A Systematic Review and Meta-Analysis of 12-Month Patency After Intervention for Iliofemoral Obstruction Using Dedicated or Non-Dedicated Venous Stents

Ghulam M. Majeed, BSc¹, Krishan Lodhia, BSc¹, Jemima Carter, BSc¹, Jack Kingdon, MBBS¹, Rachael I. Morris, MBChB, BSc¹, Adam Gwozdz, MBBS, MRCS¹, Athanasios Saratzis, PhD FRCS², and Prakash Saha, PhD, FRCS¹

Abstract

Background: Endovascular stenting of the deep venous system has been proposed as a method to treat patients with symptomatic iliofemoral outflow obstruction. The purpose of this systematic review and meta-analysis was to compare the effectiveness of this treatment at 1-year following the development of dedicated venous stents.

Method and results: We searched MEDLINE and EMBASE for studies evaluating the effectiveness of venous stent placement. Data were extracted by disease pathogenesis: non-thrombotic iliac vein lesions (NIVL), acute thrombotic (DVT), or post-thrombotic syndrome (PTS). Main outcomes included technical success, stent patency at 1 year and symptom relief. A total of 49 studies reporting outcomes in 5154 patients (NIVL, 1431; DVT, 950; PTS, 2773) were included in the meta-analysis. Technical success rates were comparable among groups (97%-100%). There were no periprocedural deaths. Minor bleeding was reported in up to 5% of patients and major bleeding in 0.5% upon intervention. Transient back pain was noted in 55% of PTS patients following intervention. There was significant heterogeneity between studies reporting outcomes in PTS patients. Primary and cumulative patency at 1 year was: NIVL—96% and 100%; DVT—91% and 97%; PTS (stents above the ligament)—77% and 94%, and; PTS (stents across the ligament)—78% and 94%. There were insufficient data to compare patency outcomes of dedicated and nondedicated venous stents in patients with acute DVT. In NIVL and PTS patients, stent patency was comparable at 1 year. There was inconsistency in the use of validated tools for the measurement of symptoms before and after intervention. When reported, venous claudication, improved in 83% of PTS patients and 90% of NIVL patients, and ulcer healing occurred in 80% of PTS patients and 32% of NIVL patients.

Conclusions: The first generation of dedicated venous stents perform comparably in terms of patency and clinical outcomes to non-dedicated technologies at 1 year for the treatment of patients with NIVL and PTS. However, significant heterogeneity exists between studies and standardized criteria are urgently needed to report outcomes in patients undergoing deep venous stenting.

Keywords
DVT, stent, thrombosis, venous occlusion, nitinol stent

Introduction

Iliofemoral venous obstruction is a common condition that affects the deep veins of the pelvis and can lead to long-term disability that is associated with impaired quality of life. The obstruction may be caused by thrombotic (acute deep vein thrombosis [DVT] or chronic post-thrombotic scarring) or non-thrombotic pathologies, including compression from overlying structures such as the right common iliac artery, or a malignancy. Symptoms can vary

¹Academic Department of Vascular Surgery, St. Thomas’ Hospital, School of Cardiovascular Medicine & Sciences, King’s College London, London, UK
²NIHR Leicester Biomedical Research Centre, Leicester, UK

Corresponding Author:
Prakash Saha, Academic Department of Vascular Surgery, St. Thomas’ Hospital, School of Cardiovascular Medicine & Sciences, King’s College London, 1st Floor North Wing, Westminster Bridge Road, London SE1 7EH, UK.
Email: prakash.saha@kcl.ac.uk
and are largely dependent upon the cause, the extent of obstruction, and the duration of the disease.

Acute iliofemoral DVT usually causes severe pain, lower extremity swelling and can lead to life-threatening pulmonary embolism. In rare cases, it may also be limb-threatening. Incomplete resolution of the initial thrombus and the formation of scar tissue in the lumen of the vein more often, however, leads to chronic outflow obstruction resulting in venous hypertension and the development of post-thrombotic syndrome (PTS). Symptoms of PTS include pain, particularly on walking (venous claudication), swelling, skin changes, and in severe cases, venous ulceration. Similar signs and symptoms may also be observed in non-thrombotic causes of chronic outflow obstruction, and both are associated with a significant psychological and financial burden.

Conservative treatment with anticoagulation and compression stockings alone may be insufficient to resolve severe symptoms, prevent recurrence, and avoid development of post-thrombotic syndrome. Therefore, in recent years, endovascular therapies have been proposed as a potential treatment for deep venous obstruction with balloon angioplasty and stenting. Good outcomes have been reported in large case series of patients using re-purposed arterial stents, however, concerns regarding complications such as stent migration, contralateral vein thrombosis caused by placement of the stent against the vessel wall of the inferior vena cava, and imprecise deployment systems, have led to the development of dedicated venous stent technology. A number of these devices have now become available worldwide, and while there have been some concerns raised about their migration and deployment mechanism leading to product recall in some instances, the use of this technology appears to be ever increasing.

A previous systematic review was carried out before the availability of these new technologies and the present study aims to see if there has been a difference in 12-month outcomes following the introduction of the first-generation of dedicated venous stents.

**Methods**

**Literature Search**

The study was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA). The search was limited to articles published in English. We also searched the reference lists of any systematic reviews our initial search returned to identify further literature. The Medline and Embase databases (both since inception) were searched for studies of stent placement for treatment of iliofemoral venous outflow obstruction using the following search terms: “venous” AND “stent” AND “thrombosis” NOT “coronary.” The final search was conducted on the December 12, 2020.

**Eligibility Criteria and Selection of Studies**

Three researchers independently selected studies for inclusion in the review. Disagreements were resolved by consensus and discussion with the senior author. The initial inclusion criteria when screening abstracts accounted for stent location in the iliocaval tract, and studies recruiting patients with acute DVT, PTS, and non-thrombotic iliac vein lesions (NIVL). Full texts of the remaining articles were retrieved and reviewed. Studies were excluded if there was: failure to adequately define pathology, stent placement at a different site such as the portal veins and venous sinus tract, conditions not relevant to the objective such as Budd-Chiari syndrome and/or Nutcracker syndrome, reporting in select groups that is, pediatric patients, patients with malignancy and/or pregnant patients and, failure to clearly report follow up for patency rate at a defined range of 12 to 24 months with available numbers at risk. Where possible, efforts were made to reduce the reporting of duplicate patients that may have occurred by their inclusion in separate manuscripts examining different questions or when there was an overlapping timeline with previous studies reporting from the same center.

Studies were identified and classified into either non-thrombotic iliac vein lesions (NIVL), acute thrombotic (DVT) or post-thrombotic pathology (PTS). Studies that reported a mix of pathologies without reporting the data for each pathology separately were excluded.

**Data Extraction**

An initial database was developed, pilot tested, and refined for subsequent use in our study. Data were extracted from peer-reviewed articles by three authors and verified by the senior author. Standardized data extraction forms were used to maintain consistency of the indications for intervention and the outcomes reported in the literature. Only data specifically involving patients receiving a stent were extracted.

