Chapter 10

Venous Thromboembolism: Management of Bleeding Complications

10

10 Venous Thromboembolism: Management of Bleeding Complications

James Chen and Deepak Sudheendra

10.1 Bleeding Complications Associated with Venous Thromboembolism Treatment

The treatment of venous thromboembolism (VTE) remains challenging and limitations to conventional treatment with systemic anticoagulation (AC) have led to the advent of catheter-directed thrombolysis (CDT) and pharmacomechanical CDT (PCDT) techniques, which more rapidly decrease clot burden and decrease the severity and rate of long-term sequelae such as postthrombotic syndrome (PTS) following deep vein thrombosis (DVT).[1,2] Both CDT and PCDT involve placement of an infusion catheter into a clot for local infusion of thrombolytic, with adjunctive techniques for thrombus removal including rheolytic systems for thromboaspiration in PCDT. Local thrombolytic infusion allows for higher local doses with less systemic exposure, affording decreased bleeding complications compared to systemic thrombolytic administration. A variety of fibrinolytics are available, such as tissue plasminogen activator (tPA) and streptokinase, all of which function by activation of plasmin, which facilitates clot lysis by fibrin degradation. Although refinements of CDT and PCDT techniques and thrombolytic agents over the past few decades have afforded improved complication profiles, there remains an elevated risk of major bleeding when using these therapies compared to systemic AC alone.

The pathophysiologies of bleeding complications during CDT/PCDT are related to a combination of thrombolytic mechanisms including plasmin-mediated degradation of fibrin, reduced plasma concentrations of fibrinogen and other clotting factors, and antiplatelet effects. Although the half-lives of thrombolytic drugs are short (i.e., tPA has a half-life of 5 minutes), the associated depletion of clotting cascade factors and antiplatelet effects leads to prolonged coagulopathic effects after cessation of infusion. Fibrinogen levels, for instance, require up to 48 hours to return to baseline levels after stopping thrombolytics. When bleeding complications occur, a large majority of the complications are venous access site–related minor bleeding episodes, which can typically be managed conservatively and do not result in long-term sequelae. Major bleeding, defined as bleeding resulting in hemodynamic compromise or intracranial hemorrhage (ICH), occurs in a small minority of cases, ranging from 2 to 3% in most modern studies.[2,3,4,5,6,7] A Cochrane analysis of CDT studies found that all cases of ICH occurred in pre-1990 studies[8] and a meta-analysis of pulmonary embolism (PE) thrombolysis reported a 0.35% rate of ICH.[9]

10.1.1 Patient Selection and Monitoring for Bleeding Complications

Although the risk of major bleeding is low, the potentially catastrophic nature of these episodes necessitates judicious patient selection for CDT/PCDT. The following absolute contraindications to CDT/PCDT have been suggested by guidelines from the Society of Interventional Radiology (SIR)[7]:

- Active internal bleeding or disseminated intravascular coagulation (DIC).
- Recent cerebrovascular accident (CVA), neurosurgery, or intracranial trauma (within 3 months).
- Absolute contraindication to AC.

During placement of the infusion catheter, ultrasound-guided venous access with a micropuncture set should be used to decrease the number of puncture attempts and reduce the risk of access site bleeding complications.[7] No arterial or intramuscular injections should be administered and no additional venous access should be attempted during thrombolysis due to bleeding risk.

The recommended tPA infusion rate for VTE is 0.01 mg/kg/hour, not to exceed 1.0 mg/hour. Concurrent AC is typically attained using heparin drip or low-molecular-weight heparin (LMWH).[10] For patients receiving heparin drip, target partial thromboplastin time (PTT) is controversial, with some groups advocating a subtherapeutic PTT target of 1.2 to 1.7 times control,[2] based on studies demonstrating elevated bleeding risk with therapeutic PTT targets.[11] At our institution, we administer enoxaparin (Lovenox) 1 mg/kg at full AC dose. We have found that this protocol allows greater ease of achieving steady-state AC, and eliminates the frequent PTT checks required with heparin drip. Patients with heparin-induced thrombocytopenia (HIT) should undergo AC with a direct thrombin inhibitor such as argatroban or bivalirudin. Patients undergoing CDT require bedrest with immobilization of the catheter-bearing limb, and vigilant clinical evaluation for any signs of impending major bleeding including acute mental status change, severe headache or abdominal pain, epistaxis, or other sentinel bleeding event. Serial laboratory evaluation of hemoglobin, PTT, and platelet levels is performed every 6 hours at our institution. The value of monitoring fibrinogen levels remains controversial, with conflicting evidence on the association between low fibrinogen level (< 1–1.5 g/L) and higher bleeding risk. An early trial citing the higher risk of bleeding with low fibrinogen levels was confounded by the use of therapeutic rather than subtherapeutic heparin doses,[11] and other studies have demonstrated discordant results in both venous and arterial thrombolysis settings.[12,13,14,15] In the absence of definitive data, society guidelines still recommend fibrinogen level monitoring,[7] and some groups advocate slowing down thrombolytic infusion rate once fibrinogen level is < 1.5 g/L and stopping the infusion completely once fibrinogen level is < 1.0 g/L.[14] At our institution, we do not routinely monitor fibrinogen levels. Higher thrombolytic doses and longer duration of infusion are associated with significantly higher risks of bleeding complication.[14]

