Chronic Inferior Vena Cava Filter-Related Occlusion: Presentation, Diagnosis, Management, and Controversy

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Abstract

Inferior vena cava filters (IVCF) are caval interruption devices designed to decrease the incidence of pulmonary embolism by capturing thrombus in-transit. Rare, long-term complications of IVCF include fracture, migration, caval perforation, recurrent deep venous thrombosis (DVT) and IVCF-related caval occlusion. Chronic IVCF-related caval occlusion is a challenging complication with a variable presentation, potential for significant morbidity, and limited evidence guiding management. In symptomatic patients, first-line treatment includes endovascular caval reconstruction utilizing various techniques including, venoplasty, thrombolysis, thrombectomy and/or stenting with or without removal of indwelling IVCF.

Keywords

vascular Imaging Modalities (VIM), ultrasound instruments (UI), Healthcare (HC), Technology (T)

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Inferior vena cava filter (IVCF) placement underwent dramatic growth in the United States during the mid-1990s and 2000s until a 2010 Food and Drug Administration advisory related to the safety of unremoved retrievable IVCFs was issued [1]. This resulted in a rapid decline in the number of filters placed [2, 3]. IVCFs removed within 90 days are generally considered safe with low complication rates [4-6]. Long-term complications of IVCF include fracture, migration, caval perforation, recurrent deep venous thrombosis (DVT), and IVCF-related thrombotic occlusion [7, 8]. Prompt IVCF removal is recommended once the indication for placement has resolved [9, 10]. One challenging complication of IVCFs is chronic caval occlusion, which has a variable clinical presentation. Symptomatic, chronic IVCF-related caval occlusion is associated with significant morbidity [11, 12]. First line treatment is endovascular caval reconstruction. Open surgical techniques are not generally considered due to high periprocedural morbidity. This article will review the presentation, diagnosis, management, and controversy surrounding chronic IVCF-related caval occlusion.

EPIDEMIOLOGY

Incidence of IVCF-related caval occlusion varies with reported rates ranging from 1.1% to 10.8% [13, 14]. Increased utilization of computed tomography (CT) is leading to increased detection of asymptomatic IVCF-related thrombosis and occlusion [15, 16]. Filter-related IVC occlusion is typically considered a delayed complication with onset reported to be between 6-24 months [17, 18]. The risk of thrombosis and occlusion increases with increased duration of implantation [19, 20]. The primary mechanism of filter-related IVC occlusion is thrombus formation and/or accumulation with resultant endothelial damage and narrowing[21]. Thrombus may represent captured thrombus in-transit versus in situ thrombus formation [22]. It is suggested, but not proven, that IVC filters are inherently thrombogenic [23]. The determination of whether IVCF thrombus is formed *in-situ* or represents successful capture of clot-in-transit is difficult [24].All filter types have been implicated in IVC thrombosis and occlusion with some studies reporting increased rates of thrombosis and occlusion in bi-conical (TrapEase and OptEase) filter designs [25, 26]. Overall, studies regarding the true incidence of filter-related caval occlusion are underpowered and inconclusive, especially given the potential prevalence of undetected asymptomatic occlusion.

CLINICAL PRESENTATION

IVCF related chronic occlusion symptoms are largely dependent on the extent of thrombosis or occlusion. While acute caval occlusion can be highly symptomatic, many patients with chronic IVCF-related thrombosis and occlusion are asymptomatic due to the development of robust collaterals [27]. Collaterals are inherently smaller in caliber compared to the native vessel, decreasing conductance in accordance with Poiseuille's law, which states that conductance is an exponential function of vessel diameter [28, 29]. This causes venous hypertension, increasing the risk for thrombus formation [30]. Symptoms can develop if the occlusion extends distally and may cause back or pelvic pain, lower extremity edema and venous ulcers [31]. Severe cases may result in the development of *phlegmasia cerulea dolens*.

DIAGNOSTIC EVALUATION

The mainstay of diagnosis is non-invasive imaging, including: ultrasound (US), contrast-enhanced computed tomography (CECT), and magnetic resonance venography (MRV) with or without intravenous contrast. Invasive venography is generally only performed prior to intervention [32].US is usually appropriate as a first-line screening modality as it is quick, readily available, non-ionizing, does not require contrast, and is less costly [33]. US limitations include variability in diagnostic utility due to operator-dependence and patient factors including body habitus and overlying bowel gas [34]. CECT is an excellent diagnostic modality due its high contrast and spatial resolution. Compared to US and MRV, CECT is the most reproducible modality amongst institutions and offers numerous reformats for preoperative planning. CECT can provide clues to thrombus etiology by depicting additional abdominal and pelvic pathology. CECT is particularly helpful for these patients with IVCFs as there is less artifact compared to MRV [35]. MRV is somewhat limited due to susceptibility artifact from the indwelling filter. MRV can also be limited by availability, variable quality, and costs. MRV is still useful for evaluating the abdomen and pelvis for additional pathology as well as the IVC and pelvic veins inferior to the filter [36].

