Frequency and Significance of Perforating Venous Insufficiency in Patients with Chronic Venous Insufficiency of Lower Extremity

Ismet Tolu, Mehmet Sedat Durmaz

ABSTRACT

Objective: The aim of this study was to reveal the frequency and impact of perforating venous insufficiency (PVI) in chronic venous insufficiency (CVI) of lower extremity (LE).

Materials and Methods: Between 2012 and 2017, a total of 1154 patients [781 females (67.68%) and 373 males (32.32%), 228 (19.76%) unilateral and 926 (80.24%) bilateral LE] were examined using Doppler ultrasound (US). A total of 2080 venous systems of LEs [31.4% male (n=653) and 68.6% female (n=1427); 1056 left LEs (50.77%) and 1024 right LEs (49.23%)] were examined. All patients had symptoms of venous insufficiency (VI).

Results: PVI was revealed in 27.5% (n=571) of LEs. Varicose veins (VVs) related with perforating vein (PV) were revealed in 44.7% of LEs (n=929). PVI was observed in 50.91% of patients with chronic deep venous thrombosis (DVT), 64.41% with deep venous insufficiency (DVI), 59.81% with great saphenous vein (GSV) insufficiency, 68.49% with small saphenous vein (SSV) insufficiency, 58.65% with accessory GSV insufficiency, and 58.77% with PV associated with VVs. There was a statistically significant relationship between PVI and chronic DVT, DVI, GSV, SSV, and accessory GSV insufficiency ($p<0.001$). A significant relationship was observed between the increase in PV diameter and the presence of PVI ($p<0.001$).

Conclusion: PVI is quite common in combined VI, and PV evaluation should be a part of LE venous system examination.

Keywords: Chronic venous insufficiency, doppler ultrasound, perforating venous insufficiency, varicose veins

Introduction

Chronic venous insufficiency (CVI) may lead to many physical and cosmetic problems that compromise the quality of life [1]. Preoperative color Doppler ultrasound (US) evaluation of the deep venous system (DVS) and superficial venous system (SVS) in terms of insufficiency and varicose veins (VV) has been considered as a routine procedure [2, 3]. Approximately half of all VIs occur in multiple levels or is combined [1, 4]. Although there are 150 perforating veins (PVs) in the lower extremity (LE), only a few of them are clinically significant [5]. Perforators are located between the deep and the superficial veins [great saphenous vein (GSV), small saphenous vein (SSV), anterior or posterior accessory GSV or VVs]. Because PVs drain into SVS from DVS by penetrating the muscle fascia, any failure in the valves of these structures directly leads to SVS insufficiency and VV [6, 7]. PV may play a critical role in the development of VV and non-healing venous ulcers by becoming the reason of venous hypertension. Despite the fact that there are many studies on PVs in the literature, its effects on hemodynamics are still controversial [6, 8, 9]. The role of PVs in the etiology and management of VVs and CVI continues to be debated [10]. The aim of this study was to assess the impact and frequency of perforating venous insufficiency (PVI) in combined CVI of LE detected by Doppler US.

Materials and Methods

This study was approved by the local research ethics committee. All patients were contacted by post, and written informed consent was obtained from each patient prior to the Doppler US examination. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable

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ORCID IDs of the authors:
İ.T. 0000-0002-1161-9998;
M.S.D. 0000-0002-1340-2477.

Department of Radiology, Health Sciences University Training and Research Hospital, Konya, Turkey

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Correspondence to: Mehmet Sedat Durmaz

E-mail: dr.msdurmaz@gmail.com

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ethical standards. This prospective controlled study was performed from April 2012 to July 2017. A total of 1154 patients [781 females (67.68%) and 373 males (32.32%)] with complaints or symptoms of venous insufficiency (VI; such as leg edema, pain, ulcers, cramps, itching, thickening of the skin, color change around the ankles of the skin, having VVs, or feeling of tension in the legs) were included in this study.

