AJR FOCUS ON:

Radiologists' Field Guide to Retrievable and Convertible Inferior Vena Cava Filters

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OBJECTIVE. Inferior vena cava (IVC) filters are commonly used in patients who are at risk for life-threatening pulmonary embolism. After the introduction of permanent devices, numerous retrievable and convertible designs became available. Inaccurate identification can lead to confusion in options for filter retrieval and anticoagulation.

CONCLUSION. This article highlights device designs of retrievable and convertible IVC filters to assist interpretation of diagnostic studies.

Keywords: inferior vena cava filters, pulmonary embolism, venous thromboembolism

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Inferior vena cava (IVC) filters are commonly used in patients who are at risk for life-threatening pulmonary embolism (PE). Inaccurate identification can lead to confusion in options for filter retrieval and anticoagulation. Since the development of the Mobin-Uddin IVC filter in 1967, at least 23 distinct filter types have come to market and been implanted in various patient populations with either known deep vein thrombosis (DVT) or for prophylaxis against potentially life-threatening PE. The large number of permanent, retrievable, and convertible designs may cause confusion about which filter is present and the best options for management. The purpose of this article is to show the normal appearance of various retrievable and convertible IVC filters and the imaging features that can be used to differentiate them.

CT Venography

CT venography is the imaging study of choice for assessing patients with IVC filters that have been indwelling for a long period of time, in particular to assess for complications in advance of attempted IVC filter retrieval [1]. The study is typically performed with a 120-second delay after IV bolus injection of 120 mL of nonionic iodinated contrast material [2]. The imaging protocol should include imaging from the lesser trochanter through the suprarenal IVC to include the common femoral vein, the confluence of the femoral vein and profunda femoris vein, and the cavoatrial junction.

Although dedicated studies to assess IVC filters before planned retrieval can follow that protocol, IVC filters are frequently identified during routine diagnostic examinations. Therefore, evaluation of filter structure, component fracture, missing components, component perforation, filter tilt, chronic posthrombotic change of the iliocaval venous segments, and attempted identification of filter type should be incorporated into routine diagnostic imaging examinations.

Image Acquisition

Photographs of individual IVC filters were obtained ex vivo using a digital single-lens reflex camera (T2i DSLR, Canon) and handheld strobe technique over a matte background. Digital fluoroscopic images were obtained by placing the filter within an acrylic tube and obtaining a digital spot image with low tube voltage (42 kVp) and manual tube current adjustment to optimize contrast. Digital images were then saved and exported from a PACS.

Images of each IVC filter are detailed in Figures 1–8, which can be used for comparison with diagnostic studies for accurate identification. Filter material composition and MRI compatibility are detailed in Table 1.

Filter Types

VenaTech Convertible Vena Cava Filter

The VenaTech Convertible vena cava filter (B. Braun Medical) received U.S. Food and Drug Administration (FDA) approval in 2016 (Figs. 1A and 1B). The convertible filter design was based on the VenaTech LP vena

TABLE 1: Inferior Vena Cava Filter Types, Materials, MRI Compatibility, and Caval Diameter

Filter Type	Materials	MRI Compatibility	Approved Caval Diameter (mm)
VenaTech Convertible[a]	Cobalt-chromium-nickel alloy (Phynox[b])	Conditional to 3 T	28
OptEase[c]	Nickel-titanium alloy (Nitinol[d])	Conditional to 3 T	30
Günther Tulip and Celect[e]	Cobalt-chromium-nickel-molybdenum-iron alloy (Conichrome[f])	Conditional to 3 T	30
Recovery, G2, G2×, Eclipse, Meridian, Denali[g]	Nickel-titanium alloy (Nitinol[d])	Conditional to 3 T	28
Optional ALN[h]	Stainless steel	Conditional to 3 T	32
Argon Option[i]	Nickel-titanium alloy (Nitinol[d])	Conditional to 3 T	30
Crux[j]	Nickel-titanium alloy (Nitinol[d]) frame with a web of expanded polytetrafluoroethylene (ePTFE) filaments	Conditional to 3 T	28
Sentry[k]	Nickel-titanium alloy (Nitinol[d]) cylindric frame and internal filter cone held together by a bioabsorbable poly-p-dioxanone synthetic polymer filament	Conditional to 3 T	28
Bioabsorbable[l]	Polydioxanone polymer	TBD	NA

Note—MRI compatibility is derived from MRIsafety.com. TBD = to be determined, NA = not applicable.
[a]B. Braun Medical.
[b]Aperam Alloys Imphy.
[c]Cordis.
[d]Naval Ordnance Laboratory.
[e]Cook.
[f]CRS Holdings.
[g]Bard.
[h]ALN Implants.
[i]Rex Medical.
[j]Crux Biomedical.
[k]Novate Medical.
[l]PDSII, Ethicon.

cava filter (B. Braun Medical) and used the same cobalt-chromium-nickel alloy (Phynox, Aperam Alloys Imphy) wire, which allows it to be converted to a stent by removing the apical hook when the risk of venous thromboembolism (VTE) has passed. The filter legs are secured at the apex of the cone by a removable head [3]. In a multicenter, prospective, single-arm study of the convertible filter, technical success of conversion was 93% for the 96 filters in which conversion was attempted [3]. Loss of filter head components in the vasculature did not occur, but there were four cases of incomplete opening of filtering legs immediately after conversion after use of ancillary tools and three reports of inability to convert the filter after failure to snare the filter hook [3]. There were no reports of filter migration or filter fracture.