**Outcome Measures**

The main outcomes of interest were technical success, adverse events, stent patency at 12 months and recorded change in patients’ symptoms. Secondary patency and cumulative patency were treated as the same. Primary patency was defined as patency following the index procedure without any further intervention. Primary assisted patency was defined as patency following intervention without stent occlusion. Secondary patency was defined as patency following intervention to open an occluded stent. Patency data were extracted from the text and (where
relevant/possible) Kaplan-Meier curves at annual intervals and only when the numbers at risk were evident. The severity of symptoms and quality of life based on the use of an individual scoring system were recorded when available.

**Assessment of Risk of Bias**

The Institute of Health Economics of Alberta Canada’s Quality Appraisal Checklist for Case Series Studies was used for assessing the quality of the included studies and the risk of bias. The checklist assesses bias based on the following 8 categories: study objective, study design, study population, interventions and co-intervention, outcome measures, statistical analysis, results/conclusions and competing interests/sources of support. Each paper is then given a final score out of 20, with higher scores indicating a lower risk of bias.

**Data Analysis**

For patient-, study-, and procedure-related data, continuous variables are reported as mean or median, and categorical variables as counts or percentages (proportions). Denominators were adjusted when appropriate to include the number of patients, limbs or procedures. Data were extracted by disease pathogenesis: acute DVT, NIVL, and PTS as well as the type of stent used: dedicated or non-dedicated venous stent technology.

Following data extraction, statistical analyses were performed using the R-package for Microsoft Windows (version 3.6). Where possible, the proportions of events per outcome of interest were combined using proportional meta-analysis (“metaprop” package). Inter-study heterogeneity was analyzed using the I² statistic. A I² value ≥ 50% reflects significant heterogeneity as a result of real differences in populations, protocols, interventions, and outcomes. A random effects model was used in all cases in this report, due to the degree of heterogeneity in reporting amongst the studies included. For each outcome of interest, the pooled weighted estimate and 95% confidence interval (CI) were calculated and reported; relevant forest plots were also generated. P values were two-sided with a significance level <.05.

**Results**

**Search Results**

After screening 551 studies for eligibility, 49 studies reporting outcomes in 5154 patients (NIVL, 1431 patients; acute DVT, 950 patients; PTS, 2773 patients) between 2005 and 2020 were included in the meta-analysis. Common reasons for exclusion included stent placement outside the cava-iliofemoral venous system, failure to specify disease pathology, failure to specify stent brand used for intervention, failure to report patency rate data at a defined follow up of 12 to 24 months, and non-stenting procedures/interventions. Overall, 11 of the 49 papers included data from multiple pathologies, 9 studies reported distinct outcomes on any two of the three pathologies analyzed and 2 studies on reported all three pathologies. As these papers made a distinction between the results for each group and reported individual outcomes for each group, they were treated as separate studies in the analysis. A flow diagram of study identification and selection is shown in Figure 1.

**Study Characteristics**

The majority of studies included in the meta-analysis were retrospective (Table 1). The median number of patients per study was 59 (range: 6-870) and the median number of limbs per study was 77 (range: 9-982). Median patients/limbs followed up at 1 year was 73% (range: 22-100) and the median follow-up was 22 months (range: 6-68).

**Assessment of Risk of Bias**

Risk of bias was assessed using The Institute of Health Economics of Alberta Canada’s Quality Appraisal Checklist for Case Series Studies. Papers were awarded a score out of 20 with higher scored indicating a lower risk of bias. Scored ranged from 8 to 15. Two papers achieved a score of 15, 3 achieved a score of 14, 10 achieved a score of 13, 11 achieved a score of 12, 13 achieved a score of 11, 8 achieved a score of 10, 1 achieved a score of 9, and 1 achieved a score of 8.

**Technical Success**

Technical success was high across all pathologies treated irrespective of the type of stent implanted. In patients with an acute DVT, it was 100% (95% CI: 91%-100%), in those with a non-thrombotic iliac vein lesion (NIVL) it was 100%, and in post-thrombotic syndrome (PTS) patients it was 97% (95% CI: 93%-98%).

**Stent Patency in All Groups**

Patency was typically evaluated by ultrasonography, but a formal definition was rarely provided, and an independent assessment of imaging quality and findings was not carried out. Only patients with a minimum follow-up of 1 year were included in the analysis. In patients with a venous stent placed for a non-thrombotic iliac vein lesion (NIVL), the primary patency was 96% (95% CI: 94%-98%); primary-assisted patency was 100%, and secondary patency was 100% (95% CI: 75%-100%) at 1 year (Supplementary Figure 1). In patients with a venous stent placed as part of
treatment for an acute DVT, the primary patency was 91% (95% CI: 88%-93%); primary assisted patency was 97% (95% CI: 93%-99%), and secondary patency was 97% (95% CI: 93%-99%) at 1 year (Supplementary Figure 2). We divided post-thrombotic syndrome (PTS) patients into studies that included patients with venous stents ending above the inguinal ligament and those who had a stent placed across it. In studies of PTS patients with stents above the inguinal ligament, the primary patency rates were 77% (95%CI: 69%-83%) at 1 year while in those with a stent placed across the ligament, the 1-year primary patency was 78% (95% CI: 73%-82%) (Supplementary Figures 3 & 4). In studies including PTS patients with stents above the inguinal ligament, the primary assisted patency rates were 83% (95% CI: 76%-89%) at 1 year while in those with a stent placed across the ligament, the one-year primary assisted patency was 88% (95% CI: 83%-92%) (Supplementary Figures 3 & 4). The secondary patency of stents placed above the ligament in PTS patients was 94% (95% CI: 88%-97%) at 1 year and in those placed across the ligament it was also 94% (95% CI: 91%-97%) at the same time point (Supplementary Figures 3 & 4). There was, however, significant heterogeneity in the PTS studies ($p < 0.01$).

