Prevalence and distribution of incompetent perforating veins in chronic venous insufficiency

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Purpose: **The purpose of this study was the investigation of the prevalence and distribution of incompetent perforating veins (IPVs) in patients with different classes of chronic venous insufficiency (CVI) as defined by the updated clinical, etiologic, anatomic, and pathologic classification (CEAP) in relation to the pattern and the extent of venous reflux.**

Material and methods: **The study included 468 limbs of 330 subjects who ranged in age from 18 to 101 years (median, 49 years). The investigation entailed a medical history, a clinical examination, and color flow duplex imaging of the lower limb veins, which were performed by the same vascular surgeon operator. The patients were classified into 7 clinical classes according to CEAP. The superficial and deep venous systems were scanned, with an emphasis on the detection of IPVs. Venous reflux was considered abnormal when its duration exceeded 0.5 seconds. IPVs were classified as medial, posterior, and anterolateral in the upper, middle, or lower third of the thigh or calf (9 thigh and 9 calf fields).**

Results: **The IPVs were found mainly in the medial aspect, more frequently in the middle third of calf, followed by the lower calf and the middle thigh. IPVs were rare in the lateral aspect of the thigh, the medial upper and posterior lower thigh and the posterior upper and lower calf. The prevalence of the IPVs and of deep vein incompetence increased significantly with the clinical severity of CVI (r = .95, P < .01, and r = .9, P < .01, respectively). In the limbs with a documented perforating vein (PV) incompetence, the ratios of calf-to-thigh IPVs and of superficial-and-deep (S + D) over superficial-alone (S; [S + D]/S] venous incompetence increase significantly (r = .87, P < .01 and r = .9, P < .01, respectively) with CEAP grade. The prevalence of reflux involving all systems (S + D + PV) increases significantly (r = .9, P < .01) with clinical severity. In legs with CVI of CEAP 2 to 6, reflux was invariably proximal (thigh) and distal (below knee).**

Conclusion: **In CVI, IPVs are located predominately in the medial aspect of the lower extremity, more often in the middle third of the calf, followed by the lower calf and middle thigh. The prevalence of IPVs and their calf-to-thigh ratio increase linearly with the clinical severity of CVI. Both the prevalence of deep vein incompetence and the ratio of superficial and deep to superficial ([S + D]/S) increase linearly with CEAP classification. These findings support the significant relationship between deep venous reflux and PV incompetence, although the latter may exist in the absence of the former. In CEAP classes 2 to 6, reflux is invariably proximal and distal. Incompetence involving all systems (S + D + PV) increases in prevalence with the severity of CVI. (J Vasc Surg 1998;28:815-25.)**

Perforating veins (PVs), which penetrate the deep fascia, connect the superficial with the deep venous system at points other than the saphenous junctions. PVs are first mentioned in 1803 by the Russian anatomist Von Loder.[1] Although the anatomy of PVs has been described by Linton,[1] Sherman,[2] Cockett,[3] and others on the basis of anatomic or surgical dissection and more recently by Townsend,[4] Hanrahan,[5] Mozes,[6] and Pierik,[7] their hemodynamic role remains controversial.[8] There are studies that claim that incompetent perforating veins (IPVs) contribute little

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to ambulatory venous hypertension,[9] the calf muscle pump function[10] or venous hemodynamics.[11] Other studies maintain that they transmit calf pressure to the skin, which causes dermal hypoxia,[12] and it has been suggested that their ablation is associated with marked clinical[13-15] and hemodynamic[16] improvement. This discrepancy should be attributed to the wide variety of patterns in venous disease related to IPVs and to the hemodynamic differences of the investigated patient groups. The hemodynamic significance of IPVs may well depend on the specific pattern and the severity of the concomitant venous incompetence.[17]

More recently, the extensive interest in minimally invasive approaches that permit the subfascial endoscopic interruption of IPVs[13,18,19] and the reported favorable results in comparison with open surgery[20] emphasize the need for a comprehensive understanding of the anatomical and functional aspects of PV incompetence.