All LE venous Doppler US examinations were performed by a single radiologist who had 10 years of experience in Doppler US (M.S.D.). The patients were in the age range of 14–87 years (mean, 46 years). All patients were evaluated using Doppler US examinations: unilateral LE was examined in 228 of them and bilateral LEs were examined in the remaining 926. A total of 2080 venous systems of LEs were examined. In total, 168 patients, including patients with acute superficial vein thrombosis (SVT) and deep vein thrombosis (DVT), elderly patients who could not stand up, and patients who did not cooperate to Valsalva's maneuver, were excluded from the study.

Doppler US was performed with a high-frequency (7.5 MHz) linear array transducer TOSHIBA Aplio 300 (Toshiba Medical System Corporation, Tokyo, Japan). All the pathological findings and levels were recorded separately. The Doppler US examination for reflux began with a standard US examination of the DVS performed with the patient in the supine position to exclude DVT and SVT. Then, the patients were evaluated while they were in an upright position, in terms of deep venous insufficiency (DVI) and superficial venous insufficiency (SVI). The patient was requested to support her/his body weight to the side that was not being examined. In this way, by shifting one's body weight, a patient could relax the muscle of the leg under examination and so the presence of reflux could be detected. The Valsalva's maneuver was used to evaluate the valvular competence of DVS. Valvular competence of SVS and PVs was evaluated at rest with the Valsalva's maneuver and on compression of the distal parts of the calf. GSV, SSV, and anterior/posterior accessory GSV territory from the thigh to calf were evaluated. Moreover, "the thigh perforators" include the medial thigh (hunter's PV), anterior thigh, and posterior thigh PVs; "the knee perforators" include the medial knee (Boyd's PV) and popliteal fossa PVs; and "the leg perforators" include the paratibial (Sherman PV), posterior tibial (Cockett's PVs), anterior leg, lateral leg, and posterior leg (medial and lateral gastrocnemius, intergemellar) PVs that were evaluated as shown in Figure 1. PVs were assessed in the transverse and oblique scanning planes, and the diameter of PVs as detected by US was noted. Maximal diameters of PVs were measured at the suprafascial–subfascial connection level (Figure 2). Augmentation of blood flow by compression of the limb below the perforator and Valsalva's maneuver was used to assess valvular integrity (Figure 3). Reflux flow of more than 0.5 s was used as criterion for significant VI and in PVs, DVS, and SVS on spectral Doppler imaging. DVI, GSV, SSV, and PVI were recorded (Figure 4). Anterior and posterior accessory GSV insufficiency were separately noted. Moreover, it was evaluated whether the relationship between the PVI or other VI existed. The duration of the examination was approximately 20 min for each LE venous system. The US reports and images were saved on a digital US database and later to a computer media (23-inch, full HD, 1920×1080 resolution, Dell, Intel Corporation, US).