10.1.2 Management of Bleeding Complications

Once a major bleeding episode is identified, the fibrinolytic and heparin infusions should be stopped immediately, and hemodynamic resuscitation should be initiated. The half-life of tPA is approximately 5 minutes. Laboratory evaluation of hemoglobin, platelet, international normalized ratio (INR), PTT, and fibrinogen levels should be attained. Depending on the laboratory findings, the patient may require blood products including fresh frozen plasma (FFP), cryoprecipitate, fibrinogen concentrate, platelets, and packed red blood cell transfusion. Some groups also administer tranexamic acid, an antifibrinolytic agent, for cases of severe hemorrhage, although in most cases, the 5-minute half-life of tPA is short enough that cessation of the infusion should be sufficient. Protamine can be administered for rapid reversal of heparin AC at a dose of 10 mg for every 100 U of heparin, with a maximum dose of 50 mg. Given the emergent nature of major bleeding complications in the setting CDT/PCDT, there is a paucity of evidence on optimal management algorithm, and specific protocols vary between providers and institutions.[16,17] Persistent bleeding may require more aggressive interventions including embolization. The management of ICH is outside of the scope of this chapter, but includes optimization of intracranial pressure, blood pressure, and respiratory status. It is important to differentiate hematuria from periprocedural hemoglobinuria, which occurs commonly following PCDT with rheolytic thrombectomy, and will typically resolve in 24 to 32 hours. Minor bleeding episodes such as pericatheter oozing can be managed conservatively with manual compression.

10.1.3 Summary

Although the rate of major bleeding during CDT/PCDT for VTE is low, careful patient selection and vigilant monitoring during thrombolysis are essential to identify and mitigate the morbidity from these bleeding episodes. Once major bleeding is identified, thrombolytic and AC infusions should be immediately stopped, and resuscitation with coagulation factors and blood products may be required. Serial monitoring of fibrinogen levels remains an area of controversy, with conflicting evidence regarding the need to reduce or cease thrombolytic infusion at lower fibrinogen levels.

References

[1] Sharifi M, Bay C, Mehdipour M, Sharifi J, TORPEDO Investigators. Thrombus Obliteration by Rapid Percutaneous Endovenous Intervention in Deep Venous Occlusion (TORPEDO) trial: midterm results. J Endovasc Ther. 2012; 19(2):273–280

[2] Enden T, Haig Y, Kløw NE, et al. CaVenT Study Group. Long-term outcome after additional catheter-directed thrombolysis versus standard treatment for acute iliofemoral deep vein thrombosis (the CaVenT study): a randomised controlled trial. Lancet. 2012; 379(9810):31–38

[3] Enden T, Kløw NE, Sandvik L, et al. CaVenT study group. Catheter-directed thrombolysis vs. anticoagulant therapy alone in deep vein thrombosis: results of an open randomized, controlled trial reporting on short-term patency. J Thromb Haemost. 2009; 7(8):1268–1275

[4] Enden T, Wik HS, Kvam AK, Haig Y, Kløw NE, Sandset PM. Health-related quality of life after catheter-directed thrombolysis for deep vein thrombosis: secondary outcomes of the randomised, non-blinded, parallel-group CaVenT study. BMJ Open. 2013; 3(8):e002984

[5] Elsharawy M, Elzayat E. Early results of thrombolysis vs anticoagulation in iliofemoral venous thrombosis. A randomised clinical trial. Eur J Vasc Endovasc Surg. 2002; 24(3):209–214

[6] Engelberger RP, Spirk D, Willenberg T, et al. Ultrasound-assisted versus conventional catheter-directed thrombolysis for acute iliofemoral deep vein thrombosis. Circ Cardiovasc Interv. 2015; 8(1):e002027

[7] Vedantham S, Sista AK, Klein SJ, et al. Society of Interventional Radiology and Cardiovascular and Interventional Radiological Society of Europe Standards of Practice Committees. Quality improvement guidelines for the treatment of lower-extremity deep vein thrombosis with use of endovascular thrombus removal. J Vasc Interv Radiol. 2014; 25(9):1317–1325

[8] Watson L, Broderick C, Armon MP. Thrombolysis for acute deep vein thrombosis. Cochrane Database Syst Rev. 2016; 11 (11):CD002783

[9] Bloomer TL, El-Hayek GE, McDaniel MC, et al. Safety of catheter-directed thrombolysis for massive and submassive pulmonary embolism: results of a multicenter registry and meta-analysis. Catheter Cardiovasc Interv. 2017; 89(4):754–760

