Endovascular Therapy for Lower Extremity Chronic Deep Venous Occlusive Disease: State of Practice

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Chronic deep venous thrombosis (DVT) of the inferior vena cava and the iliac veins, also known as chronic ilio caval thrombosis, is a cause of significant morbidity. This may lead to limb-threatening occlusive symptoms secondary to DVT in the lower extremities, phlegmasia cerulea dolens, and post-thrombotic syndrome (PTS), and may be fatal secondary to development of pulmonary embolism.^{1–10} PTS commonly presents with leg pain, swelling, venous claudication, cutaneous hyperpigmentation, varicose veins, and venous ulcers secondary to stasis. Iliocaval recanalization and reconstruction is a minimally invasive endovascular technique used in the management of chronic ilio caval thrombosis, which involves recanalization, angioplasty, and possibly stenting, with the ultimate aim of restoring in-line venous flow throughout the ilio caval system. This technique has been shown to provide significant symptomatic relief to patients while also potentially preventing recurrent thromboembolic disease.

Indications

The indications for endovascular ilio caval recanalization and reconstruction include deep venous occlusion secondary to recurrent DVT, severe PTS, and caval thrombosis leading to significant lifestyle limitations.¹¹ Acute thrombus is generally defined as those aged less than 2 weeks, while chronic thrombus is defined as being present for more than 4 weeks. Endovascular ilio caval reconstruction may be performed

with both acute and chronic thrombosis; however, the indications and techniques for recanalization of acute ilio caval thrombosis differ from those used for chronic thrombosis. Acute thrombus is soft and pliable, allowing for early thrombolysis, recanalization, angioplasty, and stent placement.¹² Subacute thrombosis (2–4 weeks old) may either be managed medically with anticoagulation, ambulation, and leg elevation or by endovascular recanalization.¹² Delaying the endovascular treatment of subacute thrombosis may lead to maturation of the thrombus. Subacute thrombus is large and bulky, which limits angioplasty and stenting and makes it less responsive to thrombolysis and thrombectomy. Chronic thrombus (>4 weeks) becomes organized and elicits inflammatory scarring in the vessel, which allows the vessel to be balloon dilated and stented more effectively after recanalization.¹² The classification of thrombus as acute, subacute, and chronic should be used as a temporal guide, and clinical evaluation of the patient should ultimately guide intervention, especially in the subacute phase.

Clinical Evaluation

Preprocedural evaluation is critical for the appropriate management of patients with ilio caval thrombosis.^{1,2,13} Relevant patient history should include the time course of symptoms, anticoagulation use, comorbidities which may affect

anesthesia needs, personal or family history of thrombophilia (which may warrant further medical evaluation for hereditary thrombophilias¹⁴), functional status related to deep venous occlusion, and prior interventions pertinent to the patient's current presentation such as inferior vena cava filter placement and surgical history.

A focused physical examination should be performed of the lower extremities, which may delineate the clinical extent of deep venous occlusion and the severity of disease.^{2,13} Lower extremity edema, cyanosis, lipodermatosclerosis, varicosities, and tenderness are some of the clinical signs that are helpful in identifying the occluded venous segments. Laterality of signs and symptoms (unilateral or bilateral) is also important to assess. Nonspecific symptoms of venous occlusion include radiculopathy and back pain secondary to dilated epidural and lumbar collaterals, postural hypotension due to pooling of blood in collaterals and decreased venous return upon standing, abdominal and pelvic pain due to mesenteric collateral drainage, and dysphagia secondary to dilated azygous and hemiazygos veins causing mass effect on esophagus. Pertinent laboratory evaluation includes coagulation parameters, such as platelets, partial thromboplastin time, prothrombin time/international normalized ratio, and some specific laboratory tests relevant to the patient, such as anti-Xa levels, Ecarin chromogenic assay, clotting time, and dilute Russell's viper venom time. Additionally, a baseline complete blood count and basic metabolic panel should be obtained to evaluate for anemia and renal function.¹³

Imaging Evaluation

A thorough review of all prior imaging examinations is critical to guide clinical decision making, plan potential interventions, gauge the location and extent of thrombosis, and evaluate the degree of collateralization and patency of access vessels. If not already available, appropriate imaging must be obtained prior to the procedure and is considered standard of care.