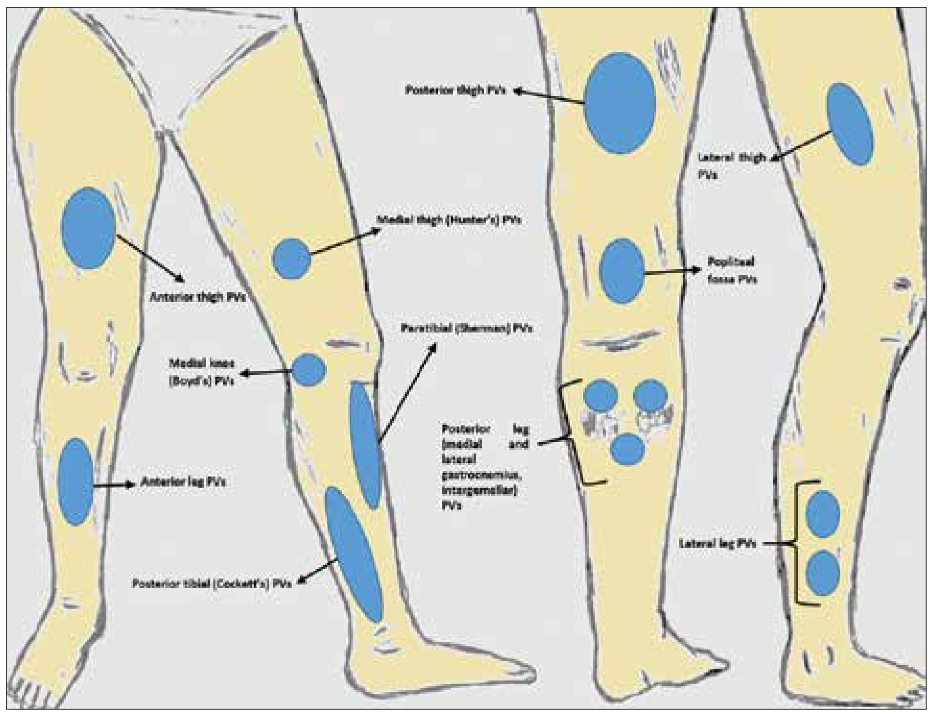

Figure 1. Schematic images of the main groups of PVs in LE

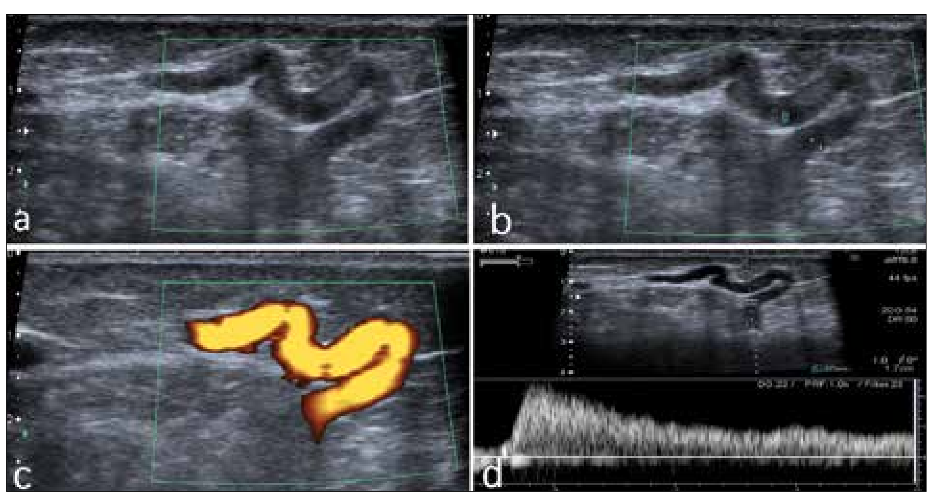

Figure 2. a-d. Sonographic evaluation of PV. PV obliquely perforates the deep muscular fascia and associates the with the superficial vein (a), diameter of PV measured at the suprafascial–subfascial connection level (b), augmentation of blood flow by compression of the limb below PV and Valsalva's maneuver are used to assess valvular integrity with color flow imaging (c), and spectral Doppler imaging (d)