OptEase Filter

The OptEase vena cava filter (Cordis) received initial FDA approval in 2002 (Fig. 2). The design is nearly identical to the TrapEase (Cordis) except that it has only cranial fixation barbs and has a dual prong caudal hook for capture with an endovascular snare. The filter is 67 mm long undeployed and shortens to 54 mm in length once deployed. The manufacturer's reported retrieval window for this device is 23 days. A single-center, retrospective study of 258 patients who had either a TrapEase or OptEase filter implanted between 2004 and 2008 reported a 50% retrieval rate in the cohort of 141 of patients who underwent attempted retrieval (62% of 228 implanted OptEase filters). Filter thrombosis and caval thrombosis were detected in 12%, precluding retrieval. Retrieval was attempted between 14 and 23 days after placement in accordance with manufacturer recommendations, and many of these filters remained in place for a longer time interval, which could have resulted in higher rates of caval thrombosis [4].

Cook Filters

The Günther Tulip vena cava filter set (Cook) received initial FDA approval in 2000 and is composed of a cobalt-chromium-nickel-molybdenum-iron alloy (Conichrome, CRS Holdings). The Günther Tulip filter has four anchoring legs, four secondary struts around each leg, and a hook at the filter apex (Fig. 3A) and has been approved for use in patients with an IVC diameter up to 30 mm. The Cook Celect vena cava filter received initial FDA approval in 2007 and is approved for use in patients with an IVC diameter up to 30 mm. The Celect filter is also composed of Conichrome with four anchoring legs, but instead of four secondary struts interwoven around each leg, it has eight separate arms (Fig. 3B). The Celect Platinum vena cava filter (Cook) received initial FDA approval in 2012 and includes a design change to the four anchoring legs (Fig. 3C). The most common complication with the Günther Tulip and Celect IVC filters is IVC perforation, which occurred with 86% of filters evaluated as part of a retrospective review up to 880 days after placement [5]. Filter tilt also occurred in 40% of cases with filter perforation present in all of the tilted filters [5].

Bard Filters

All Bard IVC filters are constructed of Nitinol (Naval Ordnance Laboratory), and each has six anchoring legs and six concentric arms for a total of 12 components approved for use in patients with IVC diameter less than 28 mm. The Recovery filter system (C.R. Bard) received initial FDA approval in 2002. It is distinguishable by the lack of

an apical retrieval hook and short concentric arms (Fig. 4A). The G2 filter system (C.R. Bard) received initial FDA approval in 2005 and was modified to have longer concentric arms but also lacks an apical filter hook (Fig. 4B). The G2× filter system (C.R. Bard) received initial FDA approval in 2008. The Eclipse filter system (C.R. Bard) received initial FDA approval in 2010. Because they have the same design, the G2× and Eclipse filters are indistinguishable on radiographic images, but the Eclipse has an electropolished finish. The appearance is similar to the G2, with the addition of an apical filter hook (Fig. 4C). The Meridian filter system (C.R. Bard) received initial FDA approval in 2011 and has the addition of stabilization barbs to the concentric arms (Fig. 4D). These five iterations of the Bard filters have had the highest incidence of filter fracture, with 157 of 500 (31%) cases reported in the Manufacturer and User Facility Device Experience (MAUDE) database [6]. In a retrospective review of 684 implanted G2 filters, the risk of filter fracture increased with increasing dwell time and reached a rate of 38% 5 years after placement [7]. This rate is similar to the 40% fracture rate at 5 years in 363 patients with the Recovery filter [8].

The Denali filter system (C.R. Bard) received initial FDA approval in 2013. The modification included all components being laser cut from a single piece of Nitinol, unlike prior Bard filters that were constructed with soldered elements. It was also modified to include stabilization barbs on the anchoring legs and elongation of two of the six legs (Fig. 4E). The Denali trial was performed as a prospective, nonrandomized, single-arm study at 21 centers in the United States and included 200 patients into whom a Denali filter was implanted [9]. New DVT occurred in 11% of patients, and worsening DVT occurred in 4% of patients [9]. Filter penetration of more than 3 mm occurred in 3% of patients, at the time of filter placement in 2% [9]. No instances of filter fracture, migration, or tilt were detected [9]. In a retrospective review of 87 Denali filters inserted at one institution, filter fracture and migration also did not occur [10].

ALN Filter

The Optional ALN vena cava filter (ALN Implants) received initial FDA approval in 2008 and is indicated for use in patients with an IVC diameter up to 32 mm. The filter design includes six short anchoring struts and three longer centering struts made from stainless steel (Fig. 5). A modification of the Optional ALN vena cava filter was approved in 2012 with the addition of an apical retrieval hook. In a prospective cohort study of 220 patients with 18-month follow-up between 1999 and 2005, 6% of cases resulted in filter tilt at the time of placement, 17% had a VTE event after placement, with 15% representing DVT and filter thrombosis in 6% after a median time of 28 days [11]. In that study, 25% of filters underwent attempted retrieval with a success rate of 93%. Filter tilt occurred in 6% of patients, and filter migration occurred in 1% of patients.

Rex Medical Filters

The Argon Option vena cava filter (Rex Medical) received initial FDA approval in 2009 and is indicated for patients with an IVC diameter less than 30 mm. The Option filter is constructed from a single piece of laser-cut Nitinol consisting of six symmetric legs, no arms, upper interstices that converge to the apex, and an apical retrieval hook that is deployed through a 6-French sheath. The Argon Option Elite vena cava filter (Rex Medical) received initial FDA approval in 2013; it includes a subtle modification of the filter hook and barbs at the ends of the filter legs (Fig. 6). The Option Elite is also available with a 100-cm deployment catheter, which allows implantation using a brachial or basilic vein puncture as opposed to femoral or internal jugular vein access. In a prospective, multicenter, single-arm trial including 100 patients who underwent implantation of the Option IVC filter for risk of PE and were followed for 180 days, there were eight cases of recurrent PE, two cases of filter migration (23-mm distance), and three cases of symptomatic caval occlusion or thrombosis [12]. There were no instances of filter fracture or filter embolization [12]. Success of filter retrieval occurred in 86% of patients in whom retrieval was attempted [12].