Duplex ultrasonography is a noninvasive imaging modality that obtains both anatomic and physiologic data regarding patency and flow characteristics of the deep venous system in the lower extremities.¹⁵ Longitudinal gray scale sonographic imaging is important in addition to the transverse views, since color Doppler masks vessel wall thickening or webs within the vein lumen. Duplex sonography is limited in the complete evaluation of the iliac veins, but may be used for screening as appropriate.¹³ The absence of spontaneous flow with respiration in the common femoral vein may raise suspicion for ilio caval obstruction, which may not be directly visualized with ultrasound. Computed tomography venography (CTV) or magnetic resonance venography (MRV) are excellent noninvasive imaging modalities used to delineate the anatomy of the ilio caval venous system, demonstrate large collaterals, visualize calcified thrombotic segments, and determine the location of intravascular foreign bodies such as inferior vena cava filters.¹⁶ CTV or MRV is particularly useful

in cases where sharp recanalization is being planned or anticipated in order to assess relevant adjacent anatomy.¹⁷

Anticoagulation

Anticoagulation is the standard of care for patients with both acute and chronic deep occlusion. Therefore, patients presenting for endovascular treatment of caval thrombosis are routinely started on anticoagulation or antiplatelet medications.^{18,19} Guidewire manipulation during recanalization carries the risk of extraluminal passage of the wire and subsequent hemorrhage; however, there are no specific guidelines for management of anticoagulation. Some practitioners suggest holding all anticoagulation and antiplatelet agents other than aspirin prior to endovascular interventions.²⁰ Warfarin and clopidogrel, for instance, should be held for 5 days; apixaban, fondaparinux, and rivaroxaban for 3 days; and enoxaparin for 24 hours. If the patient is on a heparin infusion, it may be held for 2 hours prior to intervention and restarted in the postprocedural care unit. Some authors, however, advocate continued heparin infusion during the procedure to eliminate the need for heparin titration during the procedure.

Equipment

The equipment used for ilio caval recanalization and reconstruction includes standard micropuncture sets for internal jugular vein, common femoral vein, great saphenous vein, popliteal vein, or posterior tibial vein accesses: 6-French (F), 8-F, and 10-F sheaths; vertebral tip (angled) or braided tapered tip catheters; flush catheters; stiff straight- and angle-tipped hydrophilic guidewires (Glidewire; Terumo Corporation; Shibuya, Japan); high-pressure balloons; and loop snare devices as needed to begin the recanalization. Needles that may be used for sharp recanalization include BRK and BRK-1 trans-septal (St. Jude Medical, Saint Paul, MN), Chiba (Cook Medical, Bloomington, IN), and Rösch-Uchida (Cook Medical) needles. Intravascular ultrasound (IVUS) may be useful for detecting residual mural thrombus, delineating the degree of deep venous involvement, identifying the proximity of critical structures, and determining stent sizes.²¹

Currently, all stents used for caval or iliac deep venous reconstruction are used off-label, since there are no Food and Drug Administration–approved stents for ilio caval reconstruction. Large diameter and self-expanding stents are ideal for ilio caval system (e.g., Wallstents; Boston Scientific, Natick, MA). A 10-F sheath may accommodate up to a 20-mm Wallstent; 12-F sheath, however, may be required in cases where 24-mm Wallstents need to be placed. Both Wallstents and self-expanding nitinol stents have good long-term patency and clinical outcomes.^{22–24} For venous closure, manual compression, pressure-assisted closure devices, or sutures may be used.¹²

Anesthesia

General anesthesia is preferred for chronic ilio caval thrombosis recanalization, since angioplasty of stenosed veins may be painful and because these procedures are very time

intensive. Sedation and analgesia may also be used in poor anesthetic candidates, or based on operator preference and experience. In these patients, generous use of local anesthesia at all vascular access sites is vital to ensure patient comfort. The patients' ability to follow commands is imperative, since frequent breath holds are needed for adequate quality diagnostic venograms. The patient should be typed and crossed for two units of blood prior to the procedure, to be administered in the event of serious hemorrhage.¹²

Vascular Access

From a recent survey of 107 interventionalists, the most commonly used access sites are femoral (80.8%), internal jugular (68.7%), popliteal (54.5%), and saphenous vein (27.3%), with over half of all procedures (51.5%) using two access sites, and one-third (32.3%) using three.²⁵ The optimal access route, however, is open to debate, leading to considerable heterogeneity in practice patterns. Saphenous access may have the benefit of easier postprocedural hemostasis compared with femoral access, without being limited to smaller catheter calibers. This is particularly important in patients who are at high risk of postprocedural hemorrhage, such as fully anticoagulated patients.² Posterior tibial access may be appropriate in patients with distal occlusions in the lower extremity that may not be adequately approached with femoral or saphenous access. Distal access may also be more comfortable for patients and allows for early ambulation in recovery. The tibial approach, however, is limited to 7-F catheter sizes due to small vessel caliber.