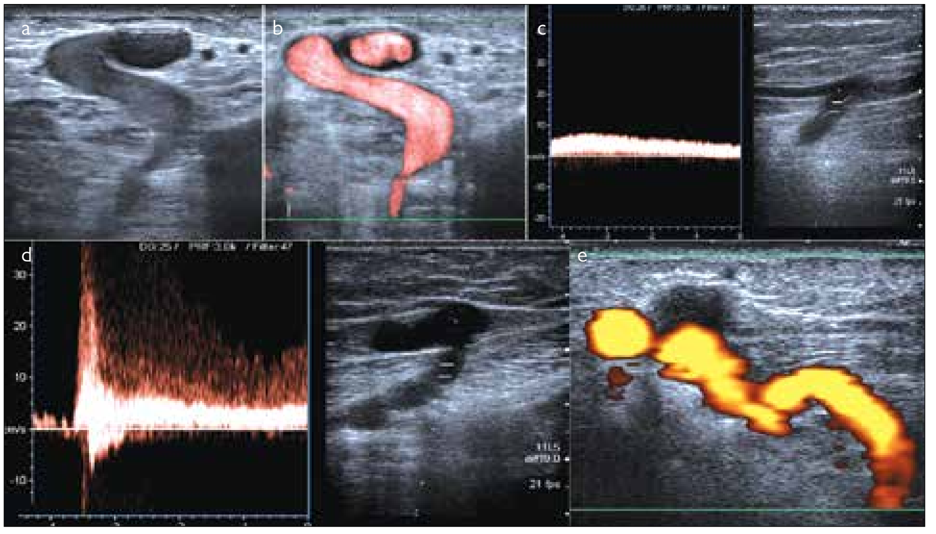

Figure 3. a-e. Sonographic imaging of perforating vein (PV) associated with varicose vein and saphenous veins. Enlarged posterior tibial (Cockett's) PV obliquely perforates the deep muscular fascia and connects with the crural varicose vein (a). Power Doppler imaging showing reflux both in the posterior tibial PV and in the varicose vein following a Valsalva's maneuver (b). Spectral Doppler imaging showing significant reflux in the paratibial (Sherman) PV following a Valsalva's maneuver (c). Spectral Doppler imaging showing significant reflux in the medial thigh (Hunter's) PV associated with saphenous vein following compression of the distal parts of the calf (d). Power Doppler imaging showing reflux in the posterior leg (lateral gastrocnemius) PV associated with small saphenous vein following a Valsalva's maneuver (e)

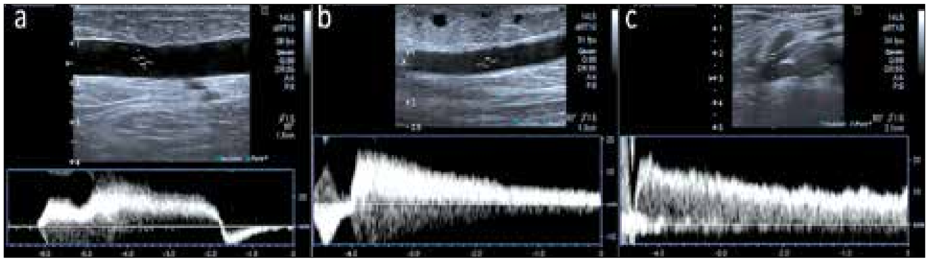

Figure 4. a-c. Reflux in saphenous veins. Longitudinal view and spectral Doppler imaging show significant reflux in the great saphenous vein at the level of distal thirds of the thigh following a Valsalva's maneuver (a). Spectral Doppler imaging showing significant reflux in the great saphenous vein at the level of distal thirds of the thigh (b) and in the small saphenous vein distal to the sapheno-popliteal junction in the proximal cruris, following compression of the distal parts of the calf (c)

Table 1. Number of incompetent PVs

Perforating vein	Number (Percent)
Medial thigh (Hunter's) perforating veins	104 (8.25 %)
Anterior thigh perforating veins	26 (2.06 %)
Posterior thigh perforating veins	78 (6.20 %)
Medial knee (Boyd's) perforating veins	188 (14.92 %)
Popliteal fossa perforating veins	89 (7.06 %)
Paratibial (Sherman) perforating veins	116 (9.20 %)
Posterior tibial (Cockett's) perforating veins	325 (25.80 %)
Anterior leg perforating veins	35 (2.77 %)
Lateral leg perforating veins	34 (2.70 %)
Posterior leg (medial and lateral gastrocnemius, intergemellar) perforating veins	265 (21.03 %)
Total	1260 (100 %)

Statistical analysis

Statistical analysis to evaluate the data was performed using SPSS packet program (Statistical Package for Social Sciences, version 15, SPSS Inc., Chicago, Illinois, USA). Normal distribution of continuous variables was tested using the Kolmogorov–Smirnov test. Primarily, the definitive statistics related to the variables were evaluated. Descriptive statistics were expressed as mean, standard deviation, frequency, and percentile. Statistical analysis was performed using the chi-square and Mann–Whitney U tests. The chi-square test was used to determine the relationship between PVI and PV associated with VVs, chronic DVT, DVI, GSV insufficiency, SSV insufficiency, and accessory GSV insufficiency. The Mann–Whitney U test was used to determine the relationship between the presence of PVI and the increase in PV diameter. Values of $p<0.05$ were considered significant.

