

Endovascular retrieval of Greenfield IVC filters 13 and 19 years post placement without major complication

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ABSTRACT

Inferior vena cava (IVC) filters were first introduced in 1967 by Kazi Mobin-Uddin and later improved by Lazar Greenfield in the 1980s becoming a major component of catastrophic pulmonary embolism prevention. Nevertheless, filters are not entirely harmless. The long term risks include caval thrombosis, visceral penetration, and filters can serve as a nidus for infection. Filter retrieval is often complicated by intimal hyperplasia especially with increased indwelling time. Historically, Greenfield filters in place for longer than 3 weeks were considered permanent due to the risks of retrieval. Herein we present 2 cases of successful retrieval of Greenfield filters 13 and 19 years post implantation.

CASE REPORT

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CASE 1:

A 32-year-old male presents to interventional radiology clinic with a history of a significant motor vehicle accident in 2002 where he sustained multiple pelvic fractures. Given his high risk for DVT and contraindication to anticoagulation, a Greenfield (Boston Scientific, Marlborough, MA) IVC filter was placed in May 2002. The patient was asymptomatic but routine laboratory testing at an outside hospital demonstrated iron deficiency anemia. The patient had an upper endoscopy (Figure 1a-d) performed on March 2015 to evaluate his anemia. Two sharp linear metallic objects were noted within the lumen of the second portion of the duodenum. The endoscopist briefly tried to explant one of the objects but there was significant resistance and only a small portion of it was removed. A noncontrast CT scan of the abdomen (Figure 2a-c) was then performed which demonstrated an infrarenal

Greenfield IVC filter with visceral penetration into the transverse duodenum as well as penetration into the right psoas muscle.

On physical examination the patient was alert and oriented and in no acute distress. He had no complaints of abdominal pain. His vitals were stable.

After obtaining informed consent, the filter retrieval procedure was performed under general anesthesia. He was placed supine and the right neck and groin were prepped and draped. A 12F sheath was placed in the right common femoral vein and a straight flush catheter was advanced into the right common iliac vein. A cavogram was performed which demonstrated mild stenosis of the IVC at the level of the filter with multiple collateral azygos, hemiazygos, and lumbar veins (Figure 3). There was a single IVC filter strut fractured within the psoas (Figure 4a). A 20F DrySeal sheath (Gore &

Associates, Flagstaff, AZ) was advanced through the right internal jugular vein over the wire and a 14F x 45 cm Performer sheath (Cook Medical, Bloomington, IN) and 11F x 60 cm sheath (Cook Medical, Bloomington, IN) were advanced through the Dryseal sheath in coaxial fashion and advanced atop the filter. A SOS catheter (Angiodynamics, Latham, NY) was introduced through this system and used to advance a hydrophilic 0.035" wire through the filter interstices and curved cranially such that the wire was looped around the nose of the filter (Figures 4b and 4c). The SOS was removed and a 25mm loop snare (Boston Scientific, Marlborough, MA) was advanced through this system alongside the wire. The wire tip was then snared and pulled back such that both ends of the wire were out of the sheath with a loop formed around the filter (Figures 4d and 4e). The 11F and 14F sheaths were then advanced to collapse the filter, the filter was captured in the 20F DrySeal sheath (Figure 4f), and the whole system was removed with filter mostly intact (Figures 5a and 5b).

The final cavogram (Figure 6) demonstrates no evidence of active extravasation of contrast. Again noted is mild narrowing of the IVC with collateral development. The patient was admitted for 23 hour observation and discharged in the morning with minimal neck discomfort and no hemodynamic instability.

CASE 2:

A 46-year-old female presented with a history of bipolar disorder, hypertension, anxiety, posttraumatic stress disorder related to a severe motor vehicle accident in 1995 which resulted in uterine rupture with loss of pregnancy at 6 months, traumatic brain injury, and coma. A Greenfield IVC filter was placed at that time to prevent pulmonary embolism. She presented to our clinic in 2014 with severe abdominal pain of a few months duration with acute worsening 3 weeks prior. She rated the pain 10 out of 10 and stated that her pain has left her unable to perform her daily activities.

She had initially presented to the Emergency Department at an outside hospital and they obtained a computed tomographic scan (Figures 7a and 7b) which demonstrated her IVC filter struts penetrating the IVC wall and adjacent to small bowel. She was referred to our institution for filter retrieval.

Physical examination revealed stable vital signs with mild tenderness in the right hemi-abdomen.