The developments in duplex ultrasound scanning (U/S) and the advent of color flow imaging in the early 1990s have provided not only the means for an accurate, reproducible, and easily repeatable evaluation of the presence or absence of reflux but also its anatomic extent.[5,7,21-26]

The aim of this study was the investigation of the prevalence and distribution of IPVs in patients with different classes of chronic venous insufficiency (CVI), as defined by the updated clinical, etiologic, anatomic, and pathologic classification (CEAP),[27] and their relation to the pattern and the extent of superficial or deep venous reflux.

MATERIAL AND METHODS

Our material consisted of 468 limbs (138 bilateral and 192 unilateral) of 330 subjects (147 men and 183 women), who were aged 18 to 101 years (median, 49 years). The distribution of the investigated limbs in the different (CVI) classes according to the CEAP classification was the following: class 0 (control), 76; class 1 (telangiectasias), 24; class 2 (varicose veins), 200 with primary valvular incompetence (PRIM) and 6 with secondary (post-phlebitic) incompetence (SEC); class 3 (varicose veins and leg oedema), 40 PRIM and 8 SEC; class 4 (skin changes), 42 PRIM and 4 SEC; class 5 (healed ulceration), 13 PRIM and 9 SEC; and class 6 (active ulceration), 39 PRIM and 7 SEC. Except for the control group (CEAP class 0, 76 limbs [29 bilateral and 18 unilateral] and 47 subjects), our material was comprised of patients with CVI clinically who were referred consecutively by their doctors—surgeons, physicians, or general practitioners of the northwest region of London—to the Irvine Laboratory for the determination of the sites and the extent of venous reflux.

The investigation entailed a detailed medical history followed by a clinical examination and color flow duplex imaging (CFDI) of the lower limb veins. The latter was performed with an Ultramark 9 HDI (ATL, Bothell, Wash) that was fitted with a 5-MHz linear array scanhead and was operated by the same examiner.

Examination protocol. The duplex scanning of the proximal venous system was performed with the patient standing on a low stool and facing the examiner. The scanned leg was slightly in front of the other leg with the knee flexed, externally rotated, and relaxed, with the foot flat on the floor. Weight bearing was transferred to the contralateral limb, and balance was assisted by the subject holding onto the frame of the duplex scanner. The common femoral vein (CFV), the superficial femoral vein (SFV), the sapheno-femoral junction (SFJ), the greater saphenous vein (GSV) above the knee, the thigh GSV tributaries, the anterior, lateral, and posterior veins, and the PVs were all studied. Once the CFV, the SFJ, and the proximal GSV were identified in cross-section with B mode and the anatomy was delineated, the color was switched on and the vessels were examined for the presence of venous reflux. The calf and thigh were compressed manually, and reverse venous flow was assessed on the release of compression. The reflux duration was measured for all of the groin veins (CFV, SFV, SFJ, GSV, and GSV tributaries) in the longitudinal plane with real-time B mode and gated Doppler U/S. Flow velocity waveforms with suboptimal tracings and noise were discarded, and a constant 60-degree insonation angle with the investigated vessel was maintained. All Doppler signal and B mode variables (gain, smoothing, edge enhancement, rejection, and post processing curves) were optimized and carefully maintained throughout the entire study. Venous reflux was considered abnormal when its duration exceeded 0.5 seconds.

The GSV in the thigh, the GSV tributaries (posteromedial and anterolateral), the SFV, and the PVs were initially examined in cross section, and reflux times were measured in longitudinal section as described. The medial aspect of the thigh was examined from the groin to the knee and followed by the investigation of the posterior and anterolateral aspects.

