

# Posture commonly and considerably modifies stenosis of left common iliac and left renal veins in women diagnosed with pelvic venous disorder



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## ABSTRACT

**Objective:** Pelvic venous incompetence or pelvic congestion syndrome (commonly referred to as pelvic venous disorder [PVD]) is increasingly diagnosed, especially in multiparous women. This may be either primary or secondary to pelvic venous outflow obstruction—left common iliac vein (LCIV) or left renal vein (LRV) stenosis. Intravascular ultrasound (IVUS) examination performed in the supine position is commonly used for diagnosis of LRV and LCIV stenosis; however, body position may affect the cross-sectional area (CSA) of both of these veins during IVUS. The aim of the study was to test the hypothesis that postural changes may significantly affect the CSA of the LRV and LCIV.

**Methods:** A single-arm, single-center cohort study of women suffering from PVD was performed at a tertiary hospital in Poland. It comprised consecutive patients with either pelvic vein reflux or suggestion of LCIV or LRV obstruction but no signs of deep venous thrombosis. IVUS examination of the iliac veins, inferior vena cava, and LRV was performed in the supine position. IVUS of the LRV and LCIV was performed also with a Valsalva maneuver and with patients lying on the left side and standing. A 60% CSA reduction was used as a cutoff value between significant and nonsignificant vein stenosis.

**Results:** A total of 41 women were examined. Significant stenosis of the LRV was seen in 22 patients (55%) supine but in only 4 (10%) patients studied when lying on the left side and in 27 (67.5%) patients studied while standing. Significant stenosis of the LCIV was seen in 26 supine patients (63.4%), in 8 lying on the left side (19.5%), and in 10 (24.4%) standing.

**Conclusions:** Postural changes dramatically affect CSA of the LCIV and LRV and thus the degree of stenosis in women diagnosed with PVD. Stenosis found in patients while supine often disappears when the position is changed to lying on the left side or to standing. Therapeutic decisions based on assessment of CSA reduction in the supine position are likely to be inadequate. (*J Vasc Surg: Venous and Lym Dis* 2019;7:845-52.)

**Keywords:** Intravascular ultrasound; Iliac vein; Renal veins; Valsalva maneuver; Cohort studies; Supine position; Posture; Pelvic venous disorder

Pelvic venous incompetence and pelvic venous outflow obstruction are increasingly diagnosed as pathologic processes affecting predominantly multiparous women.<sup>1</sup> Patients may present with a variety of symptoms, including chronic pelvic pain, perineal and vulvar varicose veins, varicose veins of the legs, dyspareunia, left flank pain, hematuria, leg edema, and venous claudication. Retrograde flow within pelvic veins and reflux into the perineal or leg veins may be either primary or

secondary to left renal vein (LRV) or left common iliac vein (LCIV) stenosis. In recognition of these overlapping pathophysiologic mechanisms, pelvic vein incompetence and pelvic outflow obstruction combined are known as pelvic venous disorder (PVD).<sup>2</sup>

Whereas assessment for pelvic vein reflux is accurate and straightforward, outflow obstruction is much more difficult to diagnose. Intravascular ultrasound (IVUS) was found to be the optimal diagnostic tool<sup>3</sup> and a 60% cross-sectional area (CSA) reduction the best cutoff value for clinically significant common iliac vein stenosis.<sup>4,5</sup> Other methods, such as multiplanar venography,<sup>4</sup> magnetic resonance venography,<sup>6</sup> computed tomography venography, and transabdominal ultrasound, are less accurate, involve substantial irradiation, or depend on the patient's anatomy or the examiner's skills.

Even though IVUS is replacing multiplanar venography as the "gold standard" for diagnosis of venous stenosis, LCIV stenting based on IVUS was only moderately effective (area under the receiver operating characteristic curve, 0.64),<sup>5</sup> and accurate diagnosis of outflow

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obstruction may involve more factors than are currently recognized. One of the members of our team (M.M.) has seen a tight stenosis of the proximal part of the LRV on abdominal ultrasound examination of a supine patient disappear completely when the patient turned to her left flank. This suggests a positional functional character of this stenosis.

To examine whether LCIV or LRV compression may in fact depend on position of the body, we designed a study in which IVUS would be performed in patients changing position from supine to lying on the left side and to standing. The aim of the study was to test a hypothesis that postural changes may significantly affect CSA and thus degree of stenosis of the LRV and LCIV.

## METHODS

The study was performed at the Department of Angiology, Jagiellonian University Medical College, in Krakow, Poland. It was designed as a single-arm, single-center, observational cohort study. It comprised consecutive female patients suffering from recurrent or atypical varicose veins of the lower legs, symptomatic perineal or vulvar varicose veins, or chronic pelvic venous disease. Excluded patients had deep venous thrombosis of the iliac veins or inferior vena cava (IVC) in the past or anatomic anomalies of these vessels. All patients had computed tomography venography and transvaginal color Doppler ultrasound examination performed as an initial assessment in which either pelvic vein reflux was documented or findings were suggestive of significant compression of the LCIV or LRV. The patients were referred for IVUS examination as a diagnostic workup from a single high-volume vein clinic between April and October 2018. All patients provided written informed consent; the study followed the principles of the Declaration of Helsinki and was approved by the Ethics Committee of the university. The study was not subject to registration at a public trial database because of its observational character.

