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A clinical guide to deep venous stenting for chronic iliofemoral venous obstruction

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ABSTRACT

Background: An increase in endovenous interventions for deep venous pathologies has been observed. This article aims to provide an overview of the role of venous stenting in the management of chronic conditions affecting the deep venous system of the lower limbs, with a focus on intervention relating to the vena cava and iliofemoral venous segments.

Methods: An overview of the literature on the minimally invasive venous stenting procedures that are being increasingly used in the management of chronic conditions affecting the deep venous system of the lower limbs.

Results: We discuss key areas of interest to a venous specialist practicing in this area, including diagnostic imaging in chronic deep venous disease, with a focus on the use of intravascular ultrasound examination in this context; the treatment of chronic venous outflow obstruction, including the rationale and structural indications for stenting, current guidance regarding stent placement, and fundamental points to consider during decision-making (endophlebectomy and stenting, stenting across the inguinal ligament, optimal sizing of venous stents, extension of venous stenting to beyond the common femoral vein confluence, the role of thrombolysis useful in chronic venous disease, and arteriovenous fistulae); outcomes and initial reports of stenting; and the future of venous stents.

Conclusions: Deep venous stenting has become a key treatment option for chronic (thrombotic or nonthrombotic) obstructive venous disease. Dedicated venous stents and intravascular ultrasound examination represent important technological advances in the minimally invasive treatment of symptomatic chronic deep venous obstruction, which previously required open surgical reconstruction. (J Vasc Surg Venous Lymphat Disord 2022;10:258-66.)

Keywords: DVT; Endovenous; Catheter-directed lysis; Thrombolysis; Venous stent; Post-thrombotic syndrome; May-Thurner syndrome

Deep venous stenting has become increasingly popular over the recent years and is now considered a common strategy for patients employed for patients with both acute and chronic venous obstruction, as well as patients with symptoms secondary to left iliac vein compression (nonthrombotic iliac vein lesion [NIVL], May-Thurner compression,[1] or Cockett's syndrome). These latter conditions are predominantly the consequence of compression of the left common iliac vein, where it traverses posterior to the right common iliac artery. This anatomic anomaly causes chronic, persistent compression of the vein which gives rise to vein fibrosis, with intraluminal synechiae and spurs with the end result being stenosis or occlusion of the lumen.[2]

Where intervention is indicated, although open surgical strategies exist, endovascular interventions in treating venous outflow lesions resulting from NIVL are currently felt to be more appropriate in the majority of these patients.[3]

The long-term sequelae of deep venous thrombosis (DVT), known as post-thrombotic syndrome (PTS), include a spectrum composed of persistent leg pain, swelling, heaviness, or venous ulcers that occurs in about 50% of patients within 1-2 years,[4] despite adequate anticoagulation therapy,[4,5] and carries significant adverse effect on quality of life[6] and the economy.[7]

The underlying pathophysiology of PTS is elevated ambulatory venous pressure that develops as a consequence of persistent venous obstruction and/or reflux.[8] With time, a proportion of these occluded vein segments partially recanalize through the creation of a new venous channel(s) through the thrombus, reestablishing a proportion of pre-DVT blood flow.[8] Given the important

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relationship between the radius of a channel and the flow within it, partially recanalized thrombus and collaterals often afford insufficient venous flow. In just more than 50% of cases, complete recanalization is achieved by 3 months after the acute episode.[9]

Unlike balloon angioplasty within arteries, when the residual venous stenosis resulting from a post-thrombotic process is treated by balloon venoplasty alone, there is resistance to dilatation with a high rate of recoil and recurrence.[4] This point is important to consider when managing venous outflow obstruction and highlights that venoplasty alone is suboptimal, necessitating stenting to maintain venous patency after venoplasty.

May-Thurner syndrome, whereby the most common irregularity is the left common iliac vein being compressed where it traverses posterior to the right common iliac artery, is a key example of a NIVL and is described frequently. As mentioned elsewhere in this article, this persistent chronic compression of the vein leads to vein fibrosis with intraluminal changes which result in occlusion or stenosis of the lumen.[2]

The available literature shows that the collective experience of venous stent placement in patients with chronic obstructive lesions (NIVL or PTS) continues to increase. However, the evidence, particularly with regard to randomized controlled trials, supporting this practice remains limited.[10]

The main aim of this article is to provide a synopsis of the management options that are now increasing accessible to patients with chronic deep venous disorders of the lower limb, with a particular emphasis on the endovenous stenting procedures and a focus on intervention relating to the vena cava and iliofemoral venous segments. In addition, infrainguinal lesions involving the popliteal and tibial veins are beyond the scope of this article; however, they are mentioned as important in relation to maintaining venous inflow and hence patency of more cephalad venous stents. Moreover, it provides a brief overview of intravascular ultrasound (IVUS) imaging that is often used to guide endovenous stent procedures.