**First Generation Dedicated Venous Stents Versus Non-Dedicated Venous Stent Patency**

There was insufficient data to compare the use of first-generation dedicated venous stents with non-dedicated venous stents in patients with acute DVT. In patients with a NIVL, the primary patency, primary-assisted and secondary patencies at 1 year in patients with a dedicated venous stent were 95% (95% CI: 89%-98%); 100%, and; 100%. This was comparable to patients who were treated with non-dedicated venous stents where the primary, primary assisted and secondary patencies at 1 year were 97% (95% CI: 94%-98%); 100%, and 100% (95% CI: 86%-100%). In patients with PTS treated with a dedicated venous stent, the primary, primary assisted and secondary patencies at 1 year were
Table 1. Characteristics of Included Studies for Analysis (*Median Values).

| Study          | Date of publication | Country       | Study design | ROB score | Number of centers | Pathology type | Treatment period       | Mean/median follow up (months) | Stent trade name | Patients Antiocoagulation | Adverse events | Age (Median/mean) | Limbs | Mean/median follow up (months) | % of patients/limbs followed up at one year |
|----------------|---------------------|---------------|--------------|-----------|-------------------|----------------|------------------------|-------------------------------|-----------------|------------------------|---------------|----------------|--------|---------------------------|----------------------------------------|
| Kwak et al.34  | 2005                | South Korea  | R            | 12        | 1                 | DVT            | 2000-2004              | 21                           | Wallstent         | 22                     | 58*           | —                      | 21     | 73                        |                                          |
| Husmann et al.35 | 2007                | Switzerland  | R            | 13        | 1                 | DVT            | 2000-2005              | 22                           | Wallstent         | 11                     | 34*           | —                      | 22     | 82                        |                                          |
| Neglén et al.22 | 2007                | USA          | R            | 14        | 1                 | NIVL           | 1997-2005              | 22                           | Wallstent         | 870                    | 54*           | 982                    | 22     | 30                        |                                          |
| Raju & Neglén23 | 2009                | USA          | R            | 13        | 1                 | PTS            | 1999-2007              | —                            | Wallstent         | 167                    | 53*           | 70                     | —      | 42                        |                                          |
| Höör et al.16  | 2010                | Germany      | R            | 10        | 1                 | DVT            | 1996-2007              | 68*                          | Wallstent         | 25                     | —             | 68*                    | 88     |                            |                                          |
| Jeon et al.27   | 2010                | South Korea  | R            | 13        | 1                 | DVT            | 1999-2007              | 6*                           | Wallstent         | 30                     | 57*           | —                      | 6*     | 70                        |                                          |
| Rosales et al.39 | 2010                | Norway       | R            | 12        | 1                 | PTS            | 2000-2009              | 33*                          | Wallstent         | 34                     | 41*           | —                      | 33*    | 62                        |                                          |
| Wahlgren et al.29 | 2010               | Sweden       | R            | 10        | 1                 | PTS            | 2003-2007              | 23                           | Wallstent         | 15                     | —             | 23                     | 69     |                            |                                          |
| Meng et al.40   | 2011                | China        | R            | 10        | 1                 | NIVL           | 1997-2008              | 46*                          | Wallstent         | 272                    | —             | 46*                    | 36     |                            |                                          |
| Heger et al.41  | 2013                | USA          | R            | 8         | 2                 | DVT            | 2006-2010              | 26*                          | Wallstent         | 70                     | 52*           | 77                     | 26*    | 73                        |                                          |
| Meng et al.42   | 2013                | China        | P            | 11        | 1                 | DVT            | 2008-2011              | 11                           | E-Luminexx       | 45                     | —             | 45                     | 11     | 89                        |                                          |
| Alarany et al.43 | 2014                | Spain        | R            | 11        | 1                 | PTS            | 2009-2012              | 21                           | Wallstent         | 36                     | 50*           | 41                     | 21     | 66                        |                                          |
| Liu et al.44    | 2014                | China        | P            | 15        | —                 | NIVL           | 2008-2012              | 12*                          | Wallstent         | 48                     | 41*           | —                      | 12*    | 49                        |                                          |
| Matsuda et al.45 | 2014                | Japan        | R            | 11        | 1                 | DVT            | 2000-2008              | 13                           | Wallstent         | 13                     | 63*           | 14                     | 13     | 77                        |                                          |
| Park et al.46   | 2014                | South Korea  | R            | 12        | 1                 | DVT            | 2005-2011              | 16                           | Wallstent         | 51                     | 70*           | —                      | 16     | 37                        |                                          |
| Sang et al.47   | 2014                | China        | R            | 11        | —                 | PTS            | 2005-2012              | 36                           | E-Luminexx       | 67                     | 44*           | —                      | 36     | 87                        |                                          |
| Ye et al.48     | 2014                | China        | R            | 13        | 1                 | PTS            | 2007-2011              | 25*                          | Wallstent         | 110                    | 51*           | 118                    | 25*    | 73                        |                                          |
| Zhu et al.49    | 2014                | China        | P            | 13        | 1                 | DVT            | 2010-2012              | 18                           | E-Luminexx       | 26                     | 54*           | —                      | 18     | 100                       |                                          |
| Fatima et al.50 | 2015                | USA          | R            | 11        | 1                 | PTS            | 2005-2014              | 10*                          | Wallstent         | 28                     | 48*           | —                      | 10*    | 46                        |                                          |
| Park & So51     | 2015                | South Korea  | R            | 11        | 1                 | DVT            | 2001-2007              | 56                           | SMART            | 37                     | 57*           | —                      | 56     | 100                       |                                          |
| Srinivas et al.52 | 2015               | India        | P            | 14        | 1                 | DVT            | 2011-2013              | 12                           | Wallstent         | 8                      | 42*           | 9                      | 12     | 88                        |                                          |
| Yin et al.53    | 2015                | China        | R            | 13        | 1                 | PTS            | 2007-2012              | 21*                          | Wallstent         | 122                    | 46*           | 122                    | 21*    | 64                        |                                          |
| Falcoz et al.54 | 2016                | France       | P            | 11        | 1                 | PTS            | 2012-2016              | 18*                          | E-Luminexx       | 21                     | 41*           | —                      | 18*    | 100                       |                                          |
| Jia et al.55    | 2016                | China        | R            | 11        | 1                 | DVT            | 2010-2013              | 22                           | E-Luminexx       | 68                     | 62*           | —                      | 22     | 94                        |                                          |