**Examination protocol.** The patients had the left common femoral vein punctured under ultrasound guidance, and a 9F, 11-cm-long sheath was placed in the vein. Venography of iliac veins, IVC, and LRV was then performed, followed by IVUS examination.

**Venography technique.** Venography was carried out in posteroanterior projection with the patient supine, holding her breath. The aim of venographic examination was to assess patency, to exclude any anatomic variants of the veins, and to check for the possible presence of collateral circulation.

To visualize right-sided iliac veins and the LRV, radiographic dye (Ultravist 370; Bayer AG, Leverkusen, Germany) was mixed 1:1 with saline and manually injected over a diagnostic catheter (JR 4F; Cordis, Bridgewater, NJ) placed into the right common femoral vein

## ARTICLE HIGHLIGHTS

- **Type of Research:** Prospective, single-arm, single-center cohort study
- **Key Findings:** Intravascular ultrasound performed in 41 women with pelvic congestion syndrome showed that posture significantly affected cross-sectional area and thus the degree of stenosis of the left common iliac vein and left renal vein. For the left renal vein, the stenosis was much more frequently seen when the patient was lying supine or standing than when lying on the left side. For the left common iliac vein, the stenosis was much more frequently seen when the patient was lying supine than when lying on the left side or standing.
- **Take Home Message:** The authors suggest that algorithms for diagnosis of the May-Thurner syndrome and nutcracker syndrome should be redefined.

and distal part of the LRV. To visualize left-sided iliac veins and the IVC, radiographic dye was manually injected through the sheath placed in the left groin; 10 mL of radiographic dye mixed with 10 mL of saline was used per segment studied.

**IVUS technique.** The IVUS catheter (Visions PV 0.035 probe; Volcano, Rancho Cordova, Calif) was advanced through the vessels over a 0.035-inch wire under fluoroscopy guidance using the sheath placed in the left groin. Initially, IVUS examination was performed with the patient supine. The probe was placed over the wire in the right common femoral vein and pulled back slowly to the left femoral vein. In the next step, it was introduced over the wire into the right atrium and pulled back slowly to the left groin. When completed, the probe was placed over a wire in the LRV and pulled back slowly to the left femoral vein. All these were performed with the patient supine and breathing freely. The probe was then placed in the LRV again and pulled back slowly to the left femoral vein while the patient was lying supine and performing a Valsalva maneuver. When completed, the probe was placed in the LRV again, and the patient was placed on her left side. The probe was then pulled back slowly to the left femoral vein in the patient on her left side, breathing freely. After that, the probe was introduced into the LRV once more, the patient would stand up, and the probe was pulled back slowly to the left femoral vein in the patient standing in a comfortable position and breathing freely. Each pullback was digitally recorded and served for vessel cross-sectional measurement once the whole study was completed.

Minimal and maximal CSA was measured for all studied veins and served for calculation of CSA reduction. The degree of stenosis was assessed in relation to maximal CSA of the vein using a formula of

$[1 - (\text{minimal CSA})/(\text{maximal CSA})] \times 100$ . We measured the CSA in patients lying on the side or standing at the same anatomic locations as we had measured with the patient supine. Consequently, we used the measurement performed proximally in place of minimal diameter and distally in place of maximal vein diameter. As a result, there may be negative figures reflecting the degree of stenosis of the LCIV and LRV.

Two examiners experienced in IVUS examination blinded to clinical signs and symptoms or to venography findings performed the measurements independently. The reduction in CSA within a vessel segment was assigned to one of two groups: no significant stenosis (reduction of CSA  $\leq 60\%$ ) and significant stenosis (CSA reduction  $>60\%$ ). Any discrepancy in assessment led to re-evaluation of recordings by both examiners, after which a final assignment was agreed on.

**Statistical analysis.** Continuous variables were presented as means, with standard deviation and range or median with the first and third quartiles. Nominal variables were summarized using counts and percentages. Repeated-measures analysis of variance was used to analyze CSAs of the LRV and LCIV in supine patients, during Valsalva maneuver, on the left side, and standing with post hoc test; pairwise *t*-test with Benjamini adjustment was performed for multiple comparisons.

*P* values  $<.05$  were assumed to indicate statistical significance. Analyses were carried out in JMP 14.0.0 (SAS Institute, Cary, NC).

## RESULTS

During a 7-month period, 41 women (aged  $44 \pm 10.3$  years) were included in the study. Descriptive characteristics of the patients are given in Table I. The most common signs and symptoms were recurrent varicose veins in the saphenous vein territory, vulvar varicose veins, and atypical varicose veins of the lower legs. History of left flank pain, nonspecific abdominal pain, chronic pelvic pain (ie, pain in the area below the umbilicus and between the hips that lasts at least 6 months), or leg edema was less frequent. Hematuria was rare (Table II). Catheterization of the LRV was unsuccessful in a single case. Accordingly, the LRV was assessed in only 40 patients.