Recanalization

Recanalization and reconstruction for lower extremity deep venous occlusive disease are shown in ►Figs. 1, 2, and 3. Recanalization is performed from peripheral to central, to direct guidewire advancement into the true thin ilio caval conduit (referred to as "string sign"; ►Fig. 1b) on subsequent contrast injections.² An 8-F sheath may be placed in the internal jugular vein and a 6-F sheath may be placed into the inferior access (such as common femoral, great saphenous, or popliteal vein), followed by advancement of a hydrophilic guidewire and vertebral catheter. Digital subtraction venographic images are obtained (following access) to determine the extent of deep venous occlusive disease and to plan the pathway for recanalization. Delayed venographic images are useful to visualize the reconstituted central segment. The string sign may be used as a guide if the identification of the channel becomes difficult to visualize among the surrounding collateral vessels. A short tapered "nub" will be present, which indicates the distal aspect of the completely occluded venous segment.

Multiple recanalization techniques have been described for chronic venous stenosis and occlusions, the most common and straightforward of which is blunt recanalization. For this technique, the operator uses a guidewire and catheter to probe through the occlusion until the catheter reaches

a patent segment.^{11,12,21} Once the occlusion is crossed, through-and-through access may be obtained by capturing an exchange-length wire placed through the catheter with a loop snare device placed from another access site. Through-and-through wire access establishes a rigid rail that may be tightened from both ends to accomplish delivery of catheters, balloons, and stents across the obstructed veins, especially the recalcitrant segments.²¹

Sharp recanalization techniques may be required when blunt recanalization techniques fail, for instance when the wire passage is not possible in areas of dense fibrosis and calcification, or when wires from central and proximal accesses may overlap in different planes and are unable to re-enter the reconstituted segment. Sharp recanalization of the obstruction involves the use of a recanalization needle or re-entry device and a loop snare. It can also be performed using a side-by-side balloon dilation in the inferior vena cava or iliofemoral segments, where two balloons are inflated in an attempt to create a common channel through which a wire may be passed to cross the obstruction and potentially to use a loop snare to entrap the wire.

In cases where standard blunt or sharp recanalization techniques fail to facilitate successful transversal of the occlusion, three-dimensional (3D) targeting of an AMPLATZER vascular plug (St. Jude Medical) or Wallstent endoprosthesis may be indicated. This technique uses a partially deployed AMPLATZER vascular plug or Wallstent endoprosthesis in the patent distal or proximal portion of the vessel which serves as a 3D target for transseptal needle localization from the opposite side. The partially deployed device may be targeted and punctured using rotational fluoroscopy which uses tactile and visual cues to help confirm the needle hitting the target. Following this, a 0.018-inch V-18 guidewire (Boston Scientific) is advanced through the interstices of the device before reconstraining the plug or stent, which establishes a through-and-through access when the device is removed from its respective sheath.²¹

Thrombectomy

Several catheter-based mechanical and pharmacomechanical thrombectomy devices are available, which may be used in acute or subacute thrombosis and aid in clearing acute on chronic clots that appear during recanalization. Catheter-directed thrombolysis with tissue plasminogen activator, alteplase, or tenecteplase infusion may be performed using infusion catheters such as EkoSonic ultrasound-enhanced thrombolysis system (EKOS; BTG, London, UK), UniFuse (Angiodynamics, Latham, NY), or the Cragg-McNamara (Covidien Ltd, Dublin, Ireland) multi-sidehole infusion catheters.²⁶ Pharmacomechanical thrombectomy devices include the AngioJet rheolytic thrombectomy system (Boston Scientific) and the Trellis device (Covidien, previously discontinued). Pure mechanical thrombectomy may be performed using Indigo System (Penumbra, Alameda, CA), Arrow-Trerotola percutaneous thrombectomy device (Teleflex Inc., Wayne, PA), Cleaner 15 and XT (Argon Medical,

Fig. 1 A 52-year-old female with quadriplegia, factor V Leiden, and antithrombin III deficiency referred for chronic ilio caval thrombosis and phlegmasia. (a) Left ilio caval venography demonstrating left common iliac occlusive disease with robust retroperitoneal collaterals. The ilio caval confluence is faintly seen (arrow). (b) Bilateral right (arrow) and left (arrowheads) ilio caval venography after blunt recanalization of the left iliac vein. (c) Bilateral right (arrow) and left (arrowheads) ilio caval venography after blunt recanalization of the right and left iliac veins. (d) Sequential angioplasty of the inferior vena cava was performed using 8 mm $\times$ 8 cm Mustang, 14 mm $\times$ 6 cm, and 18 mm $\times$ 4 cm Atlas balloons. Angioplasty of the bilateral right and left (arrow) common iliac veins was performed using 8 mm $\times$ 8 cm Mustang, 14 mm $\times$ 6 cm and 16 mm $\times$ 4 cm Atlas balloons. (e) Iliocaval reconstruction was performed using a 20 mm $\times$ 55 mm Wallstent within the inferior vena cava and 14 mm $\times$ 90 mm Wallstents within the bilateral common iliac veins. Postdeployment angioplasty was performed. (f) Completion venography showing brisk flow throughout the ilio caval venous reconstruction. A flush catheter is seen throughout the right ilio caval segments (arrows).