A number of dedicated deep venous stents are available on the market (Fig); however, clinical trial comparisons between different stent types are lacking.[12] The US Food and Drug Administration has already approved several venous stents for use in the United States (eg, Vici Venous Stent (Boston Scientific, Marlborough, Mass), Zilver Vena TM [Cook Medical, Bloomington, Ind], Venovo Venous Stent [BD, Franklin Lakes, NJ]), whereas others have received approval for use in Europe (eg, Vici Venous Stent [Boston Scientific], Zilver Vena [Cook Medical], Sinus Venous [Optimed, Ettlingen, Germany], and the Venovo Venous Stent [BD]).

In general, dedicated venous stents have been designed specifically to aid their effectiveness and ease of use during the endovascular treatment of complex venous lesions. These factors include, among others,

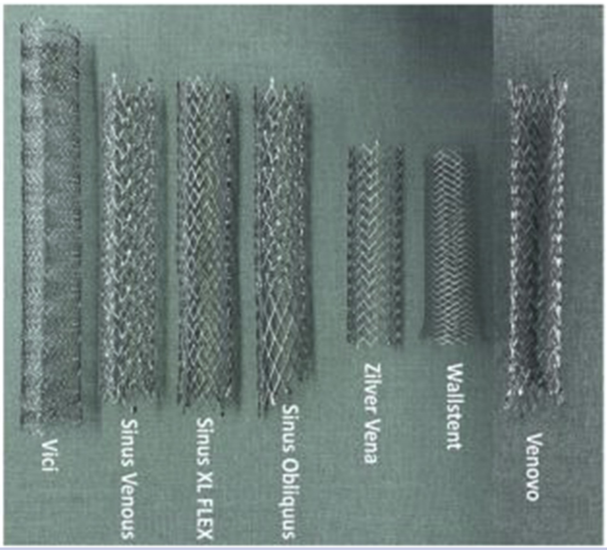

Fig. A number of different venous stents from Dabir et al.[11]

increased flexibility, expandability and improved visibility.[13] However, because of the obligatory compromise required between radial force and crush resistance of the stent while maintaining high flexibility, it is widely believed that a single perfect venous stent for the deep veins does not currently exist and that, alternatively, the type of stent used should be tailored to the needs of the specific situation. Some cases and anatomic locations require more flexibility, others (eg, crossing the inguinal ligament) there is a risk of stent fracture, with some demanding increased crush resistance and, hence, stents designed with these characteristics in mind can be selected accordingly.

DIAGNOSTIC IMAGING IN CHRONIC DEEP VENOUS DISEASE

Duplex ultrasound examination. Venous duplex scan is very often the first-line imaging modality for diagnosis and workup management in patients with chronic venous insufficiency (CVI). It provides crucial underlying pathologic and anatomic extent of the disease (reflux with or without obstruction).

Computed tomographic imaging. Pelvic imaging studies, such as computed tomography venography or magnetic resonance venography, are additionally needed to determine the extent of disease in the iliocaval segment especially in the case of inadequate information from duplex ultrasound examination (eg, when not able to adequately visualize the iliocaval segment owing to overlying bowel gas or the presence of a pelvic mass).[14] In addition, computed tomography venography/magnetic resonance venography enable exclusion of extravascular pathologies causing obstruction, like neoplasms or retroperitoneal fibrosis.[14]

IVUS examination. Lately, IVUS imaging, which allows intraluminal visualization of venous lesions, is increasingly being considered as an invaluable intraoperative tool in the diagnosis and management of deep venous conditions.[15] Indeed, the use of transfemoral venography in the assessment of iliac vein outflow obstruction has demonstrated its limitations, especially with respect to inaccuracies in terms of measurement of the degree of stenosis.[16] It has been reported that the degree of severity as well as the extent of the venous obstructions are greater when using IVUS examination compared with venographic methods, with even severe obstructions being missed on venography, giving IVUS imaging a higher sensitivity and greater diagnostic yield.[1,17] The use of IVUS imaging is not only important for diagnosis, but is also essential for accurate stent placement.