Crux Filter

The Crux vena cava filter system (Crux Biomedical) received initial FDA approval in 2012 and can be used in patients with IVC diameters less than 28 mm. The system offers two sizes: a small size for diameters of 17–22 mm and a large size for diameters of 22–28 mm. The Crux filter is a nonconical, opposing helix design of Nitinol frame with a web of expanded polytetrafluoroethylene (ePTFE) filaments in the lower helix deployed through a 6-French sheath (Fig. 7). Radiopaque retrieval hooks are present at both ends to allow retrieval and placement from jugular or femoral access. The grid elements measure 6 × 8 mm for trapping emboli. The second loop without the ePTFE helix contains three fixation anchors crimped to the framework.

The RETRIEVE trial was a prospective, multicenter, single-arm, nonrandomized clinical trial performed to evaluate the safety and effectiveness of the Crux IVC filter [13]. The study included 125 patients with the Crux filter implanted from June 2010 to June 2011 who met appropriate indications as detailed by the Society of Interventional Radiology standards of practice and were followed for 180 days. Two cases were considered technical failures at the time of deployment because of an infrarenal IVC length of 9 and 10 cm, which resulted in the filter crossing the renal veins. In these patients, the filter was removed and replaced with a commercially available IVC filter. No cases of device migration more than 20 mm, filter fracture, or embolization were recorded, and nine cases (7%) of thrombus were seen in the IVC or near the filter [13].

Sentry Filter

The Sentry IVC filter (Novate Medical) received initial FDA approval in 2017, and a trial evaluating its safety efficacy was published in 2018 [14]. The device is made from a single piece of laser-cut Nitinol and involves a cylindric frame and an internal filter cone consisting of six pairs of arms held together by a bioabsorbable poly-p-dioxanone synthetic polymer filament deployed through a 7-French sheath (Fig. 8). The filter is indicated in patients with caval diameters less than 28 mm and has a maximal deployed length of 57.7 mm. The Sentry clinical trial consisted of a prospective, multicenter, nonrandomized, single-arm trial including 129 patients at 23 sites who underwent Sentry IVC filter placement in accordance with guidelines of good clinical practice. One month after placement, 100% of the devices were in filter configuration; 96% of filters were in the converted configuration 6 months after placement [14]. No patient had symptomatic PE for the first 12 months after placement, but two cases of symptomatic caval thrombosis occurred in the cohort within 6 months of placement (2%). No instances of filter tilt, migration, perforation, embolization, or fracture were encountered during the entire study period. Imaging appearance

in the filter and converted configurations are delineated well in the published report.

Bioabsorbable Filter

A bioabsorbable IVC filter manufactured from polydioxanone (PDSII, Ethicon) is being studied in an animal model [15]. Filters were deployed within the IVC of 11 swine, and autologous thrombus was administered peripheral to the filter in seven swine 0–35 days after placement. During the follow-up period of 5 weeks, there were no instances of IVC thrombosis, device migration, caval penetration, or PE [15]. Neointimal hyperplasia had occurred around the filter implantation site by 2 weeks after insertion, and microscopic fragments were visible at 32 weeks [15].

Conclusion

Identification of permanent and retrievable IVC filters and individual filter types on diagnostic imaging is important in determining risk for VTE and device-related complications and potential for IVC filter retrieval. Because of the relatively higher reported incidence of filter fracture with the Bard family of IVC filters, the anatomic configuration and number of components must be carefully examined to exclude fragment embolization. As mentioned in the field guide to permanent IVC filters [16], acute and chronic caval thrombosis at the level of the indwelling IVC filter or peripheral to the filter in the common iliac, external iliac, or common femoral veins is important to identify and delineate in reporting. The OptEase and TrapEase filter configurations are associated with a higher incidence of caval thrombosis, which also should be evaluated critically in all implanted IVC filters. New filter designs such as the Sentry and the bioabsorbable filter may be encountered in patient care and are important to recognize because complications from these devices are and will be relatively unknown until a larger number of these filters are implanted.

This resource is meant to be used to assist in accurate identification of indwelling retrievable or convertible IVC filters to allow improved patient management for anticoagulant use and the possibility of IVC filter retrieval and removal. Reports should include accurate identification of filter type, filter position, presence or absence of thrombosis, filter tilt, and filter fracture.

