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Deep venous thrombosis associated with caval extension of iliac stents

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ABSTRACT

Background: It is generally difficult to place an iliac vein stent precisely at the iliocaval junction with venographic control or even with intravascular ultrasound guidance. Furthermore, mechanical properties of the Wallstent (Boston Scientific, Marlborough, Mass) can predispose precisely placed stents to distal displacement or stent collapse. Our center has thus advocated extending Wallstents 3 to 5 cm into the inferior vena cava to prevent complications of missed proximal lesions or stent migration. This technique has gradually been accepted, and concerns of jailing of contralateral flow were not initially recognized. We analyzed deep venous thrombosis (DVT) incidence following iliocaval stenting with two alternative techniques: (1) Wallstents with 3- to 5-cm extension into the inferior vena cava; and (2) a modified Z-stent (Cook Medical, Bloomington, Ind) technique, in which overlapping Wallstents end at the iliac confluence and caval extension is performed with a Z-stent placed at the top of the stack. The function of the Z-stent is to provide improved radial force at the iliocaval confluence and to prevent jailing of contralateral flow with larger stent interstices.

Methods: There were 755 limbs with consecutive Wallstent caval extensions (2006-2010) and 982 limbs with Z-stent extensions (2011-2015) analyzed for DVT incidence postoperatively.

Results: Demographics were similar for both groups. Mean age was 56 and 58 years in the Wallstent and Z-stent groups, respectively. There was a female predominance (Wallstent, 69%; Z-stent, 67%) and a higher incidence of left-sided disease (Wallstent, 66%; Z-stent, 56%) in both groups. There was a slightly higher incidence of post-thrombotic disease in the Z-stent subgroup (Wallstent, 53%; Z-stent, 68%). Cumulative freedom from contralateral DVT was 99% and 90% in the Z-stent and Wallstent groups, respectively ($P < .001$) during the 5 years following stent placement. However, all three patients with DVT contralateral to a Z-stent actually had high placement of the Wallstent across the confluence. Thus, no patients with proper Z-stent technique had a contralateral DVT. Cumulative freedom from ipsilateral DVT was 97% and 82% in the Z-stent and Wallstent groups, respectively ($P < .001$) during the 5 years following stent placement. The decrease in incidence of ipsilateral DVT appeared to be attributable to decreased missed distal lesions with increased operator experience and not attributable to the Z-stent itself.

Conclusions: Contralateral DVT incidence was significantly lower with the Z-stent modification. In addition, the Z-stent modification provides greater radial strength at the iliac-caval confluence and simplifies simultaneous or sequential bilateral stenting. Use of proper technique and intravascular ultrasound is essential to limit the incidence of ipsilateral DVT. (J Vasc Surg: Venous and Lym Dis 2017;5:8-17.)

Endovascular stenting has become the first-line treatment for patients with symptomatic iliofemoral stenosis or occlusion. Excellent clinical outcomes and patency can be achieved with adherence to the basic vascular principle of establishing adequate inflow and outflow. In most cases, the outflow component requires stenting of the proximal common iliac vein (CIV), which is a typical location of densely fibrotic venous lesions and is considered an anatomic choke point.

Proper stenting of the proximal CIV can be challenging for two primary reasons: (1) the difficulty in accurately locating the iliac vein confluence on venography; and (2) the limitations of current stent technology, which can lead to either cranial stent collapse with coning or downward stent migration when stents are positioned exactly at the confluence.

To mitigate the difficulties of landing stents at the confluence, it has been recommended to deploy Wallstents (Boston Scientific, Marlborough, Mass) 3 to 5 cm into the inferior vena cava (IVC).[1,2] Initial concerns that crossing the contralateral vein could cause contralateral deep venous thrombosis (DVT) were not immediately recognized.[3] Over time, however, we observed patients

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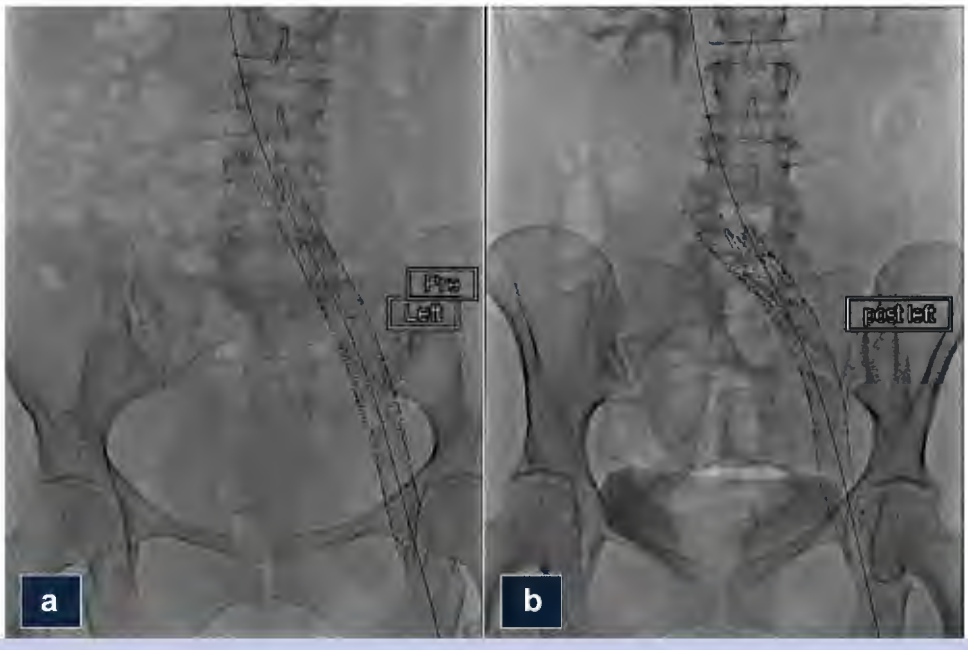

Fig 1. Before 2011, iliofemoral Wallstents were extended into the inferior vena cava (IVC) **(a)** to prevent stent collapse and distal stent migration, which could lead to recurrence of symptoms or stent occlusion. After 2011, in an attempt to prevent jailing of the opposite side and to improve radial forces at the proximal common iliac vein (CIV), an anatomic choke point, Wallstents were landed at the iliac confluence and Z-stents were taken into the IVC **(b)**.

with contralateral DVT after iliac stenting with caval extension. This finding led to an evolution of our stenting technique to include the use of a proximal Z-stent (Cook Medical, Bloomington, Ind), which has larger interstices than the Wallstent, to maintain contralateral blood flow.[4] Additional technical benefits of this stenting strategy include the greater radial strength of the Z-stent, which can help prevent stent collapse at the location of proximal fibrotic CIV lesions, and simplification of simultaneous or sequential bilateral iliac vein stenting.