The popliteal fossa and the calf venous systems were investigated with the patient sitting comfortably on a high examination couch and facing the examiner, with the scanned leg resting on a low soft stool with the knee semi-flexed. The distal SFV, the

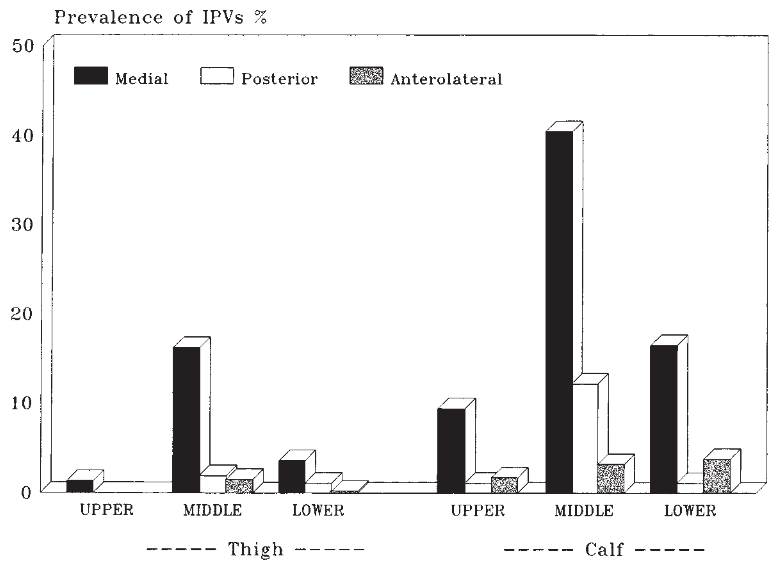


Fig 1. Prevalence of incompetent perforating veins (incompetent perforating veins/limbs) in 9 fields of thigh and 9 fields of calf.

popliteal vein, the tibioperoneal trunk, the saphenopopliteal junction, and the proximal short saphenous vein (SSV) were also visualized first in cross section and then longitudinally. After the anatomy was delineated, the reflux times in all of the vessels were obtained as described above. The GSV below the knee, the posterior and anterior GSV arches, and the SSV were all scanned separately on real-time B mode (with or without color) to identify anatomical variations, segmental reflux, and IPVs and to detect venous flow abnormalities in all associated venous systems. The identification of IPVs in the medial calf was expedited by scanning the medial calf transversely from the malleolus to the knee. Emphasis was placed on the crural veins (posterior and anterior tibial veins and peroneal veins) and muscular veins (soleal and gastrocnemial veins) and their communications with the superficial veins (posterior tibial veins with the posterior GSV arch, muscular veins in the posterior calf with the SSV, and anterior tibial veins with the anterior GSV arch). Reflux time in the calf veins was evaluated with the sudden release of manual compression of the distal calf or foot.

All aspects of the thigh and calf were investigated meticulously, and on no occasion was the examination compromised by time limitations. The average scanning time per examined leg ranged from 15 to 42 minutes (median, 22 minutes).

Perforating vein examination. A PV was considered incompetent if bidirectional or outward flow was documented using the manual compression/sudden release maneuver and if reflux time on release of compression exceeded 0.5 seconds on 3 consecutive evaluations. The PVs were identified on a cross-sectional view, and their presence was confirmed on real-time longitudinal color flow imaging. Reflux was detected initially on color mode, but its exact duration was defined with combined real-time B mode imaging and gated Doppler and longitudinal vessel insonation. The thigh and calf IPVs were classified as medial, posterior, or anterolateral. Each of these areas was further subdivided into upper, middle, or lower (9 thigh and 9 calf fields). A tape measure was used to determine the allocation of a PV in any of the aforementioned 18 fields whenever the site was not readily identifiable.

The differences in the proportions were evaluated with the χ^2 test. Univariate linear regression analysis was performed to establish associations.

RESULTS

The total prevalence of IPVs (IPVs/limbs) in relation to the 18 anatomical fields of the 468 lower limbs examined is depicted in Fig 1. The IPVs were located mainly in the medial aspect and were most frequent in the middle third of the calf, followed by the lower third of the calf and the middle third of the thigh. IPVs were rare in the lateral aspect of the thigh, the medial upper and posterior lower thigh, and the posterior upper and lower calf.