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(Figures start on next page)

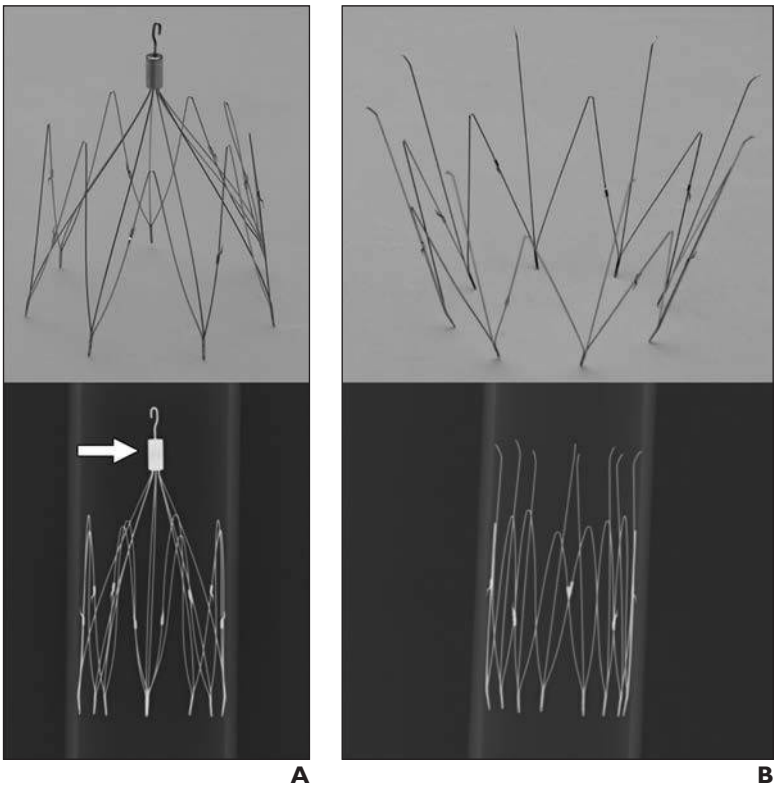


Fig. 1— VenaTech Convertible vena cava filter (B. Braun Medical).
A, Photographic (*top*) and fluoroscopic (*bottom*) images show VenaTech Convertible vena cava filter is similar to VenaTech LP vena cava filter but is secured at apex by removable head (*arrow*).
B, Photographic (*top*) and fluoroscopic (*bottom*) images of VenaTech Convertible vena cava filter converted to stent by removal of filter head.

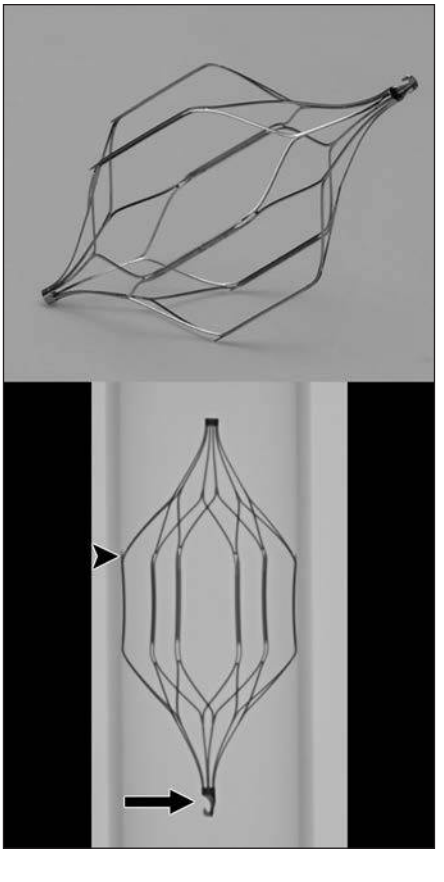


Fig. 2—Photographic (*top*) and fluoroscopic (*bottom*) images show OptEase vena cava filter (Cordis), which is nearly identical to TrapEase vena cava filter (Cordis), which is also designed as closed cage; OptEase differs in that it only has cranial fixation barbs (*arrowhead*) and adds dual prong caudal hook (*arrow*).