The purpose of this study was to evaluate the incidence of ipsilateral and contralateral DVT in patients who underwent traditional iliocaval stenting with Wallstents extended into the IVC vs those who underwent a modified technique with Z-stent placement at the confluence with a tail of Wallstent below covering the remaining iliofemoral segments (Fig 1).

METHODS

Patients. This study included all patients treated consecutively at our center from 2007 to 2015 for ipsilateral iliofemoral disease. This was a retrospective analysis of a prospectively collected data registry. Patient consent was obtained before registry entry, and St. Dominic's Hospital Institutional Review Board approval was obtained for this review.

Data collected included demographics, details of preoperative workup, disease type and extent, procedural details, and postoperative DVT outcome. Preoperative diagnostic testing consisted of clinical examination, duplex ultrasound, and venography (transfemoral venography, computed tomography venography, or magnetic resonance venography). All patients additionally underwent preoperative evaluation for thrombophilia, including protein C, protein S, and antithrombin III deficiency, as well as for the presence of lupus anticoagulant, anticardiolipin antibody, anti-β_2-glycoprotein antibody, antiphosphatidylserine antibody, factor V Leiden mutation, prothrombin G20210A mutation, increased factor VII activity, increased factor XI activity, and hyperhomocysteinemia.

Limbs were classified preoperatively using both clinical class, etiology, anatomy, and pathophysiology classification and Venous Clinical Severity Score. Patients included both those with chronic post-thrombotic disease (at least 6 months from inciting DVT) and patients with nonthrombotic iliofemoral occlusive disease. The original iliac vein disease prompting stent placement was considered nonthrombotic when one or more discrete lesions were identified at locations of external compression. Lesions were characterized as post-thrombotic when the patient had a known history of DVT or when post-thrombotic changes (wall fibrosis, trabeculae) and diffuse long-segment narrowing were visualized on duplex ultrasound, venography, or intravascular ultrasound (IVUS).

Interventions. Patients treated from 2007 to 2011 included 755 patients with traditional iliofemoral stenting and caval extension of Wallstents. Patients

treated from 2011 to 2015 included 982 patients treated with a modified technique involving Z-stent proximal extension (Fig 1).

The diagnosis of obstruction, indications for stenting, technical details of iliofemoral stenting with both caval extension of Wallstents and use of the modified Z-stent technique, and perioperative anticoagulation have all previously been described.[1-4]

Access was obtained in the ipsilateral femoral vein at mid to upper thigh level using ultrasound guidance. Iliofemoral and caval venography was performed at the start of the procedure to determine vessel patency and to provide a roadmap. Recanalization was performed of totally occluded venous segments per standard technique.[1] IVUS was used universally in all patients to determine degree of stenosis as well as the location of the iliac confluence and distal stent landing site using vertebral body features as landmarks for accurate stent deployment at preferred landing zones. All veins were predilated with large-caliber noncompliant balloons (16-20 mm) to maximum pressure (16-18 atm). Large-caliber (16-20 mm) braided stainless steel stents (Wallstents) were used in all patients. Generous overlap of at least 3 to 5 cm was used for all stent junctions. Between 2007 and February 2011, stents were extended cephalad 3 to 5 cm into the IVC to prevent proximal Wallstent collapse at the iliocaval junction. After March 2011, stenting was performed with technical modification such that Wallstents were landed just below the iliac confluence and Gianturco Z-stents were placed at the top of the Wallstent stack so that they extended approximately 2 cm into the IVC. Z-stents were oversized by 10% to 20% compared with the Wallstents to prevent stent migration or embolization. Below, Wallstents were extended into the common femoral vein if there was IVUS-determined compression at the inguinal ligament or in the common femoral vein. Extension past the inguinal ligament was nearly universal because lesions at the inguinal ligament are so common.[5] All stents were postdilated after Z-stent deployment with the same large-caliber balloons used for predilation.

Postoperative care and follow-up. There were no significant differences in postoperative anticoagulation or follow-up protocols between the two groups. All patients were maintained on lifelong antiplatelet therapy (aspirin, 81 mg). Full anticoagulation was used for patients with acute DVT, for patients with diagnosed thrombophilia, and for patients already requiring anticoagulation for another medical indication. Lifelong anticoagulation was used in patients with unprovoked DVT, recurrent DVT, or diagnosed thrombophilia. Follow-up consisted of clinical examination and duplex ultrasound at 1-, 3-, 6-, and 12-month intervals and then annually thereafter.