(continued)
| Study                  | Date of publication | Country | Study design | ROB score (20) | Number of centers | Pathology type | Treatment period | Mean/median follow up (months) | Stent trade name | Patients Anticoagulation Adverse events | Age (Median/mean) | Mean/median follow up (months) | % of patients/limbs followed up at one year |
|-----------------------|---------------------|---------|--------------|----------------|-------------------|----------------|------------------|------------------------------|-----------------|------------------------------------------|-----------------|-------------------------------|-------------------------------------|
| Ye et al.56           | 2016                | China   | R            | 13             | 1                 | PTS             | 2010-2014        | 27*                          | Wallstent        | E-Luminexx                              | 24/56*            | 45/27*                          | 83                                                 |
| Abdul-Haq et al.57    | 2017                | USA     | R            | 11             | 1                 | NIVL DVT PTS    | 2003-2015        | 20                          | Wallstent        | E-Luminexx                              | 70/42            | 74/20                          | 61                                                 |
| Engelberger et al.58  | 2017                | Switzerland | P | 12             | 1                 | DVT             | 2011-2013        | 9                           | Sinus venous Sinus XL Sinus XL superflex Zilver vena E-Luminexx SMART | 36/49           | —/9                           | 100                                                |
| Jiang et al.59        | 2017                | China   | P            | 11             | 1                 | DVT             | 2008-2012        | 24                          | Wallstent        | E-Luminexx                              | 27/53            | 28/24                          | 96                                                 |
| Murphy et al.60       | 2017                | USA     | R            | 10             | —                 | PTS             | 200-2015         | 48                          | Wallstent        | E-Luminexx                              | 71/51             | —/48                           | 83                                                 |
| Partovi et al.61      | 2017                | USA     | R            | 10             | 1                 | PTS             | 2008-2010        | 51                          | Wallstent        | E-Luminexx                              | 7/55              | —/51                           | 100                                                |
| Ruhua et al.62        | 2017                | China   | R            | 13             | 1                 | NIVL PTS        | 2013-2014        | 19*                         | Wallstent        | E-Luminexx                              | 81/57            | 81/19*                          | 89                                                 |
| van Vuuren et al.63   | 2017                | Netherlands | P | 14             | 1                 | NIVL PTS        | 2009-2016        | —                           | Sinus obliquis Sinus venous Sinus XL Sinus XL superflex Veniti vici Venovo Zilver vena E-Luminexx SMART | 369/43          | 417/—                          | 53                                                 |
| Black et al.64        | 2018                | UK      | R            | 10             | 1                 | PTS             | 2014-2016        | 20*                         | Wallstent        | E-Luminexx                              | 88/42*           | 101/20*                         | 67                                                 |
| Gresta et al.65       | 2018                | Norway  | R            | 11             | 1                 | PTS             | 2009-2016        | 44*                         | Wallstent        | Venovo                                   | 39/46*            | 39/44*                          | 69                                                 |
| Liu et al.66          | 2018                | China   | R            | 12             | —                 | DVT             | 2014-2016        | 12                          | Wallstent        | E-Luminexx                              | 91/56             | —/12                           | 95                                                 |
| Rizvi et al.67        | 2018                | USA     | R            | 11             | —                 | NIVL            | 2013-2014        | 14*                         | Wallstent        | E-Luminexx                              | 210/72           | 268/14*                         | 70                                                 |
| Ye et al.68           | 2018                | China   | R            | 12             | 1                 | PTS             | 2012-2015        | 22*                         | Wallstent        | SMART                                    | 114/49           | 114/22*                         | 62                                                 |
| Yu et al.69           | 2018                | China   | R            | 12             | —                 | DVT             | 2009-2014        | 38                          | SMART           | Wallstent                               | 40/57            | 46/38                          | 100                                                |
| Avgerinos et al.70    | 2019                | USA     | R            | 10             | —                 | DVT             | 2007-2017        | 32                          | Wallstent        | E-Luminexx                              | 72/46            | 77/32                          | 44                                                 |
| Study                | Date of publication | Country     | Study design | ROB score (20) | Number of centers | Pathology type | Treatment period | Mean/median follow up (months) | Stent trade name | Patients Anticoagulation Adverse events | Age (Median/mean) | Mean/median follow up (months) | % of patients/limbs followed up at one year |
|---------------------|---------------------|-------------|--------------|----------------|-------------------|----------------|------------------|-----------------------------|-----------------|---------------------------------------|-----------------|-------------------------------|---------------------------------------------|
| Funatsu et al.71    | 2019                | Japan       | R            | 12             | 10                | DVT            | 2000-2014        | 21*                         | Wallstent        | 59/68                                 | —               | 21*                           | 41                           |
| Gagne et al.25      | 2019                | USA         | R            | 12             | 1                 | NIVL PTs       | 2007-2014        | 50*                         | Wallstent        | 67/63                                 | 75/42           | 60                           | 87                           |
| Ignatyev et al.72   | 2019                | Russia      | R            | 9              | 1                 | NIVL PTS       | 2009-2017        | 60                          | Wallstent        | 75/42                                 | —               | 60                           | 90                           |
| Menez et al.73      | 2019                | France      | R            | 13             | 1                 | PTS            | 2010-2015        | 21                          | Sinus XL         | 95/41                                 | 108/50          | 21                           | 80                           |
| Razavi et al.74     | 2019                | USA         | P            | 13             | 22                | NIVL PTS       | 2015-2016        | 12                          | Ventic Vici       | 170/54                                 | 171/42          | 12                           | 74                           |
| Jayaraj et al.75    | 2020                | USA         | R            | 10             | 1                 | NIVL PTS       | 2014-2017        | 26*                         | Wallstent        | 555/—                                 | 474/26          | 26                           | 66                           |
| Jiang et al.76      | 2020                | China       | R            | 12             | 1                 | PTS            | 2014-2016        | 24                          | Wallstent        | 46/62                                 | —               | 24                           | 100                          |
| Lichtenberg et al.77| 2020                | Germany     | P            | 12             | 1                 | NIVL PTS       | 2016-2017        | 24                          | Venovo           | 79/57                                 | 85/46           | 22                           | 67                           |
| Moeri et al.78      | 2020                | Switzerland & Germany | P | 15             | —                 | NIVL DVT PTS   | 2008-2019        | 12*                         | Blueflow         | 150/46                                 | —               | 12                           | 22                           |
| Sebastian et al.79  | 2020                | Switzerland | P            | 15             | —                 | NIVL DVT PTS   | 2008-2019        | 21*                         | Abre             | 379/45                                 | 447/21          | 84                           | 84                           |

Abbreviations: DVT = acute thrombotic; NIVL = non-thrombotic iliac vein lesions; PTS = post-thrombotic syndrome; R/P = retrospective/prospective; ROB = risk of bias.
Patients were anticoagulated for up to 6 months in 24 studies, and 4 studies. Anticoagulation was prescribed for at least 3 months and 19% (95% CI: 75%-83%), 91% (95% CI: 85%-94%), and 95% (95% CI: 92%-97%) (Figures 2 & 3). There was, however, significant heterogeneity in the studies reporting on both first-generation venous stents and non-dedicated technology ($p < 0.01$).

Symptom Relief
Data regarding changes in venous related symptoms following stent placement was not reported in the majority of studies. Similarly, there were inconsistencies regarding the use of objective reporting tools for the assessment of patients with chronic venous insufficiency. This made any meaningful comparisons using these methods impossible. Where data were available: venous claudication, reported in 3 papers improved in 8% (95% CI: 74%-89%) of PTS patients (Figure 4), and ulcer healing, reported in 17 studies; occurred in 80% (95% CI: 75%-84%) of PTS patients, but only 32% (95% CI: 23%-43%) of NIVL patients (Figure 5).

Adverse Events and Side-Effects
The adverse events reported from each study included are shown in Supplementary Figure 5. There were no deaths reported in any of the studies. In patients with a venous stent placed as part of treatment for an acute DVT, minor bleeding occurred in 4% of patients (reported by 10 studies in 608 patients) and major bleeding in 0.8% of patients (reported by 7 studies in 344 patients). In patients with a venous stent placed as part of treatment for a non-thrombotic iliac vein lesion (NIVL), minor bleeding occurred in 5% of patients (reported by 3 studies in 151 patients) and major bleeding occurred in 0.4% of patients (reported by 4 studies in 1535 patients). In patients with a venous stent placed as part of treatment for non-thrombotic syndrome (PTS), minor bleeding occurred in 4.4% of patients (reported by 11 studies in 1085 patients) and major bleeding occurred in 0.9% of patients (reported by 8 studies in 781 patients). Transient back pain was also recorded in the PTS group in 55% of patients (reported by 6 studies in 508 patients).