Although these are all reasonable diagnostic modalities, chronic filter-related caval thrombosis is most commonly diagnosed on CT. Common findings of chronic caval filter-related occlusion include diminutive IVC below the level of the filter with robust collateralization. Expanded, thrombus filled IVC without prominent collaterals is suggestive of acute caval occlusion. Tumor thrombus can be distinguished from bland thrombus in the presence of a contiguous adjacent mass with arterially enhancing filling defects [37]. Catheter venography is the historical gold standard and carries the advantage of being able to quickly convert from diagnostic venography to intervention, if needed. Venography accurately identifies location and degree of occlusion/stenosis, collaterals, thrombus, tumor proliferation, congenital variants, and physiologic flow information. The addition of intraluminal cross-sectional imaging with intravascular ultrasound (IVUS), discussed further in the technical section, allows for three-dimensional evaluation of the vessel, delineation of stenosis, non-occlusive thrombosis, and intraluminal filling defects that may be missed on venography alone.

RATIONALE FOR INTERVENTION

Chronic thrombus causes luminal stenosis and stasis, increasing risk of recurrent DVT. In alignment with the open vein hypothesis, long term outcomes may be improved by more aggressive treatment [38]. Chronic thrombus is fibrotic and collagen rich and typically more difficult to remove compared to acute thrombus [39]. Management of chronic non-filter-bearing IVC thrombotic occlusion with endovascular techniques is well-studied [40]. The presence of a filter should not deter endovascular intervention based on concern for complications such as filter damage, migration, or caval wall penetration [41]. IVCF damage during endovascular intervention with clinically relevant complications is rare. Arabi, et al. included 44 patients who underwent endovascular treatment for IVCF associated with iliocaval thrombosis, during which 14 IVCFs were damaged without related secondary complications. The remaining IVCFs were deformed but remained intact. Evidence for management of IVCF-related caval occlusion is limited to small single-center case series and case reports.

TECHNICAL CONSIDERATIONS

Informed Consent: Informed consent is an essential component of all procedures. Key issues to discuss with patients presenting for IVCF-related caval occlusion center around the multiple intraoperative decisions that are made and their implications. These include the potential for numerous venous access sites, some of which way be large-caliber, the use of intraoperative thrombolytics, energy devices, and stent placement. Additionally, it is important to discuss postoperative care, including the need for antithrombotic medications, surveillance, risk of reintervention and post-thrombotic syndrome.

Anesthesia: Our preference is to perform complex caval interventions under monitored anesthesia care provided by an anesthesiologist [42]. Due to the anticipated long procedure duration and increased procedural complexity, an independent provider managing sedation is optimal for patient safety and comfort.

Vascular Access: The goal in venous interventions for DVT is to access normal veins above and below the thrombosed segment to optimize inflow and allow adequate treatment of the entire thrombosed segment. Pre-procedure imaging is utilized to determine the full extent of the thrombosed segment and facilitate procedural planning.

Typical access points include the right internal jugular vein, popliteal vein, common femoral vein, posterior tibial vein, or anterior tibial vein, with the most common being the popliteal vein. In cases where thrombus is limited to the IVC or iliac veins, common femoral vein, or great saphenous vein access is preferred over more peripheral sites for a multitude of reasons including more favorable push ability of devices through the occlusion and smaller volume of contrast agent required for venography. The relatively long distance between a popliteal access site and the IVC may necessitate a long sheath for additional support and push ability during guidewire/catheter manipulations. Longer sheaths are beneficial for performing follow-up venography closer to the level of the occlusion and to allow the use of less contrast agent. Issues related to working length restrictions may arise with more peripheral access sites, as preferred equipment may not be long enough to reach the cranial aspect of the IVC occlusion.

Crossing Techniques: In many cases of chronic obstruction, more than one access point may be required for “through-and-through” access. IVC occlusions related to indwelling filters can be particularly challenging to cross and crossing the filter-bearing segment may necessitate additional access. In cases where there is difficulty crossing the occlusion with a guidewire from an antegrade approach, a retrograde approach with access from the internal jugular vein may be more successful. In other cases, the occlusion may be crossed by the antegrade approach guidewire, but the catheter may not track past the filter-bearing segment. The antegrade guidewire can be snared from an internal jugular access point with the resultant “through-and-through” guidewire providing appropriate traction to allow the catheter to cross [43].

More advanced techniques can be used in an escalatory fashion, including controlled antegrade and retrograde subintimal tracking (CART), reverse CART, and balloon-assisted sharp recanalization using colapinto needle, transeptal needle or back-end of a stiff glide wire have been described but are beyond the scope of this review [44]. Radiofrequency (RF) wires have been proposed as a technique for refractory IVC occlusion [45]. This is a powerful technique with ability to recanalize vessels in other parts of the body, however, the IVC is particularly challenging due to its long length, proximity of critical structures, and constant destabilization of the RF wire due to cardiac motion [46].

Ensuring intraluminal tracking is critical during complex recanalizations. Large collateral vessels, such as lumbar veins, may be present and could complicate recanalization. For this reason, multiple obliques, IVUS, and cone-beam computed tomography may be utilized to ascertain the course of the vein and catheter within the chronically occluded cava.

Intraoperative Anticoagulation: Patients are typically transitioned or started on a continuous heparin infusion preoperatively. Heparin is held approximately one hour prior to the procedure. Intra-procedurally, patients are systemically anticoagulated with 80-100 units/kg of unfractionated heparin prior to venoplasty and stenting after crossing the occluded segment[44]. Activated clotting times are not routinely obtained. Postoperative antithrombotic management is discussed in a later section.