Table I. Patient characteristics

Demographics	Wallstent (n = 755)	Z-stent (n = 982)	*P* value
Age, years, mean ± SD	56 ± 14	58 ± 15	.5
Male	231 (31)	325 (33)	.3
CEAP classification			
C2 (pain)	45 (6)	39 (4)	.3
C3	400 (53)	495 (50)	
C4	168 (22)	271 (28)	
C5	24 (3)	48 (5)	
C6	118 (16)	129 (13)	
VCSS, median (mean)	7.0 (7.9)	7.0 (8.0)	1.0
Risk factor for DVT (after stenting)			
None	209 (28)	265 (27)	.8
Hypercoagulable disorder	52 (7)	91 (9)	.2
Paraplegia	2 (1)	1 (1)	.2
Cancer	27 (3)	37 (4)	.9
Pregnancy or OCP use	29 (4)	52 (5)	.1
Previous DVT	34 (5)	41 (4)	.3

CEAP, Clinical class, etiology, anatomy, pathophysiology; *DVT*, deep venous thrombosis; *OCP*, oral contraceptive pill; *SD*, standard deviation; *VCSS*, Venous Clinical Severity Score.
Values are reported as number (%) unless otherwise indicated.

Statistics. Cumulative freedom from contralateral and ipsilateral DVT was calculated using survival analysis with the Kaplan-Meier survival curve method because the two subsets compared had different follow-up lengths. Cumulative incidence tends to lessen time-related skewing of DVT incidence. The log-rank test was used to compare curves. Continuous variables were analyzed with the Student *t*-test, and the Fisher exact test was used for categorical data. In all cases, a P value $< .05$ was considered significant.

RESULTS

Between November 2006 and September 2015, there were 1737 patients who underwent surgical intervention for chronic ipsilateral iliofemoral disease. Traditional iliofemoral stenting with caval extension of Wallstents was performed in 755 patients between January 2007 and December 2010. Between January 2011 and September 2015, a modified technique using proximal Z-stents was used in 982 patients.

Demographics were well matched between the groups (Table I). Importantly, there was no difference in the rate of diagnosed thrombophilia between the two groups. Anatomic and operative details from the initial stenting procedure are seen in Table II. The majority of stents were placed in the left side in both the Wallstent extension (n = 501 [66%]) and Z-stent extension patients (n = 551 [56%]; $P < .001$).

There was a higher incidence of post-thrombotic disease, which is generally associated with increased

Table II. Anatomic and operative details

Operative details and outcomes of patients	Wallstent (n = 755)	Z-stent (n = 982)	*P* value
Operative side			
Right	254 (34)	431 (44)	<.0001
Left	501 (66)	551 (56)	
Etiology			
Acute DVT	0 (0)	0 (0)	<.0001
Nonthrombotic iliac lesions	309 (41)	259 (26)	
Post-thrombotic disease	398 (53)	667 (68)	
Post-thrombotic disease and nonthrombotic iliac lesions	48 (6)	56 (6)	
Degree of obstruction			
Occlusion	91 (12)	92 (9)	.08
Nonocclusive	664 (88)	890 (91)	
Stent—upper landing site			
IVC	755 (100)	982 (100)	NS
Stent—distal landing site			
CIV	19 (3)	31 (3)	.4
External iliac vein	74 (9)	14 (2)	
Common femoral vein	662 (88)	937 (95)	
Postoperative anticoagulation[a]	208/451[b] (46)	390/872[b] (45)	.6
Postoperative VCSS	4.2	4.5	.02

CIV, Common iliac vein; *DVT,* deep venous thrombosis; *IVC,* inferior vena cava; *VCSS,* Venous Clinical Severity Score.
Values are reported as number (%).
[a]All patients were taking antiplatelet agents. Anticoagulants included warfarin (Coumadin), enoxaparin (Lovenox), rivaroxaban (Xarelto), and apixaban (Eliquis).
[b]Anticoagulation data were available in a limited number of patients as indicated.

risk of stent thrombosis, in the Z-stent group ($P < .0001$). All patients were maintained on lifelong antiplatelet medications. There was no difference in the rate of postoperative anticoagulation ($P = .6$). All stents had proximal extension into the distal IVC. Caudally, the majority of stents were extended past the inguinal ligament into the common femoral vein (Wallstents, 88%; Z-stents, 95%; $P = .4$). A smaller percentage of stents were landed in the CIV or external iliac vein and were not significantly different between the groups (Table II).

Overall DVT incidence is documented in Table III. Follow-up was 29 ± 21 (range,1-107) vs 17 ± 16 (range, 1-65) months for the Wallstent and Z-stent patients, respectively ($P = .06$). Kaplan-Meier predictive analysis was used to equalize differences in length of follow-up and those lost to follow-up. DVT-free cumulative survival was significantly better for Z-stents compared with Wallstents at 93% vs 81% at 54 months, respectively (Fig 2). Freedom from contralateral DVT was also significantly improved in the Z-stent group at 99% vs 90% for Wallstents at 54 months (Fig 3). Details regarding the timing, etiology, and reinterventions for contralateral DVT are seen in Table IV.

Wallstent patients who developed contralateral DVT did so at an average of 47.5 ± 37.8 months (range, 9 days-111 months) after initial stenting. Only one Wallstent patient developed a contralateral DVT before 30 days. Reintervention was offered to 13 of the 16 patients with DVT contralateral to Wallstents crossing the confluence. Early in the series, five patients were treated with thrombolysis or percutaneous mechanical thrombectomy (PMT) without contralateral stenting; however, this failed in four of five patients. The remainder of patients who underwent reintervention for DVT contralateral to a Wallstent (n = 8/13) were treated with thrombolysis or PMT in combination with stent fenestration and contralateral stenting. Stent fenestration was accomplished with wire access through the side of the crossing contralateral wall stent. Aggressive ballooning (18-mm balloons to burst pressure) was then performed over the wire, creating a hole in the side of the prior stent. The fenestration was supported with a Z-stent to maintain its integrity. All patients surgically managed with this technique were successfully reopened (n = 8/8). The final three patients did not undergo reintervention for DVT contralateral to Wallstents secondary to deteriorating medical condition (n = 2) and refusal to follow up (n = 1).