Clinical guidance for the use of IVUS examination. In 2011, the Society for Vascular Surgery and the American Venous Forum provided their practical guidance regarding the care and management of patients with varicose veins and associated chronic venous diseases.[18] These guidelines recommended that IVUS examination be used selectively in those patients with suspected or confirmed iliac vein obstruction. With time, IVUS examination has emerged as an important imaging modality, enabling improved assessment of vessel wall morphology and permitting the identification of intraluminal abnormalities such as altered mural thickness, synechia, spurs, trabeculations, and frozen valves, as well as extrinsic compression not always visualized when using conventional deep venous angiography. Additionally, it allows accurate measurement of the degree of venous stenosis. Currently, IVUS examination is generally considered to be the gold standard imaging technique and its use in the assessment of symptomatic patients with suspected venous outflow obstruction is advocated.[19] The presence of a morphologic obstruction resulting in a decrease in flow lumen area of more than 50% measured by IVUS examination has been chosen arbitrarily as a criterion to consider proceeding to deep venous stenting.[20,21] It has become increasing evident that restricting the workup of patients with significant chronic venous disease to duplex ultrasound examination alone is inadequate, especially when views of the deep venous system are limited cephalad to the inguinal ligament.[19]

Along with its essential role as a diagnostic method, IVUS examination has become indispensable at the point of stent insertion to determine the extent of the venous lesion for accurate stent deployment.[19] The segment of vein affected is usually more considerable on IVUS than indicated by venography,[22,23] this being important because the success of deep venous stenting relies on stenting from a healthy vein segment to another healthy vein segment.

Clinical results of IVUS examination. In the study reported by Neglén and Raju (2002)[22] and involving 304 limbs in 294 patients, the authors reported that "in a comparison with IVUS as the gold standard, venography had a poor sensitivity (45%) and negative predictive value (49%) in the determination of a venous area stenosis of >70%." In addition, IVUS examination demonstrated greater severity of the stenotic area when compared with conventional venography. They concluded that the heightened ability of IVUS examination to demonstrate significant deep venous stenosis renders it the best available modality for the diagnosis of clinically important chronic iliac vein obstruction. In another study by the same authors,[24] venography was sensitive in only 66% of cases with the rest considered normal, whereas IVUS examination was sensitive in more than 90% of cases. In a recent prospective multicenter international cohort study (VIDIO Trial),[25] IVUS examination was found to be more sensitive than multiplanar venography for the diagnosis of iliofemoral venous obstruction. Moreover, IVUS examination led to a change in treatment plans from no endovascular intervention needed based on venography alone to venous stenting in 57 of 100 patients. The authors thus recommend the use of IVUS examination both for the diagnosis of iliofemoral venous obstructions and to plan endovenous treatment.

TREATMENT OF CHRONIC VENOUS OUTFLOW OBSTRUCTION

Rationale and structural indications for stenting in CVI

In general, compression therapy is the basic pillar in the management of CVI in several patients. We would advocate that an initial 6-month trial of conservative management with appropriate compression therapy should be initiated in the first instance and that, should this strategy not be successful in meeting the patient's goals of therapy, deep venous intervention can be explored.[14]

One issue to overcome when treating obstructive venous lesions is to withstand the compression by adjacent structures (eg, the right common iliac artery in May-Thurner syndrome) or intraluminal fibrosis, which can be extensive. Iliac vein stenting can be considered in symptomatic CVI patients with presence of nonthrombotic obstructive venous lesions in the iliofemoral and caval segments with a stenosis of 50% or more, often in the presence of venous collaterals.[14,26]

Many of endovenous procedures for the deep venous system are performed under general anesthesia because patients cannot tolerate multiple painful venoplasties in complex iliocaval lesions and to avoid increased postoperative pain; in addition, these procedures can be lengthy, unless if there is localized stenosis, so the patient could be placed under local anesthesia with the use of moderate sedation.

Current guidance regarding stent placement in the context of CVI

Recent guidance from European and American societies have recommended endovenous stenting for severe obstructive venous disease,[14,27] but recognize that the evidence supporting these recommendations is weak.[28] The American Heart Association gives a weak recommendation for endovascular treatment (recommendation class IIb, evidence level B).[29] However, the 2017 European Society of Vascular Surgery guidance recommends that stent placement after percutaneous transluminal venoplasty be considered for patients with chronic deep venous obstruction (recommendation class IIa, evidence level C).[15]

Regarding deep venous stenting procedure, an open-label, assessor-blinded, multicenter, randomized controlled trial (the Chronic Venous Thrombosis: Relief with Adjunctive Catheter-Directed Therapy [C-TRACT] Study[30]) was launched in May 2018 to compare catheter based-endovascular therapy with no endovascular therapy in 374 patients presenting with disabling iliac-obstructive PTS. We hope that the C-TRACT trial will contribute robust data in this area.