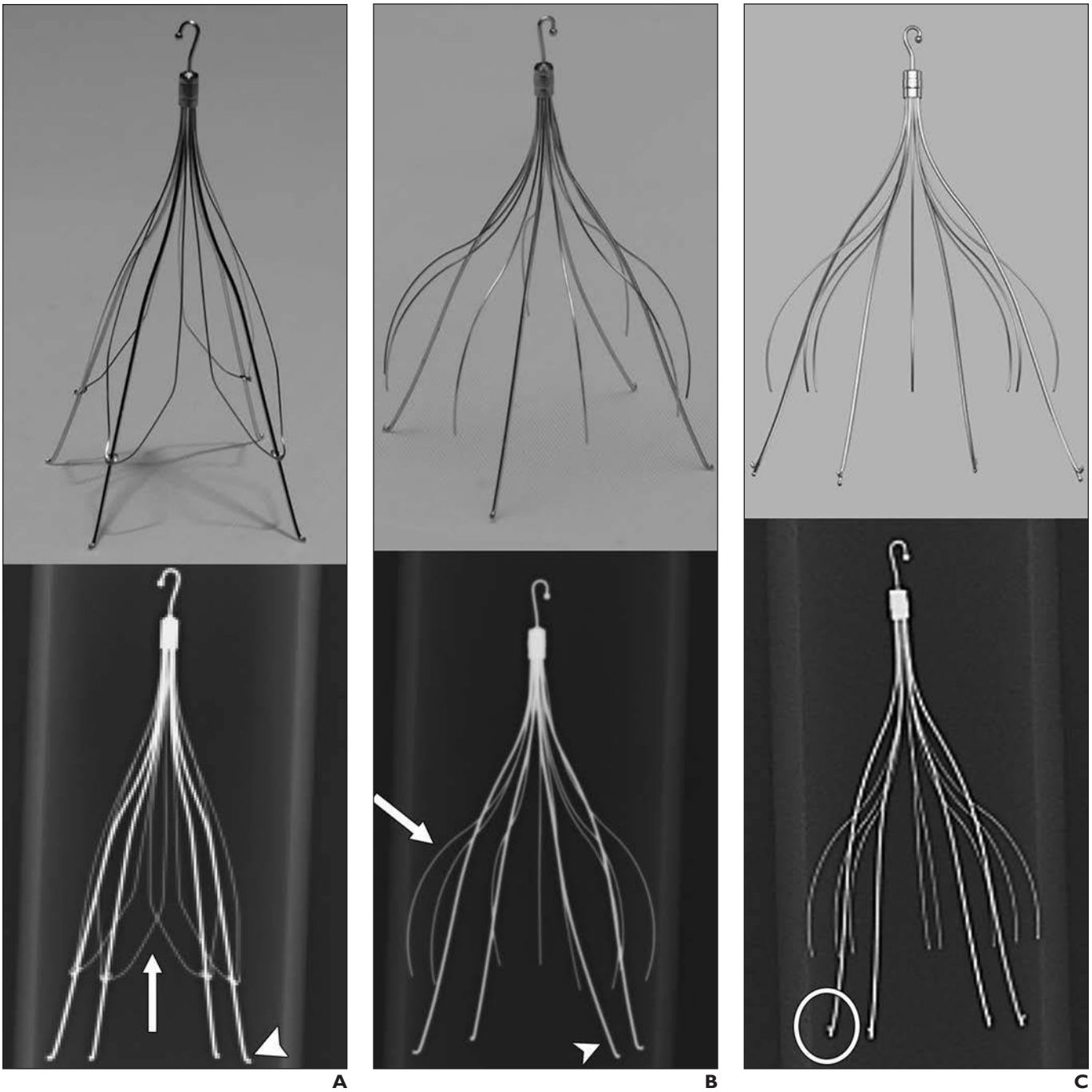


Fig. 3—Cook vena cava filters.
A, Photographic (*top*) and fluoroscopic (*bottom*) images show Günther Tulip vena cava filter with four anchoring legs (*arrowhead*), four secondary struts around each leg (*arrow*), and hook at filter apex.
B, Photographic (*top*) and fluoroscopic (*bottom*) images show Celect vena cava filter also has four anchoring legs (*arrowhead*) and eight separate arms (*arrow*).
C, Photographic (*top*) and fluoroscopic (*bottom*) images show Celect Platinum vena cava filter with modified anchoring legs (*circle*).