Anticoagulation Use
Anticoagulation was reported in 33 of the 50 studies (Supplementary figure 6). Warfarin was prescribed to patients in 32 studies, DOACs in 7 studies, and LMWH in 4 studies. Anticoagulation was prescribed for at least 3 months by 35 of the 50 studies, the remaining papers did not report the length of time patients were anticoagulated for. Patients were anticoagulated for up to 6 months in 24 studies, up to 12 months in 7 studies and for life in 4 studies. Reporting of use of multi-disciplinary teams including hematology for these decisions were variable.

Discussion
Here we carry out a meta-analysis of 1-year outcomes following deep venous stenting for obstruction along the iliofemoral venous outflow tract. Overall results of this analysis indicate that venous stent placement has a high technical success rate with a low risk of complications. Over half of patients having venous stent placement for post-thrombotic syndrome (PTS) report transient back pain, and this should be discussed during counseling of this procedure. Venous stents appear effective at restoring luminal flow in the majority of patients at 1 year, even if they cross the inguinal ligament, but challenges still remain at maintaining primary patency especially in PTS patients. Nevertheless, they appear to improve patient symptoms at 1 year with PTS patients reporting improvements in venous claudication and ulcer healing.

The first generation of dedicated venous stents were developed to overcome specific complications of existing technologies including stent migration, stent compression, kinking, and contralateral vein thrombosis due to “jailing” of the contralateral outflow tract. They were designed to be easier to deploy, have sufficient flexibility to follow the curve of the iliac vein and adequate radial resistive strength and crush resistance to withstand forces from an overlying iliac arterial pulsation, the compression points at the pubic ramus and inguinal ligament, and the recoil of fibrotic postthrombotic tissue. Several different dedicated venous stents are now commercially available worldwide. Perhaps surprisingly, however, the newer dedicated venous stents do not seem to outperform older technology that had been used off-label in studies that we were able to adequately analyze. Primary and secondary patency similar at one year in patients with NIVL and PTS. Whether the loss of stent patency is due to similar factors remains uncertain, however, as many studies inadequately reported their outcomes making it impossible to carry our subgroup analyses to identify the influence of any specific study- and/or patient-related characteristics. Differences in the rationale, suitability and indication for stent placement were evident and there was variability on the methods used to define a significant obstruction. In addition, changing interventional techniques; use of intravascular ultrasound; differences in post-operative management in terms of surveillance and the types and duration of anticoagulation and/or antiplatelets, and; inconsistent approaches to reintervention following the index procedure makes direct comparison between studies challenging. These differences may, in part, explain the significant heterogeneity in patency outcomes for stents placed in patients across the studies included in our analyses.
Figure 2. Forest plot of primary patency following stenting for treatment of post-thrombotic syndrome using (A) dedicated and (B) non-dedicated venous stents. Data are shown in descending order by year of publication with proportions of events reported. CI, confidence interval.

*Events reported per limb.

α May include some patient duplicates.

ρ Chronic total occlusions only.

γ Inclusion of 3 patients with dedicated venous stents.

ε Femoral vein intervention with angioplasty +/- stent carried out.

λ Only braided nitinol stents included from this manuscript.

# Inclusion of patients with endophlebectomy +/- fistula.
Figure 3. Secondary patency following stenting for treatment of post-thrombotic syndrome using (A) dedicated and (B) non-dedicated venous stents. Data are shown in descending order by year of publication with proportions of events reported. CI, confidence interval.

* Events reported per limb.
α May include some patient duplicates.
ρ Chronic total occlusions only.
γ Inclusion of 3 patients with dedicated venous stents.
ε Femoral vein intervention with angioplasty +/- stent carried out.
λ Only braided nitinol stents included from this manuscript.
# Inclusion of patients with endophlebectomy +/- fistula.
Nevertheless, given the high technical success of venous stenting, urgent research is now needed to understand the factors that lead to loss of stent patency. This includes finding a better method to determine inflow pre-operatively that could improve patient selection.

Our review highlights that there is a paucity of robust, high quality, level 1 evidence to support the use of venous stenting and there is significant reporting bias. Ongoing studies such as CLEAR-DVT are trying to provide the foundation for larger prospective randomized control trials in patients with acute DVT, while the results of C-TRACT, which aims to determine if endovascular therapy can benefit patients with PTS, are eagerly awaited. Inconsistent reporting of clinical outcomes has, however, highlighted an urgent need to develop a core outcome set to evaluate this procedure. In addition, an agreed disease specific tool to objectively assess the burden of disease on patients, especially in those with PTS, is required. The Villalta scale was recommended by the International Society for Thrombosis and Haemostasis (ISTH) for use in clinical trials but since its conception, the scoring system has been inconsistently modified. It is based on subjective criteria, which limits its precision, and it has been criticized for not being disease-specific.81 Qualitative studies of patient experience and expert opinion suggests that the Villalta score may also fail to capture typical PTS complaints or their importance to patients,82 and a major drawback of this tool is that it does not include an assessment of a patient’s quality of life.51 This may explain why it was infrequently used in venous stent studies to date. A more appropriate, sensitive and specific gold-standard assessment measure, which incorporates patient reported outcomes, should be developed for future applied health research in this area.

The use of dedicated venous stent technology may be questioned based on these data. We were, however, unable to appropriately analyze whether adjunctive techniques are required to facilitate satisfactory outcomes when using non-dedicated technology. Use of a Z-stent placed more caudally has, for example, been recommended to mitigate against contralateral DVT.27 Operator technique and experience is also likely to influence outcomes and complimentary tools, such as the use of intravascular ultrasound have been proposed as a method to identify a suitable landing zone for the stent, but whether they have improved outcomes remains uncertain. Dedicated venous stents are, however, easier to deploy and are available in sizes more appropriate for use in the iliofemoral venous system thereby minimizing the need for multiple stents. Their ease of use may even be one of the reasons that there has been a recent increase in the numbers of different centers reporting their use. Further developments are, however, needed especially in the treatment of patients with PTS. Drug-eluting technologies either with drug-coated balloons or drug-eluting stents are likely to be developed in the future but further research is first needed to identify which mechanisms drive in-stent stenosis in the veins, which could then be targeted. Innovative tools are also required for reinterventions to prevent the need for repeated venoplasty and/or stent re-lining. Given the young age of patients that are being treated, maintaining stent patency will likely become a bigger challenge in the future.