Fundamental points to consider during decision-making

Deep venous stenting is currently the first interventional option in the management of both thrombotic and nonthrombotic chronic venous obstruction. However, it is important to emphasize a number of fundamental points to consider during the decision-making process when managing patients with CVI owing to venous obstructive lesions in lower limbs:

Endophlebectomy and stenting. The decision as to whether endophlebectomy (surgical removal of synechiae and septae from within the occluded venous segment) is necessary is basically related to whether a common inflow (ie, from the profunda and femoral veins) can be identified and maintained into the outflow stent system. The decision to proceed to endophlebectomy is often based on IVUS examination in addition to the preoperative imaging, intraprocedural venography, and patient factors (eg, a hostile groin).[31] If a sufficient landing zone for the stent can be identified (even if small), this will allow the inflow from femoral veins to run into the stent system. Furthermore, it is important to evaluate and identify any trabeculations that, if stented, may decreased flow from the profunda femoris vein, with the patient needing endophlebectomy.

Venous stenting is feasible option strategy if a common luminal inflow channel can be identified, aiming for landing zone just before the profunda femoris vein (PFV) origin. In contrast, if a common inflow channel cannot be identified, an endophlebectomy will be necessary to clear up both femoral and profunda veins.[31] Moreover, the presence of severely impaired inflow from both the PFV and the superficial femoral vein should be excluded as a possible contraindication for consideration of any kind of invasive treatment (with or without endphlebectomy), because even a perfect common femoral veins and iliac veins will not improve lower limb drainage if the PFV and superficial femoral vein are severely impaired.[32]

Endophlebectomy can be accompanied by a temporary arteriovenous fistula formed in the groin with a loop fistula.[32] There are reported complications with endophlebectomy, including a significant rate of groin wound infection (≤30%).[33]

Stenting across the inguinal ligament. Stenting across the inguinal ligament is another controversial topic. In arterial disease, the published literature traditionally did not recommend stenting across joints, because of the increased possible risk of in-stent focal hyperplasia, stent compression, or fracture by joint motion and decreased long-term patency.[34] This view has been relaxed to some extent with the availability of arterial stents engineered for use in such circumstances, for example, the popliteal artery at the level of the knee joint. Therefore, there is a concern that such issues would arise when stents are placed under similar circumstances in the venous system and may negatively affect outcomes. However, the negative experience obtained from arterial stenting may not apply to stenting within the venous system.[34] Indeed, Neglén et al[34] reported that it is practice relatively safe to extend stenting of the involved segment across the inguinal ligament when the obstructive venous lesion involves the common femoral vein; the failure or inability to do so in this context frequently results in early stent occlusion. They also reported that there was a nonsignificant difference regarding the overall patency in limbs stented above vs below the inguinal ligament (7% and 11%, respectively; $P = .6393$).[17] Moreover, the study concluded that the patency rate is not related to the length of stented venous segment or the stent placement across the inguinal ligament. However, the overall patency is mainly related to the underlying etiology and the obstructive nature of the treated PTS lesion (either occlusive or nonocclusive). In recent study reported by Black et al,[26] a durable secondary patency rate (82% and 87% at 1 and 2 years of follow-up, respectively), with substantial symptomatic resolution has been reported in patients with chronic post-thrombotic occlusions. In addition, there were no significant differences in both clinical and stent outcomes regarding stent placement above or below the inguinal ligament, thereby confirming that stenting across the inguinal ligament is not a major factor in patency outcome[26] (Table I).

Optimal sizing of venous stents. In general, iliac vein stents should be of an appropriate size so as to facilitate venous outflow with relatively lower resistance to normalize the existing higher venous pressure and congestion in the diseased lower extremity. The