**Table I.** Descriptive statistics of patients included in the study (N = 41)

	Mean $\pm$ SD	Range
Age, years	44.4 $\pm$ 10.3	24-70
Body mass index, kg/m <sup>2</sup>	24.6 $\pm$ 4.1	17.9-33.3
No. of pregnancies	2.5 $\pm$ 1.1	0-5
No. of births	2.3 $\pm$ 1.0	0-4
SD, Standard deviation.		

Posture greatly affected CSA of the LRV and LCIV and thus the degree of stenosis (Table III; Supplementary Table I, online only; Figs 1-4). Minimal CSA of the LRV changed from a median of 29.0 mm<sup>2</sup> to 68.1 mm<sup>2</sup> and to 26.1 mm<sup>2</sup> in patients supine, lying on the left side, and standing, respectively (the differences in measurements were highly significant between patients lying on the left side and patients supine or standing, whereas measurements did not significantly differ between patients who were supine and patients who were standing). Similar but much less pronounced changes were found for maximal CSA of the LRV; it was a median of 76.9 mm<sup>2</sup>, 89.2 mm<sup>2</sup>, and 77.0 mm<sup>2</sup> in patients supine, lying on the left side, and standing, respectively. Accordingly, the degree of stenosis changed significantly for many patients as they changed position. When studied supine, 22 patients (55%) had the LRV significantly stenosed, but this dropped to four (10%) when lying on the left side and increased to 27 (67.5%) on standing. Only 2 patients (5%) were concordant positive for LRV stenosis (ie, a significant stenosis present irrespective of postural changes), 11 (27.5%) were concordant negative (ie, lack of significant stenosis irrespective of postural changes), and the remaining changed the degree of stenosis from nonsignificant to significant with change of the position of the body.

For the LCIV, minimal CSA changed from a median of 52.2 mm<sup>2</sup> to 100.1 mm<sup>2</sup> and to 106.2 mm<sup>2</sup> in patients supine, lying on the left side, and standing, respectively (the differences in measurements were highly significant between patients supine and patients lying on the left side or standing, whereas measurements did not significantly differ between patients lying on the left side and patients standing). Similar but less pronounced changes were found for maximal CSA of the LCIV; it was a median of 149.6 mm<sup>2</sup>, 192.3 mm<sup>2</sup>, and 192.6 mm<sup>2</sup> in patients supine, lying on the left side, and standing, respectively. Accordingly, the degree of stenosis changed significantly for many patients as they changed position. When studied supine, 26 patients (63.4%) had the LCIV significantly stenosed, but this dropped to eight (19.5%) when lying on the left side and to 10 (24.4%) on standing. Only 5 patients (12.2%) were concordant positive for LCIV stenosis (ie, a significant stenosis present irrespective of postural changes), 12 (29.3%) were concordant negative (ie, lack of significant stenosis irrespective of postural changes), and the remaining changed the degree of stenosis from nonsignificant to significant with change of the position of the body (Supplementary Table II, online only).

In the supine position, a significant reduction of CSA was also found in the IVC of 16 (39%) patients, in the right external iliac vein of 2 (4.9%) patients, and in the right common iliac vein of 2 (4.9%) patients (Supplementary Table III, online only). Postural changes occasionally

**Table II.** Frequency of symptoms and signs (N = 41)

	No. (%)
<b>Symptoms</b>	
Chronic pelvic pain <sup>a</sup>	10 (24.4)
Left flank pain	17 (41.5)
Other abdominal pain	14 (34.1)
History of leg edema	16 (39.0)
Venous claudication	1 (2.5)
<b>Signs</b>	
Varices in saphenous vein territory	27 (65.9)
Vulvar or perineal varices	25 (61)
Atypical varices of lower legs <sup>b</sup>	21 (51.2)
Asymmetry in calf circumference <sup>c</sup>	14 (34.1)
Erythrocyturia	2 (5)

<sup>a</sup>Pain in the area below the umbilicus and between the hips that lasts 6 months or longer.  
<sup>b</sup>Varices located on the lateral or posterior aspect of the leg or in the pudendal and perineal area that do not arise from incompetent long saphenous vein, short saphenous vein, medial thigh, or lower leg communicating veins.<sup>7</sup>  
<sup>c</sup>Difference in calf circumference >0.5 cm; measurements taken at 20 cm and 40 cm below the patellar base.

resulted in markedly pronounced CSA changes of the LRV and LCIV that could exceed those seen with the Valsalva maneuver (Supplementary Table III, online only).

The number of patients studied does not allow meaningful assessment of predictive value of signs, symptoms, or venographic abnormalities traditionally connected with LRV or LCIV stenosis. However, it seems that although they may be sensitive, they lack specificity (Supplementary Tables IV-VI, online only). The complete set of results is presented as a full database listing in Supplementary Table IV (online only).

