CLINICAL STUDY

Endovascular Removal of Inferior Vena Cava Filters with Arterial Penetration

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ABSTRACT

Purpose: To evaluate the safety and outcomes of endovascular percutaneous removal of inferior vena cava filters (IVCFs) with elements penetrating an artery.

Materials and Methods: From an IVCF retrieval database, computerized tomographic scans of patients who underwent IVCF retrieval from 2011 to 2017 were reviewed for IVCF elements penetrating through the caval wall and into an adjacent arterial wall (AW) or penetrating into an adjacent arterial lumen (AL). Forty-two patients were identified, including 20 with elements penetrating into an AW and 22 with elements penetrating into an AL; 30 of these IVCFs were tip embedded.

Results: All of the filters in both groups were removed. Of the arterial-interacting filters, 9 were removed with the use of standard techniques and 33 with the use of endobronchial forceps. Arterial access was obtained before removal in 3 patients (7%) with post-removal arteriography revealing no abnormalities, such as extravasation, pseudoaneurysm, or new fractured components. There was no significant difference between groups in tip embedding, retrieval technique, or fluoroscopy time.

Conclusions: Endovascular removal of IVCFs with elements that have penetrated into adjacent arterial walls or lumens can be performed safely in the majority of patients.

ABBREVIATIONS

AL = arterial lumen, AW = arterial wall, IVCF = inferior vena cava filter

The majority of inferior vena cava filters (IVCFs) are designed with expandable elements that use axial force and small hooks to prevent device migration. This design may promote penetration of elements through the walls of the inferior vena cava, a finding seen in up to 19% of IVCFs and 1 that increases with longer dwell times (1). Given the proximity of arterial vasculature, penetration into these structures occurs and the optimal method for managing arterial penetration is not well established.

A wide range of management techniques have been reported in the literature, ranging from expectant management to open aortic repair (2–9). We are aware of no case series describing this finding and no subgroup analysis in the literature. Sequelae of penetration into the aorta have been described from asymptomatic and detected incidentally on imaging to published individual cases associated with development of mycotic aneurysms and periaortic abscesses (2,10,11). Given the paucity of data, the optimal management of IVCFs with penetration into adjacent arteries is unknown. The purpose of the present study was to evaluate the safety and outcomes of percutaneous removal of IVCFs that have penetrated into adjacent arterial vasculature.

MATERIALS AND METHODS

Patient Selection and Data Collection

This study was carried out in compliance with the Health Information Portability and Accountability Act and was approved by the Institutional Review Board. A review of

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From the SIR 2017 Annual Scientific Meeting.

S.O.T. receives royalties from Cook Medical (Bloomington, Indiana) and Teleflex (Wayne, Pennsylvania) and is a paid consultant for Medcomp (Harleysville, Pennsylvania), Bard Peripheral Vascular (Tempe, Arizona), Lutonix (Minneapolis, Minnesota), Cook Medical, Teleflex, W.L. Gore and Associates (Newark, Delaware), Orbimed (New York, New York), and B. Braun (Melsungen, Germany). S.W.S. is a paid consultant for Bard Peripheral Vascular and receives research funding from B. Braun, Cook Medical, and Sillajen (San Francisco, California). The other author has not identified a conflict of interest.

J Vasc Interv Radiol 2018; 29:486–490

https://doi.org/10.1016/j.jvir.2017.12.018

Figure. A 39-year-old woman with history of ulcerative colitis and large-volume deep-vein thrombosis with IVCF placed at an outside hospital 796 days before the removal procedure. (**a**) Preoperative CT angiography performed the day of removal demonstrates a Celect filter (Cook Medical, Bloomington, Indiana) with an element penetrating the aortic lumen with surrounding thrombus. The patient had been recommended to have an aortic endograft placed over the filter element and clot. She sought a second opinion. (**b**) Cavogram demonstrates a fractured tip-embedded filter. (**c**) Both common femoral arteries were accessed by means of surgical cut-down and temporarily occluded to prevent distal emboli. Aortography was performed, redemonstrating thrombus adherent to the penetrating IVCF leg. (**d**) Cavogram after endobronchial forceps removal of the IVCF and fractured elements via the right internal jugular vein demonstrates no arteriovenous fistula. (**e**) Balloon thrombectomy was attempted without success in removing the thrombus. Postoperative CT angiography demonstrates unchanged thrombus adherent in the aorta. (**f**) Patient was started on therapeutic anticoagulation with resolution of thrombus on follow-up CT angiography and no clinical sequelae during ongoing follow-up to 820 days.