Table I. Results of deep venous stenting studies for chronic venous disease

Study reference	Venous stenting alone			
	No. of patients	**Stent type(s)**	**Technical success**	**Patency**
Neglén et al[1] (2000)	139 limbs; 61 MTS; 78 PTS	Wallstent endoprosthesis, Schneider, [U.S.A.] Inc., Pfizer Medical Technology Group, Minneapolis, MN, U.S.A.); mostly 16 mm stents	Early postoperative (8%, 6/78) occlusion occurred only in PTS limbs	Primary, primary-assisted and secondary cumulative patency rates of the stented area were 52%, 88% and 90%, respectively, in the PTS group as compared with 60%, 100% and 100%, respectively, in the MTS group (24 months).
Hartung et al[35] (2009)	89 patients	121 stents (12-16 mm in diameter and 40-90 mm in length) were used and the mean number of stents for treating the lesions per patient was 1.3	98%	Primary, primary-assisted and secondary cumulative patency rates of the stented area were 83%, 89% and 93%, respectively, (3 and 10 years).
Neglén et al[36] (2007)	982 patients	Wallstents (Boston Scientific, Natick, Mass) were placed in 963 limbs (98%), and 19 limbs (2%) had nitinol stents placed	Thrombotic events were rare (1.5%) during the postoperative period (<30 days) and during later follow-up (3%)	Primary, primary-assisted and secondary cumulative patency rates of the stented area were 79%, 100%, and 100%, respectively, in NIVL and 57%, 80%, and 86%, respectively, in PTS (72 months).
Razavi MK et al[38] (2015)	2869 patients from 37 studies; 1122 NIVL; 629 acute thrombotic; 1118 chronic PTS	Wallstents (Boston Scientific) were used in 78% of included studies. Only 1 study (3%) used a stent specifically manufactured for venous applications in 3 (0.1%) limbs; Sinus-XL, Zilver Vena, Andrastent XL dedicated venous stents	Ranging from 94% to 96%	At 1 year, primary and secondary patency were 96% and 99%, respectively, for NIVL 87% and 89%, respectively, for acute thrombotic and 79% and 94%, respectively, for chronic PTS.
Wen-da et al[37] (2016)	1987 patients from 14 studies; 43.2% PTS; 56.8% NIVL	Wallstents and Luminex nitinol self-expandable stents. The mean number of stents used per patient was 1.1-3.0 in the included studies	30-Day thrombotic rate was higher in PTS (4%)	The primary, assisted-primary, and second patent rates were 91.4%, 95.0%, and 97.8%, respectively, at 12 months, 77.1%, 92.3%, 94.3%, respectively, at 36 months.
Seager MJ et al[28] (2016)	2,649 limbs of 2,431 patients from 16 studies	Wallstent, S.M.A.R.T., Sinus-XL, Zilver Vena, Andrastent XL, nitinol Luminex and Gianturco Z stent	97.6%	Primary patency ranges between 32% and 98.7%, and secondary patency rates of 66% to 96% in both PTS and MTS patients.
de Wolf MA et al[39] (2015)	76 limbs of 70 patients	Sinus Venous (OptiMed, Ettlingen, Germany)	Primary, assisted-primary and secondary patency rates at 12 months were 51%, 70% and 83%, respectively	
Tosenovsky P[40] (2019)	118 limbs; 83% NIVL and PTS; remainder were acute DVT or pelvic congestion syndrome PCS)	Zilver Vena (Cook, USA), Sinus Venous, Sinus XL (PyraMED, Australia, Optimed, Germany); these 3 stents were used in more than 95% of cases. Veniti stents were also used (Boston Scientific)	Patency rates of the stents in chronic cases (combined PTS and NIVL) 93.1%, 91%, and 89.9% in 3, 6, and 12 months, respectively.	

Table I. Continued.

	Venous stenting alone			
Study reference	**No. of patients**	**Stent type(s)**	**Technical success**	**Patency**
Neglén et al[34] (2008)	177 limbs	Braided stainless steel stents (Wallstents Boston Scientific) were most frequently used, but in 18 limbs (10%) nitinol mesh stents were placed	Cumulative patency in limbs stented cephalad and caudal to the inguinal ligament were 7% and 11%, respectively ($P = .6393$).	
Black et al[26] (2018)	101 limbs of 88 patients	Vici Venous Stent (VENITI, Fremont, Calif)	Primary, assisted-primary and secondary patency rates at one year were 59%, 78%, and 87%, respectively, and 2 years 51%, 73%, and 82%, respectively; no significant differences were found in clinical and stent outcomes in patients with stenting terminating above or below the inguinal ligament.	

DVT, Deep vein thrombosis; *MTS,* May-Thurner syndrome; *NIVL,* nonthrombotic iliac vein lesion; *PTS,* post-thrombotic syndrome.

optimum stent size is more difficult to determine than it would seem, with Raju et al[41] recently reporting different methods, including duplex scan data from healthy volunteers, patient IVUS data, the Poiseuille equation, and Young's scaling rule. Table II summarizes the recommendations from Raju et al. Raju et al[41] recommended using the obtained optimal caliber to grade the severity of stenosis rather than relying on the contralateral lumen. Moreover, he also suggested oversizing the stent by another 2 mm above this recommended caliber, with postdilatation maneuvers restricted to the optimum venous outflow caliber for this diseased segment. The undersizing of a venous stent is also felt to be more detrimental than minor oversizing, because this practice may cause permanent iatrogenic venous stenosis, which would be difficult to correct. Raju et al[41] concluded that the optimal stent size is unknown, but should ideally at least match the normal caliber of the vessel. Currently, there is no evidence to suggest the optimal option and it should be guided by the discretion, experience, and expertise of the vascular interventionalist. But according to our experience, Sinus venous XL flex stent is usually used for IVC and VICI Veniti stents are used for iliac and femoral venous segments.