## DISCUSSION

Postural changes seriously affect CSA of the LCIV and LRV in women diagnosed with PVD. Significant stenosis of the LCIV as assessed by CSA reduction was most often present in the supine position, whereas it was much less frequent when patients changed the position to lying on the left side or standing. Concordance of diagnosis of significant LCIV stenosis (ie, stenosis present irrespective of body position) was seen in only 5 of 26 women whose

LCIVs were significantly stenosed in the supine position. Likewise, a significant stenosis of the LRV was frequently seen in patients supine or standing, but it was much less frequent in patients lying on the left side. Concordance of diagnosis of significant LRV stenosis was noted in only 2 of 22 women whose LRVs were significantly stenosed in the supine position.

Concordance of negative diagnosis (ie, of lack of significant stenosis irrespective of posture) was also low. It was 12 of 25 cases for the LCIV without significant stenosis in the supine position and 11 of 18 cases for the LRV.

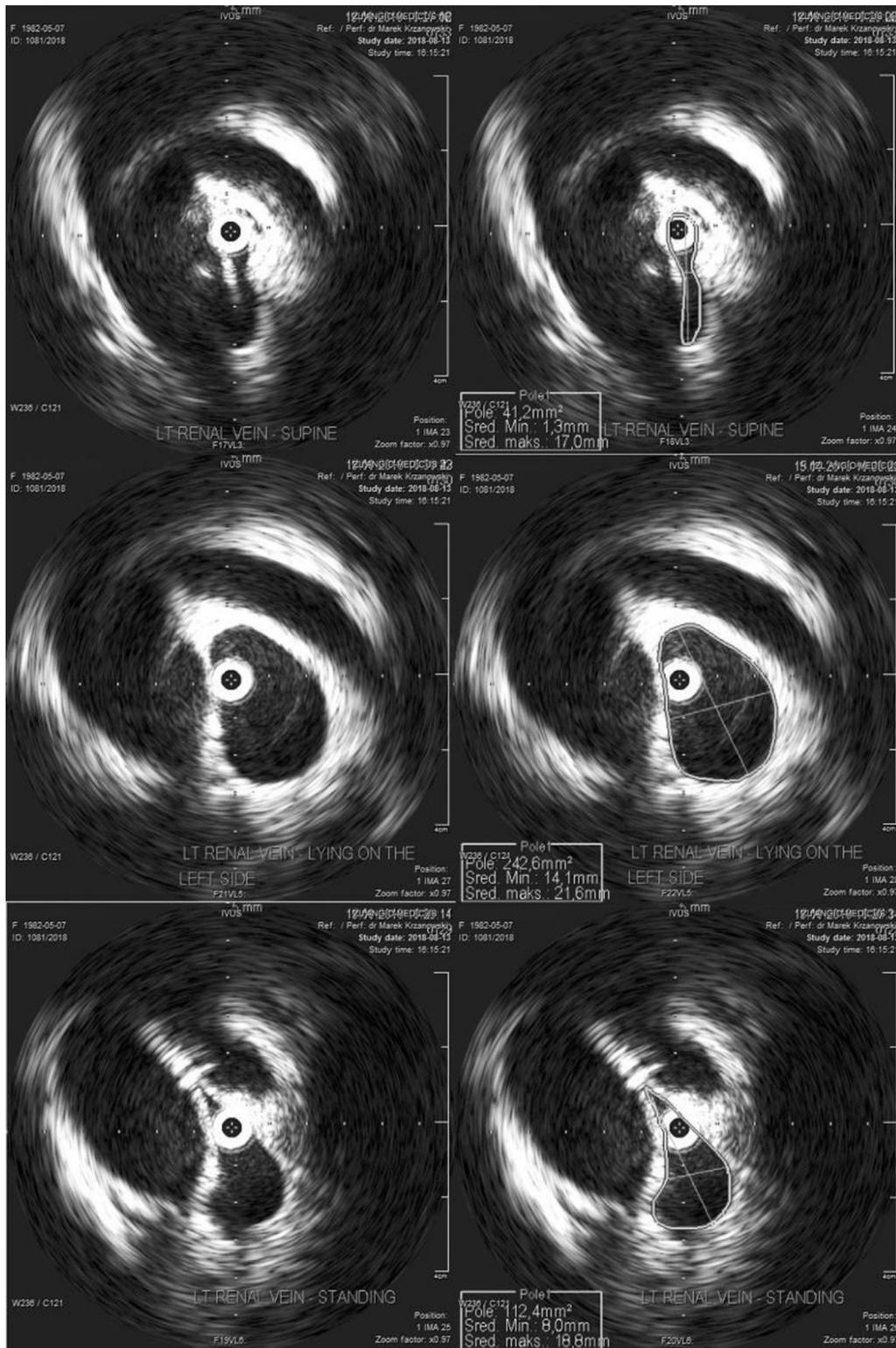
Significant variation of CSA after postural changes leads to uncertainty about the optimal management of the patients. Whereas the decision that should be taken seems straightforward in patients with concordant results, it is baffling in cases of patients with discordant results. Some patients with posture-dependent stenosis may in fact profit from vein dilation (percutaneous stenting or open surgery of the vein), but others probably will not. This might be one of the reasons that Gagne et al<sup>4</sup> noted a relatively large percentage of nonresponders after left iliac vein stenting for May-Thurner syndrome (the diagnosis was established by CSA reduction of the LCIV in patients supine). Clinical significance of stenosis in cases with discordant results may depend on the most prevalent position of the body throughout the day, and this should probably be taken into account in planning therapy.