[10] Foegh P, Jensen LP, Klitfod L, Broholm R, Bækgaard N. Editor's choice: factors associated with long-term outcome in 191 patients with ilio-femoral DVT treated with catheter-directed thrombolysis. Eur J Vasc Endovasc Surg. 2017; 53(3):419–424

[11] Ouriel K, Veith FJ, Sasahara AA, Thrombolysis or Peripheral Arterial Surgery (TOPAS) Investigators. A comparison of recombinant urokinase with vascular surgery as initial treatment for acute arterial occlusion of the legs. N Engl J Med. 1998; 338(16):1105–1111

[12] Results of a prospective randomized trial evaluating surgery versus thrombolysis for ischemia of the lower extremity. The STILE trial. Ann Surg. 1994; 220(3):251–266, discussion 266–268

[13] Skeik N, Gits CC, Ehrenwald E, Cragg AH. Fibrinogen level as a surrogate for the outcome of thrombolytic therapy using tissue plasminogen activator for acute lower extremity intravascular thrombosis. Vasc Endovascular Surg. 2013; 47(7): 519–523

[14] Lee K, Istl A, Dubois L, et al. Fibrinogen level and bleeding risk during catheter-directed thrombolysis using tissue plasminogen activator. Vasc Endovascular Surg. 2015; 49 (7):175–179

[15] Ouriel K, Kandarpa K, Schuerr DM, Hultquist M, Hodkinson G, Wallin B. Prourokinase versus urokinase for recanalization of peripheral occlusions, safety and efficacy: the PURPOSE trial. J Vasc Interv Radiol. 1999; 10(8):1083–1091

[16] Makris M, Van Veen JJ, Tait CR, Mumford AD, Laffan M, British Committee for Standards in Haematology. Guideline on the management of bleeding in patients on antithrombotic agents. Br J Haematol. 2013; 160(1):35–46

[17] Rasler F. Emergency treatment of hemorrhagic complications of thrombolysis. Ann Emerg Med. 2007; 50(4):485

10.2 Quality Improvement and Safety of Treatment of Thromboembolic Disease and Guidelines and Complication Thresholds for Treatment of DVT and PE

Boris Nikolic

The risks associated with deep vein thrombosis (DVT) are considerable and include pulmonary embolism (PE), postthrombotic syndrome, paradoxical (functionally patent foramen ovale–related) embolization, or limb or life loss due to venous gangrene and congestion with potentially massive fluid sequestration that may lead to circulatory collapse (phlegmasia cerulea dolens). Although clinical information is not always reliable, a dichotomization into acute and Chronic DVT based on DVT presence of less than or more than 3 weeks, respectively, is scientifically well grounded in histopathological findings. As with any treatment, therapeutic success is dependent upon diagnostic accuracy. Acute DVTs are not always distinguishable from chronic DVTs based on clinical history and acute on chronic manifestations may occur. As such, initiation of thrombolysis that is not primarily or that is incompletely successful may guide the interventional operator to acknowledge the presence of chronic thrombus and to proceed with mechanical recanalization and venous stent placement. Furthermore, it is important to recognize distinct underlying pathologies, such as May–Thurner (Cockett's) syndrome, venous compression by tumor, or hypercoagulable states, and to address those specifically as indicated and feasible.[1] This author generally advocates for the existence of institutional, evidence-based treatment algorithms, including one for patients referred for endovascular therapy of DVT and meeting such criteria, as exemplified in ▶ Fig. 10.1.

Endovascular venous thrombus removal can occur with pharmacological (systemic thrombolysis, flow-directed thrombolysis, catheter-directed intrathrombus thrombolysis) or mechanical means (clot pulverization), but a combined pharmacomechanical approach is often the preferred one, where mechanical clot pulverization increases the exposed clot target surface area for plasminogen-activated thrombolysis, thus reducing hospital and ICU stay. In considering the indication for endovascular treatment of acute DVT, assessment of clinical severity is of particular relevance. The ATTRACT (Acute Venous Thrombosis: Thrombus Removal with Adjunctive Catheter-Directed Thrombolysis) trial (currently unpublished data)—largely considered sentinel in addressing the topic of approaching therapy of acute DVT—failed to show the superiority of endovascular treatment compared to systemic treatment in reducing future development of postthrombotic syndrome or in lowering treatment-related adverse event rates. Consequently, an interventional approach would generally not be justified in asymptomatic patients, which more commonly have thrombus limited to the femoropopliteal system. However, in severely symptomatic patients and in those with acutely threatened limbs—where iliac venous system