Extension of venous stenting to beyond the common femoral vein confluence. Stenting caudal to the common femoral vein confluence offers further challenges and most guidelines, in fact, do not recommend stenting below the inguinal ligament and beyond the common femoral confluence.[14,43] This recommendation is due in part to the possible risk of postoperative stent-related complications, including fracture or kinking. The initial experience using dedicated deep venous stents drew attention to some favorable characteristics, making caudal stenting a feasible option.[44] There is also concern regarding compressing or jailing the profunda vein, negatively impacting on inflow into the stent. Moreover, the only remaining option if the primary surgical option fails seems to be extension of the distal stent to preserve inflow. Last, there is a concern regarding stenting of veins with small calibers.

The aim of a study reported by De Wolf et al[44] was to determine the feasibility and clinical effectiveness of venous stenting into one inflow vessel (ie, caudal to the common femoral vein) should the strategy to reconstruct iliofemoral deep venous lesion with endophlebectomy fail. This study concluded that this was treatment strategy indeed acceptable, with relative high patency rates and clinical improvement. The reported primary, assisted primary, and secondary patency rates were 60 %, 70%, and 70%, respectively, at 12 months of follow-up. This finding was associated with significantly improved Villalta score and venous clinical severity score ($P < .001$ and $P = .034$, respectively).[44] Despite this finding, many practitioners abstain from stenting below the inguinal ligament, even in cases involving the common femoral vein.[34] However, stenting below the inguinal ligament should be considered and is supported by a recently reported study by Black et al.[26]

Is thrombolysis useful in chronic disease?. Catheter-directed thrombolysis is a recognized treatment option for acute proximal iliofemoral DVT,[45] particularly considered with symptoms of less than 14 days' duration. Efficacy in terms of successful clearance of thrombus drops precipitously after 3 to 4 weeks of symptoms.[3] In chronic established DVTs, the aim of thrombolysis would be to dissolve any fibrinous strands in the obstructed veins or to treat superimposed venous thrombus. However, the use of thrombolysis in chronic DVT has been rather disappointing so far, with a technical success rate of 66.7% (before any attempt at venoplasty or stenting).[3] This likely due to the fact that, in chronic DVT, the thrombus is replaced by synechiae and septae with a significant type I collagen content, which are not amenable to clearance by thrombolysis. In general, recommendation from our experience is against considering thrombolysis during a deep venous stenting procedure.

Table II. Recommended stent diameters and post-stent intravascular ultrasound (IVUS) areas for different vein segments[41,42]

Vessel segment	Diameter, mm	Area, mm^2
Inferior vena cava	24	300-400
Common iliac vein	16-18	200-254
External iliac vein	14	150
Common femoral vein	12	110

Are arteriovenous fistulae required to preserve patency of iliac venous stents?. Arteriovenous fistulae are often used as temporary measures to maintain a high flow rate through stented venous segments,[46] although the outcomes were not superior enough to advocate their routine use.[3] Nazarian et al[46] reported primary, assisted primary, and secondary patency rates for stented patients with adjunctive arteriovenous fistula of 20 %, 71%, and 100%, respectively, if compared with those without adjunctive fistulae 62%, 67%, and 74% at the 12-months follow-up.[46] Arteriovenous fistulae may, however, be used selectively in patients with poor inflow and/or in the context of endophlebectomy. In addition, the decision to create an adjunctive arteriovenous fistula is based on the completion imaging, specifically the clearance of contrast after venography with a slow hand injection of contrast and appearances on IVUS imaging.

Example algorithm for the management of patients with chronic deep venous occlusive disease. An example algorithm that illustrates an up-to-date treatment protocol for patients with chronic thrombotic and nonthrombotic iliac lesions (NIVL) is presented in the Supplementary Fig (online only).