Restoration of Inline Flow: Techniques for restoring inline flow include thrombolysis, thrombectomy, venoplasty, and stenting.

Catheter directed thrombolysis (CDT) is more effective in acute thrombus and is not adequate for chronic thrombus [47, 48].

Mechanical thrombectomy devices have been successfully used in the treatment of acute iliofemoral DVT, with advantages including reduced thrombolytic dose, rapid restoration of a flow channel, and shortened lysis infusion times. Additionally, mechanical thrombectomy devices have shown promise in removing chronic thrombus.

Venoplasty plays an important role allowing for maceration of thrombus, disruption of neointimal hyperplasia, and restoration of luminal diameter [49]. Balloon maceration of thrombus creates a flow channel[29]. Aggressive venoplasty is often required in cases of chronic occlusion in order to enlarge the lumen sufficiently to pass additional devices. Typically, the balloon is upsized by 25%, breaking any synechiae associated with chronic thrombotic changes. Venoplasty along the filter-bearing segment poses risks of balloon rupture, filter deformation and filter fracture and should be avoided if possible. Venoplasty of the filter-bearing segment is typically performed following filter removal. High-pressure, rupture-resistant balloons are recommended [50].

Particular challenges should be noted regarding thrombus removal in cases of chronic occlusion and in patients with indwelling filters. The population of patients with indwelling filters may be inherently hypercoagulable. More thrombus may be visualized within the filter-bearing segment after initially thrombectomy or venoplasty, possibly related to embolization of chronic thrombus into the filter from lower extremity or pelvic sources and subsequent active thrombus deposition due to slow flow. Filter struts may limit thrombus maceration due to impeded access of thrombectomy devices and balloons to certain portions of the vessel. Further, chronic thrombus may be resistant to complete removal [51].

Intravascular Ultrasound. Intravascular ultrasound (IVUS) provides intraoperative cross-sectional images of the blood vessels [52]. Routine use of IVUS in venous interventions is a debated topic, however, its utilization is increasing. It is useful for characterization of stenosis (intrinsic vs. extrinsic and degree of compression); thrombus burden, location, and composition; and stent sizing and deployment [53]. It can reduce procedural time, intravascular contrast dose, and radiation exposure[53]. In the setting of chronic IVCF caval occlusion, IVUS can also be used to confirm in-line wire access through occluded segments or collateral pathways [54]. Additionally, it is useful to determine thrombectomy endpoints and assess residual stenosis post angioplasty and stenting [55].

TO REMOVE OR NOT TO REMOVE

Rationale. Vessel patency is a function of proper inflow, outflow and avoiding intraluminal obstruction. Following these principles, the removal of an IVCF alone in a chronically occluded cava will not restore vessel patency. Therefore, caval reconstruction is the standard of care for symptomatic IVCF-related thrombosis/occlusion [56].

Figure 1. IVC filter retrieval and caval stent placement. IVC Option Elite filter placed 7 years prior for retroperitoneal mass with associated iliofemoral and caval thrombus with contraindication to anticoagulation. Patient presented 7 years later with bilateral lower extremity swelling. Initial cavogram during IVC filter retrieval (panel a) demonstrates chronic appearing occlusion of the IVC below the filter. Unable to be removed using snare, endobronchial forceps (panel b) were used to remove the filter. Shortly after, the patient was taken for venography which demonstrated multifocal severe stenoses of the infra-renal IVC (panel c). Through and through access was obtained from the internal jugular and common femoral veins followed by serial multistation venoplasty of the stenotic segments (panel d). Post venoplasty venography demonstrated brisk outflow with persistent focal stenosis (panel e). Symptoms did not improve therefore two overlapping Cook Z-stents were placed with brisk outflow and resolution of residual stenosis (panel f).

The question becomes: how to approach the IVCF? The IVCF must either be removed or excluded in order to restore luminal patency and inflow to decrease the risk of in-stent thrombosis and occlusion. The presumed risks associated with intervening on the filter-bearing IVC include IVC rupture and IVCF fracture, increasing the risk for subsequent pulmonary embolism [57]. Venoplasty alone has limited efficacy in the setting of chronic thrombotic occlusion due to venous recoil, low flow, and endothelial damage, increasing the risk of re-thrombosis and occlusion. Therefore, caval stenting is required to maintain luminal diameter [58].

Evidence. Data for caval stenting in filter-related occlusion is limited to predominantly single center, retrospective studies [59]. An expert panel in a 2021 report recommended iliocaval reconstruction in the setting of IVCF-related caval occlusion but did not reach consensus regarding IVCF removal versus stent exclusion. There are several factors to consider in caval stenting. Long segment occlusion or extensive thrombus may require stenting across one or both renal veins[8]. The covered portion of the stent grafts may cover collateral pathways and inappropriately sized grafts may result in redundant material within the vessel lumen, increasing thrombogenicity.