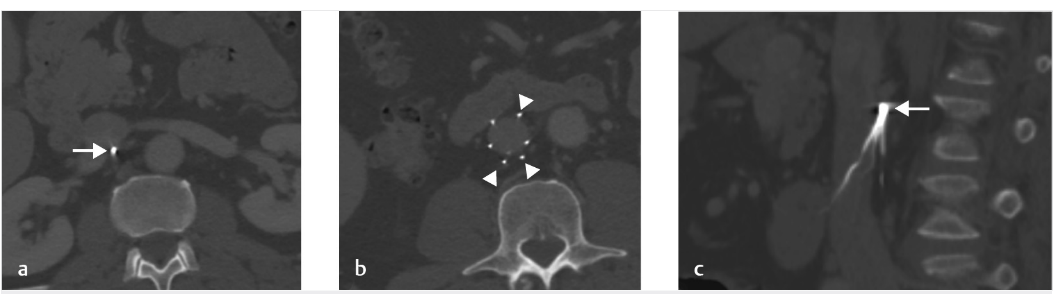

Fig. 10.1 Axial **(a)** and coronal **(b)** computed tomography images demonstrating peripheral calcifications of the lower IVC And iliac veins as sequalae of chronic venous occlusion. **(c)** coronal computed tomography images demonstrating the top of the filter penetrating outside of the caval wall (arrow).
Source: *Samuel M, Nahab B, Chadalavada S. Balloon-assisted retrieval of a retained vascular sheath during complex inferior vena cava filter removal. Semin Intervent Radiol. 2023; 40(3):298–303.*

involvement is typical—endovascular therapy is preferable over open surgical treatment.[2,3,4]

The most common major adverse event associated with endovascular treatment of DVT is substantial bleeding—with its intracranial manifestation being most feared.[5] Occurrence of symptomatic PE has also been reported. Frequency and severity of adverse events can often be reduced with proper patient selection and properly rigorous intra- and periprocedural monitoring. With regard to the former, patients with absolute contraindications, that is, active internal hemorrhage, recent stroke, transient ischemic attack (TIA) or cerebral trauma, or absolute contraindication to anticoagulation, should be excluded from thrombolysis considerations. With regard to the latter, initial micropuncture set venous access, a recombinant tissue plasminogen activator dose of < 1 mg/h, presence of frequent nurse-to-patient contact, monitoring of fibrinogen levels, immobilization of the punctured extremity, avoidance of stand-alone mechanical thrombolysis, and assurance of subtherapeutic effects of any anticoagulants that had previously been administered to the patient lower the risk profile for the occurrence of adverse events.[6,7]

Procedural efficacy outcome has been measured based on removal of > 50% of thrombus resulting in restoration of iliofemoral flow and absence of early (1–3 months postprocedural) thrombosis recurrence.[7] Corresponding practice thresholds for both parameters, below which an internal investigation should be considered, have been set by the Standards of Practice Committee of the Society of Interventional Radiology (SIR) as 80% each, provided that intrathrombus thrombolytic therapy occurred, treated thrombus was predominantly acute, heparin-based therapy could be administered during catheter manipulation and postprocedure completion, and that underlying flow-limiting stenoses were appropriately therapeutically addressed with venoplasty or stent placement.[8,9,10,11,12]

As for any complex interventional procedure, care is incomplete and inadequate without postprocedural clinical follow-up. In the case of endovascular DVT therapy, this entails at least two follow-up clinic visits with evaluation for postthrombotic syndrome (in > 80% of patients), postprocedural administration of anticoagulation for at least 3 months if DVT was related to a major initiating event (e.g., major surgery, trauma, etc.) and for 6 months in the absence of such event as well as arrangements for inferior vena cava (IVC) filter removal, if placed intraprocedurally. With regard to the latter, it is notable, however, that procedure-related PE is uncommon[9] and the appropriateness of IVC filter placement is therefore unclear.[13] Longer-term postprocedural (i.e., 2-year-long) application of elastic compression stockings has not proven more effective than placebo in more recent investigation but may be beneficial for more rapid reduction of swelling during the initial postprocedural weeks and for longer-term postthrombotic syndrome management in individual patients.[14]

In summary, a distinction between mostly acute and mostly chronic presence of DVT fundamentally impacts the type of treatment and endovascular technique. Patients with acute DVT, where endovascular management is considered, should be carefully selected, well monitored periprocedurally, and rigorously followed clinically for outcome. Based on most recent data, a highly symptomatic and threatened limb seems to present the most convincing indication for endovascular intervention.