The prevalence of IPVs in relation to the medial, posterior, and anterolateral fields in the thigh and

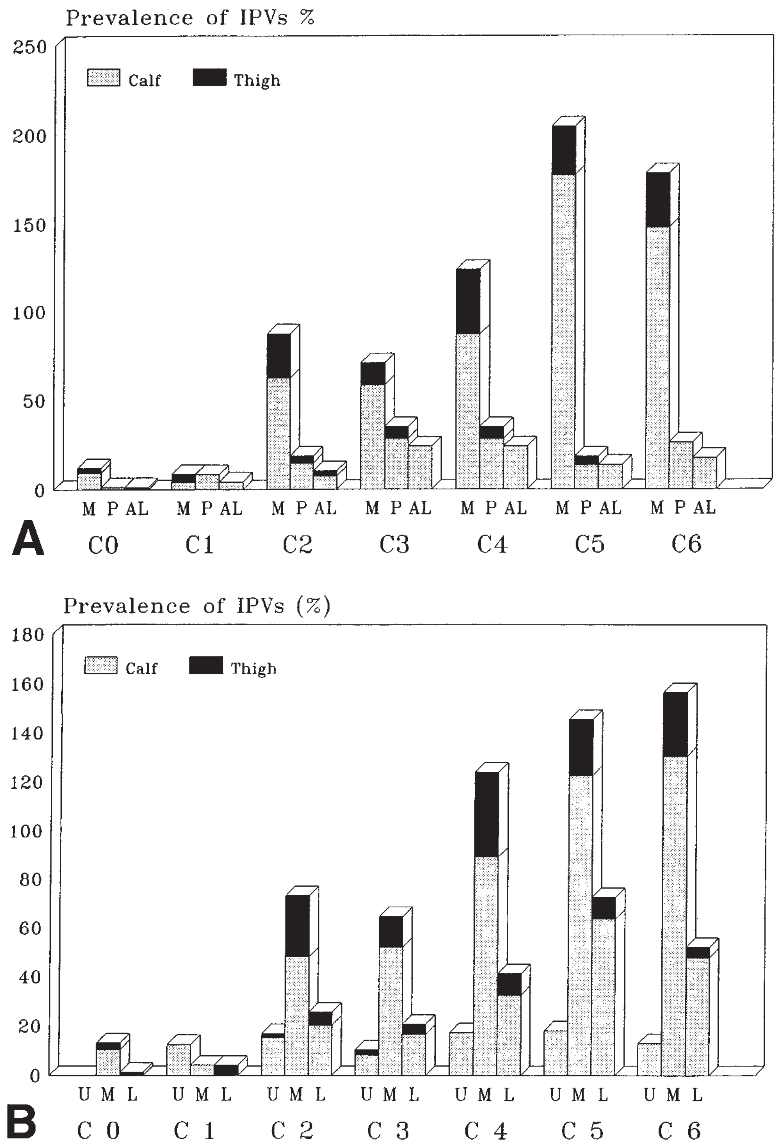


Fig 2. A, Prevalence of incompetent perforating veins (incompetent perforating veins/limbs in each class) in relation to medial, posterior, and anterolateral aspects of lower limb across clinical spectrum of CVI. **B,** Prevalence of incompetent perforating veins (incompetent perforating veins/limbs in each class) in relation to upper, middle, and lower thirds of thigh and calf across clinical spectrum of CVI.

the calf across the clinical spectrum of disease is depicted in Fig 2*A*. In CEAP classes 2 to 6, IPVs occurred predominantly in the medial aspect of the calf. The prevalence of IPVs in relation to the upper, middle, or lower third of the thigh and the calf across the different CEAP grades is shown in Fig 2*B*. In CEAP classes 2 to 6, IPVs occurred predominantly in the middle third of the calf.

The prevalence of IPVs (Fig 3*A*) and the absolute number of detected IPVs (in limbs with PV incompetence) increase linearly (Fig 3*B*) with the clinical severity of CVI ($r = .95$, $P < .01$, and $r = .9$, $P < .01$, respectively).

The ratio of calf-to-thigh IPVs increases linearly ($r = .87$, $P < .01$) with CEAP grade in the limbs with PV incompetence (Fig 4*A*). The ratio of superficial and deep over superficial only (S + D/S) venous incompetence (in legs with IPV) increases significantly ($r = .95$, $P < .01$) with clinical severity (Fig 4*B*).