In an early study from 2003, Vedantham et al. reported 7 cases of balloon exclusion and stent placement within an occluded filter-bearing IVC. One filter fractured during exclusion without clinical sequelae and there was no evidence of filter propagation or caval perforation. Ye et al. described successful stenting across a filter-bearing cava in 24 patients with severe PTS using wallstents (Boston Scientific) and Luminexx stents (BD Interventional). Neglen et al. described successful stenting across occluded filter-bearing cava in 25 patients. Wallstents were used in all patients. In a regression model comparing caval stenting in filter-bearing IVCs vs. non-filter bearing IVCs, postoperative patency rates were most influenced by the severity of post-thrombotic disease rather than the fact that a filter was stent excluded. Additionally, 36% of patients developed in-stent stenosis or occlusion requiring re-intervention[58].

Erben et al. [57]described successful caval reconstruction in 25 patients with IVCF-related chronic cava occlusion. All IVCF were stent-excluded, none were removed. Several different types of stents were used in the IVC, including Wallstent, Z-stent (Cook Medical), and Protege (Medtronic). Raju et al. evaluated outcomes of IVC stenoses and occlusions. They report a 67% (14/21) success rate for the recanalization of occluded IVCs, including nine cases (100% success) that required stenting across an IVCF. Wallstents were used in all cases. Chick et al. analyzed results from 120 patients with filter-related caval thrombosis. IVC reconstruction utilizing stents was successful in all patients, with IVCFs removed in 24% of patients and excluded in 76%. They report 96% clinical success at 6 months and 87.2% at 2 years, with no difference in success rates between IVCF removal and exclusion groups. Significant complications related to IVC filter exclusion (i.e. caval rupture, perforation, PE etc) are rare and should be considered in comparison to the risk profile associated with IVC filter retrieval - in particular, advanced retrievals associated with long-term, permanent, or tilted filters[60].

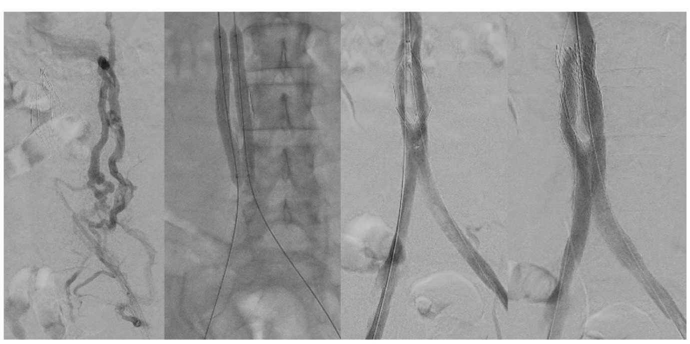

Figure 2. TrapEase IVCF placed approximately 20 years ago complicated by chronic IVC and iliac vein occlusion (panel a). The filter was unable to be retrieved despite multiple advanced techniques, including forceps and laser sheath (not pictured). Bilateral antegrade access across the filter was obtained and serial venoplasty of the bilateral iliac limbs and cava performed (panel b). Post venoplasty venogram demonstrated improved, but sluggish, outflow (panel c). Double barrel Abre venous self-expanding stents were deployed across the excluded filter with brisk outflow (panel d).

Additionally, no studies included in this review reported a difference in patency rates of iliocaval reconstruction between retrieved and excluded filters. Development of in-stent stenosis/occlusion in these patients would likely require re-intervention. Postoperative antithrombotic management is separately discussed.

Advanced retrieval techniques are commonly needed with bi-conical filters, significant filter tilt, embedded filter tip, significant strut penetration, or prolonged dwell time [61]. In light of this, it is this group's opinion that IVC filter retrieval should be attempted if possible; however, special consideration should be given if a retrieval is deemed too high risk or standard and feasible advanced techniques are not successful.

IVC FILTER REMOVAL

Advanced retrieval maneuvers may be employed after failure of the standard snare and sheath method and can include the loop-snare technique, the Hangman technique, endobronchial forceps-assisted technique, balloon displacement, and laser sheath-assisted technique [62]. Caval occlusion is a common reason for requiring advanced techniques [63].

Endobronchial forceps may be used to remove embedded filters, with a success rate of 96.7% and complication rate of 6.7% [64]. Laser-sheaths may be advantageous in cases where filter-retrieval is refractory to high-force retrieval attempts, in which added force would pose a risk of device deformity, filter breakage, or vessel injury. Of note, laser sheaths are not available worldwide. A prospective study by Kuo et al. that included 500 patients who underwent laser-assisted filter retrieval found a 99.4% success rate. Their protocol involved removal of chronic thrombotic material by atherectomy or balloon venoplasty [65]. Three retrieval failures were due to calcified thrombus within the cylindrical components, which was refractory to thrombectomy and prevented the filter from being captured into the sheath. The major complication rate was 2.0%, including three cases of IVC hemorrhage due to factors that prevented the laser sheath from being centered within the IVC [66].

CAVAL STENTING

There are currently 3 stents approved for use in the iliac and femoral veins (Venovo, BD Interventional; Zilver Vena, Cook Medical; and Abre, Medtronic). There is currently no stent on the market approved for use in the IVC. Various stents have been used off-label with the Wallstent and Z-stent being the most commonly reported in the caval stenting literature. Special consideration is made for stenting of the suprarenal cava and iliofemoral disease, which is beyond the scope of this article [67, 68].