References

[1] Goldman RE, Arendt VA, Kothary N, et al. Endovascular management of May-Thurner syndrome in adolescents: a single-center experience. J Vasc Interv Radiol. 2017; 28(1):71–77

[2] Patel NH, Plorde JJ, Meissner M. Catheter-directed thrombolysis in the treatment of phlegmasia cerulea dolens. Ann Vasc Surg. 1998; 12(5):471–475

[3] Weaver FA, Meacham PW, Adkins RB, Dean RH. Phlegmasia cerulea dolens: therapeutic considerations. South Med J. 1988; 81(3):306–312

[4] Robinson DL, Teitelbaum GP. Phlegmasia cerulea dolens: treatment by pulse-spray and infusion thrombolysis. AJR Am J Roentgenol. 1993; 160(6):1288–1290

[5] Patel N, Sacks D, Patel RI, et al. Technology Assessment Committee of the Society of Cardiovascular & Interventioanal Radiology. SCVIR reporting standards for the treatment of acute limb ischemia with use of transluminal removal of arterial thrombus. J Vasc Interv Radiol. 2001; 12(5):559–570

[6] Uflacker R. Mechanical thrombectomy in acute and subacute thrombosis with use of the Amplatz device: arterial and venous applications. J Vasc Interv Radiol. 1997; 8(6):923–932

[7] Delomez M, Beregi JP, Willoteaux S, et al. Mechanical thrombectomy in patients with deep venous thrombosis. Cardiovasc Intervent Radiol. 2001; 24(1):42–48

[8] Mewissen MW, Seabrook GR, Meissner MH, Cynamon J, Labropoulos N, Haughton SH. Catheter-directed thrombolysis for lower extremity deep venous thrombosis: report of a national multicenter registry. Radiology. 1999; 211(1):39–49

[9] Enden T, Haig Y, Kløw NE, et al. CaVenT Study Group. Long-term outcome after additional catheter-directed thrombolysis versus standard treatment for acute iliofemoral deep vein thrombosis (the CaVenT study): a randomised controlled trial. Lancet. 2012; 379(9810):31–38

[10] Haig Y, Enden T, Slagsvold CE, Sandvik L, Sandset PM, Kløw NE. Determinants of early and long-term efficacy of catheter-directed thrombolysis in proximal deep vein thrombosis. J Vasc Interv Radiol. 2013; 24(1):17–24, quiz 26
[11] Mickley V, Schwagierek R, Rilinger N, Görich J, Sunder-Plassmann L. Left iliac venous thrombosis caused by venous spur: treatment with thrombectomy and stent implantation. J Vasc Surg. 1998; 28(3):492–497
[12] Vedantham S, Sista AK, Klein SJ, et al. Society of Interventional Radiology and Cardiovascular and Interventional Radiological Society of Europe Standards of Practice Committees. Quality improvement guidelines for the treatment of lower-extremity deep vein thrombosis with use of endovascular thrombus removal. J Vasc Interv Radiol. 2014; 25(9):1317–1325
[13] Sharifi M, Bay C, Skrocki L, Lawson D, Mazdeh S. Role of IVC filters in endovenous therapy for deep venous thrombosis: the FILTER-PEVI (filter implantation to lower thromboembolic risk in percutaneous endovenous intervention) trial. Cardiovasc Intervent Radiol. 2012; 35(6):1408–1413
[14] Kahn SR, Shbaklo H, Shapiro S, et al. SOX Trial Investigators. Effectiveness of compression stockings to prevent the post-thrombotic syndrome (the SOX Trial and Bio-SOX biomarker substudy): a randomized controlled trial. BMC Cardiovasc Disord. 2007; 7:21

10.3 Filter-Related Adverse Events and Thresholds

Boris Nikolic

Monitoring and evaluating inferior vena cava (IVC) filter-related adverse events should never be considered or analyzed in isolation, but be embedded into an adequately comprehensive quality improvement program. Additional parameters, such as appropriateness of indication and patient selection, adequacy of preprocedural preparation, postprocedural patient monitoring, and retrieval rate for temporary IVC filters are additional parameters that fundamentally affect quality. These factors may also be causally related to adverse event occurrences. Some examples are permanent IVC filter placement in a preprocedurally bacteremic patient (where a subsequently placed IVC filter acts as a constant nidus for ongoing infection), wrong patient IVC filter insertion, allergic reaction to contrast media administration due to failure of preprocedural review of such available history, filter malpositioning or filter embolization in patients with anatomic variations or mega vena cava, respectively, that could have been recognizable during additional preprocedural review of existing cross-sectional imaging, etc. Along similar lines, premature discharge of a patient that is not fully awake and alert after receiving moderate sedation or puncture site hematoma formation may result from inadequate postprocedural patient monitoring.