The distribution of limbs with 1, 2, 3, 4, or more

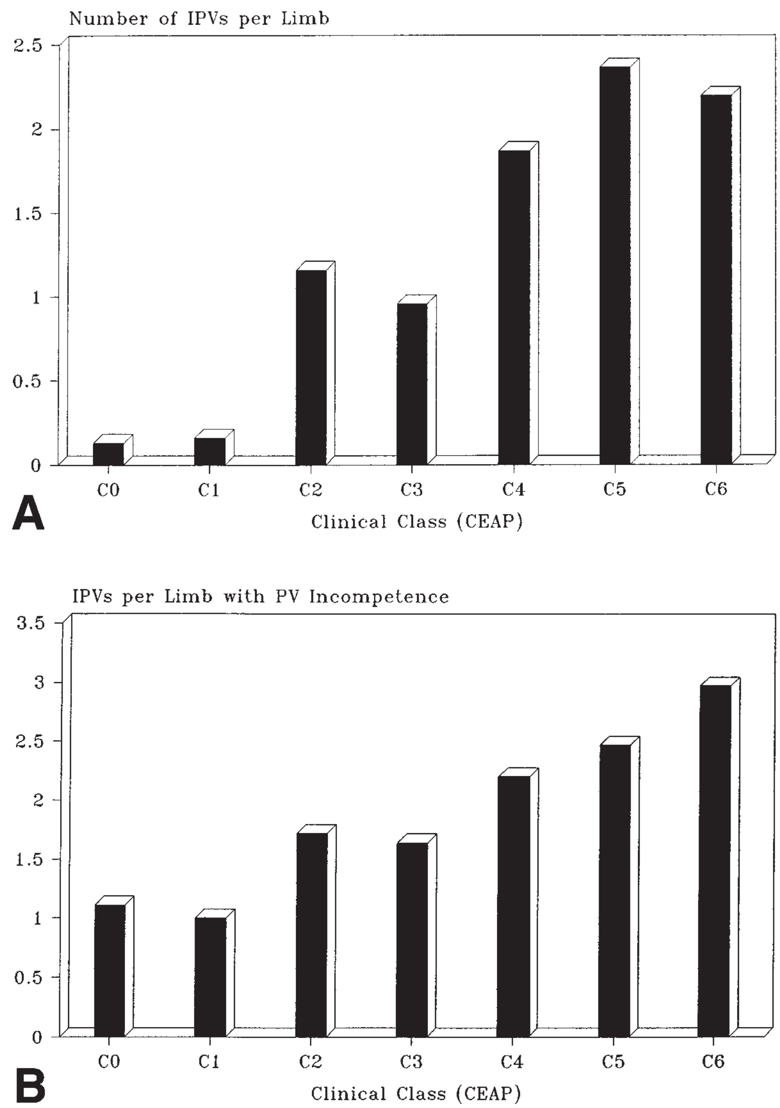


Fig 3. A, Prevalence of incompetent perforating veins (incompetent perforating veins/limbs in each class) in different CEAP classes of chronic venous insufficiency (r = .95, P < .01). **B,** Number of incompetent perforating veins per limb with documented perforating vein incompetence in different CEAP classes of chronic venous insufficiency (r = .9, P < .01).

IPVs across the clinical spectrum of CVI is depicted in Fig 5. Most of the limbs with PV incompetence in CEAP classes 4 to 6 have 3 or more IPVs. In contrast, classes 0 to 3 are characterized by limbs with 1 to 2 IPVs (P < .001). The prevalence of limbs with 3 or more IPVs increases significantly with CEAP grade (r = .9, P < .01).

The main anatomic patterns of PV incompetence in the different clinical classes of CVI are shown in Table 1.

The extent of venous reflux in the different classes of CVI is shown in Fig 6*A*. In the legs with CVI that were classified as 2 to 6, reflux was invariably proximal and distal. The axial type (deep or superficial) of proximal and distal reflux did not change from classes 2 to 6.

The overall prevalence of superficial, deep, and perforating vein incompetence for the spectrum of CVI classes is depicted in Fig 6*B*. The prevalence of deep vein incompetence increases significantly with CEAP grade (r = .9, P < .01).