Notably, a different approach to diagnosis of a significant iliac vein stenosis was suggested by Raju et al,<sup>7</sup> whereby CSA is measured and compared with a recommended threshold value that equals 200 mm<sup>2</sup> for the common iliac vein, 150 mm<sup>2</sup> for the external iliac vein, and 300 mm<sup>2</sup> for the IVC. Whenever the CSA is below the recommended threshold, the vein is considered stenosed, irrespective of any possible differences of CSA along the course of the vessel. By use of this methodology, in our cohort of women suffering from PVD, all LCIVs were significantly stenosed when the patients were supine and remained below the threshold value in 39 of 41 patients when they changed posture. Significant stenoses were also found in the supine position in nearly all right-sided iliac veins or left external iliac veins and in the IVC of nearly all patients. As Raju does not provide

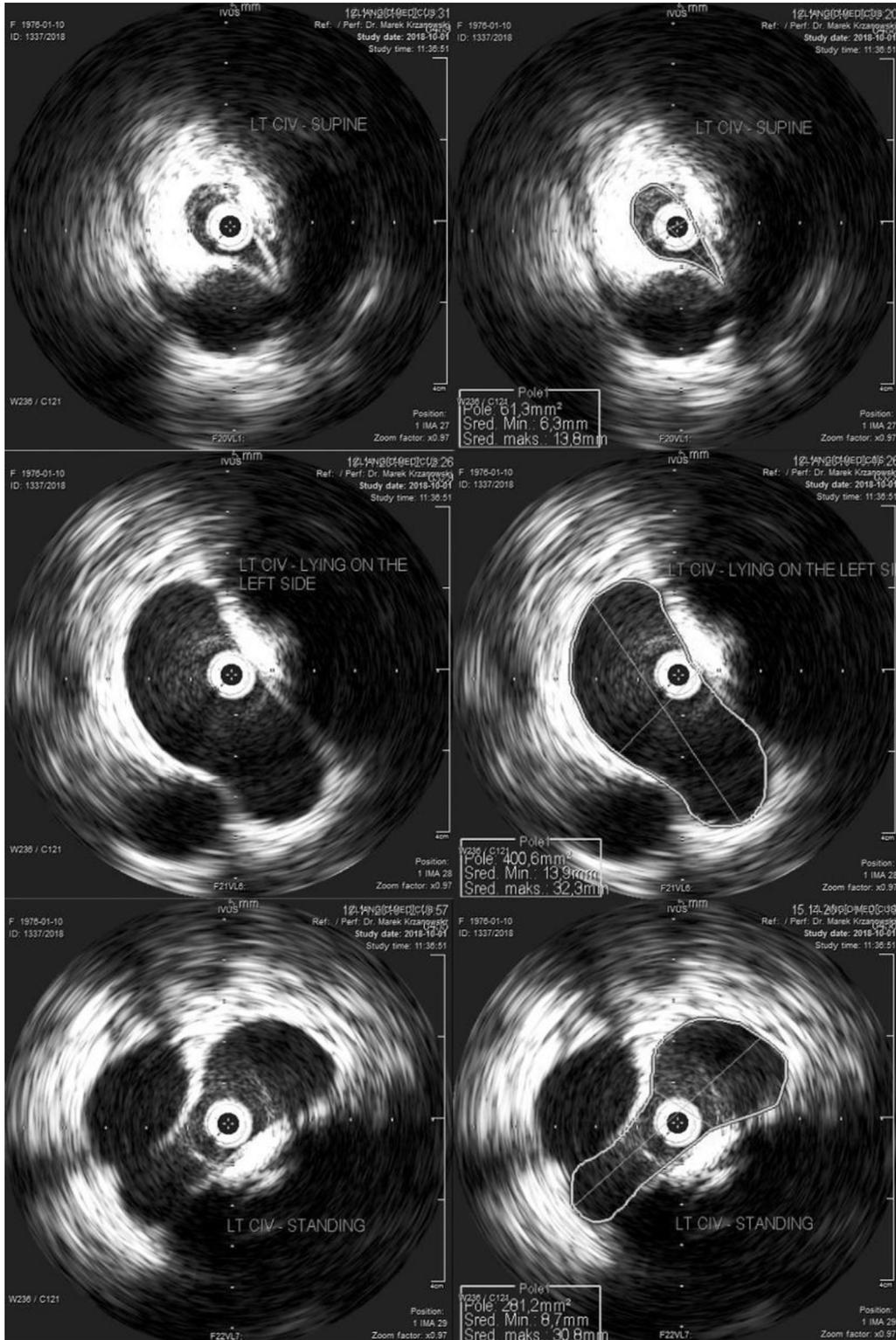
**Table III.** Relation between position of the body and stenosis of left renal vein (LRV) and left common iliac vein (LCIV)

