech (B. Braun, Bethlehem, PA) devices.

Greenfield Filter

The Greenfield filter was the first IVCF model to be utilized on a mass market scale.¹⁵ The initial iteration of this device required surgical venotomy for access during the placement procedure; the first true percutaneous model received Food and Drug Administration (FDA) approval in 1981. Design of the Greenfield IVCF was the result of collaboration between vascular surgeon Lazar Greenfield and petroleum engineer Garman Kimmel.^{16,17} Modeled on devices utilized in the oil

industry for filtering sludge in pipes, the Greenfield IVCF was constructed of stainless steel and featured a conical design now common to many IVCF models, which forced entrapped material to the center while permitting flow at the periphery, theoretically resulting in autolysis of trapped thrombi over time. This was a significant improvement over previous designs, which were plagued by frequent IVC occlusion.^{15,17} Subsequent iterations of the Greenfield IVCF include a titanium version introduced in 1989 designed to limit metal-induced magnetic resonance imaging susceptibility artifact.¹⁶

Retrieval Procedure

In our experience, the dominant obstacle in retrieval of Greenfield IVCF is the recurved hooks at the end of each strut. These were designed with the intent of limiting caval penetration; however, during the retrieval procedure, they are a significant impediment to disengagement of the filter from the caval wall. We have found success using large sheaths from right internal jugular access; we generally use 16F sheaths (Performer, Cook Medical, Bloomington, IN) but have used up to a 26F sheath (DrySeal, W.L. Gore, Flagstaff, AZ). Obtaining control of the filter at the apex is critical; we use rigid endobronchial forceps (Lymol Medical, Woburn, MA), or a looped Glidewire to apply firm traction-countertraction to free the filter from the caval wall.^{18,19} Forceps in particular have several advantages, permitting application of more forceful traction-countertraction and control compared with the looped Glidewire technique, and, if necessary, the ability to “micro-dissect” adherent fibrin as previously described.^{14,18} The use of other advanced techniques may also be necessitated by factors complicating retrieval, such as a fibrin cap formation and strut fracture.

Case

A 36-year-old woman with L2 paraplegia due to a gunshot wound sustained 14 years ago presents for removal of her

Greenfield IVCF placed prophylactically after her injury for prolonged immobilization. Preprocedural CT venogram demonstrated two fractured struts, confirmed fluoroscopically (►Fig. 1a), one which is entirely extracaval. After obtaining right internal jugular access, a 10-mm loop snare (OneSnare, Merit Medical, South Jordan, UT) is utilized to capture the intraluminal component of the cranial fractured strut, which is subsequently removed (►Fig. 1b). An 18F sheath (Performer, Cook Medical) is then deployed; the apex of the filter is secured with forceps. After engagement of the filter apex, traction-countertraction is applied and the filter collapses within the sheath (►Fig. 1c) and is successfully removed. Postprocedural cavography demonstrates no luminal irregularities or extravasation (►Fig. 1d).

TrapEase Filter

The TrapEase filter received FDA approval in 2000 and features a trapezoidal shape with broad caval fixation zones.¹⁶ The double-basket configuration provides two levels of filtration, and is fixed via anchoring barbs with an antiparallel orientation on both ends of the side rails. It is constructed of nitinol, a thermosensitive nickel-titanium alloy, and features a 6F deployment system. A retrievable version, OptEase, was approved in 2002 with features of unidirectional hooks that allowed for retrieval from femoral venous access. Initial studies suggested excellent PE prophylaxis, with no symptomatic PE 1 year in a series of 42 patients.²⁰ However, device fracture emerged as a concern; one series noted fracture rates in excess of 50%, which appeared to increase with dwell time.²¹ Caval occlusion arose as a concern as well; in a prospective randomized controlled trial, TrapEase filters demonstrated significantly higher rates of ilio caval thromboses compared with Greenfield models, hypothesized to be caused by greater flow disturbance within the filter owing to its unique geometry.²²