POSTOPERATIVE MANAGEMENT

Antithrombotic Management. There are no large prospective randomized controlled trials regarding antithrombotic therapy after venous stenting [69]. Most practice patterns are derived from the arterial literature. Milinis et al.[70] surveyed multiple endovascular specialties and found a general consensus. They report that anticoagulation is preferred 6-12 months following venous stenting and lifelong anticoagulation is reserved for those with recurrent DVT. Antiplatelet therapy after stent placement for thrombotic disease decreases risk of in-stent restenosis [71]. A recent systematic review of antithrombotic therapy following venous stent placement for thrombotic disease recommended direct-acting oral anticoagulant (DOAC) and daily aspirin (81mg) or clopidogrel (75mg) for 6-12 months following stent placement[67]. In patients with contraindication to DOACs, warfarin can be used. In patients with recurrent DVT or complicated hematologic conditions, hematology consultation is recommended given their likely need for long-term antithrombotic management.

Surveillance Imaging. Routine imaging after caval stenting is variable. Ultrasound is the most commonly used modality and is performed at variable intervals - typically within 1 month after the procedure followed by 3, 6, and 12 month follow-up. CT venography can also be considered.

CONCLUSIONS

Symptomatic, chronic IVCF-related caval occlusion is associated with significant morbidity. Management of chronic IVCF-related caval occlusion is complex with a relative paucity of high-level evidence. First-line treatment in symptomatic patients is endovascular caval reconstruction. Numerous techniques can be implemented and used in combination with the goal of recanalizing the vessel, restoring luminal diameter and in-line flow.

Techniques include thrombolysis, venoplasty, thrombectomy and stenting with or without removal of indwelling IVCF. This group's opinion is that IVCF retrieval should be attempted if possible, but avoided if retrieval is deemed too high risk or standard and feasible advanced techniques are not successful. Iliocaval reconstruction should be performed in all symptomatic cases.