Three patients developed contralateral DVT after treatment with Z-stent extension at an average of 8 ± 1.7 months postoperatively (range, 6-9 months). However, on review of imaging, all Z-stent patients with contralateral DVT had high placement of Wallstents before Z-stent placement such that the Wallstent actually extended past the caval confluence (Fig 4). Thus, no

Table III. Overall incidence of deep venous thrombosis (DVT) among Wallstent and Z-stent patients

	Contralateral (<30 days)	Contralateral (≥30 days)	Total contralateral	Ipsilateral (<30 days)	Ipsilateral (≥30 days)	Total ipsilateral	Total
Wallstent (n = 755)	1 (0)	15 (2)	16 (2)	18 (2)	19 (3)	37 (5)	53 (7)
Z-stent (n = 982)	0 (0), NS	3 (0)[a]	3 (0)[a]	12 (1)[a]	0 (0)[a]	12 (1)[a]	15 (2)[a]

NS, Nonsignificant.
Values are reported as number (%).
[a]$P < .001$.

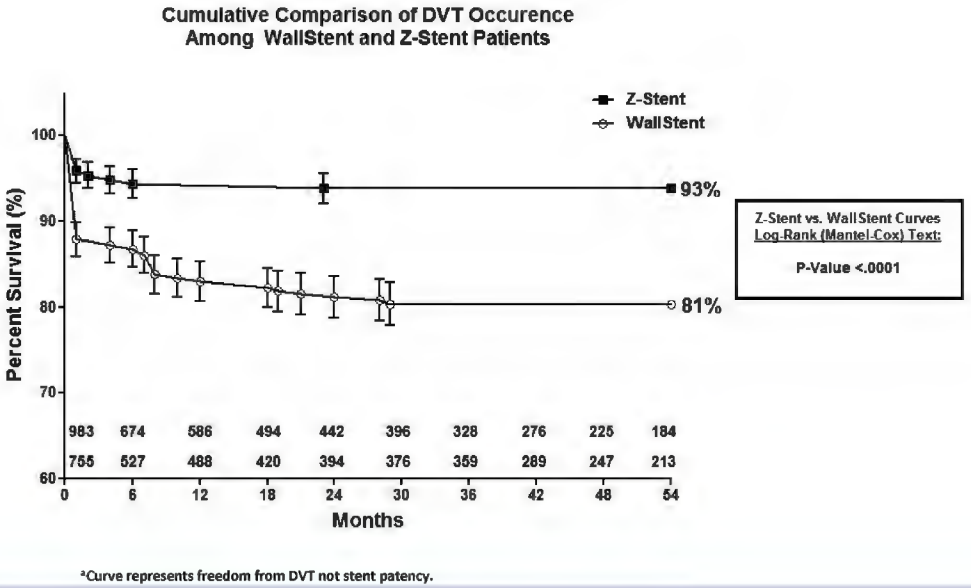

Fig 2. Cumulative freedom from ipsilateral or contralateral deep venous thrombosis (*DVT*) in 982 patients treated with caval extension of Wallstents vs 755 patients treated with caval extension of Z-stents.

patient with accurate placement of the Wallstent distal to the confluence and only Z-stent extension into the IVC developed a contralateral DVT. The three Z-stent patients with DVT underwent successful lysis or PMT with stent fenestration and contralateral stenting.

Freedom from ipsilateral DVT was also significantly better in the Z-stent group at 97% vs 82% for Wallstents at 54 months (Fig 5). Details regarding the timing, etiology, and reinterventions for ipsilateral DVT are seen in Table IV.

The majority of ipsilateral DVT in Z-stent patients (n = 7 [58%]) was attributable to access site thrombosis. This complication was accountable for an equal number (n = 7) but smaller overall percentage (19%) of ipsilateral DVT in the Wallstent group. All access site DVT presented within the first 30 days (range, 1-28 days). In both groups, 71% (n = 5/7) had access-only DVT involving the femoral vein. Clot extended into the ipsilateral stent in the remaining patients.

Ipsilateral DVT in the Wallstent group was more frequently attributable to missed distal lesions (n = 14 [38%]), with a smaller component due to poor inflow (n = 7 [14%]). Missed lesions were defined as chronic venous lesions identified on IVUS at the time of the

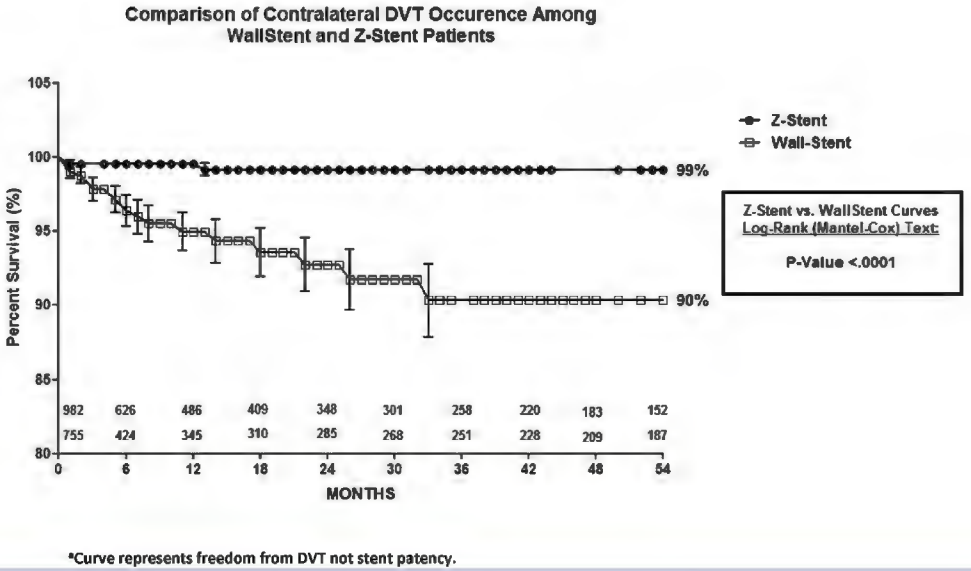

Fig 3. Freedom from contralateral deep venous thrombosis (*DVT*) in 982 patients treated with caval extension of Wallstents vs 755 patients treated with caval extension of Z-stents.