Plano, TX), and AngioVac aspiration thrombectomy system (Angiodynamics).^{27,28}

Reconstruction

Following wire recanalization of the occluded deep venous segments, the tract should be interrogated using angiogra-

phy (with iodinated contrast or CO₂) and possibly IVUS for integrity and transversal of adjacent arteries and organs prior to balloon angioplasty and stenting. IVUS may delineate the locations of vessel reconstitution or reentry, which may serve as landmarks for balloon inflation and stenting landing zones.²¹ After confirmation of tract safety, systemic heparin should be initiated with a goal activated clotting

Fig. 2 A 46-year-old male with esophageal cancer–associated hypercoagulability and inferior vena cava filter–associated chronic ilio caval thrombosis and left lower extremity ulceration (Clinical, Etiology, Anatomy, and Pathophysiology class 6 disease). (a) Bilateral ilio caval venography demonstrates chronic thrombotic changes throughout the iliac vein and inferior vena cava (arrow). Multiple lumbar and retroperitoneal venous collaterals are seen. (b) Fluoroscopic image showing a Denali inferior vena cava filter (arrow) causing chronic filter-associated ilio caval thrombosis. (c) The Denali inferior vena cava filter (arrow) was removed using the standard Cook retrieval set (arrowheads). (d) Angioplasty of the inferior vena cava using a 14-mm high-pressure balloon (arrow). (e) Angioplasty of the inferior vena cava using an 18-mm high-pressure balloon (arrow). (f) A 20 mm × 55 mm Wallstent was deployed in the inferior vena cava and 14 mm × 60 mm Wallstents were placed within the common iliac veins. Completion venography demonstrated robust in-line venous flow throughout both iliac veins. (g) Venography demonstrated in-line flow throughout the inferior vena cava.

time (ACT) of more than 230 (unless continuous heparin infusion is used). To insert the appropriately sized balloons for the next step, an 8-F sheath, at minimum, must be inserted. It may be necessary to predilate the tract with a 4- to 6-mm balloon to advance the 8-F sheath across the occlusion. The IVC is then sequentially angioplastied to 18 to 20 mm, the common iliac vein to 16 mm, and the external iliac and common femoral veins to 14 mm.^{12,29} There is a risk of postprocedural rethrombosis in the recanalized lumen containing residual thrombus. The residual thrombus may be visualized using IVUS or outlined by contrast on angiography, and if present, there should be a low threshold for stenting, preferably using self-expanding stents. These stents

have minimal foreshortening, good flexibility, and high resistive force.^{30,31}

Long-term stent patency requires maintenance of adequate inflow into the reconstructed inferior vena cava or iliac veins.³² Inflow is evaluated in the common femoral, femoral, profunda femoris, and popliteal veins. If venography of these veins demonstrates significant stasis of flow below or within the stented segments, or significant flow through collaterals, additional angioplasty or stenting may be required in these segments. Venography of these veins may be performed from internal jugular, popliteal, or posterior tibial approaches. IVUS may be used as an adjunct to increase the sensitivity of postprocedural evaluation.³³ Patients who suffer from

Fig. 3 A 61-year-old male with methylenetetrahydrofolate reductase and smoking history with inferior vena cava filter-associated chronic ilio caval thrombosis and left lower extremity pain and swelling (Clinical, Etiology, Anatomy, and Pathophysiology class 4 disease). (a) Right ilio caval venography demonstrated venous irregularity consistent with chronic ilio caval thrombosis of the right ilio caval segment (arrow). (b) Initial attempts to cross the inferior vena cava filter-associated ilio caval thrombosis using a guidewire and glide catheter (arrow) were unsuccessful. (c) Fluoroscopic image demonstrating the Trapeze inferior vena cava filter (arrow) causing chronic filter-associated ilio caval thrombosis. Sharp recanalization was performed using a BRK needle and a loop snare. (d) Attempts to remove the inferior vena cava filter were unsuccessful. Angioplasty across the inferior vena cava filter was performed using a 4-mm Sterling balloon (arrow). (e) The infrarenal inferior vena cava was angioplastied using an 18-mm balloon. (f) A 20 mm × 55 mm Wallstent was deployed in the inferior vena cava and 12 mm × 90 mm Wallstents were deployed in the common iliac veins (arrows). (g) Completion venography demonstrated a briskly filling ilio caval reconstruction with Trapeze inferior vena cava filter sequestration (arrow).