Results

In total, 2080 venous systems of LEs were examined. PVI was observed in 1260 PVs and 27.5% (n=571) of LEs. Significant reflux was most commonly detected in the posterior tibial, posterior leg, and medial knee PVs (Table 1). VVs related with PVs were revealed in 44.7% of LEs (n=929). Doppler US examination showed reflux in these VVs. PVI was observed in 546 of the 929 LEs (58.77%) in which LEs PVs were associated with VVs. The reflux started from an incompetent PV located directly at the peripheral side of VVs. There was a statistically significant relationship between PVs associated with VVs and PVI ($p<0.001$) (Table 2). Chronic DVT was observed in 2.6% (n=55) of LEs. PVI was also observed in 50.91% of patients with chronic DVT. There was a statistically significant relationship between chronic DVT and PVI ($p<0.001$).

DVI was revealed in 295 (14.2%) of LEs. DVI was observed only in the main femoral vein (FV) 172 (58.3%), only in the FV 21 (7.12%), only in the deep FV 3 (1.02%), only the in popliteal vein 27 (9.15%), in multiple veins 72 (21.24%) of 295 LEs with DVI. PVI was observed in 190 (64.41%) of 295 LEs with DVI. There was a statistically significant relationship between DVI and PVI ($p<0.001$).

GSV insufficiency was revealed in 34.80% (n=724) of LEs. PVI was observed in 59.81% (n=433) of patients with GSV insufficiency. There was a statistically significant relationship between GSV insufficiency and PVI ($p<0.001$).

SSV insufficiency was revealed in 10.5% (n=219) of LEs. PVI was observed in 150

Table 2. Degrees of association between duration of hemodialysis and clinical measurements in CKD group

		Perforating vein associated with varicose veins			
		Absent	Present	Total	p
Perforating venous insufficiency	Absent	1126	383	1509	<0.001
	Present	25	546	571	

p<0.05 was considered to be statistically significant.

Table 3. Relationship between PV insufficiency and chronic DVT, DVI, GSVI, SSVI, and accessory GSVI

		Perforating venous insufficiency		
		Absent	Present	p
Chronic deep venous thrombosis	Absent	1482	543	<0.001
	Present	27	28	
Deep venous insufficiency	Absent	1404	381	<0.001
	Present	105	190	
Great saphenous vein insuffiency	Absent	1218	138	<0.001
	Present	291	433	
Small saphenous vein insuffiency	Absent	1440	421	<0.001
	Present	69	150	
Accessory great saphenous vein insufficiency	Absent	1466	510	<0.001
	Present	43	61	
Total		1509	571	

p<0.05 was considered to be statistically significant.

(68.49%) patients with SSV insufficiency. There was a statistically significant relationship between SSV insufficiency and PVI (p<0.001).

We also found anterior and/or posterior accessory GSV insufficiency in 5% (n=104) of LEs. PVI was observed in 58.65% (n=61) of patients with accessory GSV insufficiency. There was a statistically significant relationship between accessory GSV insufficiency and PVI (p<0.001). PVI frequency increased with increasing number of veins with VI in deep and superficial veins, and a statistically significant relationship was found (p<0.001).

The smallest diameter of PV with insufficiency was 2.0 mm, and the largest diameter was 5.1 mm. The mean diameter of PVs with insufficiency was 3.24 mm. PVs that were detected during US examination but were not insufficient had a mean diameter of 1.85 mm. A significant relationship was observed between the increase in PV diameter and the presence of PVI (p<0.001).

In conclusion, we found a statistically significant relationship between PVI and PV associated with VVs, chronic DVT, DVI, GSV, SSV, and accessory GSV insufficiency (p<0.001). These parameter values related to PVI are presented in detail in Table 3. Moreover, PVI frequency increased with increasing number of veins with VI, and a statistically significant relationship was found (p<0.001).