Table IV. Patient outcomes and reinterventions

DVT and reinterventions	Wallstent	Z-stent
Ipsilateral	(n = 37)	(n = 12)
Timing		
Early (<30 days)	18 (49)	12 (100)
Late (>30 days)	19 (51)	—
Etiology		
Access site DVT	7 (19)	7 (58)
Missed distal lesion	14 (38)	2 (17)
Poor inflow	7 (19)	3 (25)
Technical problem	1 (3)	—
Active cancer	1 (3)	—
Unclear	7 (19)	—
Reinterventions for occlusion		
PMT, CDT	9 (24)	2 (17)
PMT, CDT, dilation	11 (30)	5 (42)
PMT, CDT, stent extension	14 (38)	5 (42)
No intervention	3 (8)	—
Procedural success	32/34 (94)	12/12 (100)
Contralateral	(n = 16)	(n = 3)
Timing		
Early	1 (6)	—
Late	15 (94)	3 (100)
Etiology		
Wallstent across confluence	16 (100)	3 (100)
Reinterventions for occlusion		
PMT, CDT	5 (32)	—
PMT, CDT, contralateral stent	8 (50)	3 (100)
No intervention	3 (19)	—
Procedural success	9/13 (69)	3/3 (100)

CDT, Catheter-directed thrombectomy; *DVT,* deep venous thrombosis; *PMT,* percutaneous mechanical thrombectomy.
Values are reported as number (%).

reintervention, below the level of a prior stent. Poor inflow was a subjective assessment made by the operating surgeon. Currently, there is no way to quantitate inflow or to determine adequate inflow. However, we generally use this term to describe patients with stents supplied by severely diseased or occluded femoral veins often with accompanying profunda vein disease. In the most severe cases, only collateral veins serve to provide inflow to the stents.

Other less common reasons for ipsilateral DVT, observed in the Wallstent group only, included a new cancer diagnosis (n = 1 [3%]) and a technical error resulting in DVT (n = 1 [7%]). The technical error involved stent placement into the saphenous vein, which resulted in occlusion. This was opened with fenestration from the femoral vein and stent dilation after PMT or thrombolysis. A contributing factor was not identified in seven Wallstent patients.

All patients in the Z-stent group and the majority of patients in the Wallstent group with ipsilateral DVT underwent reintervention. Reintervention was deferred in three cases in the Wallstent group secondary to minimal clot at the access site treated with anticoagulation (n = 1), a new cancer diagnosis with access site DVT only (n = 1), and a high-risk medical condition with the patient's declining further intervention (n = 1). Overall, reintervention procedural success was 94% and 100% in the Wallstent and Z-stent groups, respectively.

DISCUSSION

The bulk of the experience with iliofemoral venous stenting has been with the use of Wallstents, largely because of the availability of these stents in sizes large enough to match the normal iliac veins (1620 mm). Results have been excellent, with significant improvement in clinical symptoms and reasonable durability.[1-4] However, through our large-volume experience, we have uncovered several limitations of Wallstent use in iliofemoral stenting that are worth discussing. An evolving understanding of the structural features of the stent, its performance within a challenging anatomic location at the iliac vein confluence, and a complex disease process has shaped our practice patterns with time.

The optimal procedural outcome of iliac vein stenting would allow placement of the stent exactly at the confluence such that it is positioned entirely within the CIV. This necessitates, first, being able to identify the precise location of the confluence and, second, having the ability to deploy the stent exactly at the desired location. Unfortunately, achieving both of these requirements to the level of precision needed is currently a problem.

Venography is altogether inaccurate to determine the location of the confluence. The anatomic junction is not circular but rather an oblique oval that may be altered further by the encroachment of the primary or post-thrombotic lesion on the vena cava. Alternatively, IVUS offers an accurate assessment of the confluence in an estimated 80% to 90% of cases.[2,5,6]

Nonetheless, even when detailed effort is put into identifying the confluence, the Wallstent mechanical properties are not designed for accurate placement or to withstand the external compression forces often present at the proximal CIV. The relatively weak radial force at the ends of the Wallstent (compared with the body of the stent) cannot maintain an adequate lumen in the presence of densely fibrotic lesions often present in the cranial portion of the CIV; the stent is thus compressed into a tapering cone shape[7,8] that can have both immediate and long-term consequences. Intraoperatively, this may result in "watermelon seeding" of the stent in the caudal direction. Alternatively, even if it is deployed precisely in the desired location, the stent can still migrate caudally during postdilation, leading to