After obtaining informed consent, the filter retrieval procedure was performed under conscious sedation in the angiography suite with the patient in supine position. The procedure was performed in similar fashion as previously described via transjugular approach. The filter was identified under fluoroscopy (Figure 8a) and IVC cavogram demonstrated the IVC to be widely patent and normal in caliber without thrombus (Figure 8b). After both ends of the wire could be grasped with the loop formed within the filter, the coaxial 22F, 18F, and 14F sheaths were advanced over the filter which partially collapsed but remained adherent to the IVC. A longer 11F sheath was advanced within the 14F sheath and all 3 sheaths were advanced over the filter. The filter collapsed and was successfully removed in its entirety (Figures

9a and 9b). A repeat IVC cavogram was performed through the sheath in the right common femoral vein and demonstrated a small, self-contained extravasation into the retroperitoneum. A 32mm CODA balloon (Cook Medical, Bloomington, IN) was advanced and gently inflated at the region of extravasation. After three-15 minute episodes of balloon inflation and deflation, the balloon was removed and final cavogram performed which demonstrated no evidence of extravasation (Figure 10). The patient remained hemodynamically stable throughout the entirety of the procedure. She was admitted for 23hour observation and discharged pain free the next morning.

DISCUSSION

Inferior vena cava (IVC) filters were first introduced in 1967 by Kazi Mobin-Uddin and later improved by Lazar Greenfield in the 1980s and became a major component of catastrophic pulmonary embolism prevention [1,2]. IVC filters are generally placed in the vena cava below the level of the lowest lying renal vein (typically the left) however knowledge of variant anatomy such as circumaortic left renal veins, caval duplication, and megacava are crucial to proper filter placement, filter type, and number of filters as correctly placed IVC filters have a role in protecting patients from life threatening pulmonary embolisms; however there are associated risks that have led to the FDA issuing a device warning in 2010 and a follow up message in 2014 recommending that filters be removed 1-2 months after placement. The risks include strut fracture, visceral penetration, infection, filter migration, embolization, thrombosis and loss of caval patency with rates of caval occlusion up to 30% [3-6]. The primary factor that complicates removal of IVC filters is intimal hyperplasia which the underlying mechanism is poorly understood but seems to be more prevalent in objects with longer indwelling times [7].

Intimal hyperplasia is a multifactorial process. A combination of inflammatory factors, thrombogenic mechanisms and cell proliferation by means of numerous growth factors and cytokines such as platelet-derived growth factor (PDGF), tumor growth factor (TGF)- β , Interleukin (IL)-1, IL-6 and IL-8, and thrombin have been described as etiologic factors. Platelet activation, leucocyte recruitment, activation of the coagulation cascade, smooth muscle cells migration and ultimately smooth muscle cell proliferation are the events leading to intimal hyperplasia [8].

Wu et al. also have shown that mechanical stretch may contribute to intimal hyperplasia in veins by stimulating early growth response-1 (Egr-1) mRNA and protein in vascular smooth muscle cells. Egr-1 regulates insulin-like growth factor -1 receptor (IGF-1R) transcription. IGF-1 pathway plays an important role in intimal hyperplasia. This later factor may specifically play an important role in intimal hyperplasia of IVC around the filter struts as the radial force of the filter stretches the IVC wall at the insertion site of the struts [9].

With respect to permanent filters there have been a few retrieval techniques reported such as blunt dissection, Excimer laser ablation, and piecemeal removal by intentional mechanical fracture [10-12]. We combined the double sheath dissection principle, furthering with 4 coaxial sheaths, with the snare-loop technique first described by Rubenstein to successfully retrieve our two filters [13]. Retrieval of permanent IVC filters after long indwelling times, including one at 6663 days have been reported [12]. One of the filters we retrieved had an indwelling time of 7000 days making it the oldest filter retrieved to date.

Due to the long indwelling time there was difficulty with retrieving the filters. This was overcome by many strategic technical maneuvers. First, using multiple sheaths as described to reinforce the retrieval unit. Second, the additional femoral access enabled us to ensure the safety of this procedure. In case of IVC rupture a balloon can be inflated in the IVC. Third, with passing a wire under the filter apex, the filters were completely captured despite the lack of an apical hook. Fourth, IVC rupture was prevented by simultaneous pushing of the sheaths over the filter and pulling the wire under the apex of the filter to release the struts and cover the filter inside the sheaths. With this technique, the filter does not move vertically and the struts have no chance to damage the IVC. Last, when the filter is closed but the sheath cannot be pushed over the filter, it means that the struts are still in the IVC wall and the IVC is closed as well. Prolonged IVC closure may lead to thrombosis. After about a minute of closing the filter if the filter was not captured in the sheath, the filter was released in order to allow blood flow in the IVC and prevent thrombosis.