ilio caval thrombosis may also have thrombus extending inferiorly to the common femoral vein. For successful recanalization, stenting of this area may also be required. Note that the profunda femoris vein may serve as the primary or secondary drainage of lower extremity following ilio caval reconstruction. Preservation of its inflow is thus important whenever possible.³⁴

Technical Considerations

During recanalization of an obstruction, it is possible for the needle or guidewire to pass outside the vessel lumen.^{35,36}

Due to low pressures within the venous system, however, short segments of extraluminal passage of needle or guidewire in areas of chronic thrombosis have not been found to be clinically significant. Major venous tears, if encountered, may be managed with self-expanding stent grafts, such as conformable TAG or Viabahn (Gore Medical, Flagstaff, AZ). Alternatively, anticoagulation may be temporarily held and uncovered stents may be placed across the tear.³⁷

Recanalization at the left ilio caval confluence near the right iliac artery bifurcation and near the renal artery poses some risk of arterial injury, particularly when sharp recanalization is used. In these cases, IVUS or placement of arterial

angiography catheter and intermittent injection of contrast may be used to assist in localizing the arteries to avoid injury when passing the guidewire or needle. Ureteral injuries may be prevented by nephroureteral stent or JJ ureteral stent placement preprocedurally, if sharp recanalization is required near the ureter crossing.

Inferior vena cava filter-associated ilio caval thrombosis presents an added obstacle for recanalization. Filter retrieval should be attempted for both retrievable and permanent filters.^{38–40} Several studies have shown safe retrieval of permanent filters using advanced techniques.^{41–44} If the filter cannot be retrieved, angioplasty and placement of a self-expanding 18- to 24-mm stent across the filter may be performed to exclude the filter from the reconstructed lumen.^{45,46} Studies have shown similar long-term patency rates for both filter retrieval and exclusion techniques.¹¹

Complications

Immediate complications are related to vascular access and self-limiting access site hematomas or bleeding, which may be managed with manual compression or pressure-assisted devices. Arterial injuries leading to retroperitoneal or access site hematomas are rare and may lead to hemodynamic compromise, requiring blood transfusions.¹² Computed tomography angiography may be considered for clinical suspicion and arterial angiography and embolization as warranted. Antiplatelet agents such as clopidogrel and aspirin should be held if hemorrhage persists. Stent migration is the most common complication after stent placement, and if this does occur, an additional stent may be placed between the stents to reduce the risk of restenosis or interstent thrombosis.²⁹

Postprocedural Care

There are no specific anticoagulant recommendations regarding anticoagulation following ilio caval reconstruction for deep venous occlusive disease. Anticoagulant prophylaxis with enoxaparin or low-molecular-weight heparin may be considered during the immediate postprocedural period. Some authors opine the use of baby aspirin (81 mg) daily, clopidogrel 75 mg daily, and enoxaparin 1 mg/kg twice daily prior to discharge.^{2,5,6,11,22,47} Enoxaparin is preferred for its rapid onset, reliable anticoagulation (unlike warfarin), and potential anti-inflammatory action. Some authors, on the other hand, use anticoagulants only during the acute phase within 6 months of a diagnosed venous thromboembolism or known thrombophilia. In cases without venous thromboembolism or thrombophilia, use of dual-platelet therapy with aspirin and clopidogrel with an anticoagulant is recommended. Patients should be seen in the outpatient clinic within 2 weeks post-procedure and may be transitioned to warfarin or direct oral anticoagulant. In patients with body mass index of greater than 40 or cachexia, low-molecular-weight heparin dose of 1 mg/kg may be supratherapeutic, and anti-Xa levels should be checked.

Long-term treatment recommendations are variable; however, lifelong aspirin and several months of anticoagulation are recommended except in patients with underlying

thrombophilia. Patients with recurrent venous thromboembolic disease or thrombophilia should be referred to a hematologist or vascular medicine physician, and are typically anticoagulated indefinitely.⁴⁸ Some authors discontinue clopidogrel after 2 months and maintain aspirin therapy indefinitely. Anticoagulation is typically maintained for at least 6 months and discontinued based on clinical status, laboratory values, and results of imaging studies, if available. For lower-risk patients, some operators may choose to limit anticoagulants for shorter periods.