REFERENCES

1. E. J. Keller and R. L. Vogelzang, "Providing context: medical device litigation and inferior vena cava filters," in *Seminars in Interventional Radiology*, 2016, vol. 33, no. 02: Thieme Medical Publishers, pp. 132-136.
2. E. Morris, R. Duszak Jr, A. K. Sista, J. Hemingway, D. R. Hughes, and A. B. Rosenkrantz, "National trends in inferior vena cava filter placement and retrieval procedures in the Medicare population over two decades," *Journal of the American College of Radiology,* vol. 15, no. 8, pp. 1080-1086, 2018.
3. "Food and Drug Administration. Removing Retrieval Inferior Vena Cava Filters: Initial Communication. ," Published onlineAugust 9, 2010.
4. J. Brown, D. Raissi, Q. Han, V. Adams, and J. Talbert, "Vena cava filter retrieval rates and factors associated with retrieval in a large US cohort," *Journal of Vascular Surgery: Venous and Lymphatic Disorders,* vol. 6, no. 1, pp. 135-136, 2018.
5. D. L. Gillespie, J. B. Spies, F. S. Siami, J. E. Rectenwald, R. A. White, and M. S. Johnson, "Predicting the safety and effectiveness of inferior vena cava filters study: design of a unique safety and effectiveness study of inferior vena cava filters in clinical practice," *Journal of Vascular Surgery: Venous and Lymphatic Disorders,* vol. 8, no. 2, pp. 187-194. e1, 2020.
6. M. S. Johnson *et al.*, "Predicting the safety and effectiveness of inferior vena cava filters (PRESERVE): outcomes at 12 months," *Journal of Vascular and Interventional Radiology,* vol. 34, no. 4, pp. 517-528. e6, 2023.
7. A. Kesselman, T. H. Oo, M. Johnson, M. S. Stecker, J. Kaufman, and D. Trost, "Current controversies in Inferior vena cava filter placement: AJR expert panel narrative review," *American Journal of Roentgenology,* vol. 216, no. 3, pp. 563-569, 2021.
8. M. Arabi *et al.*, "Endovascular treatment of thrombosed inferior vena cava filters: techniques and short-term outcomes," *Indian Journal of Radiology and Imaging,* vol. 25, no. 03, pp. 233-238, 2015.
9. P. D. Stein, F. Matta, and A. Y. Yaekoub, "Incidence of vena cava thrombosis in the United States," *The American journal of cardiology,* vol. 102, no. 7, pp. 927-929, 2008.
10. M. Nazzal *et al.*, "Complications related to inferior vena cava filters: a single-center experience," *Annals of vascular surgery,* vol. 24, no. 4, pp. 480-486, 2010.
11. W. Clements, "Inferior vena cava filters in the asymptomatic chronically occluded cava: to remove or not remove?," *CardioVascular and Interventional Radiology,* vol. 42, no. 2, pp. 165-168, 2019.
12. I. Ahmad, K. Yeddula, S. Wicky, and S. P. Kalva, "Clinical sequelae of thrombus in an inferior vena cava filter," *Cardiovascular and interventional radiology,* vol. 33, pp. 285-289, 2010.
13. P. D. Stein *et al.*, "Outcome and complications of retrievable inferior vena cava filters," *The American journal of cardiology,* vol. 94, no. 8, pp. 1090-1093, 2004.
14. D. Zhou, J. Spain, E. Moon, G. Mclennan, M. J. Sands, and W. Wang, "Retrospective review of 120 celect inferior vena cava filter retrievals: experience at a single institution," *Journal of Vascular and Interventional Radiology,* vol. 23, no. 12, pp. 1557-1563, 2012.
15. F. Abtahian *et al.*, "Inferior vena cava filter usage, complications, and retrieval rate in cancer patients," *The American Journal of Medicine,* vol. 127, no. 11, pp. 1111-1117, 2014.
16. Y. Pan, J. Zhao, J. Mei, M. Shao, J. Zhang, and H. Wu, "Retrievable inferior vena cava filters in trauma patients: prevalence and management of thrombus within the filter," *European Journal of Vascular and Endovascular Surgery,* vol. 52, no. 6, pp. 830-837, 2016.
17. C. A. Athanasoulis, J. A. Kaufman, E. F. Halpern, A. C. Waltman, S. C. Geller, and C.-M. Fan, "Inferior vena caval filters: review of a 26-year single-center clinical experience," *Radiology,* vol. 216, no. 1, pp. 54-66, 2000.
18. M. A. Passman, "Complications of inferior vena cava filters," *Journal of Vascular Surgery: Venous and Lymphatic Disorders,* vol. 5, no. 1, p. 7, 2017.
19. J. P. Morales, X. Li, T. Z. Irony, N. G. Ibrahim, M. Moynahan, and K. J. Cavanaugh Jr, "Decision analysis of retrievable inferior vena cava filters in patients without pulmonary embolism," *Journal of Vascular Surgery: Venous and Lymphatic Disorders,* vol. 1, no. 4, pp. 376-384, 2013.
20. Y. Golowa, M. Warhit, F. Matsunaga, and J. Cynamon, "Catheter directed interventions for inferior vena cava thrombosis," *Cardiovascular Diagnosis and Therapy,* vol. 6, no. 6, p. 612, 2016.
21. J. Coughlan, T. J. Kiernan, and S. Arnous, "Alternative access for transcatheter aortic valve implantation: current evidence and future directions," *Vascular & Endovascular Review,* vol. 2, no. 1, pp. 23-7, 2019.