Discussion

PVs connect collecting and saphenous veins with tibial, femoral, popliteal, and sinusoidal deep veins by obliquely perforating the deep muscular fascia [6, 11]. Large PVs contain valves that direct flow from superficial vessels to deep veins and generally run along the perforated artery [11]. Among many PVs, the medial calf perforators are probably the most important [5, 12]. PVs have varying appearances in terms of size and distribution. The prevalence of PVI increases linearly as the severity of DVI and SVI increases [13]. PVI is most frequently associated with reflux in SVS, followed by reflux in both SVS and DVS. DVI is rarely the primary cause. The correlation between the occurrence of insufficiency of GSV and PVs has been revealed [6, 14-17]. In many studies and our study, PVI was found to be most frequently associated with insufficiency in deep veins, GSV, SSV, anterior/posterior accessory GSV, and chronic DVT. We found statistically significant relationship between PVI and chronic DVT, DVI, GSV insufficiency, SSV insufficiency, and accessory GSV insufficiency (p<0.001). There was a statistically significant correlation between PVI and PV related with VVs (p<0.001). These results have indicated that incompetent PVs play a critical role in CVI. We detected a meaningful relationship between PV associated with VVs and PVI (p<0.001). PVs, especially those associated with VV, should be examined for reflux, regardless of whether they are enlarged or not. We found a significant relationship between the increase in PV diameter and the presence of PVI (p<0.001). However, PVs in which reflux was detected had a very small diameter, whereas PVs in which reflux was not detected in our study had a diameter >4 mm. Because of this, the size cannot be considered as the only criterion for PVI diagnosis.

Mechanism of valve dysfunction of PVs leading to CVI and hemodynamic role of PV has not yet been completely elucidated [13, 18, 19]. One of the asserted mechanisms of the incompetency is enlargement of the diameter, in which incompetent PVs may serve as the re-entry point for superficial blood flow into DVS of patients with VVs [20, 21]. The other proposed mechanism of incompetency is dysfunction due to irreversible valvular damage [19, 21, 22]. Irreversible valvular damage of incompetent PVs might be associated with recurrence of VVs after operating SVI; therefore, this type of incompetent PVs may require simultaneous treatment with SVI [19, 21, 22].

The presence of incompetent PVs after treatment of SVI has been defined as a major risk factor for non-healing and recurrent leg ulcers and for recurrence of varicosities in patients with CVI. Residual incompetent PVs associated with failure of treatment and aggressive procedures to manage incompetent PVs have improved the surgical outcome. The experiences gathered in clinical studies have also demonstrated that incompetent PVs are likely to be more important in the development of VVs [2, 10, 23]; if incompetent PVs can be selectively treated, more satisfactory results could be achieved [19, 22]. Several authors suggest treating incompetent PVs in cases of focal swelling, pain, associated VVs, focal skin irritation, discoloration, venous ulceration in the area of the incompetent PVs, clinical severity, etiology, anatomy, and pathophysiology score more than four [24]. In particular, treatment of incompetent PV is recommended in which the VV is non-saphenous and starts from the periphery of incompetent PV. PVI is important for the development and maintenance of these peripherally located VV [19]. Some patients have enlarged incompetent PVs and severe limb symptoms, including ulceration. In the treatment of venous ulcers that are located above the ankle, it is recommended to include treatment of incompetent PV in combination with SVI therapy [19, 25]. In patients with a combination of SVI and PVI, routine PVI treatment is recommended by some authors, along with SVI treatment because of the risk of recurrence [6, 25-27]. Incompetent PVs can be treated with surgical ligation, US-guided sclerotherapy, endovascular thermal, laser therapy, or radiofrequency ablation [24]. It is still not known whether preoperative identification of PVI could facilitate more effective treatment. If the radiologists are not aware of the importance of PVI and do not mention it in their reports and only SVI is treated, recurrences in this group of patients will be inevitable. Because of these reasons, evaluation of PVs should be a part of LE venous system examination, and radiologists should indicate the presence of any PVI in the reports.