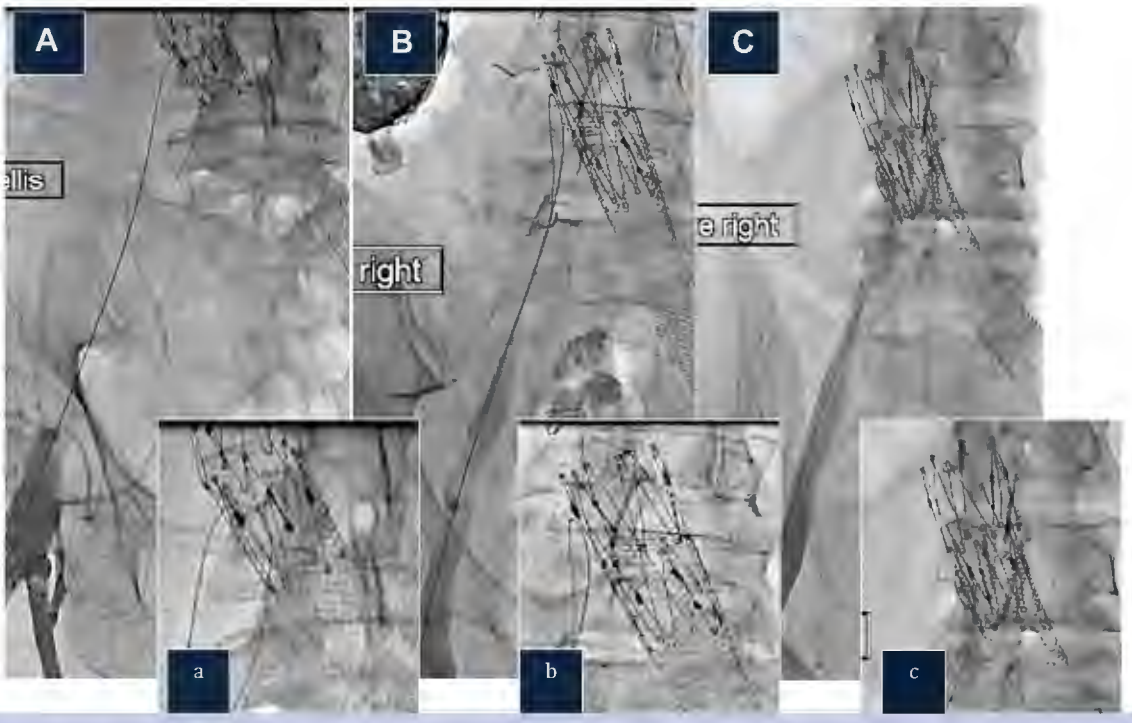

Fig 4. Three patients developed contralateral deep venous thrombosis (DVT) after stenting with the modified Z-stenting technique **(A, B, C)**. On case review, it can be seen that the Wallstent portion of the stent was deployed high in all cases and crossed the bifurcation in addition to the Z-stent **(a, b, c)**.

inadequate final positioning and missed lesions. Postoperatively, the high forces within the proximal CIV can cause ipsilateral cranial stent collapse with DVT or caudal stent migration with symptom recurrence[7,8] (Fig 6).

In attempts to mitigate the difficulties with landing of the Wallstent at the confluence, our center adopted the now generally accepted technique of landing the Wallstent several centimeters into the IVC, far enough that the stent touches the contralateral caval wall.

Several problems arise from this technique. The first, as documented in this series, is a subtle but significant increased risk in the incidence of contralateral DVT.

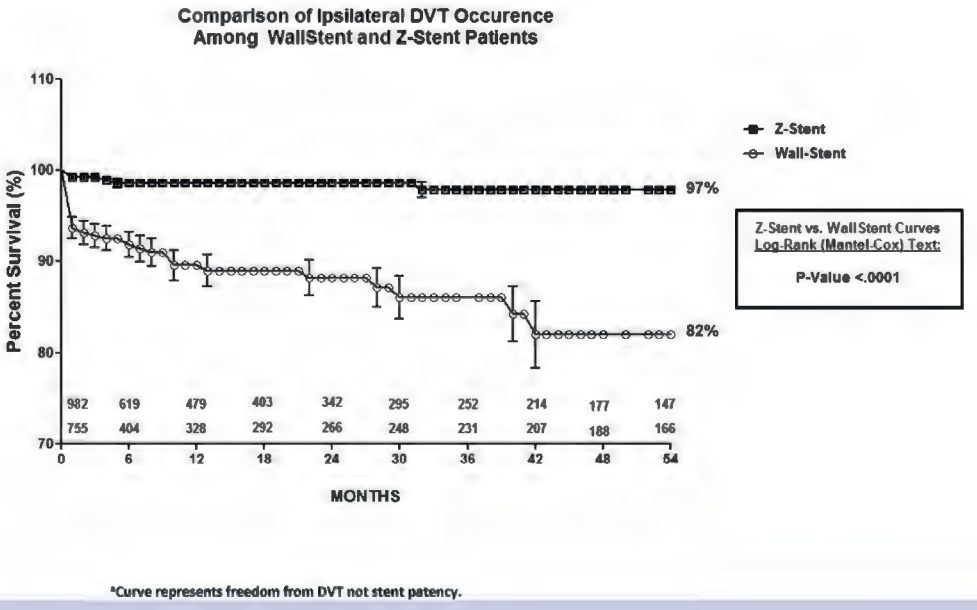

Fig 5. Freedom from ipsilateral deep venous thrombosis (*DVT*) in 982 patients treated with caval extension of Wallstents vs 755 patients treated with caval extension of Z-stents.