Potential access site–related adverse events in association with IVC filter insertion include bleeding (6–15%)[1] and thrombosis (3–10%),[2] although the true incidence in general—and for individual operators/facilities in particular—is largely uncertain given the variability of patient follow-up and probable lack of clinical manifestation in most patients. Arteriovenous fistula formation and incomplete filter opening during deployment are theoretical risks but without respective recent reporting of incidences of occurrence. Aside from filter misplacement within the IVC, nontarget filter deployment into the gonadal vein, superior mesenteric vein, aorta, and within the spinal canal have all been reported.[3,4,5,6,7] Other than a minor malposition near the target area, filter malpositioning seems an avoidable phenomenon with proper utilization of image guidance (intravenous cavography and intravascular ultrasound). Similarly, upside-down filter placement should be considered a never event in interventional radiology. Specific thresholds for potential IVC filter-related adverse events have previously been established by the Standards of Practice Committee of the Society of Interventional Radiology (▶ Table 10.1). Performance of an internal institutional investigation is usually recommended when any of these thresholds are exceeded. However, factors such as patient sampling/selection bias or device failure and specifics may well contribute to such a scenario and early assignment of blame to the operator is therefore generally misguided. An additional caveat for threshold application arises if a specific procedure is rare at an institution, so that individual adverse events have disproportionate impact on the overall procedural volume percentage, which may even be the case for IVC filter placement and/or removal at some facilities. Impact of specific device or patient-related factors may further compound analysis of additional potential adverse events such as filter tilt, caval wall perforation, filter fracture, pulmonary embolism recurrence, and IVC thrombus formation or occlusion, which would likewise complicate determination of corresponding specific thresholds, rendering such attempt arguably inappropriate at this time. At the same time, rigorous patient follow-up, reporting, and scientific study for all of these events is highly warranted, so that thresholds can be appropriately refined where they exist and operator-related influences can be scientifically uncovered where thresholds are currently lacking.

Over the last few years, much discussion has evolved around adverse events that may more

Table 10.1 Reported inferior vena cava filter complication rates

Complication	Reported rates (%)	Threshold (%)
Death	0.12	< 1
Filter embolization	0.1	1
Filter malposition	1–9	0
Access site occlusive thrombosis	3–10	3

Source: *Molvar C. Interior vena cava filtration in the management of venous thormboembolism: filtering the data. Semin Intervent Radiol. 2012; 29(3):204–217.*

commonly afflict some types of retrievable IVC filter, such as filter fractures, migration as well as embolization of filter parts or the entire devices, device tilt, and caval wall perforation.[8,9,10,11] For IVC filters that are implanted if only temporary protection from pulmonary embolism is needed, relevance and requirement of patient monitoring often extends many weeks beyond the immediate postprocedural recovery time. Lack of patient tracking and filter retrieval seems to be associated with generally higher frequencies of fracturing of filter material or caval wall perforation, at least for individual device types.[12,13] A number of adverse events including but not limited to fragment embolization to the right heart, pulmonary arterial system, pericardium, iliac vein, and kidney have all been reported. The sequelae of caval wall perforation and filter migration may cause symptoms such as back pain, retroperitoneal hematoma, lumbar artery pseudoaneurysm formation, or gastrointestinal injury.[13,14,15,16,17] Careful patient follow-up and introduction of dedicated filter retrieval clinics have therefore been advocated, implementation of which has been accompanied by the expected increases in reported filter retrieval rates.[18,19,20,21,22,23] Analysis of the MAUDE database seems to suggest that adverse events are significantly more frequent in retrievable IVC filters than in permanent IVC filters; however, more rigorous follow-up and higher reporting rates for retrievable filters may well account for or contribute to this finding.[24] Generalized judgment regarding retrievable IVC filters may frequently be inappropriate, given the differences in individual filter design, variability of reporting and reported rates of adverse events for individual filters, evolution of individual filters in terms of manufacturing process, required retrieval technique and needed supplies, as well as overwhelmingly lower levels of evidence in the currently existing body of literature, typically presented as retrospective, single-center studies.[25,26]

Benefits of retrieval of IVC filters that are designed and labeled for such procedure as soon as their presence is no longer indicated have been well documented, because longer filter dwell times have been associated with increased risks of DVT as well as device fractures, limb perforation, and migration for at least some filter types.[9,14,27,28,29,30] At the same time, successful filter removal has been accomplished after 6 months for a variety of filter types, because of which such longer dwell time alone should generally not discourage retrieval attempts.[31,32,33] Specific parameters known to potentially complicate filter retrieval are filter tilt, IVC wall perforation, and fractured or intraretrieval fracturing of filter material, and advanced retrieval techniques may be required for device removal under these circumstances.[34] A larger portion of published literature is dedicated to description of such advanced retrieval techniques, which include bronchial forceps use, balloon disruption, loop snare technique, and laser assistance.[8,35,36] Lower incidences of strut penetration and filter tilt have been reported for Denali filters compared to Celect filters.[26] As advanced technique applications may be associated with a higher adverse event rate, a more cautious approach in utilization of these techniques seems prudent.[8] Adverse events described with filter retrieval include IVC intussusception and dissection, filter fracturing, and hemorrhage (MAUDE). The general rule is to exercise the best case-based judgement in deciding whether filter retrieval or leaving a given filter in situ has the lower risk-to-benefit ratio prevails here as much as elsewhere in the practice of medicine. Referring the patient to a high-volume center with vast experience in filter retrieval may sometimes be most advisable for these generally elective procedures.