	Significant stenosis <sup>a</sup>			Concordant for significant stenosis <sup>b</sup>	Concordant for no significant stenosis <sup>c</sup>
	Patient supine	Patient lying on left side	Patient standing		
LRV	22 (55)	4 (10)	27 (67.5)	2 (5)	11 (27.5)
LCIV	26 (63.4)	8 (19.5)	10 (24.4)	5 (12.2)	12 (29.3)

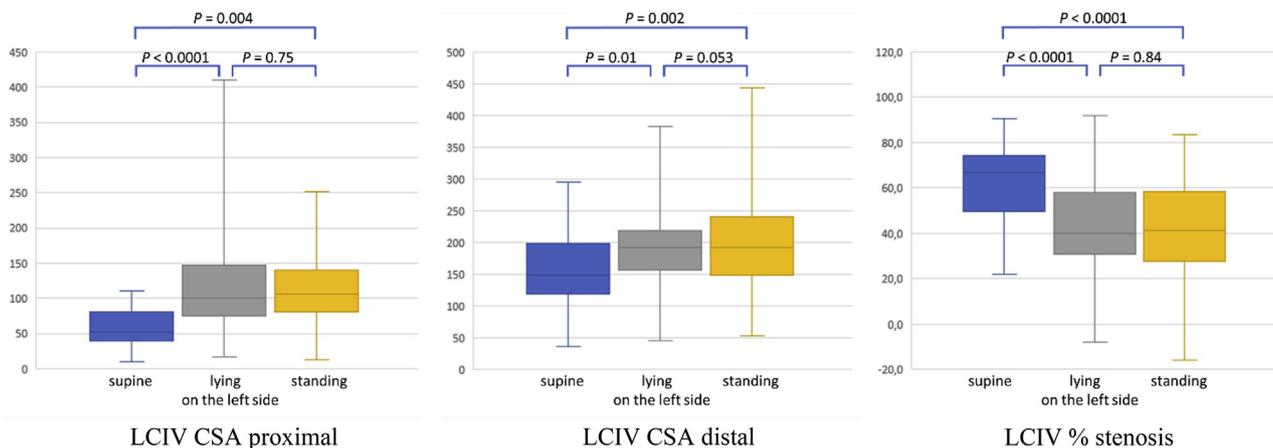
CSA, Cross-sectional area.  
 Values are reported as number (%).  
<sup>a</sup>CSA reduction >60%.  
<sup>b</sup>CSA reduction >60% in all positions of the body: supine, lying on the left side, and standing.  
<sup>c</sup>CSA reduction ≤60% in all positions of the body: supine, lying on the left side, and standing.



**Fig 1.** Minimal cross-sectional area (CSA) of the left renal vein (LRV) changes with the patient's posture from 41.2 mm<sup>2</sup> in supine position (*upper row*) to 242.6 mm<sup>2</sup> when lying on the left side (*medial row*) and to 112.4 mm<sup>2</sup> when standing (*lower row*).



**Fig 2.** Minimal cross-sectional area (CSA) of the left common iliac vein (LCIV) changes with the patient's posture from 61.3 mm<sup>2</sup> in supine position (*upper row*) to 400.6 mm<sup>2</sup> when lying on the left side (*medial row*) and to 281.2 mm<sup>2</sup> when standing (*lower row*).



**Fig 3.** Median (line within the box), interquartile range (box), and minimum-maximum values for cross-sectional area (CSA, mm<sup>2</sup>) and degree of stenosis of left common iliac vein (LCIV, %) in lying supine, in lying on the left side, and in standing position (N = 41).

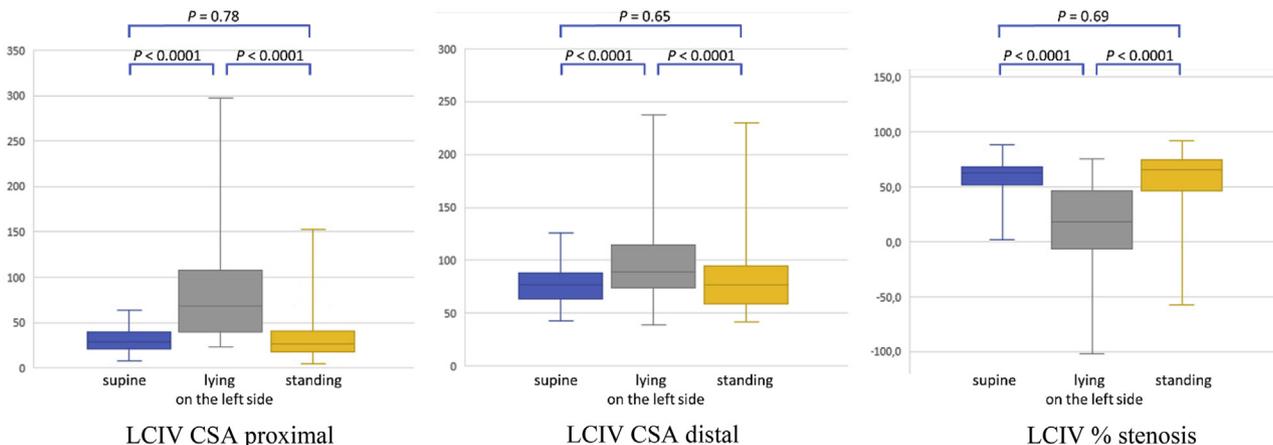
threshold CSA values for renal veins, we are unable to perform a parallel assessment of the LRV. Raju's data have not been clinically validated, and intuitively we were reluctant to accept that almost all of our patients required a complex iliac vein and IVC dilation and stenting. To our knowledge, many centers still use CSA methodology rather than the Raju approach to stenosis detection and clinical decision-making.