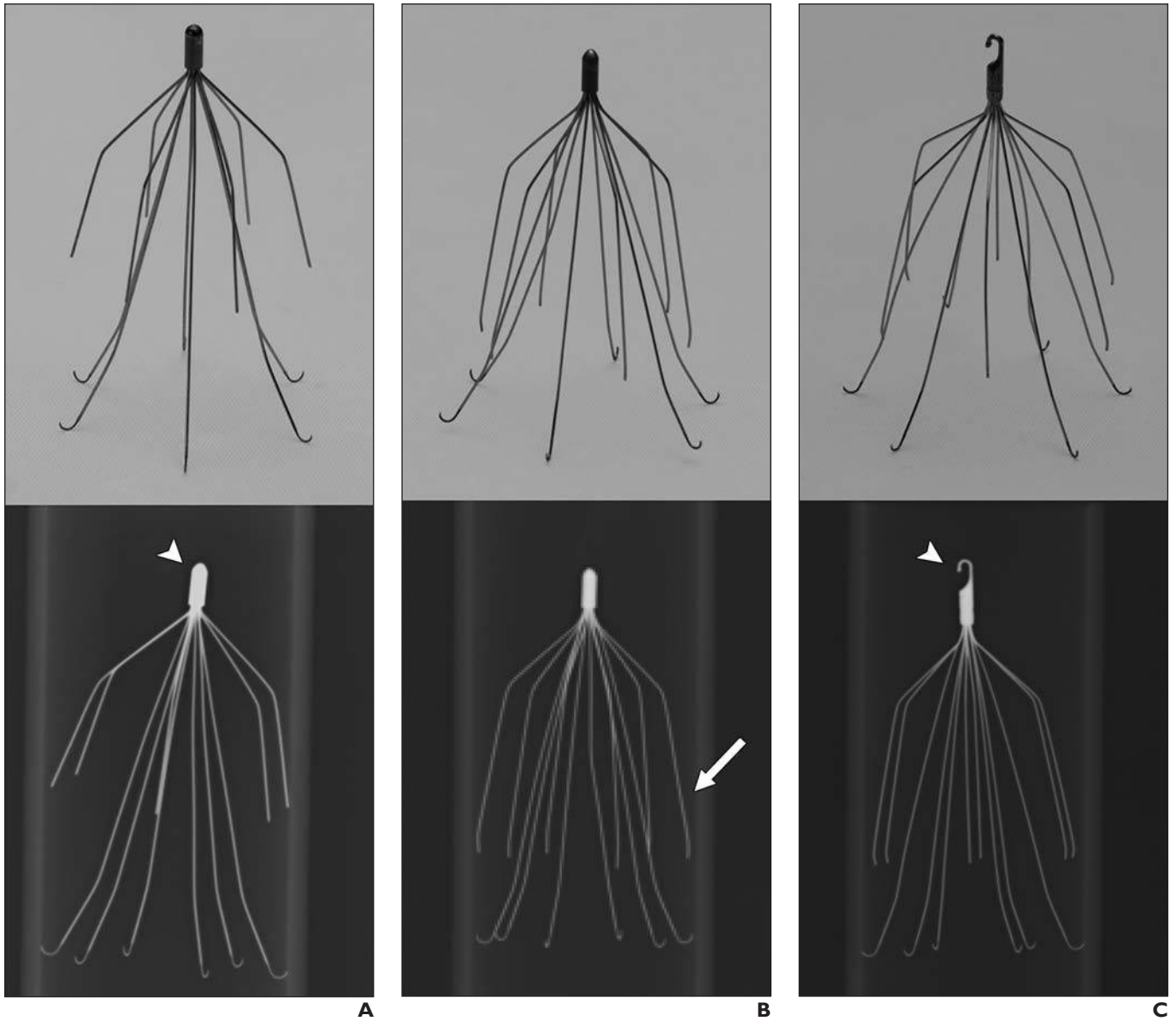
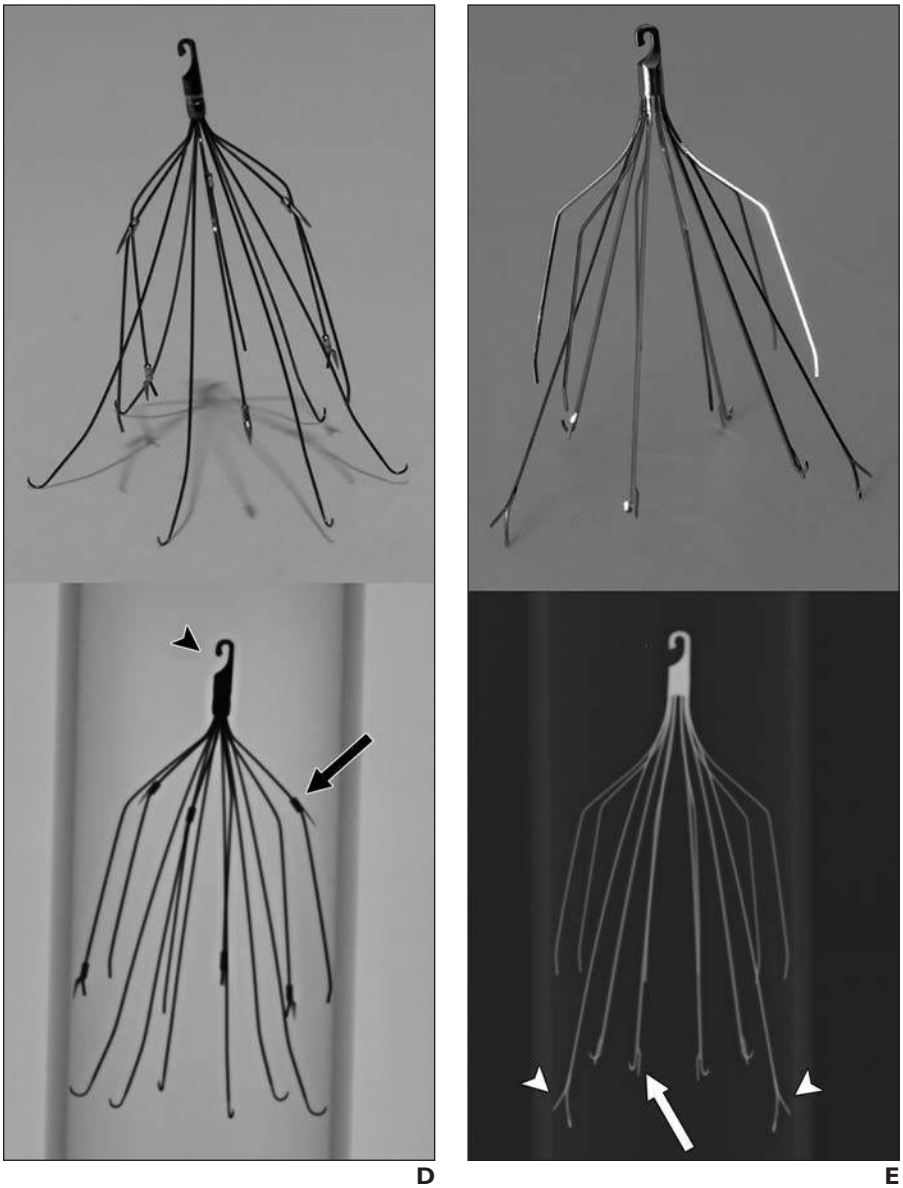


Fig. 4—Bard inferior vena cava (IVC) filters with six anchoring legs and six concentric arms.
A, Photographic (*top*) and fluoroscopic (*bottom*) images show Recovery filter, which lacks apical retrieval hook (*arrowhead*) and has short concentric arms.
B, Photographic (*top*) and fluoroscopic (*bottom*) images show G2 filter with longer concentric arms (*arrow*) and lacking apical filter hook.
C, Photographic (*top*) and fluoroscopic (*bottom*) images show G2× and Eclipse filters are similar in appearance to G2 with addition of apical filter hook (*arrowhead*).

(Fig. 4 continues on next page)



D E

Fig. 4 (continued)—Bard inferior vena cava (IVC) filters with six anchoring legs and six concentric arms.
D, Photographic (*top*) and fluoroscopic (*bottom*) images show Meridian filter with stabilization barbs (*arrow*) to concentric arms and apical filter hook (*arrowhead*).
E, Photographic (*top*) and fluoroscopic (*bottom*) images show Denali filter includes stabilization barbs to anchoring legs (*arrow*) and elongation of two of six legs (*arrowheads*).