**Limitations**

Several limitations exist in our study. Many of the studies included in the meta-analysis were single-site, retrospective, level 4 studies and reporting was inconsistent. We were unable to analyze the data by the specific type of stent used due to small numbers and it is possible that certain types of stent design may perform better than others. Stent patency was largely based on ultrasonography...
and there are no agreed criteria of how to assess a venous stent using this method. Assessment of stent patency with this imaging modality can also be variable and is user dependent. In addition, the threshold for reintervention was not always defined, and when it was, it was variable between studies. The follow-up is also modest across the majority of the literature in this clinical area. Many patients that undergo deep venous interventions are younger than those having arterial interventions from which stent technology is based. Any stent that has been placed will need to function for many more years, and often for decades and longer-term outcomes are required before a true assessment of their effectiveness can be established.

Figure 5. Ulcer healing rates following venous stenting for (A) non-thrombotic iliac vein lesions and (B) post-thrombotic syndrome. Data are shown in descending order by year of publication with proportions of events reported. CI, confidence interval.

*Events reported per limb.
α May include some patient duplicates.
ρ Chronic total occlusions only.
γ Inclusion of 3 patients with dedicated venous stents.
e Femoral vein intervention with angioplasty +/- stent carried out.
# Inclusion of patients with endophlebectomy +/- fistula.
Conclusion

Venous stent placement for iliofemoral venous outflow obstruction has a high rate of technical success and satisfactory 1 year patency outcomes. Improvement in clinical symptoms and quality of life can be achieved, but they are inconsistently reported in the literature and specific patient reported outcome measures are required to improve future applied health research in this area. In addition, agreed inclusion criteria for venous stenting are still urgently needed. Finally, a detailed classification of patient pathology should be used to facilitate a more accurate comparison of patient outcomes between studies and the types of interventions that have been carried out. From the available data, the first generation of dedicated venous stents have comparable performance to non-dedicated technologies in patients with NIVL and PTS but the length of follow-up is modest and longer-term data are needed to evaluate their true effectiveness. Outcomes for patients with post-thrombotic disease are inferior to those treated for non-thrombotic or acute thrombotic disease, but irrespective of stent type, a better understanding of factors that lead to loss of patency is required.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: P Saha has received honorarium from Medtronic. The remaining authors have no other disclosures to declare.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs

Jack Kingdon https://orcid.org/0000-0002-7612-7812
Prakash Saha https://orcid.org/0000-0002-9591-1063

Supplemental Material

Supplemental material for this article is available online.

References

1. Phillips T, Stanton B, Provan A, et al. A study of the impact of leg ulcers on quality of life: Financial, social, and psychologic implications. J Am Acad Dermatol. 1994;31(1):49–53.
2. Prandoni P, Lensing AWA, Cogo A, et al. The long-term clinical course of acute deep venous thrombosis. Ann Intern Med. 1996;125:1–7.
3. WIKHS, Wik HS, Jacobsen AF, et al. Prevalence and predictors for post-thrombotic syndrome 3 to 16 years after pregnancy-related venous thrombosis: a population-based, cross-sectional, case-control study. J Thromb Haemost. 2012;10(5):840–847.
4. Farrell JJ, Sutter C, Tavri S, et al. Incidence and interventions for post-thrombotic syndrome. Cardiovasc Diagn Ther. 2016;6(6):623–631.
5. Smith JJ, Guest MG, Greenhalgh RM, et al. Measuring the quality of life in patients with venous ulcers. J Vasc Surg. 2000;31:642–649.
6. Delis KT, Bountouroglou D, Mansfield AO. Venous claudication in iliofemoral thrombosis. Ann Surg. 2004;239(1):118–126.
7. Broholm R, Sillesen H, Damsgaard MT, et al. Postthrombotic syndrome and quality of life in patients with iliofemoral venous thrombosis treated with catheter-directed thrombolysis. J Vasc Surg. 2011;54(suppl):18S–25S.
8. Kahn SR, Hirsch A, Shrier I. Effect of postthrombotic syndrome on health-related quality of life after deep venous thrombosis. Arch Intern Med. 2002;162:1144–1148.
9. Sarwar S, Narra S, Munir A. Phlegmastia curulea dolens. Tex Heart Inst J. 2009;36:76–77. ncbi.nlm.nih.gov.
10. Colwell CW, Hardwick ME. Natural history of venous thromboembolism. Tech Orthop. 2004;19:236–239.
11. Schleimer K, Barbati ME, Grommes J, et al. Update on diagnosis and treatment strategies in patients with post-thrombotic syndrome due to chronic venous obstruction and role of endovenous recanalization. J Vasc Surg Venous Lymphat Disord. 2019;7(4):592–600.
12. Hunter R, Lewis S, Noble S, et al. “Post-thrombotic panic syndrome”: A thematic analysis of the experience of venous thromboembolism. Br J Health Psychol. 2017;22(1):8–25.
13. Hunter R, Noble S, Lewis S, et al. Long-term psychosocial impact of venous thromboembolism: A qualitative study in the community. BMJ Open. 2019;9:e024805.
14. Douglas V. Living with a chronic leg ulcer: an insight into patients’ experiences and feelings. J Wound Care. 2001;10(9):355–360.
15. Ashrani AA, Heit JA. Incidence and cost burden of post-thrombotic syndrome. J Thromb Thrombolysis. 2009;28(4):465–476.
16. Kachroo S, Boyd D, Bookhart BK, et al. Quality of life and economic costs associated with postthrombotic syndrome. Am J Heal Pharm. 2012;69:567–572.
17. Douketis JD, Crowther MA, Foster GA, et al. Does the location of thrombosis determine the risk of disease recurrence in patients with proximal deep vein thrombosis. Am J Med. 2001;110(7):515–519.
18. Kahn SR. Determinants and time course of the postthrombotic syndrome after acute deep venous thrombosis. Ann Intern Med. 2008;149:698.
19. Seager MJ, Busuttil A, Dharmarajah B, et al. Editor’s choice—A systematic review of endovenous stenting in chronic venous disease secondary to iliac vein obstruction. Eur J Vasc Endovasc Surg. 2016;51:100–120.
20. Williams ZF, Dillavou ED. A systematic review of venous stents for iliac and venacaval occlusive disease. J Vasc Surg Venous Lymphat Disord. 2019;8:145–153.
21. Dharmarajah B, Soudnerajah V, Rowland S, et al. Aging techniques for deep vein thrombosis: a systematic review. Phlebology. 2015;30(2):77–84.
22. Neglen P, Hollis KC, Olivier J, et al. Stenting of the venous outflow in chronic venous disease: Long-term stent-related
outcome, clinical, and hemodynamic result. *J Vasc Surg.* 2007;46(5):979–990.

23. Raju S, Neglen P. Percutaneous recanalization of total occlusions of the iliac vein. *J Vasc Surg.* 2009;50:360–368.

24. Grotta O, Enden T, Sandbaek G, et al. Patency and clinical outcome after stent placement for chronic obstruction of the inferior vena cava. *Eur J Vasc Endovasc Surg.* 2017;54(5):620–628.

25. Gagne PJ, Gagne N, Kucher T, et al. Long-term clinical outcomes and technical factors with the Wallstent for treatment of chronic iliocostal venous obstruction. *J Vasc Surg Venous Lymphat Disord.* 2019;7(1):45–55.