TEACHING POINT

Long indwelling inferior vena cava filters can be removed safely via a percutaneous endovascular approach even up to 7000 days after implantation.

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FIGURES

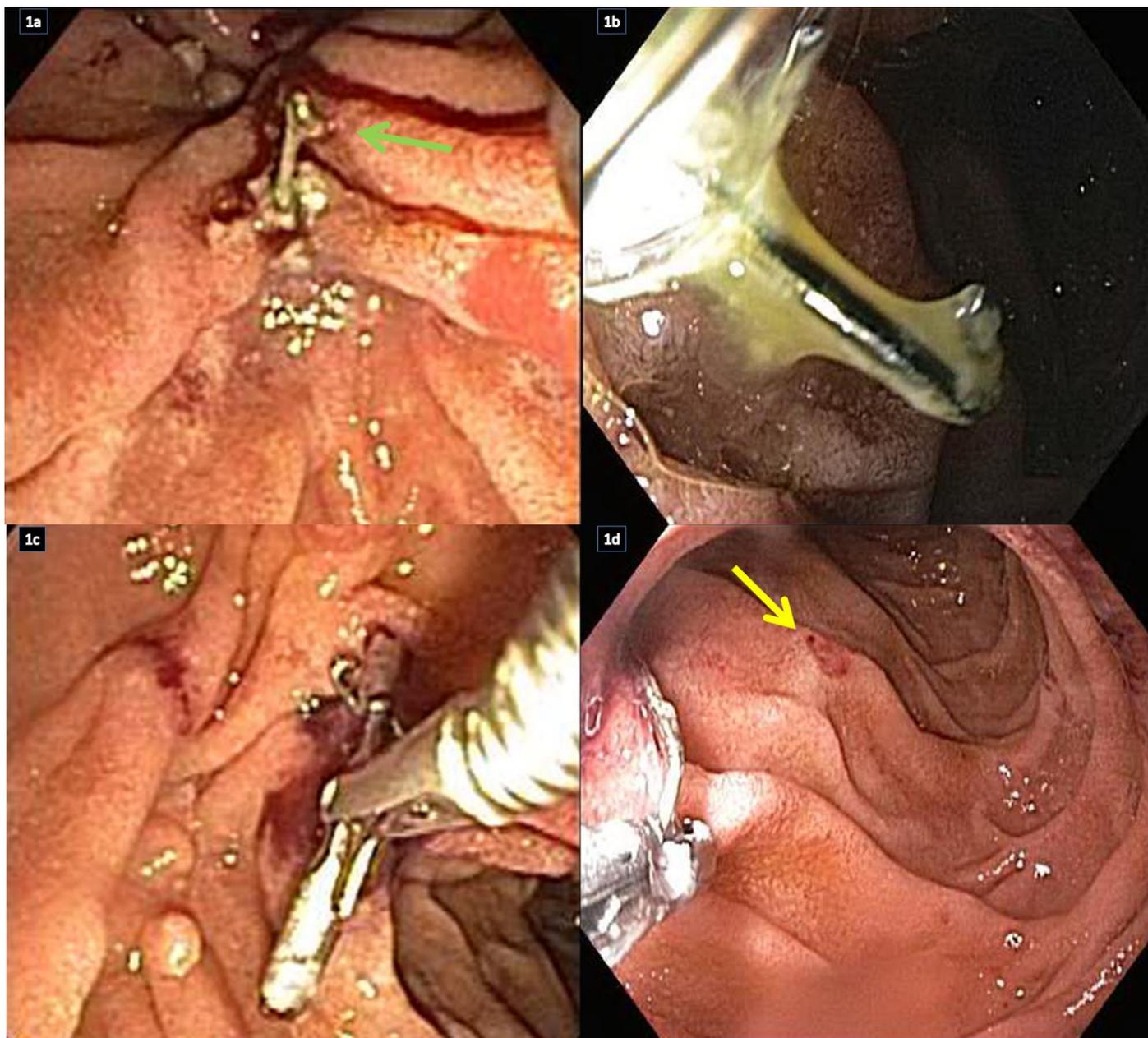


Figure 1: 32 year old male with anemia secondary to strut penetration into the duodenum.