Improvement of the pelvic or leg venous outflow will probably require alleviation of all venous stenoses along the way to the heart rather than simple dilation of the LCIV or LRV. It is noteworthy that significant stenosis of the IVC was found in the supine position in a significant fraction of our patients. Any possible influence of posture on the patency of all the other veins that drain the legs and pelvis should probably also be taken into account. Moreover, Raju et al<sup>8</sup> have documented in an experimental setting that the perivascular (intra-abdominal) pressure is one of the key factors that may limit the

impact of local stenosis on the venous outflow and thus applicability of dilation and stenting. It seems that the decision regarding the most appropriate therapy for PVD should include substantially more factors than are presently recognized, and further studies are required to propose a comprehensive diagnostic protocol. The clinical value of such a protocol should be addressed in a well-designed, multicenter, prospective trial.

To facilitate diagnosis, a better, more practical diagnostic tool that could optimally be noninvasive and fast and allow complex anatomic and functional assessment of pelvic and abdominal veins in different body positions, preferably also with assessment of the structures adjacent to the veins, would be of value. Novel advances in nuclear magnetic resonance technology may be helpful in this regard (M. Mielnik, personal communication).

A substantial increase of CSA of the LRV was noticed when patients change position or perform a Valsalva maneuver.



**Fig 4.** Median (line within the box), interquartile range (box), and minimum-maximum values for cross-sectional area (CSA, mm<sup>2</sup>) and degree of stenosis of left renal vein (LRV, %) in lying supine, in lying on the left side, and in standing position (N = 40).

This may explain why stents implanted into the LRV often dislocate to the IVC or even to the right side of the heart.<sup>9</sup>

Some authors suggested that a Valsalva maneuver should be used for proper sizing of stents implanted into renal veins.<sup>10</sup> It is noteworthy that LRV CSA may increase even more secondary to postural changes than in response to a Valsalva maneuver, and assessment of CSA in different body positions may be useful for stent sizing. The same may hold true for LCIV stenting as stent dislocation has been described for iliac vein intervention.<sup>11</sup>

## CONCLUSIONS

CSA of the LRV and LCIV and the degree of stenosis (as assessed by CSA reduction method) substantially change with posture. Therapeutic decisions in patients with PVD taken on the basis of significant CSA reduction on IVUS examination performed in the supine position might be inadequate. A more complex diagnostic protocol for a comprehensive treatment plan aiming at correction of the venous outflow from the legs and pelvis is required.

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## AUTHOR CONTRIBUTIONS

Conception and design: MK, LP, MM, AS, TAK

Analysis and interpretation: MK, LP, LD, KrM

Data collection: MK, LP, LD, MM, MF, AS, KaM, TAK

Writing the article: MK, LP, KrM, AS

Critical revision of the article: MK, LP, LD, MM, MF, KrM, AS, KaM, TAK

Final approval of the article: MK, LP, LD, MM, MF, KrM, AS, KaM, TAK

Statistical analysis: MK, LP, KrM

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Overall responsibility: MK

MK and LP contributed equally to this article and share co-first authorship

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**Supplementary Table I (online only).** Minimal and maximal cross-sectional area (CSA) for left renal vein (LRV) and left common iliac vein (LCIV) in different positions of the body and during the Valsalva maneuver

	Supine	Valsalva maneuver	Lying on left side	Standing	P value total
LRV					
Minimal CSA, mm <sup>2</sup>	29.0 (21.2-39.1); 8.4-64.3	18.7 (14.0-44.4); 5.3-147	68.1 (39.8-107.4); 23.3-296	26.1 (17.4-41.2); 5.0-151.4	<.0001
Maximal CSA, mm <sup>2</sup>	76.9 (62.3-88.4); 42.3-125.7	72.7 (55.9-94.0); 31.9-132.0	89.2 (74.1-114.3); 39.2-238.2	77 (58.6-95.0); 42.1-228.0	<.0001
LCIV					
Minimal CSA, mm <sup>2</sup>	52.2 (38.1-80.4); 9.7-110.7	67.0 (36.3-98.6); 8.0-260.8	100.1 (71.8-146.5); 16.1-409.3	106.2 (77.9-141.8); 12.4-253.0	<.0001
Maximal CSA, mm <sup>2</sup>	149.6 (119.2-199.9); 37.2-220.4	161.7 (117.6-195.5); 44.2-380.0	192.3 (155.4-225.7); 43.8-383.0	192.6 (149.0-243.5); 53.8-442.0	<.0001
Values are reported as median (interquartile range); range.					