26. Shida T, Umezu M, Iwasaki K. Investigation of adverse events associated with an off-label use of arterial stents and CE-marked iliac vein stents in the iliac vein: insights into developing a better iliac vein stent. *J Artif Organs.* 2018;21(2):254–260.

27. Murphy EH, Johns B, Varney E, et al. Deep venous thrombosis associated with caval extension of iliac stents. *J Vasc Surg Venous Lymphat Disord.* 2017;5(1):8–17.

28. Khairy SA, Neves RJ, Hartung O, et al. Factors Associated with Contralateral Venous Thrombosis after Iliacstent Venous Stenting. *Eur J Vasc Endovasc Surg.* 2017;54(6):745–751.

29. Lichtenberg MKW, de Graaf R, Stahlhoff WF, et al. Venovo venous stent in the treatment of non-thrombotic or post-thrombotic iliac vein lesions—short-term results from the arnsberg venous registry. *Vasa-Eur J Vasc Med.* 2019;48.

30. Razavi MK, Jaff MR, Miller LE. Safety and effectiveness of stent placement for iliocostal venous outflow obstruction: systematic review and meta-analysis. *Circ Cardiovasc Interv.* 2015;8(10):e002772.

31. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PloS Med.* 6(7):e100097.

32. Edmonton AB. Institute of Health Economics [IHE]. Quality Appraisal of Case Series Studies Checklist. Institute of Health Economics; 2014.

33. Khairy SA, Neves RJ, Hartung O, et al. Factors Associated with Contralateral Venous Thrombosis after Iliacstent Venous Stenting. *Eur J Vasc Endovasc Surg.* 2017;54(6):745–751.

34. Kwon HS, Han YM, Lee YS, et al. Stents in common iliac vein obstruction with acute ipsilateral deep venous thrombosis: Early and late results. *J Vasc Interv Radiol.* 2005;16(6):815–822.

35. Husmann MJ, Heller G, Kalka C, et al. Stenting of common iliac vein occlusion combined with regional thrombolysis and thrombectomy in acute deep vein thrombosis. *Eur J Vasc Endovasc Surg.* 2007;34:87–91.

36. Höpffer P, Kotelis D, Attighan N, et al. Longterm results after surgical thrombectomy and simultaneous stenting for symptomatic iliocostal venous thrombosis. *Eur J Vasc Endovasc Surg.* 2010;39(3):349–355.

37. Jeon UB, Chung JW, Jae HJ, et al. May-Thurner syndrome complicated by acute iliofemoral vein thrombosis: Helical CT venography for evaluation of long-term stent patency and changes in the iliac vein. *AJR Am J Roentgenol.* 2010;195(3):751–757.

38. Rosales A, Sandbaek G, Jørgensen JJ. Stenting for chronic post-thrombotic vena cava and iliocostal venous occlusions: Mid-term patency and clinical outcome. *Eur J Vasc Endovasc Surg.* 2010;40(2):234–240.

39. Wahlgren CM, Wåhlberg E, Olofsson P. Endovascular treatment in postthrombotic syndrome. *Vasc Endovascular Surg.* 2010;44:356–360.

40. Meng QY, Li XQ, Qian AM, et al. Endovascular treatment of iliac vein compression syndrome. *Chin Med J (Engl).* 2011;124:3281–3284.

41. Hager ES, Yuo T, Tahara R, et al. Outcomes of endovascular intervention for May-Thurner syndrome. *J Vasc Surg Venous Lymphat Disord.* 2013;1(3):270–275.

42. Meng QY, Li XQ, Jiang K, et al. Stenting of iliac vein obstruction following catheter-directed thrombolyis in lower extremity deep vein thrombosis. *Chin Med J (Engl).* 2013;126(18):3519–3522.

43. Alenany MB, Izquierdo Lamoca LM, Ramirez Ortega M, et al. Endovascular treatment of iliocostal venous chronic post-thrombotic venous flow obstruction. *J Vasc Surg Venous Lymphat Disord.* 2014;2(1):2–7.

44. Liu Z, Gao N, Shen L, et al. Endovascular treatment for symptomatic iliac vein compression syndrome: A prospective consecutive series of 48 patients. *Ann Vasc Surg.* 2014;28(3):695–704.

45. Matsuda A, Yamada N, Ogihara Y, et al. Early and long-term outcomes of venous stent implantation for iliac venous stenosis after catheter-directed thrombolyis for acute deep vein thrombosis. *Circ J.* 2014;78(5):1234–1239.

46. Park JY, Ahn JH, Jeon YS, et al. Iliac vein stenting as a durable option for residual stenosis after catheter-directed thrombolyis and angioplasty of iliocostal deep vein thrombosis secondary to may-thurner syndrome. *Phlebology.* 2014;29(7):461–470.

47. Sang H, Li X, Qian A, et al. Outcome of endovascular treatment in postthrombotic syndrome. *Ann Vasc Surg.* 2014;28(6):1493–1500.

48. Ye K, Lu X, Jiang M, et al. Technical details and clinical outcomes of transpostiteal venous stent placement for post-thrombotic chronic total occlusion of the iliocostal vein. *J Vasc Interv Radiol.* 2014;25(6):925–932.

49. Zhu QH, Zhou CY, Chen Y, et al. Percutaneous manual aspiration thrombectomy followed by stenting for iliac vein compression syndrome with secondary acute isolated iliocostal deep vein thrombosis: A prospective study of single-session endovascular protocol. *Eur J Vasc Endovasc Surg.* 2014;47(1):68–74.

50. Fatima J, AlGaby A, Benj J, et al. Technical considerations, outcomes, and durability of inferior vena cava stenting. *J Vasc Surg Venous Lymphat Disord.* 2015;3(4):380–388.

51. Park C, So BJ. Long-term results of catheter-directed thrombolyis combined with iliac vein stenting for iliocostal deep vein thrombosis. *Vasc Specialist Int.* 2015;31(2):47–53.

52. Srinivas BC, Patra S, Reddy B, et al. Outcome of venous stenting following catheter directed thrombolyis for acute proximal lower limb venous thrombosis: a prospective study with venous Doppler follow-up at 1-year. *Cardiovasc Interv Ther.* 2015;30(4):320–326.
Jia Z, Tu J, Zhao J, et al. Aspiration thrombectomy using a large-size catheter for acute lower extremity deep vein thrombosis. *J Vasc Endovasc Surg*. 2015;50(1):101–107.

Falcoz M-T, Falvo N, Aho-Gléel S, et al. Endovascular stent placement for chronic post-thrombotic symptomatic iliofemoral venous obstructive lesions: a single-center study of safety, efficacy and quality-of-life improvement. *Quant Imaging Med Surg*. 2016;6(4):342–352.

Jia Z, Tu J, Zhao J, et al. Aspiration thrombectomy using a large-size catheter for acute lower extremity deep vein thrombosis. *J Vasc Surg Venous Lymphat. Disord*. 2016;4(2):167–171.