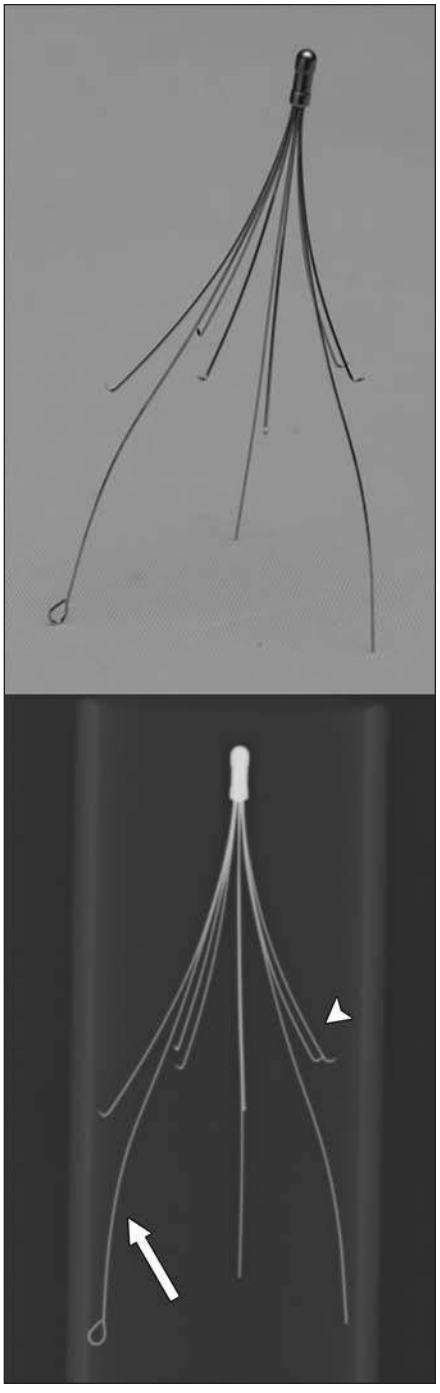


Fig. 5—Photographic (*top*) and fluoroscopic (*bottom*) images show Optional ALN vena cava filter (ALN Implants) with six short anchoring struts (*arrowhead*) and three longer centering struts (*arrow*) made from stainless steel.

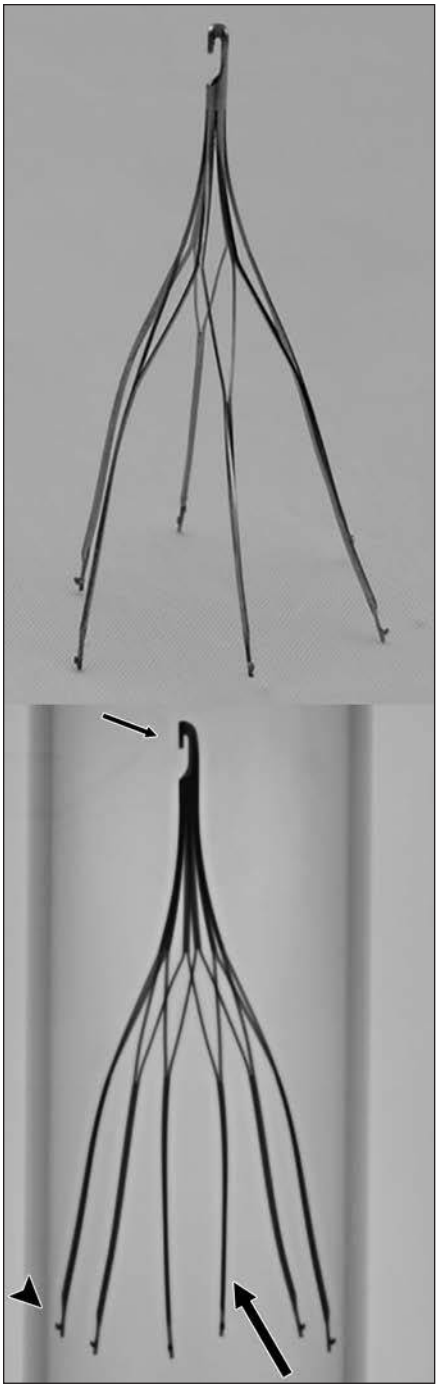


Fig. 6—Photographic (*top*) and fluoroscopic (*bottom*) images show Argon Option Elite vena cava filter (Rex Medical) has six symmetric legs (*thick arrow*) and upper interstices that converge to apex and apical retrieval hook (*thin arrow*). Option Elite also has subtle barbs at ends of filter legs (*arrowhead*).