patients who underwent percutaneous removal of an IVCF with elements penetrating into an arterial wall from August 1, 2011, to October 1, 2017, at a tertiary academic medical center was performed. Study subjects were identified from a dedicated prospectively acquired IVCF removal quality assurance (QA) database compiled daily from the interventional radiology division's master QA database (Hi-IQ; Conexsys, Lincoln, Rhode Island). Arterial interaction was determined by evaluating preoperative computerized tomographic (CT) imaging. Patients were classified into groups as non–arterial interacting and wall penetrating. Wall penetration was defined as the element abutting the wall without a definite intraluminal component. Lumen penetration was defined as a portion of the IVCF element visualized within the arterial lumen.

The electronic medical records and procedure notes of each patient were examined for details including technical success and complications, comorbidities, age at time of procedure, type of IVCF, placement and removal indications according to Society of Interventional Radiology Quality Improvement Guidelines, previous removal attempts, element complications, tip embedded, removal technique, contrast volume, fluoroscopy time and dose, and availability and results of follow-up CT (12). Cross-sectional imaging of the IVCF and abdomen before and after the removal procedure was reviewed and recorded.

All procedures were performed by 1 of 7 interventional radiologists (all certificate of added qualifications certified or eligible) or by trainees under the direct supervision of an attending physician, board certified or board eligible, with an average experience of 16 years (range 6–24 y). All patients were seen by the performing interventional radiologist in the outpatient clinic before the scheduled removal procedure. Patients with indwelling IVCFs for >6 months underwent preoperative CT venography. Preoperative imaging was reviewed prospectively by the performing interventional radiologist, and relevant findings, including arterial penetration and risks, described and explained to the patient and documented.

The procedures were performed on an outpatient basis under moderate sedation with combined ultrasound (US) and fluoroscopic guidance in dedicated interventional radiology suites. A single procedure (Fig) was performed in a hybrid operating suite. Early in the experience, catheters were placed in the aorta of arterially penetrated patients before filter removal to allow pre- and post-removal arteriography. In some patients, unenhanced cone-beam CT was performed after removal at the discretion of the performing provider. No dedicated postoperative imaging (CT, US, magnetic resonance imaging) was scheduled after discharge. Follow-up was performed at an office visit 1 month after the procedure or, if the patient was from a distant location, by telephone, with the telephone call documented in the medical record.

There were 42 patients with arterial-interacting components identified: 25 women and 17 men; 22 patients had components penetrating into the aortic or common iliac arterial lumen, and 20 patients had components penetrating an arterial wall without a component entering the lumen. Mean patient age was 50 years (range 20–74 y). Data from some patients (n = 32) in this study have been previously reported, but detailed analysis regarding arterial interaction was not previously performed (13,14).

The majority of IVCF placements were in patients with known deep vein thrombosis or pulmonary embolism, as opposed to prophylactic indications (Table 1). All IVCFs were located in the infrarenal inferior vena cava. Retrieval indications varied, as presented in Table 1, with symptoms of pain prompting a filter retrieval attempt in 7 lumen-penetrating (7/22, 32%) and 4 wall-penetrating (4/20, 20%) cases. Failed retrieval attempt at an outside facility had occurred in 4 patients (4/22, 18%) in the lumen-penetrating group and 14 patients (14/20, 70%) in the wall-penetrating group. Preoperative CT imaging findings are detailed in Table 2.