Findings:

- a) A sharp metallic object (Green arrow) is seen projecting into the lumen of the duodenum with blood oozing around the entry site.
- b) A close-up evaluation of the object.
- c) Endoscopic forceps were utilized to the object
- d) Site of ulceration at the site of penetration (Yellow arrow).

Technique: Upper GI endoscopy

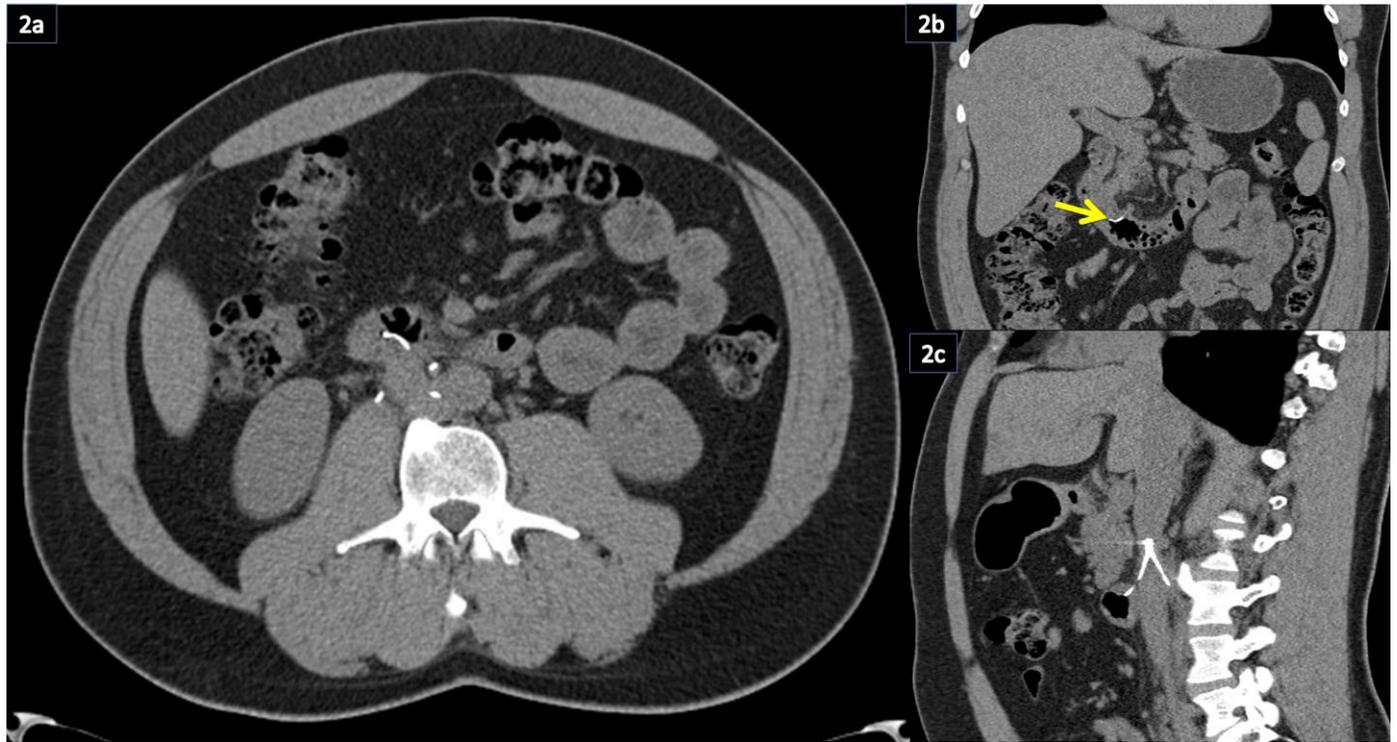


Figure 2: 32 year old male with anemia secondary to strut penetration into the duodenum.

Findings:

- a) Axial image at the level of the midabdomen demonstrating penetration of multiple filter struts through the wall of the inferior vena cava noting a single anteriorly directed strut projecting within the lumen of the adjacent duodenum. Minimal nonspecific periduodenal stranding is noted. There is questionable extension of a strut into the right psoas muscle.
- b) Coronal image demonstrates the strut within the lumen of the duodenum near the duodenal sweep (yellow arrow).
- c) Sagittal image demonstrating the strut penetrating the entire substance of the duodenum.