There are no guidelines regarding postprocedure imaging. Duplex sonography of iliac veins and vena cava should be performed soon after the procedure to evaluate the stent patency and inflow.⁴⁹ Stent evaluation time periods by imaging may be performed at 2-month, 6-month, and 1-year intervals unless symptoms recur or worsen, although this is variable. Venographic evaluation may be performed at 6, 12, and 24 months, which may allow precise quantification of in-stent stenosis and potential for IVUS and intravascular biopsy for assessment of mural composition (at some institutions). Clinical follow-up is important to assess symptoms and compliance with antithrombotic regimens.

Outcomes

Ilio caval recanalization and reconstruction are considered the standard of care for chronic ilio caval occlusive disease, with multiple studies reporting favorable technical success rates and high patency.^{49–56} The longest European study comprising 89 patients demonstrated primary, assisted primary, and secondary patency rates of 83, 89, and 93%, respectively.⁷ In a recent study of 120 patients with inferior vena cava filter-associated ilio caval thrombosis, ilio caval reconstruction was shown to have 100% technical success rate and 2-year primary-assisted and secondary patency rates of 90 and 94%, respectively.¹¹ Additional studies are warranted.

Conclusion

Ilio caval recanalization stent reconstruction is the treatment of choice for symptomatic lower extremity chronic deep venous occlusive disease and is associated with high technical success rates, low complications, favorable clinical outcomes, and favorable long-term stent patency rates. It is an effective intervention for ilio caval thrombosis and has the potential to substantially improve the patient's quality of life.

References

- 1 Raju S. Treatment of iliac-caval outflow obstruction. *Semin Vasc Surg* 2015;28(01):47–53
- 2 Williams DM. Ilio caval reconstruction in chronic deep vein thrombosis. *Tech Vasc Interv Radiol* 2014;17(02):109–113
- 3 de Graaf R, de Wolf M, Sailer AM, van Laanen J, Wittens C, Jalaie H. Ilio caval confluence stenting for chronic venous obstructions. *Cardiovasc Intervent Radiol* 2015;38(05):1198–1204
- 4 Neglén P, Raju S. Balloon dilation and stenting of chronic iliac vein obstruction: technical aspects and early clinical outcome. *J Endovasc Ther* 2000;7(02):79–91