The retrieval procedure began with magnified spot radiographs, frontal and both obliques, of the IVCF to evaluate for interval fracture. Next, the right internal jugular vein was accessed with the use of the micropuncture technique, and a flush catheter was placed and rotational cavography performed to evaluate for IVCF position and caval thrombus. Subsequent technique was then tailored based on whether IVCF was tip or wall embedded, in which case endobronchial forceps (no 4162; Lymol Medical, Woburn, Massachusetts) were used through a 16-F sheath (15). IVCFs that were not tip or wall embedded were removed with the use of a snare or Recovery Cone (Bard Peripheral Vascular, Tempe, Arizona) through a 12–16-F sheath. No other devices were used for removal. Following removal, IVCFs were visually inspected for fracture and integrity. Intravascular fragments, if present, were attempted to be removed with the use of the endobronchial forceps if in the inferior vena cava and with the use of a snare if in the pulmonary arteries or heart. A venogram was then performed and the sheath removed, and hemostasis was attained at the access site with manual pressure.

Table 1. Patient Demographics

Characteristic	Wall penetrating	Lumen penetrating
Sex		
Male	10	7
Female	10	15
Age (y)	45 (20–66)	52 (29–74)
Dwell time (d)	782 (98–3,336)	1,867 (3–5,110)
Filter type		
Cook Günther Tulip*	0	3
Cook Celect*	9	7
Bard G2†	4	6
Bard Recovery†	0	1
Bard Eclipse†	6	5
Bard Meridian†	0	0
Bard Denali†	0	0
Option‡	1	0
Placement indication		
Therapeutic	17	16
Prophylactic	3	6
Retrieval indication§		
Resolution of high-risk factors	6	9
Therapeutic on anticoagulation	13	11
Pain/symptoms attributed to IVCF	4	7

*Cook Medical, Bloomington, Indiana.
†Bard Peripheral Vascular, Tempe, Arizona.
‡Argo, Plano, Texas.
§Values are not additive owing to multiple possible retrieval indications for each patient.

Data Interpretation and Statistical Analysis

Statistical analysis was performed with the use of SPSS statistical software (version 18; SPSS, Chicago, Illinois). Median and range was used to report central tendency in non-normally distributed variables. Mean and range was used to report central tendency in normally distributed variables, including patient age. Categoric variables were analyzed with the use of the chi-squared test and Fisher exact test as appropriate with sample size. Continuous variables were analyzed with the use of a two-sided Student *t* test or analysis of variance as appropriate. The significance level was defined as $P < .05$ with the use of two-tailed tests.

RESULTS

Technical success, defined as removal of the main filter body, was 100% with no immediate complications. Eighteen intravascular fragments were removed and 9 extravascular fragments remained; 1 fracture was associated with element aortic penetration and was removed successfully. One patient who had been noncompliant with anticoagulation developed abdominal pain and was found to have new iliocaval thrombosis (not at the removal site), small

Table 2. Preoperative CT Findings

Finding	Wall penetrating	Lumen penetrating	*P* value
Outside hospital removal attempted	70% (14/20)	18% (4/22)	.046
Tip embedded	75% (15/20)	73% (16/22)	1.0
CT findings			
1 element penetrating aorta	11	14	–
2 elements penetrating aorta	4	1	–
>2 elements penetrating aorta	2	1	–
1 element penetrating a common iliac artery	2	4	–
2 elements penetrating a common iliac artery	0	2	–
1 element penetrating a common iliac artery and 1 element penetrating aorta	1	0	–

Table 3. Retrieval Details

Parameter	Wall penetrating	Lumen penetrating	*P* value
Retrieval technique*			
Snare	3	3	1.0
Endobronchial forceps	16	17	1.0
Recovery Cone	1	2	1.0
Fluoroscopy time, min (at 7.5 pulses/sec)	10.6 (3.3–37.2)	7.8 (3.1–58.1)	1.0
Fluoroscopy dose, mGy	490 (187.1–2027)	393 (62.4–1129)	1.0
Contrast volume, mL	65 (30-120)	60 (10-200)	1.0
Patient follow-up, d	33 (1–1076)	73 (1–1566)	1.0