Color Doppler US has become a major diagnostic tool in the evaluation of patients with VI symptoms [28]. Gray-scale US examination with color Doppler and spectral analysis have become increasingly important and are now more frequently used for the diagnosis and treatment of VI [12]. Doppler US examination for reflux begins with a standard US examination of DVS performed with the patient in the supine position for excluding DVT. Doppler US assessment of VI should always be performed with the patient in the standing position [28]. The examination of deep, superficial, and PVs should be performed at the same time because all of them will play an important role in the patient's diagnosis and future treatment [2, 28, 29].

The limitation of the study is that interobserver variation could not be evaluated because of the length of the examination time and all patients were observed by a single experienced radiologist. In conclusion, our study showed that PVI is quite common in combined VI and that there is a statistically significant relationship between PVI and chronic DVT, DVI, GSV, SSV, and accessory GSV insufficiency. PVI frequency increased with increasing number of veins with VI, and a statistically significant relationship was found. Incompetent PVs play a significant role in CVI. Doppler US is a safe and effective technique for evaluating LE CVI before planning the treatment course. PV evaluation should be a part of LE venous system examination in VI, and size alone cannot be the criterion for PVI diagnosis.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Selçuk University (2017/19-2017/319).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - M.S.D.; Design - M.S.D., İ.T.; Supervision - İ.T.; Resources - M.S.D.; Materials - M.S.D.; Data Collection and/or Processing - İ.T., M.S.D.; Analysis and/or Interpretation - M.S.D.; Literature Search - İ.T., M.S.D.; Writing Manuscript - M.S.D., İ.T.; Critical Review - İ.T., M.S.D.