Technique: CT: axial, sagittal and Coronal. Siemens, mAs 271, kVp 120, 3.0 mm slice thickness, no contrast.



Figure 3 (left): 32 year old male with anemia secondary to strut penetration into the duodenum.

FINDINGS: Digital subtraction cavagram demonstrating stricture (red arrow) of the distal IVC with numerous venous collaterals suggesting long standing stenosis. No evidence of infra filter thrombus. IVC filter is faintly noted (blue oval).

TECHNIQUE: Digital subtraction venography of the IVC, injection of 30 cc of Omnipaque 350 contrast in posterior-anterior projection.



Figure 4: 32 year old male with anemia secondary to strut penetration into the duodenum.

FINDINGS:

- Intraoperative PA radiograph demonstrating the inferior vena cava (IVC) filter with a fractured strut (red arrow) within the right psoas muscle. This minimally displaced fractured fragment is apparent upon subsequent images within this series.
 - Intraoperative PA radiograph demonstrating advancement a 20F Dryseal sheath, 14Fx45 cm Performer sheath (Cook Medical, Bloomington, IN) and 11Fx60cm sheath (Cook Medical, Bloomington, IN) atop the filter with a caudally directed wire through the filter interstices. Note there is a cranially directed wire from the right femoral access visualized on all subsequent images of this series.
 - Intraoperative PA radiograph demonstrating a cranially directed wire through a reverse curve SOS catheter with a loop formed through the filter interstices.
 - Intraoperative PA radiograph demonstrating snaring of the cranially directed wire.
 - Intraoperative PA radiograph demonstrating advancement of the coaxial system upon the filter and tension-counter tension was applied.
 - Intraoperative PA radiograph demonstrating the collapsed filter within the Dryseal sheath (Blue arrow).
- Technique: Single radiographs of the abdomen in posterior-anterior (PA) projection.