- 5 Neglén P, Darcey R, Olivier J, Raju S. Bilateral stenting at the ilio-caval confluence. *J Vasc Surg* 2010;51(06):1457–1466
- 6 Raju S, Owen S Jr, Neglen P. The clinical impact of iliac venous stents in the management of chronic venous insufficiency. *J Vasc Surg* 2002;35(01):8–15
- 7 Hartung O, Loundou AD, Barthelemy P, Arnoux D, Boufi M, Alimi YS. Endovascular management of chronic disabling ilio-caval obstructive lesions: long-term results. *Eur J Vasc Endovasc Surg* 2009;38(01):118–124
- 8 Hartung O, Otero A, Boufi M, et al. Mid-term results of endovascular treatment for symptomatic chronic nonmalignant ilio-caval venous occlusive disease. *J Vasc Surg* 2005;42(06):1138–1144, discussion 1144
- 9 Knipp BS, Ferguson E, Williams DM, et al. Factors associated with outcome after interventional treatment of symptomatic iliac vein compression syndrome. *J Vasc Surg* 2007;46(04):743–749
- 10 Amin VB, Lookstein RA. Catheter-directed interventions for acute ilio-caval deep vein thrombosis. *Tech Vasc Interv Radiol* 2014;17(02):96–102
- 11 Chick JFB, Jo A, Meadows JM, et al. Endovascular ilio-caval stent reconstruction for inferior vena cava filter-associated ilio-caval thrombosis: approach, technical success, safety, and two-year outcomes in 120 patients. *J Vasc Interv Radiol* 2017;28(07):933–939
- 12 Hage AN, Srinivasa RN, Abramowitz SD, Chick JFB. Management and treatment of ilio-caval thrombosis using endovascular recanalization, stenting, and reconstruction: what all practitioners should know. *J Radiol Nurs* 2017;36(04):218–223
- 13 Mahnken AH, Thomson K, de Haan M, O'Sullivan GJ. CIRSE standards of practice guidelines on ilio-caval stenting. *Cardiovasc Intervent Radiol* 2014;37(04):889–897
- 14 Rosendaal FR, Reitsma PH. Genetics of venous thrombosis. *J Thromb Haemost* 2009;7(Suppl 1):301–304
- 15 Aurshina A, Ascher E, Hingorani A, Salles-Cunha SX, Marks N, Iadgarova E. Clinical role of the “venous” ultrasound to identify lower extremity pathology. *Ann Vasc Surg* 2017;38:274–278
- 16 Tamura K, Nakahara H. MR venography for the assessment of deep vein thrombosis in lower extremities with varicose veins. *Ann Vasc Dis* 2014;7(04):399–403
- 17 Karande GY, Hedgire SS, Sanchez Y, et al. Advanced imaging in acute and chronic deep vein thrombosis. *Cardiovasc Diagn Ther* 2016;6(06):493–507
- 18 McAree BJ, O'Donnell ME, Fitzmaurice GJ, Reid JA, Spence RA, Lee B. Inferior vena cava thrombosis: a review of current practice. *Vasc Med* 2013;18(01):32–43
- 19 Saha P, Black S, Breen K, Patel A, Modarai B, Smith A. Contemporary management of acute and chronic deep venous thrombosis. *Br Med Bull* 2016;117(01):107–120
- 20 Arabi M, Vellody R, Cwikiel WB, Gemmete JJ. Endovascular treatment of lower gastrointestinal bleeding from systemic-to-mesenteric venous collateral vessels caused by inferior vena cava occlusion: report of two cases. *J Vasc Interv Radiol* 2011;22(07):1035–1038
- 21 Khaja MS, Chick JFB, Schuman AD, et al. Fluoroscopic targeting of Wallstents and Amplatzer Vascular Plugs in sharp recanalization of chronic venous occlusions. *Cardiovasc Intervent Radiol* 2017;40(11):1777–1783
- 22 Raju S, Neglen P. High prevalence of nonthrombotic iliac vein lesions in chronic venous disease: a permissive role in pathogenicity. *J Vasc Surg* 2006;44(01):136–143, discussion 144
- 23 Stoeckel D, Pelton A, Duerig T. Self-expanding nitinol stents: material and design considerations. *Eur Radiol* 2004;14(02):292–301
- 24 DeRubertis BG, Alktaifi A, Jimenez JC, Rigberg D, Gelabert H, Lawrence PF. Endovascular management of nonmalignant ilio-caval venous lesions. *Ann Vasc Surg* 2013;27(05):577–586
- 25 Hage AN, Srinivasa RN, Abramowitz SD, Gemmete JJ, Reddy SN, Chick JFB. Endovascular ilio-caval stent reconstruction for ilio-caval thrombosis: a multi-institutional international practice pattern survey. *Ann Vasc Surg* 2018;49:64–74
- 26 Chen JX, Sudheendra D, Stavropoulos SW, Nadolski GJ. Role of catheter-directed thrombolysis in management of iliofemoral deep venous thrombosis. *Radiographics* 2016;36(05):1565–1575
- 27 Lee KH, Han H, Lee KJ, et al. Mechanical thrombectomy of acute iliofemoral deep vein thrombosis with use of an Arrow-Trerotola percutaneous thrombectomy device. *J Vasc Interv Radiol* 2006;17(03):487–495
- 28 Behrens G, Bjarnason H. Venous thromboembolic disease: the use of the aspiration thrombectomy device AngioVac. *Semin Intervent Radiol* 2015;32(04):374–378
- 29 Murphy EH, Johns B, Varney E, Buck W, Jayaraj A, Raju S. Deep venous thrombosis associated with caval extension of iliac stents. *J Vasc Surg Venous Lymphat Disord* 2017;5(01):8–17
- 30 Duda SH, Wiskirchen J, Tepe G, et al. Physical properties of endovascular stents: an experimental comparison. *J Vasc Interv Radiol* 2000;11(05):645–654
- 31 Neglén P, Tackett TP Jr, Raju S. Venous stenting across the inguinal ligament. *J Vasc Surg* 2008;48(05):1255–1261
- 32 van Vuuren TM, Kurstjens RL, de Wolf MA, van Laanen JH, Witten CH, de Graaf R. Stent extension into a single inflow vessel is a valuable option after endophlebectomy. *Phlebology* 2017. Doi: 10.1177/0268355517739766 [Epub ahead of print]
- 33 McLafferty RB. The role of intravascular ultrasound in venous thromboembolism. *Semin Intervent Radiol* 2012;29(01):10–15
- 34 Vogel D, Comerota AJ, Al-Jabouri M, Assi ZI. Common femoral endovenectomy with ilio-caval endoluminal recanalization improves symptoms and quality of life in patients with post-thrombotic iliofemoral obstruction. *J Vasc Surg* 2012;55(01):129–135
- 35 Aborahma AM. Use of a percutaneous puncture needle for true lumen re-entry during subintimal recanalization of the superficial femoral artery. *J Vasc Surg Cases Innov Tech*. 2016;2(03):108–110
- 36 Liang HL, Li MF, Chiang CL, Chen MCY, Wu CJ, Pan HB. The use of a Colapinto TIPS Needle under cone-beam computed tomography guidance for true lumen re-entry in subintimal recanalization of chronic iliac artery occlusion. *J Chin Med Assoc* 2017;80(06):371–375
- 37 Vedantham S, Kahn SR, Goldhaber SZ, et al. Endovascular therapy for advanced post-thrombotic syndrome: proceedings from a multidisciplinary consensus panel. *Vasc Med* 2016;21(04):400–407
- 38 Angel LF, Tapson V, Galgon RE, Restrepo MI, Kaufman J. Systematic review of the use of retrievable inferior vena cava filters. *J Vasc Interv Radiol* 2011;22(11):1522–1530.e3
- 39 Sildiroglu O, Ozer H, Turba UC. Management of the thrombosed filter-bearing inferior vena cava. *Semin Intervent Radiol* 2012;29(01):57–63
- 40 Doshi MH, Narayanan G. Late endovascular removal of Günther-Tulip inferior vena cava filter and stent reconstruction of chronic post-thrombotic ilio-caval obstruction after 4753 days of filter dwell time: a case report with review of literature. *Radiol Case Rep* 2016;11(04):348–353
- 41 Iliescu B, Haskal ZJ. Advanced techniques for removal of retrievable inferior vena cava filters. *Cardiovasc Intervent Radiol* 2012;35(04):741–750
- 42 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(06):933–939, quiz 940
- 43 Al-Hakim R, McWilliams JP, Derry W, Kee ST. The hangman technique: a modified loop snare technique for the retrieval of inferior vena cava filters with embedded hooks. *J Vasc Interv Radiol* 2015;26(01):107–110
- 44 Tamrazi A, Wadhwa V, Holly B, et al. Percutaneous retrieval of permanent inferior vena cava filters. *Cardiovasc Intervent Radiol* 2016;39(04):538–546