Retrieval Procedure

Retrieval of TrapEase filters is technically challenging, due to broad zone of caval fixation and antiparallel anchoring mechanism. Thus, our approach has been dual telescoping sheath method (via right internal jugular and right femoral access) with offset sizes; other centers have used this approach as well.²³ After initial venous access, we place an 18F sheath in one access and 16F sheath in the other. Subsequently, the cranial and caudal apices of the IVCF are engaged with reverse curve catheters and after retrograde advancement of a hydrophilic wire (Glidewire, Terumo, Tokyo, Japan); the free end is snared and externalized to form a loop wire snare of the cranial and caudal IVCF apices. Once device control is obtained, the filter is elongated with gentle tension from one access; from the opposite access, an Excimer laser sheath (Spectranetics, Colorado Springs, CO) is introduced and photothermal ablation of adherent fibrin is performed while sequentially collapsing the IVCF.²⁴ Frequently, the laser sheath must be used via the opposing access to permit complete collapse of filter elements. This technique is performed in a stepwise progression until the filter is freed from the caval wall; at this point, the laser sheath is usually inside of the sheath from the opposing access, thereby “excluding” the IVCF from the caval lumen. With this configuration, the filter and looped wires are removed from one of the accesses, with care taken not to expose the explanted filter, or glidewires, to the caval lumen by maintaining a telescoped sheath configuration.

Case

A 74-year-old woman presented with a past medical history significant for ovarian cancer complicated by PE who was transferred from an outside hospital for management of acute, extensive ilio caval thrombosis. Outside imaging demonstrates an indwelling TrapEase filter placed 9 years before with nonocclusive clot burden extending to the

Fig. 1 (a) Fluoroscopic spot image demonstrating fractured cranial (arrow) and extracaval caudal (dashed arrow) filter struts. (b) Fluoroscopic image demonstrating snare retrieval of fractured strut. (c) Fluoroscopic image demonstrating use of rigid endobronchial forceps to capture and collapse the filter. (d) Postprocedure digital-subtraction venography demonstrated no luminal irregularities or extravasation.

apex of the filter. The patient has been stable on an anticoagulation regimen started at the outside institution, and a decision was made to perform ilio caval thrombolysis and remove the filter, as it was presumed that the filter was essentially a fixed outflow obstruction. Venous access was obtained in both femoral veins and thrombolysis of both iliac segments and the inferior vena cava was performed. Following overnight thrombolysis with alteplase (Genentech, South San Francisco, CA), venography demonstrated residual irregularity, though significant improvement of her thrombus burden (►Fig. 2a). Tandem 12-mm balloon angioplasty (Atlas, Bard Peripheral Vascular, Tempe, AZ) was performed via each access at the level of the caudal inferior vena cava and greater venous confluence (►Fig. 2b). The right femoral access was increased to 18F, and right internal jugular access was obtained with placement of a 16F sheath. A SOS catheter (Angiodynamics, Latham, NY) was then used from the opposing jugular and right femoral accesses to engage the cranial and caudal filter apices with a hydrophilic wire via loop wire technique. A 14F Excimer laser sheath was then sequentially advanced with concurrent photothermal fibrin ablation over the cranial and caudal loop wires with exclusion of the filter from the caval lumen (►Fig. 2c, d). The larger, cranial sheath was advanced over the smaller, caudal sheath to maintain filter exclusion; the filter and looped wire were explanted via the right internal jugular access site. At this point, it was noted that significant flow-limiting irregularity was present in the caudal inferior vena cava and iliac veins. Bilateral, tandem stent deployment from the caudal IVC into the iliac veins was then performed, with brisk flow noted on postprocedure venography (►Fig. 2e).

Simon Nitinol Filter

Introduced in 1989, the Simon Nitinol permanent IVCF is constructed of nitinol and employs two filtration layers that include a lower, conical strut configuration and a cranial

“umbrella” designed to trap smaller emboli.¹⁶ One series noted lower rates of recurrent PE when compared with other models of permanent filters, though this has not been reliably replicated in other series.²⁵ Some reports have noted higher rates of filter/caval occlusion and IVC perforation.^{26,27} Iliocaval occlusion was postulated to be due to flow disruption at the cranial filtration level resulting in thrombosis.²⁶

Retrieval Procedure

The retrieval of Simon Nitinol filters is often complex, and can require the application of several different techniques for success. Critical to retrieval success is the use of a large diameter sheath to facilitate collapse of the bulky cranial filtration level; we have used 16, 18, and on occasion 26F sheaths. Control of the IVCF can be obtained with a snare device using standard technique, or if the apex is embedded, loop wire method or forceps may be necessary. As there is a large area of fixation between the caval wall and the cranial filtering element, use of the Excimer laser sheath is frequently necessary to ablate the associated fibrin.²⁴