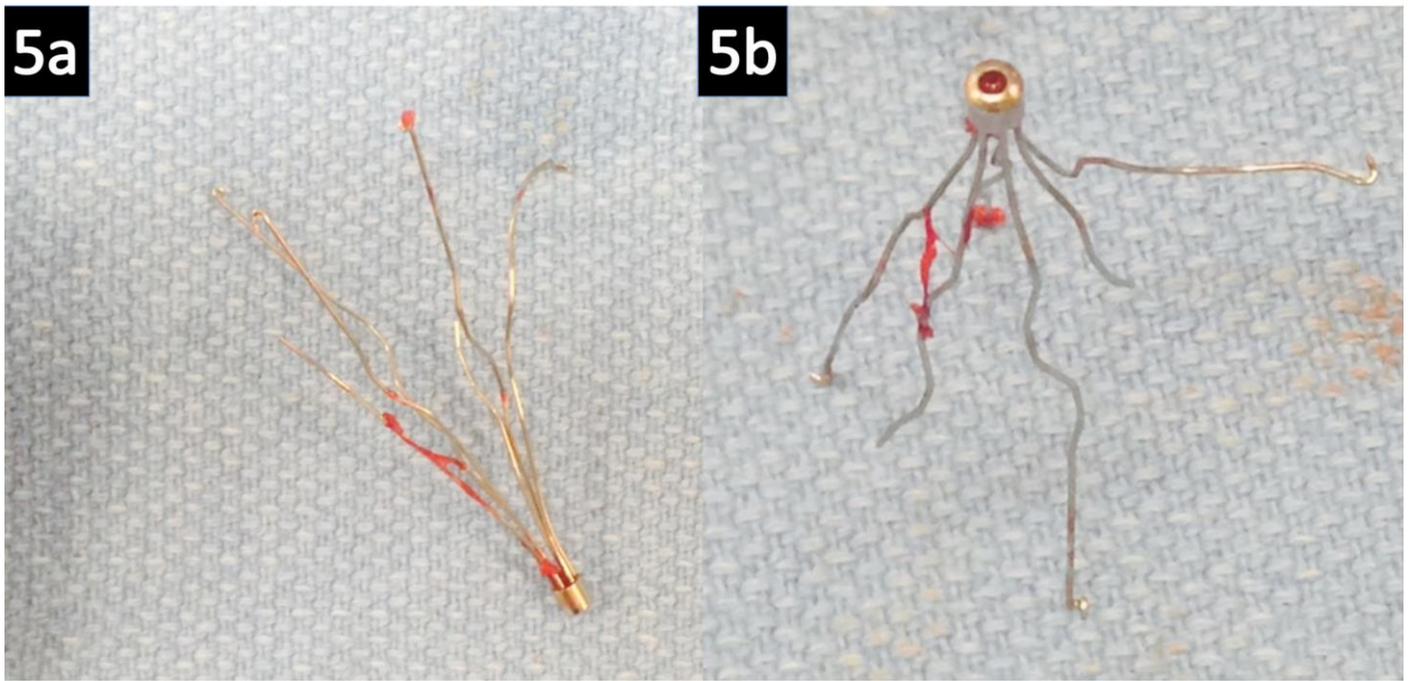


Figure 5: 32 year old male with anemia secondary to strut penetration into the duodenum.
FINDINGS: Intraoperative photographs of the retrieved Greenfield IVC filter.
TECHNIQUE: Intraoperative photograph



Figure 6 (left): 32 year old male with anemia secondary to strut penetration into the duodenum.
FINDINGS: Digital subtraction cavagram demonstrates no extravasation. Note fragment is retained within the psoas muscle (red arrow)
TECHNIQUE: Digital subtraction venography of the IVC, injection of 30 cc of Omnipaque 350 contrast in posterior-anterior projection.

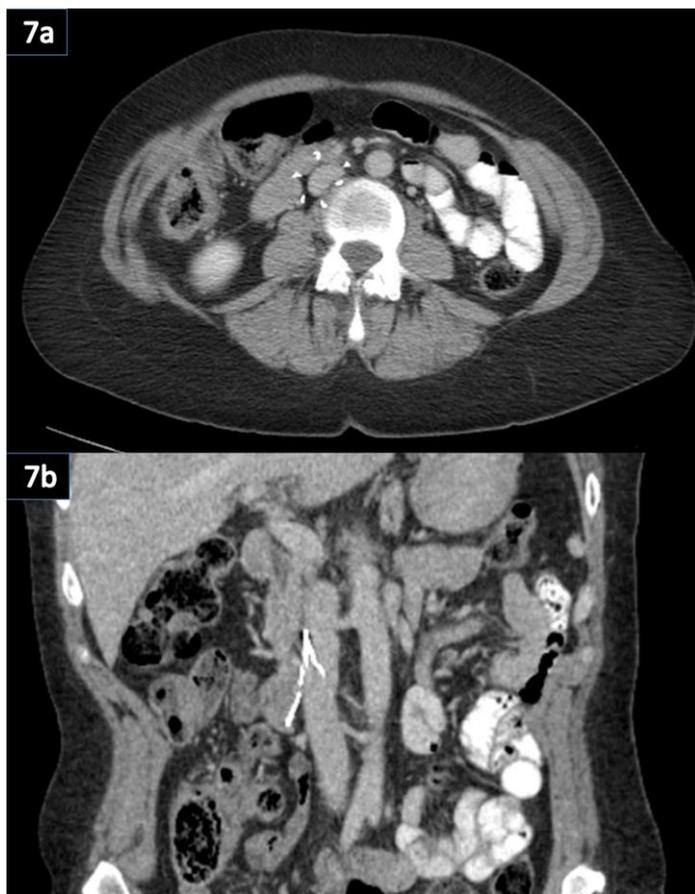


Figure 7 (left): 46 year old female with abdominal pain secondary to penetration of filter struts.

Findings:

a) Axial image through the midabdomen demonstrating caval perforation of all six filter struts protruding beyond the walls of the IVC.

b) Coronal image demonstrating abutment and questionable visceral penetration of a lateral projecting strut.

Technique: CT: axial and coronal. Siemens, mAs 271, kVp 120, 3.0 mm slice thickness, no contrast.



Figure 8: 46 year old female with abdominal pain secondary to penetration of filter struts.

FINDINGS:

a) Intraoperative radiograph demonstrates an upright filter within the inferior vena cava.

b) Digital subtraction venogram demonstrates no thrombus beneath the filter.

TECHNIQUE: Single radiograph of the abdomen in posterior-anterior projection and digital subtraction venography of the IVC, injection of 30 cc of Omnipaque 350 contrast in posterior-anterior projection.