- 45 Kuo WT, Cupp JS, Louie JD, et al. Complex retrieval of embedded IVC filters: alternative techniques and histologic tissue analysis. *Cardiovasc Intervent Radiol* 2012;35(03):588–597
- 46 Neglén P, Oglesbee M, Olivier J, Raju S. Stenting of chronically obstructed inferior vena cava filters. *J Vasc Surg* 2011;54(01):153–161
- 47 Raju S. Best management options for chronic iliac vein stenosis and occlusion. *J Vasc Surg* 2013;57(04):1163–1169
- 48 Connors JM. Thrombophilia testing and venous thrombosis. *N Engl J Med* 2017;377(12):1177–1187
- 49 Nazarian GK, Bjarnason H, Dietz CA Jr, Bernadas CA, Hunter DW. Iliofemoral venous stenoses: effectiveness of treatment with metallic endovascular stents. *Radiology* 1996;200(01):193–199
- 50 Arabi M, Krishnamurthy V, Cwikiel W, et al. Endovascular treatment of thrombosed inferior vena cava filters: techniques and short-term outcomes. *Indian J Radiol Imaging* 2015;25(03):233–238
- 51 Blättler W, Blättler IK. Relief of obstructive pelvic venous symptoms with endoluminal stenting. *J Vasc Surg* 1999;29(03):484–488
- 52 Hurst DR, Forauer AR, Bloom JR, Greenfield LJ, Wakefield TW, Williams DM. Diagnosis and endovascular treatment of ilio caval compression syndrome. *J Vasc Surg* 2001;34(01):106–113
- 53 Kurklinsky AK, Bjarnason H, Friesen JL, et al. Outcomes of venoplasty with stent placement for chronic thrombosis of the iliac and femoral veins: single-center experience. *J Vasc Interv Radiol* 2012;23(08):1009–1015
- 54 Neglén P, Hollis KC, Olivier J, Raju S. Stenting of the venous outflow in chronic venous disease: long-term stent-related outcome, clinical, and hemodynamic result. *J Vasc Surg* 2007;46(05):979–990
- 55 Neglén P, Thrasher TL, Raju S. Venous outflow obstruction: an underestimated contributor to chronic venous disease. *J Vasc Surg* 2003;38(05):879–885
- 56 O'Sullivan GJ, Semba CP, Bittner CA, et al. Endovascular management of iliac vein compression (May-Thurner) syndrome. *J Vasc Interv Radiol* 2000;11(07):823–836