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References

1. Thorisson HM, Pollak JS, Scoutt L. The role of ultrasound in the diagnosis and treatment of chronic venous insufficiency. Ultrasound Q.2007; 23: 137-50. [CrossRef]
2. Liu CH, Wu CJ, Yu CY, Liu CH, Chang CW, Huang GS. Evaluation of lower limb varicose vein by ultrasonic venous duplex examination. J Med Ultrasound 2013; 21: 76-80. [CrossRef]
3. Coleridge-Smith P, Labropoulos N, Partsch H, Myers K, Nicolaides A, Cavezzi A. Duplex ultrasound investigation of the veins in chronic venous disease of the lower limbs-UIP consensus document. Part I. Basic principles. Eur J Vasc Endovasc Surg 2006; 31: 83-92. [CrossRef]
4. Stuart WP, Lee AJ, Allan PL, Ruckley CV, Bradbury AW. Most incompetent calf perforating veins are found in association with superficial venous reflux. J Vasc Surg 2001; 34: 774-8. [CrossRef]
5. Mozes G, Gloviczki P. Venous embryology and anatomy. In: Bergan JJ, Paquette NB editors. The vein book. 2th ed. San Diego, California: Elsevier Academic Press; 2007. pp. 20-24 [CrossRef]
6. Krnić A, Vucić N, Sucić Z. Correlation of perforating vein incompetence with extent of great saphenous insufficiency: Cross sectional study. Croat Med J 2005; 46: 245-1.
7. Van Neer PA, Veraart JC, Neumann HA. Venae perforantes: a clinical review. Dermatol Surg 2003; 29: 931-42. [CrossRef]
8. Labropoulos N, Mansour MA, Kang SS, Gloviczki P, Baker WH. New insights into perforator vein incompetence. Eur J Vasc Endovasc Surg 1999; 18: 228-34. [CrossRef]
9. Stuart WP, Adam DJ, Allan PL, Ruckley CV, Bradbury AW. The relationship between the number, competence, and diameter of medial calf perforating veins and the clinical status in healthy subjects and patients with lower-limb venous disease. J Vasc Surg 2000; 32: 138-43. [CrossRef]
10. Ozkan U. The fate of calf perforator veins after saphenous vein laser ablation. Diagn Interv Radiol 2015; 21: 410-4. [CrossRef]
11. Min RJ, Khilnani NM, Golia P. Duplex ultrasound evaluation of lower. J Vasc Interv Radiol 2003;14: 1233-41. [CrossRef]
12. Oğuzkurt L. Ultrasonographic anatomy of the lower extremity superficial veins. Diagn Interv Radiol 2012; 18: 423-30.
13. Delis KT, Husmann M, Kalodiki E, Wolfe JH, Nicolaides AN. In situ hemodynamics of perforating veins in chronic venous insufficiency. J Vasc Surg 2001; 33: 773-82. [CrossRef]
14. Labropoulos N, Tassiopoulos AK, Kang SS, Mansour MA, Littooy FN, Baker WH. Prevalence of deep venous reflux in patients with primary superficial vein incompetence. J Vasc Surg 2000; 32: 663-8. [CrossRef]
15. Al-Mulhim AS, El-Hoseiny H, Al-Mulhim FM, et al. Surgical correction of main stem reflux in the superficial venous system: does it improve the blood flow of incompetent perforating veins? World J Surg 2003; 27: 793-6. [CrossRef]
16. Rutherford EE, Kianifard B, Cook SJ, Holdstock JM, Whiteley MS. Incompetent perforating veins are associated with recurrent varicose veins. Eur J Vasc Endovasc Surg 2001; 21: 458-60. [CrossRef]
17. Delis. K.T. Leg perforator vein incompetence: functional anatomy. Radiology 2005; 235: 327-34. [CrossRef]
18. Yamamoto N, Unno N, Mitsuoka H, et al. Preoperative and intraoperative evaluation of diameter-reflux relationship of calf perforating veins in patients with primary varicose vein. J Vasc Surg 2002; 36: 1225-30. [CrossRef]
19. Lawrence PF, Alktaifi A, Rigberg D, DeRubertis B, Gelabert H, Jimenez JC. Endovenous ablation of incompetent perforating veins is effective treatment for recalcitrant venous ulcers. J Vasc Surg 2011; 54: 737-42. [CrossRef]
20. Uchinol J. Incompetent perforating veins of the foot. Inter J of Angiol 2004; 13: 97-100. [CrossRef]
21. Mendes RR, Marston WA, Farber MA, Keagy BA. Treatment of superficial and perforator venous incompetence without deep venous insufficiency: Is routine perforator ligation necessary? J Vasc Surg 2011; 54: 737-42.
22. Haruta N, Shinhara R, Sugino K, et al. Endoscopic anatomy of perforating veins in chronic venous insufficiency of the legs: "solitary" incompetent perforating veins are often actually multiple vessels. Inter J of Angiol 2004; 13: 31-6. [CrossRef]
23. De Maeseneer MG, Pichot O, Cavezzi A, et al. Duplex ultrasound investigation of the veins of the lower limbs after treatment for varicose veins-UIP consensus document. Eur J Vasc Surg 2011; 42: 89-102. [CrossRef]
24. Kuyumcu G, Salazar GM, Prabhakar AM, Ganguli S. Minimally invasive treatments for perforator

vein insufficiency. Cardiovasc Diagn Ther 2016; 6: 593-8. [CrossRef]
25. Klem TM, Wittens CH. Cryoperforator surgery: a new treatment of incompetent perforating veins. Vasc Endovasc Surg 2008; 42: 239-42. [CrossRef]
26. Tenbrook JA, Iafrati MD, O'donnell TF, et al. Systematic review of outcomes after surgical management of venous disease incorporating subfascial endoscopic perforator surgery. J Vasc Surg 2004; 39: 583-9. [CrossRef]
27. Roka F, Binder M, Bohler-Sommeregger K. Mid-term recurrence rate of incompetent perforating veins after combined superficial vein surgery and subfascial endoscopic perforating vein surgery. J Vasc Surg 2006; 44: 359-63. [CrossRef]
28. Hamper UM, DeJong MR, Scoutt LM. Ultrasound evaluation of the lower extremity veins. Radiol Clin North Am 2007; 45: 525-47. [CrossRef]
29. Cavezzi A, Labropoulos N, Partsch H, et al. Duplex ultrasound investigation of the veins in chronic venous disease of the lower limbs-UIP consensus document. Part II. Anatomy. Eur J Vasc Endovasc Surg 2006; 31: 288-99. [CrossRef]