Note–Values are presented as n or median (range).
*Values are not additive owing to multiple possible retrieval techniques for each patient.

pulmonary emboli, and a small asymptomatic aortic intramural hematoma incidentally identified on CT in the follow-up period. No other patients developed immediate or delayed complications. Mean follow-up was 10 months (range 0–52; Table 3). There was no significant difference in removal technique, fluoroscopy time, or contrast volume between arterial lumen–penetrating and arterial wall–penetrating retrievals (Table 2). There was a significant difference in outside hospital retrieval attempts, with wall-penetrating IVCFs having significantly more attempts than lumen-penetrating (Table 2). One patient in the wall-penetrating group had carbon dioxide used as the contrast agent. Patients were not started on anticoagulation unless recommended by their referring clinician or, in the unusual circumstance of aortic thrombus, as detailed below.

Simultaneous arteriography was performed in 3 different patients, all with lumen-penetrating IVCFs. Two of these patients demonstrated no findings of arteriovenous fistula or pseudoaneurysm after IVCF removal. The third procedure with arterial access was performed in a hybrid operating room because of a known clot demonstrated on the IVCF leg within the aortic lumen on preoperative CT imaging (Fig).

Following IVCF removal, cavography was performed in all patients in accordance with departmental protocol; post-retrieval cavography was not performed in routine removals, because it has been shown not to change the management (16). Four patients (4/22) in the lumen-penetrating group had post-retrieval noncontrast cone-beam CT performed, demonstrating no findings of hematoma or other abnormality. No patient in the wall-penetration group had post-retrieval cone-beam CT performed.

DISCUSSION

Retrievable IVCFs are increasingly recognized as devices that should be used for finite periods in carefully selected patients (17–19). Complex IVCF retrievals, including those with tip embedding and element penetration, are increasingly performed with high technical success rates (14,20–24). The typical location of IVCFs in the infrarenal inferior vena cava may predispose to complications with element penetration owing to the proximity of adjacent structures (1,25,26).

IVCF penetration into adjacent bowel and organs is a well described complication, but penetration into adjacent high-pressure arterial structures poses unique management challenges. Scattered case reports in the literature describe a variety of management techniques, including 5 cases using laparotomy, 1 case in which the IVCF was left in place, 1 case in which the IVCF was removed with simultaneous aortic endograft placement, and 2 cases in which the IVCFs were removed percutaneously (5–9). In 1 case with endovascular retrieval, the aortic-penetrating component

fractured and embolized distally during the removal procedure; the fragment was then captured and removed by means of arterial access (27). This highlights the need for diligence during filter retrieval, including detailed gross inspection of the IVCF after removal to ensure that fractures occurring during retrieval are detected.

The present case series demonstrates high success and safety of percutaneous removal of IVCFs penetrating into adjacent arterial vasculature. Of the 7 patients with immediate post-removal imaging (3 arteriography, 4 cone-beam CT) no complications were identified. In the single patient (**Fig**) with intra-aortic thrombus identified on preoperative imaging, the pre- and post-removal arteriograms were identical as well. As a result, the vast majority of procedures in this study were performed without arterial access. The safety of this approach is demonstrated by the lack of clinically significant sequelae on postoperative imaging or during the follow-up period.

There are limitations to this study. As with any retrospective analysis, selection bias may have been present based on referral. In addition, this is a small study, so a true determination of safety can only be suggested. Several patients did not receive long-term follow-up owing to the tertiary referral nature of our IVCF removal practice, and long-term follow-up, although systematically attempted, was not always available and patients may have experienced delayed complications not captured in this study. The IVCF removals were performed by a highly experienced team, and the results demonstrated here may not be applicable to other practices. Not all commercially available IVCF types were included in this series (**Table 1**), and thus the results may not be generalizable to all IVCFs.

In conclusion, endovascular removal of IVCFs with elements that have penetrated into adjacent arterial vasculature may be performed safely and successfully, often without simultaneous arteriography if no related arterial complications, such as thrombus, are identified on preoperative imaging.

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