Placement of filters in the suprarenal IVC and superior vena cava (SVC) has been described anecdotally and in smaller case series.[37] Meaningful generalized conclusions cannot be drawn from the currently existing literature, and the potential for adverse events may be partly similar to what has been described for IVC filters placed in the infrarenal position. IVC filter placement is rarely indicated in pediatric patients and is often performed in patients with very limited prognosis where filter removal may therefore not be required.

In summary, the myriad of existing filter types and rapid generational evolution of devices frequently limits generalized conclusions and comparability among filters. Placement of retrievable filters should be followed by rigorous follow-up and device removal—if possible—as soon as its use is no longer indicated. Filter retrieval should always be attempted in completeness and include efforts to retrieve fractured fragments, if feasible. Scientifically rigorous efforts to prove IVC filtration effectiveness on the basis of strong evidence seem to be one of the most challenging yet meaningful tasks at this time.

References

[1] Joels CS, Sing RF, Heniford BT. Complications of inferior vena cava filters. Am Surg. 2003; 69(8):654–659

[2] Caplin DM, Nikolic B, Kalva SP, Ganguli S, Saad WE, Zuckerman DA, Society of Interventional Radiology Standards of Practice Committee. Quality improvement guidelines for the performance of inferior vena cava filter placement for the prevention of pulmonary embolism. J Vasc Interv Radiol. 2011; 22(11): 1499–1506

[3] Martin MJ, Blair KS, Curry TK, Singh N. Vena cava filters: current concepts and controversies for the surgeon. Curr Probl Surg. 2010; 47(7):524–618

[4] Cronin B, Nguyen L, Manecke G, Pretorius V, Banks D, Maus T. Foreign body located intraoperatively using transesophageal echocardiography. J Cardiothorac Vasc Anesth. 2014; 28(3): 852–853

[5] Tan WP, Sherer BA, Khare N. Unfriendly filter: an unusual cause of hydronephrosis and hematuria. Urology. 2016; 87: e9–e10

[6] Cuadra SA, Sales CM, Lipson AC, Armstrong CA. Misplacement of a vena cava filter into the spinal canal. J Vasc Surg. 2009; 50(5):1170–1172

[7] Grewal S, Chamarthy MR, Kalva SP. Complications of inferior vena cava filters. Cardiovasc Diagn Ther. 2016; 6(6): 632–641

[8] Al-Hakim R, Kee ST, Olinger K, Lee EW, Moriarty JM, McWilliams JP. Inferior vena cava filter retrieval: effectiveness and complications of routine and advanced techniques. J Vasc Interv Radiol. 2014; 25(6):933–939, quiz 940

[9] Kuo WT, Robertson SW, Odegaard JI, Hofmann LV. Complex retrieval of fractured, embedded, and penetrating inferior vena cava filters: a prospective study with histologic and electron microscopic analysis. J Vasc Interv Radiol. 2013; 24 (5):622–630.e1, quiz 631

[10] Dinglasan LA, Trerotola SO, Shlansky-Goldberg RD, Mondschein J, Stavropoulos SW. Removal of fractured inferior vena cava filters: feasibility and outcomes. J Vasc Interv Radiol. 2012; 23(2):181–187

[11] Vijay K, Hughes JA, Burdette AS, et al. Fractured Bard Recovery, G2, and G2 express inferior vena cava filters: incidence, clinical consequences, and outcomes of removal attempts. J Vasc Interv Radiol. 2012; 23(2):188–194

[12] Durack JC, Westphalen AC, Kekulawela S, et al. Perforation of the IVC: rule rather than exception after longer indwelling times for the Günther Tulip and Celect retrievable filters. Cardiovasc Intervent Radiol. 2012; 35(2):299–308

[13] An T, Moon E, Bullen J, et al. Prevalence and clinical consequences of fracture and fragment migration of the Bard G2 filter: imaging and clinical follow-up in 684 implantations. J Vasc Interv Radiol. 2014; 25(6):941–948

[14] Hull JE, Han J, Giessel GM. Retrieval of the recovery filter after arm perforation, fracture, and migration to the right ventricle. J Vasc Interv Radiol. 2008; 19(7):1107–1111

[15] Kendirli MT, Sildiroglu O, Cage DL, Turba UC. Inferior vena cava filter presenting as chronic low back pain. Clin Imaging. 2012; 36(3):236–238

[16] Jehangir A, Rettew A, Shaikh B, et al. IVC filter perforation through the duodenum found after years of abdominal pain. Am J Case Rep. 2015; 16:292–295

[17] Skeik N, McEachen JC, Stockland AH, et al. Lumbar artery pseudoaneurysm caused by a Gunther Tulip inferior vena cava filter. Vasc Endovascular Surg. 2011; 45(8):756–760

[18] Minocha J, Idakoji I, Riaz A, et al. Improving inferior vena cava filter retrieval rates: impact of a dedicated inferior vena cava filter clinic. J Vasc Interv Radiol. 2010; 21(12):1847–1851