Ye K, Lu X, Li W, et al. Outcomes of stent placement for chronic occlusion of a filter-bearing inferor vena cava in patients with severe post-thrombotic syndrome. *J Vasc Endovasc Surg*. 2016;52(6):839–846.

Abdul-Haq R, Novak Z, Pearce BJ, et al. Routine extended follow-up surveillance of iliac vein stents for iliocaval venous obstruction may not be warranted. *J Vasc Surg Venous Lymphat. Disord*. 2017;5:500–505.

Engelberger RP, Stuck A, Spirk D, et al. Ultrasound-assisted versus conventional catheter-directed thrombolysis for acute iliofemoral deep vein thrombosis: 1-year follow-up data of a randomized-controlled trial. *J Thromb Haemost*. 2017;15(7):1351–1360.

Jiang K, Li X-Q, Sang H-F, et al. Mid-term outcome of endovascular treatment for acute lower extremity deep venous thrombosis. *Phlebolology*. 2017;32(3):200–206.

Murphy EH, Johns B, Varney E, et al. Endovascular management of chronic total occlusions of the inferior vena cava and iliac veins. *J Vasc Surg Venous Lymphat. Disord*. 2017;5(1):47–59.

Partovi S, Kalva SP, Walker TG, et al. Long term follow-up of endo-vascular recanalization of chronic inferior vena cava occlusion secondary to inferior vena cava filters. *Vasa*. 2017;46(2):121–126.

Ruhua W, Xin W, Guang L, et al. Technique and clinical outcomes of combined stent placement for postthrombotic chronic total occlusions of the iliofemoral veins. *J Vasc Interv Radiol*. 2017;28(3):373–379.

van Vuuren TMAJ, de Wolf MAF, Arnoldussen CWKP, et al. Editor’s Choice—Reconstruction of the femoro-ilio-caval outflow by percutaneous and hybrid interventions in symptomatic deep venous obstruction. *Eur J Vasc Endovasc Surg*. 2017;54(4):495–503.

Black S, Gwozdz A, Karunanithy N, et al. Two year outcome after chronic iliac vein occlusion recanalisation using the Vici Venous stent®. *Eur J Vasc Endovasc Surg*. 2018;56(5):710–718.

GrÄta, O, Enden T, Sandheg G, et al. Infrarenal and endovenous stent placement in iliofemoral post-thrombotic obstructions. *CVIR Endovasc*. 2018;1(1):29.

Liu G, Qin J, Cui C, et al. Comparison of direct iliofemoral stenting following angiojet rheolytic thrombectomy vs staged stenting after angiojet rheolytic thrombectomy plus catheter-directed thrombolysis in patients with acute deep vein thrombosis. *J Endovasc Ther*. 2018;25(1):133–139.

Rizvi SA, Ascher E, Hingorani A, et al. Stent patency in patients with advanced chronic venous disease and nonthrombotic iliac vein lesions. *J Vasc Surg Venous Lymphat Disord*. 2018;6(4):457–463.

Ye K, Shi H, Yin M, et al. Treatment of femoral vein obstruction concomitant with iliofemoral stenting in patients with severe post-thrombotic syndrome. *Eur J Vasc Endovasc Surg*. 2018;55(2):222–228.

Yu H, Du X, Li W, et al. The midterm effect of iliac vein stenting following catheter-directed thrombolysis for the treatment of deep vein thrombosis. *Ann Vasc Surg*. 2018;50:1–7.

Averginos ED, Saadeddin Z, Abou Ali AN, et al. Outcomes and predictors of failure of iliac vein stenting after catheter-directed thrombolysis for acute iliofemoral thrombosis. *J Vasc Surg Venous Lymphat Disord*. 2019;7(2):153–161.

Funatsu A, Anzai H, Komiyama K, et al. Stent implantation for May–Thurner syndrome with acute deep venous thrombosis: acute and long-term results from the ATOMIC (AcTive stenting for May–Thurner Iliac Compression syndrome) registry. *Cardiovasc Interv Ther*. 2019;34(2):131–138.

Ignatyev IM, Pokrovsky A, Gradusov E. Long-term results of endovascular treatment of chronic iliofemoral venous obstructive lesions. *Vasc Endovascular Surg*. 2019;53(5):373–378.

Menez C, Riodiere M, Ghelfi J, et al. Endovascular treatment of post-thrombotic venous ilio-femoral occlusions: prognostic value of venous lesions caudal to the common femoral vein. *Cardiovascular Interv Radiol*. 2019;42(8):1117–1127.

Razavi MK, Black S, Gagne P, et al. Pivotal study of endovenous stent placement for symptomatic iliofemoral venous obstruction. *Circ Cardiovasc Interv*. 2019;12(12):e008268.

Jayaraj A, Noel C, Kuykendall R, et al. Long-term outcomes following use of a composite Wallstent-Z stent approach to iliofemoral venous stenting. *J Vasc Surg Venous Lymphat. Disord*. 2020;9:393–400.e2.

Jiang C, Zhao Y, Wang X, et al. Midterm outcome of pharmacomechanical catheter-directed thrombolysis combined with stenting for treatment of iliac vein compression syndrome with acute iliofemoral deep venous thrombosis. *J Vasc Surg Venous Lymphat. Disord*. 2020;8(1):24–30.

Lichtenberg MKW, Stahlhoff WF, Stahlhoff S, et al. Venovenous stent for treatment of non-thrombotic or post-thrombotic iliac vein lesions-long-term efficacy and safety results from the Arnsberg venous registry. *Vasa-Eur J Vasc Med*. 2021;50:52–58.

Moeri L, Lichtenberg M, Gnanapiragasam S, et al. Braided or laser-cut self-expanding nitinol stents for the common femoral vein in patients with post-thrombotic syndrome. *J. Vasc. Surg. Venous Lymphat. Disord*. 2021;9(3):760–769.

Sebastian T, Gnanapiragasam S, Spirk D, et al. Self-expandable nitinol stents for the treatment of nonmalignant deep venous obstruction. *Circ Cardiovasc Interv*. 2020;366–374.

Cheng CP, Dua A, Suh GY, et al. The biomechanical impact of hip movement on iliofemoral venous anatomy and stenting for deep vein thrombosis. *J Vasc Surg Venous Lymphat. Disord*. 2020;8(6):953–960.

Engeseth M, Enden T, Sandset PM, et al. Limitations of the Villalta scale in diagnosing post-thrombotic syndrome. *Thromb Res*. 2019;184:62–66.

Engeseth M, Enden T, Andersen MH, et al. Does the Villalta scale capture the essence of postthrombotic syndrome? A qualitative study of patient experience and expert opinion. *J Thromb Haemost*. 2019;17(10):1707–1714.

Soosainathan A, Moore HM, Gohel MS, et al. Scoring systems for the post-thrombotic syndrome. *J Vasc Surg*. 2013;57(1):254–261.