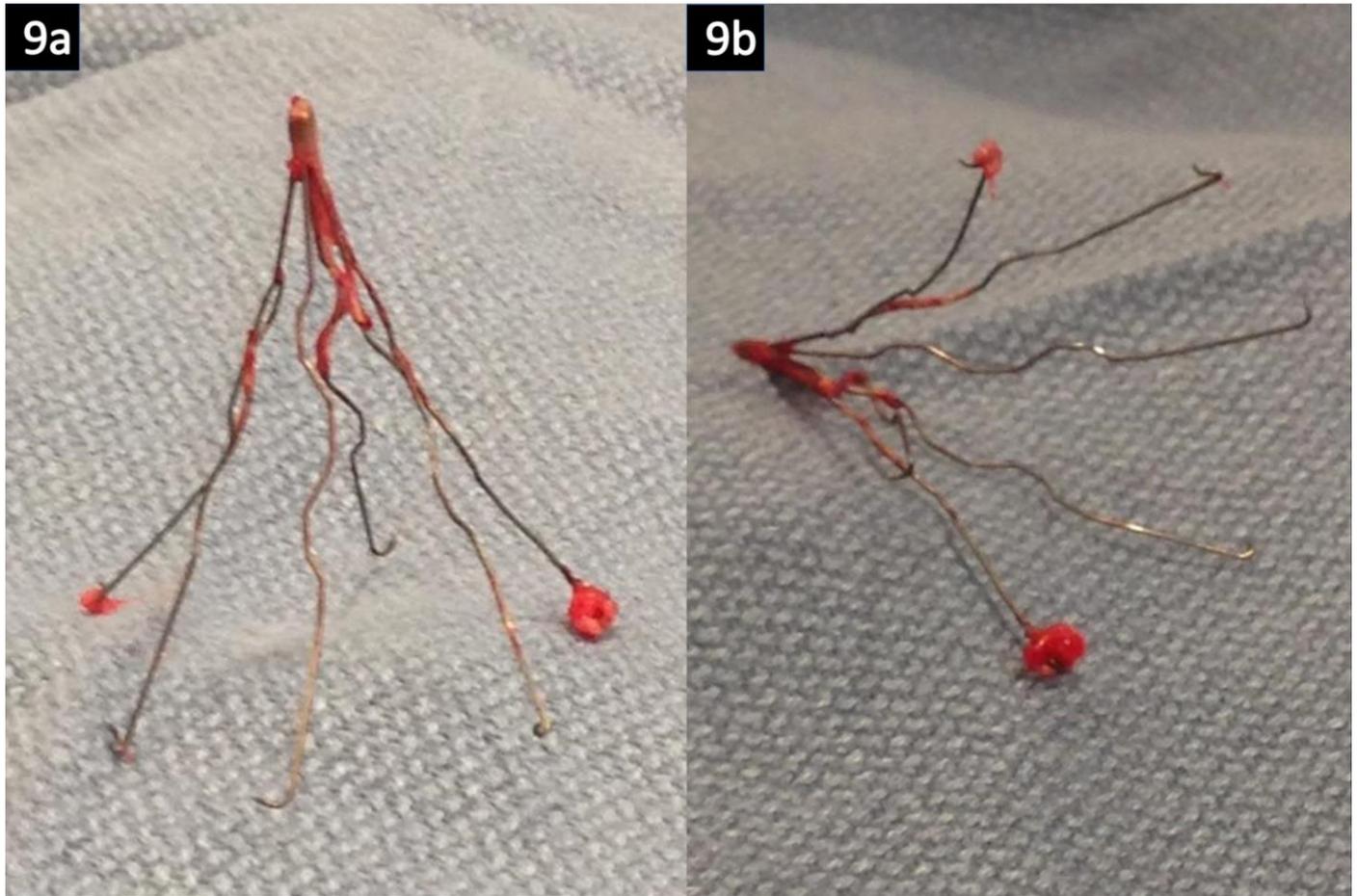


Figure 9: 46 year old female with abdominal pain secondary to penetration of filter struts.
FINDINGS: Intraoperative photographs of the retrieved Greenfield filter.
TECHNIQUE: Intraoperative photograph



Figure 10 (left): 46 year old female with abdominal pain secondary to penetration of filter struts.
FINDINGS: Digital subtraction venogram demonstrating a small extravasation at the level of the previously removed filter. A CODA balloon was inflated for three 15 minute episodes and the final cavogram (not shown) was unremarkable.
TECHNIQUE: Digital subtraction venography of the IVC, injection of 30 cc of Omnipaque 350 contrast in posterior-anterior projection.