[19] Ko SH, Reynolds BR, Nicholas DH, et al. Institutional protocol improves retrievable inferior vena cava filter recovery rate. Surgery. 2009; 146(4):809–814, discussion 814–816

[20] Lynch FC. A method for following patients with retrievable inferior vena cava filters: results and lessons learned from the first 1,100 patients. J Vasc Interv Radiol. 2011; 22(11): 1507–1512

[21] Rogers FB, Shackford SR, Miller JA, Wu D, Rogers A, Gambler A. Improved recovery of prophylactic inferior vena cava filters in trauma patients: the results of a dedicated filter registry and critical pathway for filter removal. J Trauma Acute Care Surg. 2012; 72(2):381–384

[22] Ryu RK, Parikh P, Gupta R, et al. Optimizing IVC filter utilization: a prospective study of the impact of interventional radiologist consultation. J Am Coll Radiol. 2012; 9(9):657–660

[23] Lee MJ, Valenti D, de Gregorio MA, Minocha J, Rimon U, Pellerin O. The CIRSE retrievable IVC filter registry: retrieval success rates in practice. Cardiovasc Intervent Radiol. 2015; 38(6):1502–1507

[24] Andreoli JM, Lewandowski RJ, Vogelzang RL, Ryu RK. Comparison of complication rates associated with permanent and retrievable inferior vena cava filters: a review of the MAUDE database. J Vasc Interv Radiol. 2014; 25(8):1181–1185

[25] Hoffer EK, Mueller RJ, Luciano MR, Lee NN, Michaels AT, Gemery JM. Safety and efficacy of the Gunther Tulip retrievable vena cava filter: midterm outcomes. Cardiovasc Intervent Radiol. 2013; 36(4):998–1005

[26] Bos AS, Tullius T, Patel M, et al. Indwelling and retrieval complications of Denali and Celect infrarenal vena cava filters. J Vasc Interv Radiol. 2016; 27(7):1021–1026

[27] Group PS, PREPIC Study Group. Eight-year follow-up of patients with permanent vena cava filters in the prevention of pulmonary embolism: the PREPIC (Prevention du Risque d'Embolie Pulmonaire par Interruption Cave) randomized study. Circulation. 2005; 112(3):416–422

[28] Mismetti P. Randomized trial assessing the efficacy of the partial interruption of the inferior vena cava by an optional vena caval filter in the prevention of the recurrence of pulmonary embolism. PREPIC 2 trial: prevention of embolic recurrences by caval interruption (prospective, multicentric, randomised, open trial). Rev Pneumol Clin. 2008; 64(6):328–331

[29] Tam MD, Spain J, Lieber M, Geisinger M, Sands MJ, Wang W. Fracture and distant migration of the Bard Recovery filter: a retrospective review of 363 implantations for potentially life-threatening complications. J Vasc Interv Radiol. 2012; 23(2): 199–205.e1

[30] Zhou D, Moon E, Bullen J, Sands M, Levitin A, Wang W. Penetration of Celect inferior vena cava filters: retrospective review of CT scans in 265 patients. AJR Am J Roentgenol. 2014; 202(3):643–647

[31] Binkert CA, Sasadeusz K, Stavropoulos SW. Retrievability of the recovery vena cava filter after dwell times longer than 180 days. J Vasc Interv Radiol. 2006; 17(2, Pt 1):299–302

[32] Lynch FC, Kekulawela S. Removal of the G2 filter: differences between implantation times greater and less than 180 days. J Vasc Interv Radiol. 2009; 20(9):1200–1209

[33] Zhu X, Tam MD, Bartholomew J, Newman JS, Sands MJ, Wang W. Retrievability and device-related complications of the G2 filter: a retrospective study of 139 filter retrievals. J Vasc Interv Radiol. 2011; 22(6):806–812

[34] Dinglasan LA, Oh JC, Schmitt JE, Trerotola SO, Shlansky-Goldberg RD, Stavropoulos SW. Complicated inferior vena cava filter retrievals: associated factors identified at preretrieval CT. Radiology. 2013; 266(1):347–354

[35] Stavropoulos SW, Dixon RG, Burke CT, et al. Embedded inferior vena cava filter removal: use of endobronchial forceps. J Vasc Interv Radiol. 2008; 19(9):1297–1301

[36] Stavropoulos SW, Ge BH, Mondschein JI, Shlansky-Goldberg RD, Sudheendra D, Trerotola SO. Retrieval of tip-embedded inferior vena cava filters by using the endobronchial forceps technique: experience at a single institution. Radiology. 2015; 275(3):900–907

[37] Owens CA, Bui JT, Knuttinen MG, Gaba RC, Carrillo TC. Pulmonary embolism from upper extremity deep vein thrombosis and the role of superior vena cava filters: a review of the literature. J Vasc Interv Radiol. 2010; 21(6):779–787