22. W. Clements *et al.*, "A retrospective cohort study assessing the incidence of inferior vena cava (IVC) occlusion following prophylactic IVC filter insertion: Is anticoagulation necessary during filter dwell?," *Injury,* vol. 53, no. 8, pp. 2763-2767, 2022.
23. H. Decousus *et al.*, "A clinical trial of vena caval filters in the prevention of pulmonary embolism in patients with proximal deep-vein thrombosis," *New England Journal of Medicine,* vol. 338, no. 7, pp. 409-416, 1998.
24. T. W. Hajduk B, Małek G, Davidson BL, "Vena Cava Filter Occlusion and Venous Thromboembolism Risk in Persistently Anticoagulated Patients," *Chest,* vol. 137, pp. 877–882, 2010.
25. S. E. Deso, I. A. Idakoji, and W. T. Kuo, "Evidence-based evaluation of inferior vena cava filter complications based on filter type," in *Seminars in Interventional Radiology*, 2016, vol. 33, no. 02: Thieme Medical Publishers, pp. 093-100.
26. G. D. Ayad MT, "Long-term complications of inferior vena cava filters. ," *Journal of Vascular Surgery: Venous and Lymphatic Disorders.,* vol. 7, pp. 139-144, 2019.
27. S. Raju, K. Hollis, and P. Neglen, "Obstructive lesions of the inferior vena cava: clinical features and endovenous treatment," *Journal of vascular surgery,* vol. 44, no. 4, pp. 820-827, 2006.
28. O. Sildiroglu, H. Ozer, and U. C. Turba, "Management of the thrombosed filter-bearing inferior vena cava," in *Seminars in interventional radiology*, 2012, vol. 29, no. 01: Thieme Medical Publishers, pp. 057-063.
29. S. Raju, A. Knight, L. Lamanilao, N. Pace, and T. Jones, "Peripheral venous hypertension in chronic venous disease," *Journal of Vascular Surgery: Venous and Lymphatic Disorders,* vol. 7, no. 5, pp. 706-714, 2019.
30. B. Harrison, F. Hao, N. Koney, J. McWilliams, and J. M. Moriarty, "Caval thrombus management: the data, where we are, and how it is done," *Techniques in Vascular and Interventional Radiology,* vol. 21, no. 2, pp. 65-77, 2018.
31. J. Park *et al.*, "Sonographic evaluation of inferior vena caval obstruction: correlative study with vena cavography," *American journal of roentgenology,* vol. 145, no. 4, pp. 757-762, 1985.
32. K. R. Desai *et al.*, "Retrievable IVC filters: comprehensive review of device-related complications and advanced retrieval techniques," *Radiographics,* vol. 37, no. 4, pp. 1236-1245, 2017.
33. A. Jaberi, M. J. Tao, N. Eisenberg, K. Tan, and G. Roche-Nagle, "IVC filter removal after extended implantation periods," *The Surgeon,* vol. 18, no. 5, pp. 265-268, 2020.
34. A. S. Nathan and J. Giri, "Reexamining the open-vein hypothesis for acute deep venous thrombosis," vol. 139, ed: Am Heart Assoc, 2019, pp. 1174-1176.
35. R. Ramaswamy, A. Guttikonda, and M. D. Kaplan, "Mechanical extraction of chronic venous thrombus using a novel device: a report of two cases," *Journal of Vascular Surgery Cases, Innovations and Techniques,* vol. 8, no. 4, pp. 752-755, 2022.
36. "American Society of Anesthesiologists: Committee on Economics. Distinguishing Monitored Anesthesia Care (MAC) from Moderate Sedation Analgesia (Conscious Sedation)."
37. S. Vedantham *et al.*, "Endovascular recanalization of the thrombosed filter-bearing inferior vena cava," *Journal of Vascular and Interventional Radiology,* vol. 14, no. 7, pp. 893-903, 2003.
38. K. Igari, T. Kudo, T. Toyofuku, and Y. Inoue, "Controlled antegrade and retrograde subintimal tracking technique for endovascular treatment of the superficial femoral artery with chronic total occlusion," *Annals of Vascular Surgery,* vol. 29, no. 6, pp. 1320. e7-1320. e10, 2015.
39. M. Megaly *et al.*, "Retrograde approach to chronic total occlusion percutaneous coronary intervention," *Circulation: Cardiovascular Interventions,* vol. 13, no. 5, p. e008900, 2020.
40. M. D. Rivers-Bowerman, C. B. Lightfoot, R. P. Meagher, M. D. Carter, and R. F. Berry, "Percutaneous sharp recanalization of a membranous IVC occlusion with an occlusion balloon as a needle target," *Radiology Case Reports,* vol. 12, no. 3, pp. 537-541, 2017.
41. A. Salaskar *et al.*, "Radiofrequency wire 'power wire'recanalization of calcified chronically occluded inferior vena cava," *CVIR endovascular,* vol. 1, no. 1, pp. 1-4, 2018.
42. E. J. Keller, S. A. Gupta, S. Bondarev, K. T. Sato, R. L. Vogelzang, and S. A. Resnick, "Single-center retrospective review of radiofrequency wire recanalization of refractory central venous occlusions," *Journal of Vascular and Interventional Radiology,* vol. 29, no. 11, pp. 1571-1577, 2018.
43. K. R. Desai *et al.*, "Single-session inferior vena cava filter removal, recanalization, and endovenous reconstruction for chronic iliocaval thrombosis," *Journal of Vascular Surgery: Venous and Lymphatic Disorders,* vol. 7, no. 2, pp. 176-183, 2019.
44. A. K. Sista, S. Vedantham, J. A. Kaufman, and D. C. Madoff, "Endovascular interventions for acute and chronic lower