OUTCOMES AND INITIAL REPORTS OF STENTING FOR CVI RELATED TO DEEP VEIN OBSTRUCTION

The first large study on the subject of stenting for CVI was in 2000 by Neglén et al[1] reviewing the results of recanalization of the iliac venous outflow tract by balloon venoplasty plus stenting through percutaneous femoral venous access. Since then, endovascular interventions in deep venous occlusive disease have come into wider use.[29]

In a report published in 2009, Hartung et al[35] explored patency rates in 89 patients with nonmalignant obstructive iliocaval disease and found that there was a 98% technical success rate for patients treated with balloon venoplasty and stenting. It reported primary, assisted-primary, and secondary patency rates of 83%, 89%, and 93%, respectively, at 3 and 10 years, with improved patient's quality of life (venous disability score of 1).[33]

A large study in 2007 by Neglén et al[36] looked at the long-term results (≤72 months) of deep venous stenting in 982 nonmalignant obstructive lesions of femoroiliocaval veins. In this study, long-term patency in terms of primary, assisted primary, and secondary patency rates were relatively high (79%, 100%, and 100%, respectively) in nonthrombotic disease compared with thrombotic disease (57%, 80%, and 86%, respectively). Moreover, a low rate of severe in-stent restenosis (>50%) was reported in 5% of limbs at 72 months (10% in PTS limbs, 1% in NIVL limbs).[36]

A meta-analysis by Wen-da et al[37] in 2015 analyzed 14 studies investigating the use of stents in chronic venous disease related to deep venous obstruction. They reported that venous stenting may be a relatively effective and safe minimally invasive technique for both thrombotic (PTS) and nonthrombotic NIVL patients because of the increased long-term patency rates and relatively low complication rates. A further systematic review reported primary patency rates after venous stenting in PTS and May-Thurner syndrome ranging between 32% and 98.7%, and secondary patency rates of 66% to 96%.[28] Moreover, another systematic review reported overall high long-term patency rates (primary, assisted primary, and secondary rates of 71%, 89%, and 91%, respectively) at a median follow-up of 23.5 months. Furthermore, this study recorded lower primary patency rate in the PTS group (73%) vs the NIVL group (96%) with a low overall major perioperative complication rate (<1%).[12]

Moreover, systematic reviews reported low complication rates (0%-8.7%) with high technical success rates (≤98%) for deep venous recanalization by stenting.[28,38] In addition, these reviews recorded patients' symptoms improvement in terms of lower limb oedema and persistent pain relief in up to 64% to 68% and 82% of patients, respectively. One systematic review reported a potentially positive impact on the quality of life after endovenous stenting in patients with CVI.[28] Despite these reports demonstrating benefit, the evidence is still weak since most of them were retrospective cohort studies undertaken at a single center (Table I).

In a large follow-up study by Neglén et al in 2007,[29] 982 patients (464 of these with PTS) with prior stent venoplasty of the iliac outflow tract were recruited. There were no reported mortalities in this study. In patients with PTS, the primary and secondary patency rates were 57% and 86%, respectively, after a 72-months follow-up period with ulcer healing achieved in 58% of 148 limbs.

Despite the widespread recommendation[14,27] for the use of endovenous stenting in chronic venous disease related to deep venous outflow obstructive lesions owing to either post-thrombotic changes or underlying nonthrombotic NIVL, a systematic review dedicated to the topic failed to report guideline standards owing to lack of high-quality studies to be able to issue robust recommendations.[28]

FUTURE OF VENOUS STENTS

Dedicated venous stent technology is advancing at a rapid pace alongside the increased undertaking of endovascular deep venous stent reconstruction in the management of iliofemoral and caval venous pathologies (including common femoral vein). Considering these together, it is likely that endovenous stenting will become more commonplace. However, sustained development work on stent technology and the techniques related to their use are needed, such as venous confluence devices, venous stents for use at inguinal ligament level, and drug-eluting venous stents to prevent in-stent stenosis and thrombosis.

CONCLUSIONS

Deep venous stenting is safe and effective in chronic venous outflow obstruction and has high patency rates with acceptable complication rates. In addition, the use of IVUS imaging is not only important for diagnosis, but also for the guidance of accurate stent placement. Further studies, including randomized and nonrandomized trials with long-term follow-up, will strengthen the evidence available to reinforce the ongoing use of deep venous stent reconstruction in clinical practice.