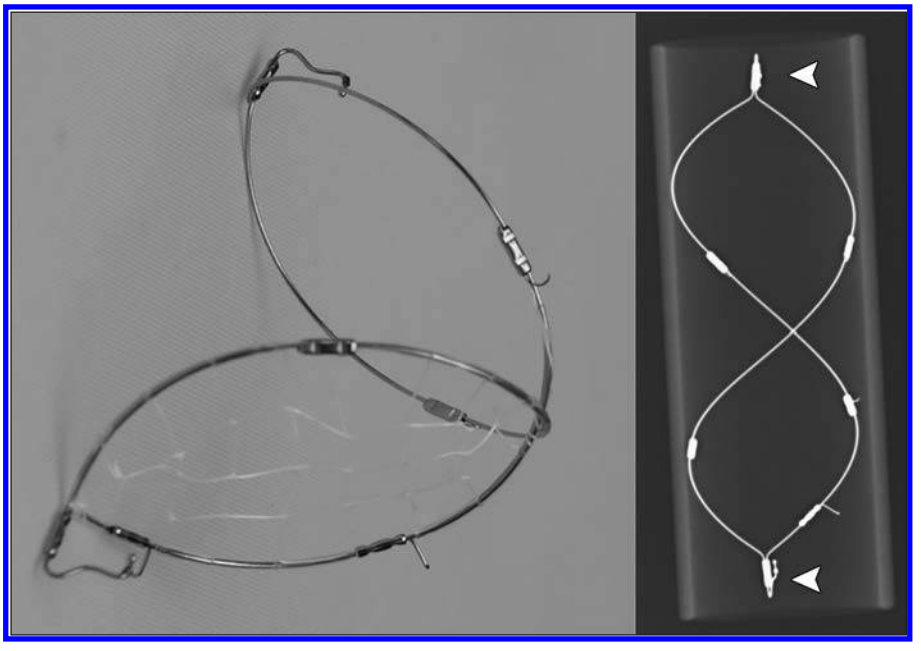


Fig. 7—Photographic (*top*) and fluoroscopic (*bottom*) images show Crux vena cava filter (Crux Biomedical) with nonconical, opposing helix design web of expanded polytetrafluoroethylene filaments in lower helix (not radiopaque). Radiopaque retrieval hooks (*arrowheads*) are present at both ends.

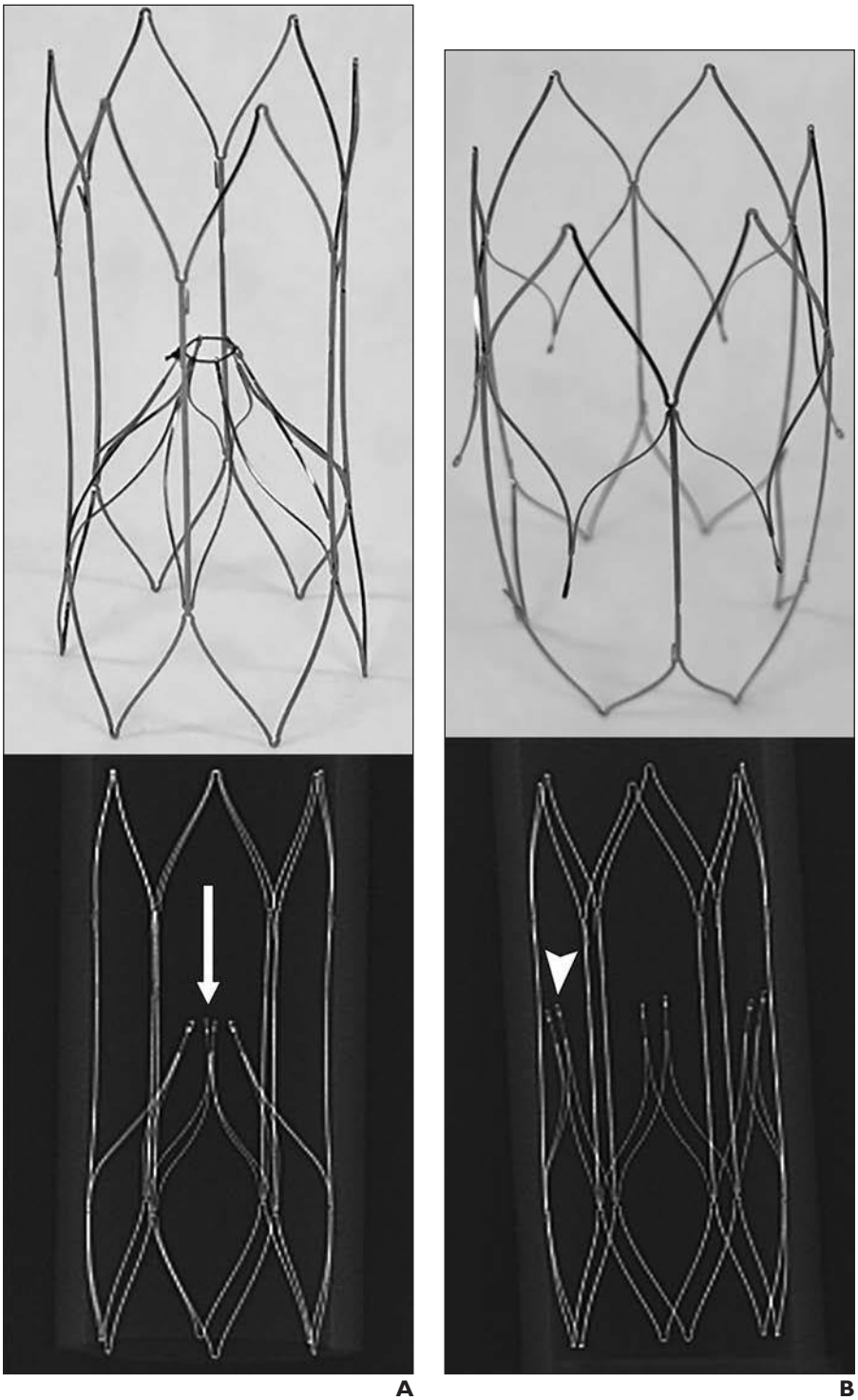


Fig. 8—Sentry device (Novate Medical).
A, Photographic (*top*) and fluoroscopic (*bottom*) images show single piece of laser-cut nickel-titanium alloy (Nitinol, Naval Ordnance Laboratory) in cylindric frame with internal filter cone consisting of six pairs of arms held together by bioabsorbable poly-p-dioxanone synthetic polymer filament (*arrow*) when in filtration configuration.
B, Photographic (*top*) and fluoroscopic (*bottom*) images show that once filament is completely absorbed, arms flare open into stent configuration (*arrowhead*).

FOR YOUR INFORMATION

The reader's attention is directed to a related article, titled "Radiologists' Field Guide to Permanent Inferior Vena Cava Filters," which begins on page 762.