extremity deep venous disease: state of the art," *Radiology,* vol. 276, no. 1, pp. 31-53, 2015.
45. E. H. Murphy, B. Johns, E. Varney, and S. Raju, "Endovascular management of chronic total occlusions of the inferior vena cava and iliac veins," *Journal of Vascular Surgery: Venous and Lymphatic Disorders,* vol. 5, no. 1, pp. 47-59, 2017.
46. M. W. Mewissen, G. R. Seabrook, M. H. Meissner, J. Cynamon, N. Labropoulos, and S. H. Haughton, "Catheter-directed thrombolysis for lower extremity deep venous thrombosis: report of a national multicenter registry," *Radiology,* vol. 211, no. 1, pp. 39-49, 1999.
47. A. Sailer *et al.*, "Deep Vein Thrombosis: Update on Mechanical Thrombectomy and Intravascular US," *RadioGraphics,* vol. 42, no. 6, pp. E184-E185, 2022.
48. S. Divakaran *et al.*, "Utilization of and Outcomes Associated with Intravascular Ultrasound during Deep Venous Stent Placement among Medicare Beneficiaries," *Journal of Vascular and Interventional Radiology,* vol. 33, no. 12, pp. 1476-1484. e2, 2022.
49. P. J. Gagne *et al.*, "Analysis of threshold stenosis by multiplanar venogram and intravascular ultrasound examination for predicting clinical improvement after iliofemoral vein stenting in the VIDIO trial," *Journal of Vascular Surgery: Venous and Lymphatic Disorders,* vol. 6, no. 1, pp. 48-56. e1, 2018.
50. P. J. Gagne *et al.*, "Venography versus intravascular ultrasound for diagnosing and treating iliofemoral vein obstruction," *Journal of Vascular Surgery: Venous and Lymphatic Disorders,* vol. 5, no. 5, pp. 678-687, 2017.
51. L. M. Tran *et al.*, "Intravascular ultrasound evaluation during iliofemoral venous stenting is associated with improved midterm patency outcomes," *Journal of Vascular Surgery: Venous and Lymphatic Disorders,* vol. 10, no. 6, pp. 1294-1303, 2022.
52. M. A. Woods *et al.*, "Intravascular US: Applications in Interventional Radiology," *RadioGraphics,* vol. 42, no. 6, pp. 1742-1757, 2022.
53. J. F. B. Chick *et al.*, "Endovascular iliocaval stent reconstruction for inferior vena cava filter–associated iliocaval thrombosis: approach, technical success, safety, and two-year outcomes in 120 patients," *Journal of Vascular and Interventional Radiology,* vol. 28, no. 7, pp. 933-939, 2017.
54. P. Neglén, M. Oglesbee, J. Olivier, and S. Raju, "Stenting of chronically obstructed inferior vena cava filters," *Journal of vascular surgery,* vol. 54, no. 1, pp. 153-161, 2011.
55. R. I. Morris, A. Smith, and S. A. Black, "Response to "Re. A Systematic Review of the Safety and Efficacy of Inferior Vena Cava Stenting"," *European Journal of Vascular and Endovascular Surgery,* vol. 66, no. 2, pp. 290-291, 2023.
56. K. Ye *et al.*, "Outcomes of stent placement for chronic occlusion of a filter-bearing inferior vena cava in patients with severe post-thrombotic syndrome," *European Journal of Vascular and Endovascular Surgery,* vol. 52, no. 6, pp. 839-846, 2016.
57. Y. Erben, H. Bjarnason, G. L. Oladottir, R. D. McBane, and P. Gloviczki, "Endovascular recanalization for nonmalignant obstruction of the inferior vena cava," *Journal of Vascular Surgery: Venous and Lymphatic Disorders,* vol. 6, no. 2, pp. 173-182, 2018.
58. M. Elboraey, B. B. Toskich, A. R. Lewis, C. A. Ritchie, G. T. Frey, and Z. Devcic, "Iliocaval reconstruction of chronically thrombosed cylindrical inferior vena cava filters with balloon expandable covered stent-grafts," *Journal of Vascular Surgery Cases, Innovations and Techniques,* vol. 7, no. 3, pp. 454-457, 2021.
59. K. B. Quencer *et al.*, "Procedural complications of inferior vena cava filter retrieval, an illustrated review," *CVIR endovascular,* vol. 3, no. 1, pp. 1-11, 2020.
60. W. T. Kuo, A. A. Doshi, J. M. Ponting, J. K. Rosenberg, T. Liang, and L. V. Hofmann, "Laser-Assisted removal of embedded vena cava filters: a first-in-human escalation trial in 500 patients refractory to high-force retrieval," *Journal of the American Heart Association,* vol. 9, no. 24, p. e017916, 2020.
61. S. E. Fletcher, S. Jasuja, L. P. Lawler, and J. M. Moriarty, "Catheter-directed thrombolysis and mechanical intervention in deep venous thrombosis: what is the status after the ATTRACT trial?," *Postgraduate Medicine,* vol. 133, no. sup1, pp. 42-50, 2021.
62. S. Tavri, I. J. Patel, P. Kavali, Z. Irani, S. Ganguli, and T. G. Walker, "Endobronchial forceps-assisted complex retrieval of inferior vena cava filters," *Journal of Vascular Surgery: Venous and Lymphatic Disorders,* vol. 7, no. 3, pp. 413-419, 2019.
63. W. T. Kuo, J. I. Odegaard, J. K. Rosenberg, and L. V. Hofmann, "Laser-assisted removal of embedded vena cava filters: a 5-year first-in-human study," *Chest,* vol. 151, no. 2, pp. 417-424, 2017.
64. Anon, "Endovascular Today United States Device Guide," 2023.
65. J. F. B. Chick *et al.*, "Stent placement across the renal vein inflow in patients undergoing venous reconstruction preserves renal function and renal vein patency: experience in 93 patients," *Journal of Endovascular Therapy,* vol. 26, no. 2, pp. 258-264, 2019.
66. S. Vedantham *et al.*, "Society of Interventional Radiology Position Statement on the endovascular management of acute iliofemoral deep vein thrombosis," *Journal of Vascular and Interventional Radiology,* vol. 34, no. 2, pp. 284-299. e7, 2023.
67. N. Xiao, M. Genet, M. Khaja, and K. R. Desai, "Antithrombotic Therapy after Deep Venous Intervention," in *Seminars in Interventional Radiology*, 2022, vol. 39, no. 04: Thieme Medical Publishers, Inc. 333 Seventh Avenue, 18th Floor, New York, NY ..., pp. 357-363.
68. K. Milinis, A. Thapar, J. Shalhoub, and A. H. Davies, "Antithrombotic therapy following venous stenting: international Delphi consensus," *European Journal of Vascular and Endovascular Surgery,* vol. 55, no. 4, pp. 537-544, 2018.
69. R. H.-J. Bertrand ME, Urban P, Gershlick AH, "Investigators for the C. Double-Blind Study of the Safety of Clopidogrel With and Without a Loading Dose in Combination With Aspirin Compared With Ticlopidine in Combination With Aspirin After Coronary Stenting: The Clopidogrel Aspirin Stent International Cooperative Study (CLASSICS)." *Circulation,* vol. 102, pp. 624–629, 2000.
70. L. J. Padrnos and D. Garcia, "May-Thurner syndrome and thrombosis: a systematic review of antithrombotic use after endovascular stent placement," *Research and Practice in Thrombosis and Haemostasis,* vol. 3, no. 1, p. e12156, 2019.
71. R. de Graaf, M. de Wolf, A. M. Sailer, J. van Laanen, C. Wittens, and H. Jalaie, "Iliocaval confluence stenting for chronic venous obstructions," *CardioVascular and Interventional Radiology,* vol. 38, pp. 1198-1204, 2015.