AUTHOR CONTRIBUTIONS

Conception and design: MT, ABu, RB, BT, ABa, HH, JS, AD
Analysis and interpretation: MT, JS, AD
Data collection: MT
Writing the article: MT, ABu, RB, BT, ABa, HH, JS, AD
Critical revision of the article: MT, ABu, RB, JS, AD
Final approval of the article: MT, ABu, RB, BT, ABa, HH, JS, AD
Statistical analysis: MT, ABu, RB, JS, AD
Obtained funding: MT
Overall responsibility: MT

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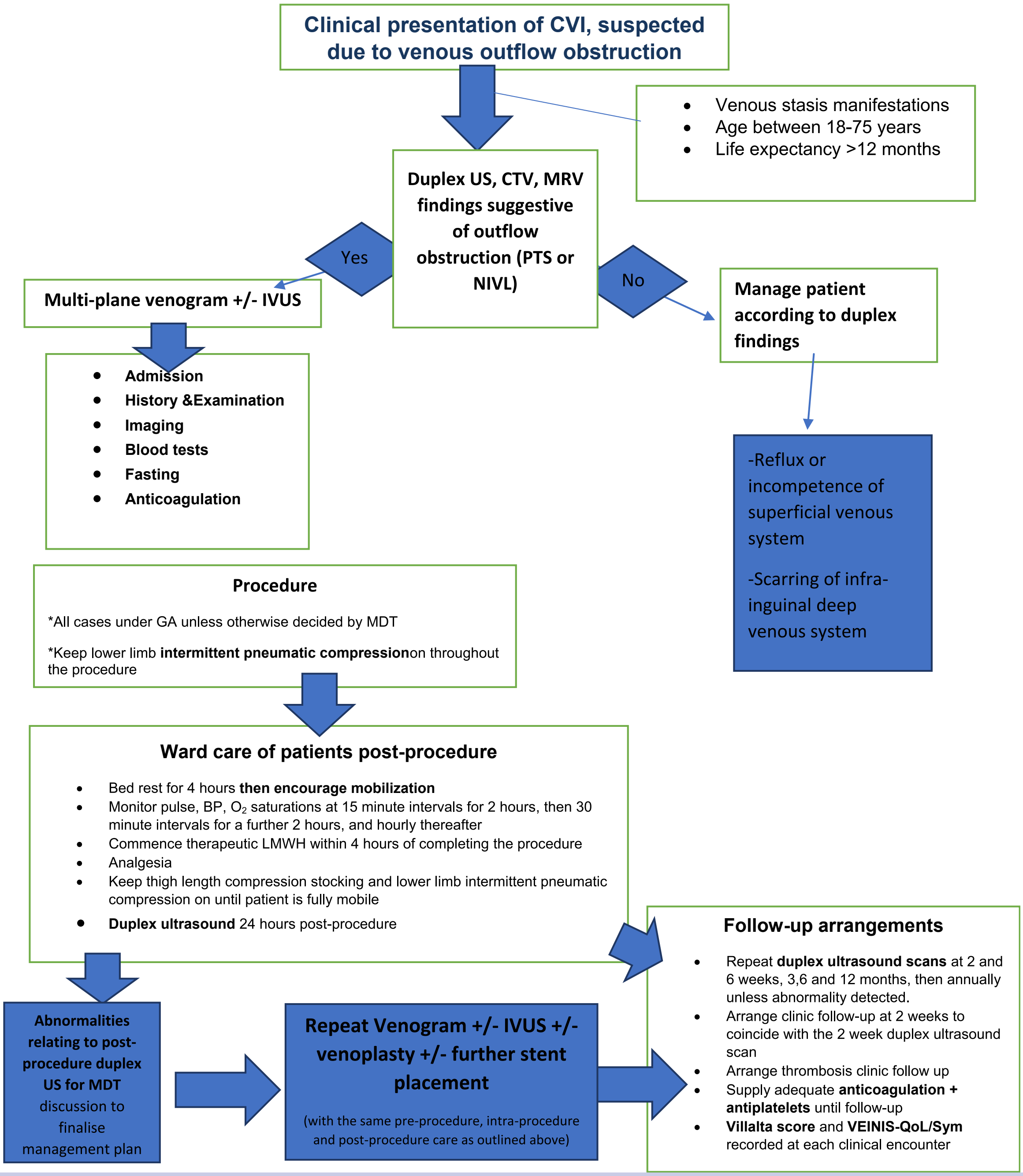

Supplementary Fig (online only). An example algorithm for management of patients with chronic iliac venous obstruction (thrombotic and nonthrombotic).[47] *BP,* Blood pressure; *CTV,* computed tomography venography; *GA,* general anasthesia; *LMWH,* low-molecular-weight heparin; *MDT,* multi-disciplinary team; *MRV,* magnetic resonance venography; *NIVL,* nonthrombotic iliac vein lesion; *PTS,* post-thrombotic syndrome.