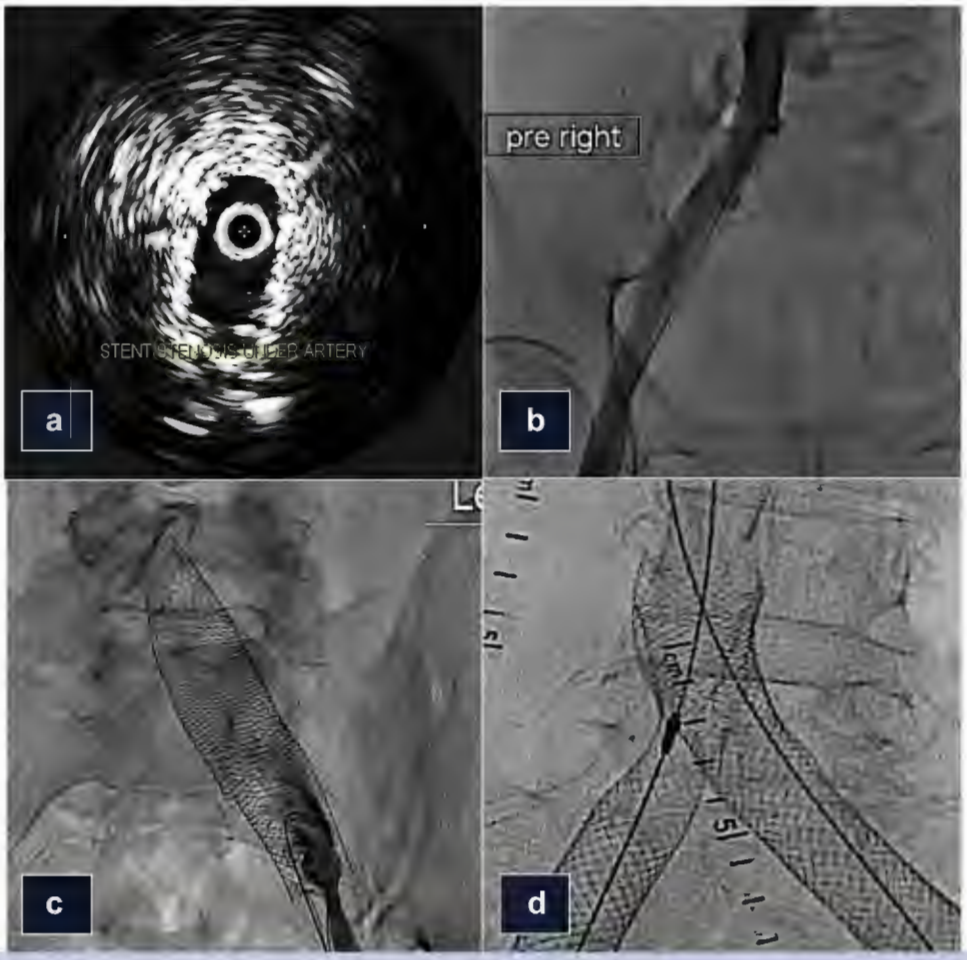

Fig 6. Wallstents landed at the iliac confluence are subject to stent collapse because of lack of radial forces at the stent ends **(a),** distal stent migration **(b),** and occlusion secondary to collapse and coning of the proximal stent **(c)**. Furthermore, bilateral stenting requires fenestration of the contralateral stent **(d)** because double-barrel techniques routinely fail.

Patients presented with contralateral acute DVT anywhere from 9 days to just after 9 years from initial stent placement. It appears that the small interstices of the Wallstent gradually become lined with neointima. Eventually in this case, the stent assumes the properties of a covered stent, resulting in increased flow resistance and possible occlusion or thrombosis of the contralateral iliac vein. Our intraoperative experience lends further credence to this theory. In fact, it is common during reintervention to have difficulty in cannulating through the side of the crossing Wallstent, implying that neointimal coverage is present. Furthermore, the thrombus distal to the crossing Wallstent is often soft and responsive to lysis or PMT, whereas the flow limitation of the Wallstent interstices is almost completely resistant to these treatments. Not surprisingly, all but one patient treated with only lysis and PMT for DVT contralateral to a crossing Wallstent remained permanently occluded (n = 4/5). Thus, in the setting of contralateral DVT related to a crossing Wallstent, we now opt for lysis or PMT followed by revision of the confluence; a wire is advanced through the side of the crossing Wallstent, and the interstices are balloon fractured and stented open. On several occasions, passing a wire through the jailing stent was so difficult that we had to use a transjugular intrahepatic portosystemic shunt needle to assist in fenestration. Since employing this more aggressive surgical treatment plan, including revision of the confluence in addition to PMT or thrombolysis, we have experienced a 100% reinterventional success rate for contralateral DVT after previous Wallstent (n = 8/8) or Z-stent (n = 3/3) extension into the IVC.

Whereas the overall success of reintervention after contralateral DVT resulting from Wallstent jailing has now become essentially 100%, a technique that avoids placement of a crossing Wallstent remains strongly preferable. Contralateral fenestration of the crossing Wallstent often predisposes patients long term to fenestral stenosis or stenosis of the ipsilateral stent just below the fenestration. The latter occurs as a result of the

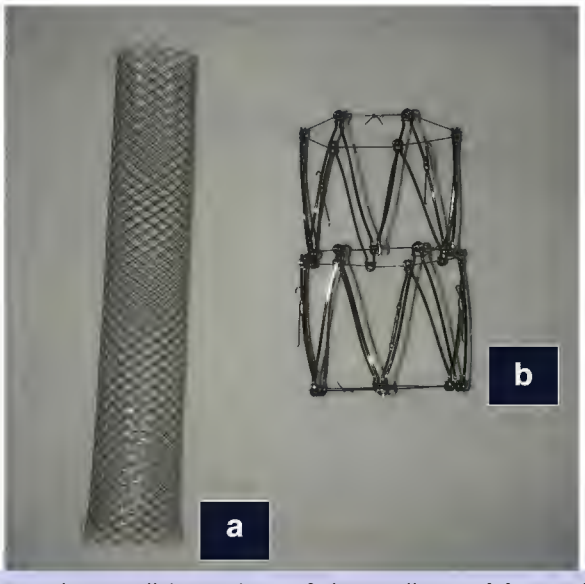

Fig 7. The small interstices of the Wallstent **(a)** may be prone to neointimal coverage over time. The larger interstices of the Z-stent **(b)** are more resistant to neointimal coverage and allow greater flow in crossing of the confluence.

mechanical properties of the Wallstent, which result in narrowing of the Wallstent adjacent to a point of overdilation (ie, the creation of the fenestration).

Over time, our center has evolved to a modified Z-stent technique to facilitate bilateral stenting, avoiding the crossing Wallstent and complications thereof. This technique requires landing the Wallstent in the CIV within 1 cm of the confluence and extending a Gianturco Z-stent just into the IVC. The Z-stents have larger interstices (Fig 7), which maintain greater flow, are less prone to coverage by fibrous tissue growth, and allow interdigitation of stent struts, facilitating bilateral stenting (Fig 8). In addition, they provide improved radial support at the proximal CIV, exactly where the weak distal end of the Wallstent is positioned. To date, we have had no instances of contralateral DVT with proper Z-stent modification technique.