**Supplementary Table II (online only).** Degree of stenosis of left renal vein (LRV) and left common iliac vein (LCIV) in different positions of the body and during the Valsalva maneuver

	Supine	Valsalva maneuver	Lying on the left side	Standing	P value total
% LRV stenosis					
Mean ± SD	58.8 ± 18.3	61.0 ± 38.2	16.6 ± 38.3	56.8 ± 31.8	<.0001
Median (IQR)	62.3 (52.1-67.8)	72.9 (57.4-79.5)	17.7 (-6.7 to 46.6)	65.8 (46.3-74.3)	<.0001
% LCIV stenosis					
Mean ± SD	61.9 ± 17.9	51.7 ± 26.9	40.0 ± 29.8	43.6 ± 21.0	<.0001
Median (IQR)	66.6 (49.4-75.2)	54.4 (38.1-70.9)	40.1 (29.9-58.1)	41.5 (27.4-59.9)	<.0001
IQR, Interquartile range; SD, standard deviation. The % stenosis was calculated using a formula of $[1 - (\text{minimal CSA})/(\text{maximal CSA})] \times 100$ .					

**Supplementary Table III (online only).** Minimal and maximal cross-sectional area (CSA) and degree of stenosis of iliac veins, inferior vena cava (IVC), and left renal vein (LRV) in patients supine, breathing freely (n = 40 for LRV; otherwise n = 41)

	Maximal CSA, mm <sup>2</sup>	Minimal CSA, mm <sup>2</sup>	% Stenosis <sup>a</sup>	No. of veins significantly stenosed <sup>a</sup>	No. of CSAs reduced below threshold value <sup>b</sup>
RCIV	160.0 (135.5-181.0)	130.0 (99.0-168.5)	15.9 ± 19.1	2	37
LCIV	149.6 (119.2-199.9)	52.2 (38.1-80.4)	61.9 ± 17.9	26	41
REIV	116.0 (95.0-135.5)	83.6 (68.0-112.0)	22.6 ± 20.1	2	39
LEIV	101.0 (89.0-127.5)	78.8 (56.0-110.0)	20.8 ± 17.5	0	36
IVC	294.0 (249.0-409.5)	134.0 (100.5-214.0)	53.8 ± 19.6	16	40
LRV	76.9 (62.3-88.4)	29.0 (21.2-39.1)	58.8 ± 18.3	23	NK

LCIV, Common iliac vein; LEIV, external iliac vein; NK, not known—no threshold established; RCIV, common iliac vein; REIV, external iliac vein. Values are reported as median (interquartile range) or mean ± standard deviation.  
<sup>a</sup>Maximal vs minimal CSA method. The % stenosis was calculated using a formula of  $[1 - (\text{minimal CSA})/(\text{maximal CSA})] \times 100$ .  
<sup>b</sup>Recommended by Raju et al.<sup>7</sup> CSA for external iliac vein,  $\geq 150$  mm<sup>2</sup>; common iliac vein,  $\geq 200$  mm<sup>2</sup>; inferior vena cava,  $\geq 300$  mm<sup>2</sup>.

**Supplementary Table V (online only).** Signs and symptoms in patients with and without significant stenosis of left common iliac vein (LCIV) on intravascular ultrasound examination (IVUS)

	Concordant positive <sup>a</sup> for LCIV stenosis (n = 6)	Concordant negative <sup>b</sup> for LCIV stenosis (n = 12)	Either positive or negative for LCIV stenosis, depending on posture (n = 23)
LCIV compression on phlebography (n = 19)	5	0	14
Filling of collaterals on phlebography (n = 25)	4	3	18
Left calf circumference > right calf circumference <sup>c</sup> (n = 21)	5	1	15
History of left leg edema (n = 16)	1	5	10

<sup>a</sup>Concordant positive for LCIV stenosis: >60% cross-sectional area reduction, irrespective of posture.  
<sup>b</sup>Concordant negative for LCIV stenosis: cross-sectional area reduction is  $\leq 60\%$ , irrespective of posture.  
<sup>c</sup>Left calf circumference as measured either 20 cm below patellar base or 40 cm below patellar base exceeds the corresponding circumference of the right calf by at least 0.5 cm.

**Supplementary Table VI (online only).** Signs and symptoms in patients with and without significant left renal vein (LRV) stenosis on intravascular ultrasound examination (IVUS)

	Concordant positive for LRV stenosis <sup>a</sup> (n = 2)	Concordant negative for LRV stenosis <sup>b</sup> (n = 11)	Either positive or negative for LRV stenosis, depending on posture (n = 27)
LRV compression on phlebography (n = 12)	1	2	9
Filling of collaterals on phlebography (n = 21)	2	4	15
Left flank pain (n = 17)	2	6	8
Erythrocyturia (n = 2)	1	1	0

<sup>a</sup>Concordant positive for LRV stenosis: >60% cross-sectional area reduction, irrespective of posture.  
<sup>b</sup>Concordant negative for LRV stenosis: cross-sectional area reduction is  $\leq 60\%$ , irrespective of posture.