Case

A 62-year-old woman with a history of DVT/PE presented to the emergency department with dyspnea, chest, back, and right leg pain. Initial imaging ruled out recurrent PE, but demonstrated penetration of her duodenum and pancreatic head by the struts of an indwelling Simon Nitinol filter, as well as a right psoas hematoma (►Fig. 3a). The decision was made to remove her filter. Initially, a 16F sheath via an internal jugular approach and snare device were used to attempt to engage the filter apex, which was unsuccessful. Forceps was then used to dissect the overlying fibrin cap, and most of the cranial component of the filter was subsequently collapsed into the sheath (►Fig. 3b). Once partially sheathed, a loop snare was used to capture the filter within the sheath; the Excimer laser sheath was then used to ablate adherent fibrin and free the remainder of the cranial component from the filter wall (►Fig. 3c). Subsequent

Fig. 2 (a) Digital subtraction venography demonstrating residual irregularity of the common iliac veins. (b) Fluoroscopic images demonstrating tandem angioplasty of the caudal vena cava and great venous confluence. (c, d) Fluoroscopic images demonstrating loop wire technique to engage the cranial and caudal filter apices and application of the Excimer laser sheath for photothermal ablation of adherent fibrin. (e) Digital subtraction venography following placement of bilateral ilio-caval stents for persistent flow-limiting ilio-caval irregularity.

Fig. 3 (a) Axial CT image demonstrating right psoas enlargement secondary to a right psoas hematoma. Struts from the filter are also seen penetrating the duodenum and pancreatic head. (b) Fluoroscopic spot image demonstrating use of rigid endobronchial forceps to capture the filter apex and partially sheath the cranial component. (c) Fluoroscopic spot image demonstrating Excimer laser sheath-assisted photothermal ablation followed by successful collapse into the sheath and removal. (d) Digital subtraction venography postretrieval demonstrating significant inferior vena cava stenosis. (e) Fluoroscopic image demonstrating balloon angioplasty of the stenotic segment. (f) Digital subtraction venography demonstrating resolution of the caval stenosis.

venography demonstrated caval stenosis, which resolved with 18-mm balloon angioplasty (►Fig. 3d-f) (Atlas, Bard Peripheral Vascular).

VenaTech Filter

The VenaTech LGM model was introduced in 1989, and is composed of phynox (alloy of cobalt–chromium–nickel).¹⁶ The LP model, featuring a redesign of the struts, was approved in 2001. The VenaTech filters are unique among IVCF in that they rely on radial force and eventual IVC wall incorporation, rather than anchoring hooks, to secure their position in the vessel. The filter struts are interdependent, and move in conjunction with one another. This arrangement allows for reliable centering within the IVC.²⁷ As with Simon Nitinol filters, there are reports of caval obstruction and occlusion likely related to fibrin deposition.²⁷

Retrieval Procedure

VenaTech devices are difficult to remove due to the filter design. Three reports exist and describe different retrieval

approaches. In a case report, Kuo and colleagues described the successful removal of an LGM device through intentional mechanical fracture with rigid endobronchial forceps.²⁸ When external overload stress was applied from a cranial direction, the filter components fracture at points of weakness, which are usually perforations in the sidewall struts, or weld points. All obstructing segments were successfully removed, and the patient had resolution of symptoms. Kuo and colleagues also described retrieval of an LP device utilizing a bisheath–bisure technique.²⁹ In this technique, dual access is gained at the right internal jugular and common femoral veins. From the internal jugular access site, a 9F sheath is advanced to the cranial aspect of the filter and engaged with an Ensnare. The cranial aspect is retracted into the sheath causing tenting of the inferior aspects. A 14F sheath is then advanced from below with a coaxial gooseneck snare used to engage the tented components. With application of traction, the 14F sheath is used to sequentially liberate the adherent anchoring leaflets, with collapse into the sheath. The superior components, held within the superior 9F sheath, can be advanced into the

larger, inferior sheath, allowing for removal by the femoral access site.

A more recent report describes the successful removal of three LP-type models via a different method.³⁰ Using a coaxial system of 12 and 9F sheaths, with a gooseneck snare to engage the cranial filter aspect, simultaneous traction is applied with the 9F sheath and gooseneck snare to “peel-away” the V-shaped anchoring leaflets. This inverts the leaflets, and, when liberated from the IVC wall, the filter can be retracted and explanted through the larger 12F system.

Conclusion

Though utilization of permanent IVCs has decreased in recent years with the introduction of retrievable devices, they continue to be placed in patients thought to have ongoing contraindication to anticoagulation or failure of anticoagulation with necessity for permanent mechanical caval prophylaxis. Complications, while rare, occasionally necessitate retrieval of these devices. Utilizing methods developed to retrieve embedded retrievable filters, along with novel methods unique to a specific device, permanent devices can be successfully retrieved. However, given the complex nature of these procedures, percutaneous retrieval of these devices should ideally be performed in centers with experience in advanced IVCF retrieval.

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