Etiology	Intimal Hyperplasia
Incidence	Variable and semi-dependent on duration of implantation
Gender ratio	NA
Age predilection	NA
Risk factors	Prolonged indwelling time.
Treatment	Mechanical or energy based excision.
Prognosis	NA
Imaging Findings	Static images are not sensitive nor specific however real time evaluation (intraoperative fluoroscopy) may demonstrate flow voids or intraluminal contour deformities on angiography/venography

Table 1: Summary table for filter embedment.

Name	Manufacturer	FDA approval year / Miscellaneous
Stainless Steel Greenfield IVC Filter	Boston Scientific Corp Watertown, MA, USA	1985
Titanium Greenfield IVC Filter	Boston Scientific Corp Watertown, MA, USA	1987
Vena Tech LGM IVC Filter	B Braun Evanston, IL, USA	1989
Cook Medical Birds Nest IVC Filter	Cook Incorporated Bloomington, IN, USA	1989 / indicated for inferior vena cava diameters of >28mm
Bard Simon Nitinol IVC Filter	Bard Peripheral Vascular, INC Tempe, AZ, USA	1990
Cordis TrapEase IVC Filter	Cordis, A Johnson & Johnson Co. Fremont, CA, USA	2000
Cook Gunther Tulip IVC Filter	Cook Incorporated Bloomington, IN, USA	2000/ one of the first retrievable filters approved in USA. Has recovery hook.
Vena Tech LP IVC Filter	B Braun Evanston, IL, USA	2001
Cordis OptEase IVC Filter	Cordis, A Johnson & Johnson Co. Fremont, CA, USA	2002
Bard Recovery IVC Filter	Bard Peripheral Vascular, INC Tempe, AZ, USA	2002/ Retrievable filter without hook. Discontinued.
Bard G2 IVC Filter	Bard Peripheral Vascular, INC Tempe, AZ, USA	2005/ Discontinued.
Cook Platinum Celect IVC Filter	Cook Incorporated Bloomington, IN, USA	2007
ALN Optional IVC Filter	ALN Implants Chirurgicaux Atlanta, GA, USA	2008
Bard G2 Express IVC Filter	Bard Peripheral Vascular, INC Tempe, AZ, USA	2008
SafeFlo IVC Filter	Rafael Medical Technologies Ltd. Philadelphia, PA, USA	2009
Rex Medical Option Elite	Rex Medical Northborough, MA, USA	2009
Bard Eclipse IVC Filter	Bard Peripheral Vascular, INC Tempe, AZ, USA	2010/ Discontinued.
Bard Meridian IVC Filter	Bard Peripheral Vascular, INC Tempe, AZ, USA	2011/ Discontinued.
Crux IVC Filter	Crux Biomedical Menlo Park, CA, USA	2012
Bard Denali IVC Filter	Bard Peripheral Vascular, INC Tempe, AZ, USA	2013
Vena Tech Convertible IVC Filter	B Braun Bethlehem, PA, USA	2016

Table 2: FDA Approved Inferior Vena Cava (IVC) Filters.

Retrieval Technique	Description of Technique	When to use this technique
Regular retrieval with snare	A loop snare is used to snare the retrieval hook. The filter is then oversheathed and removed.	Used for retrievable filters with a retrieval hook in uncomplicated position.
Wire under the filter technique	A wire is guided between the interstices of the snare and then directed cranially. The filter is then repositioned, oversheathed, and removed.	Used for filters without a hook or if the hook is embedded in the IVC wall.
Multiple sheaths technique	Similar to regular retrieval except the use of multiple coaxial sheaths during the oversheathing process.	Used for filters with long indwelling time to reinforce the retrieval unit and avoid buckling of the sheath
Laser Catheter	A laser is used to ablate the fibrous tissue holding the struts in place prior to filter retrieval.	Used for long indwelling time to release the struts from the IVC wall. Not FDA approved.
Endobronchial forceps	Endobronchial forceps are used to dissect the fibrin from the struts thus freeing the filter for retrieval.	Used for long indwelling time to release the struts from the IVC wall.

Table 3: Summary table for various caval filter retrieval methods. There are multiple ways to remove filters of various degrees of difficulty. It is important to note that the advantages and disadvantages of different techniques have not been described.

ABBREVIATIONS

CT = Computed tomography
 DVT = Deep vein thrombosis
 Egr-1 = Early growth response-1
 IGF-1R = Insulin-like growth factor -1 receptor
 IL = Interleukin
 IVC = Inferior Vena Cava
 PDGF = Platelet-derived growth factor
 TGF = Tumor growth factor

KEYWORDS

IVC; Filter; Loop-snare; Endovascular; Venous

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