A crux of the Z-stent technique is that its success in preventing contralateral DVT still remains dependent on landing of the Wallstent portion of the stent configuration in the CIV or just at the confluence. Whereas there is slightly more flexibility in the cranial landing zone of the Wallstent with this technique, in cases in which it is deployed higher than intended, the risk of jailing contralateral flow would be expected to equate to that observed in the non-Z-stent group. In fact, on review of the three cases of contralateral DVT after use of the modified Z-stent technique, the Wallstent portion of the stent configuration was unintentionally landed too proximal into the cava, crossing over the contralateral iliac.

Overall, the most common reasons for ipsilateral stent occlusion were (1) access site DVT, (2) missed distal lesions, and (3) poor inflow. Access site DVT is a risk with any venous intervention and often does not involve the stent. This was a rare occurrence in both groups. We generally recommend treatment of all but the most minimal access thrombus in an attempt to protect the stent from thrombus propagation.

Inflow is difficult to assess as there is no established means to adequately measure the robustness of flow

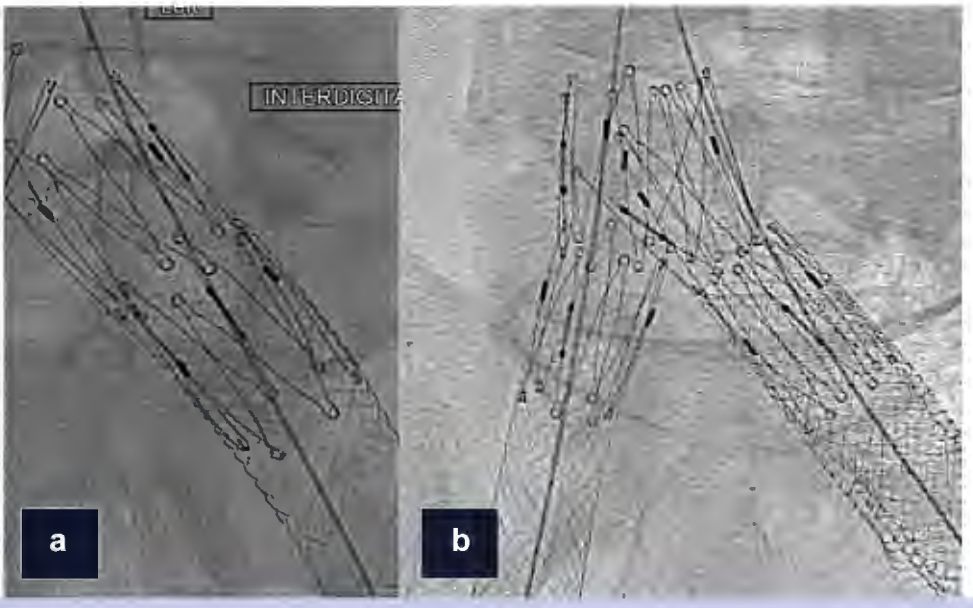

Fig 8. Z-stent extension into the inferior vena cava (IVC) allows improved contralateral flow secondary to the wide interstices of the proximal struts **(a)**. In addition, the wide interstices facilitate contralateral stenting by allowing interdigitation of the proximal struts **(b)**.

that may predict future stent patency. Thus, some degree of failure attributable to poor inflow is expected in treating severe post-thrombotic disease. In fact, thrombosis related to poor inflow occurred with similar frequency in both groups. This is perhaps the most difficult subset of patients to treat adequately; however, many of these patients will maintain secondary patency after thrombolysis and redilation. We routinely attempt revascularization in cases of ipsilateral DVT at least once to rule out a missed distal lesion or any other technical errors. If the patient immediately reoccludes after reintervention, then 6 months of anticoagulation with physical therapy and vigorous exercise is prescribed in an effort to improve inflow.

Missed lesions, on the other hand, result from a failure to identify treatable distal disease. Venography is not adequate to identify an appropriate distal landing zone as distal stenosis can be easily overlooked. Thus, routine use of IVUS during initial stent placement as well as during any reintervention is mandatory. It is essential to extend the Wallstents to the best possible distal landing zone, avoiding the temptation to limit stent length or to evade extending across the inguinal ligament. As a more aggressive approach to treating distal lesions was instituted at our center, we noted substantially fewer missed distal lesions with a corresponding decrease in the incidence of ipsilateral DVT. There was no ipsilateral DVT in the Wallstent group attributable to proximal stent collapse or stent migration; therefore, it is unlikely that the Z-stent technique itself contributed to the decrease in ipsilateral DVT.

This latter finding leads us to one of the limitations of this study, the fact that patients treated with the new technique were compared with a historical cohort. Over time, increased experience led to improved selection of patients and operative techniques. Thus, both groups, although similar, are not entirely comparable. It seems clear that this was the primary reason for the decrease in ipsilateral DVT seen in the Z-stent patients compared with the Wallstent patients. This may also result in a decrease in the incidence of contralateral DVT in the Z-stent group over time as we are now even more diligent in preventing encroachment of the Wallstent into the IVC with this technique.

Overall, the future of iliac vein stenting requires the ability to more gracefully handle the iliac confluence, including patients with coincident disease of the IVC. All current technology has limitations in this domain.

CONCLUSIONS

The Z-stent modification of iliac stenting technique appears to be associated with a significant overall decrease in contralateral DVT rate. The Z-stent has significantly larger interstices compared with the Wallstent, allowing greater flow through the side struts, and they are therefore less prone to coverage with neointimal growth. The decreased rate of ipsilateral DVT appears to be related to increased experience and fewer missed distal lesions. Adhering to the basic principle of establishing adequate inflow and outflow will allow operators to obtain the best possible results with current technology. Future stent design projects should ideally address the confluence more elegantly.

AUTHOR CONTRIBUTIONS

Conception and design: EM, SR
Analysis and interpretation: EM, BJ, EV, WB
Data collection: EM, BJ, EV, WB, AJ, SR
Writing the article: EM
Critical revision of the article: EM, AJ, SR
Final approval of the article: EM, BJ, EV, WB, AJ, SR
Statistical analysis: EM, BJ, EV, WB
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Overall responsibility: EM

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