The distribution of different complex patterns of

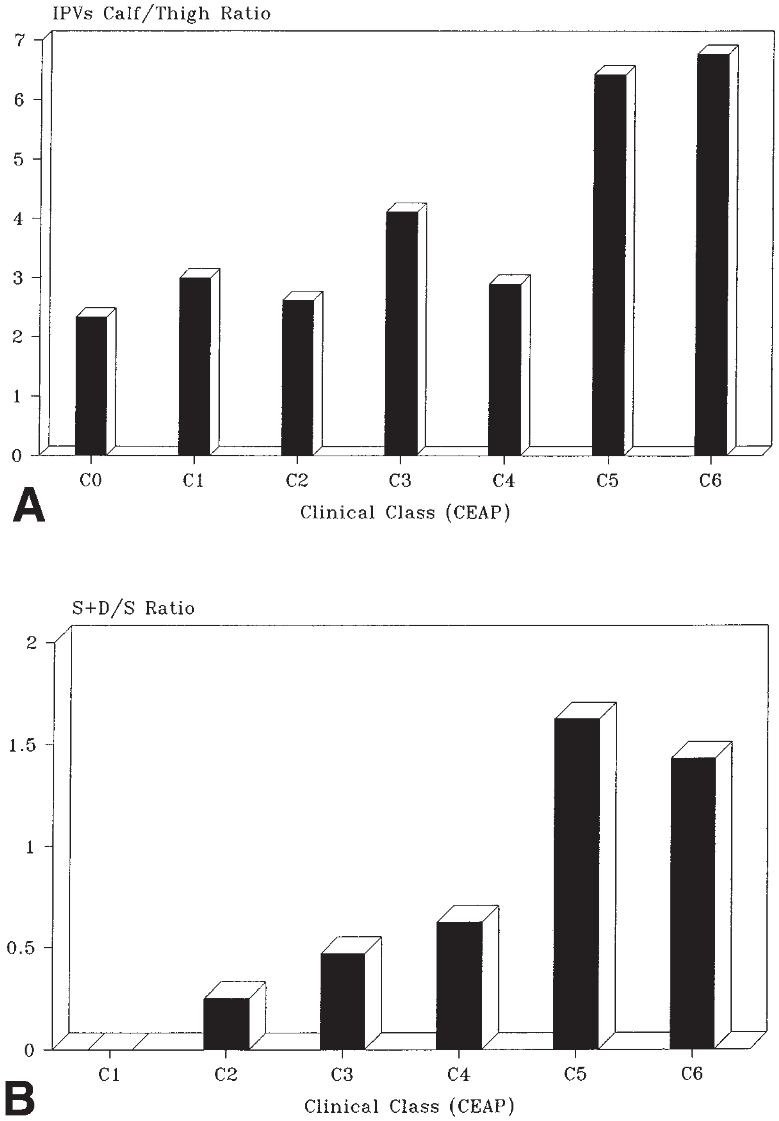


Fig 4. A, Ratio of calf-to-thigh incompetent perforating veins in limbs with documented perforating vein incompetence in different clinical classes of chronic venous insufficiency. There is significant increase with class (CEAP; $r = 0.87$, $P < .01$). **B,** Ratio of superficial and deep over superficial alone ([S + D]/S) vein incompetence in limbs with documented incompetent perforating veins across clinical spectrum of chronic venous insufficiency ($r = .9$, $P < .01$).

Table I. Anatomic patterns of perforator incompetence in limbs with 3 or more incompetent perforating veins in relation to their prevalence (%) across the spectrum of chronic venous insufficiency (classes 2-6)

CEAP 2	MMC (83%) ± MMT (58%) ± MLC (53%) ± PMC (25%)
CEAP 3	MMC (100%) ± MMT (100%) ± PMC (50%)
CEAP 4	MMC (88%) ± MLC (50%) ± PMC (38%) ± MMT (38%)
CEAP 5	MMC (83%) ± MLC (58%) ± PMC (17%) ± MMT (17%)
CEAP 6	MMC (100%) ± MLC (65%) ± LLC (52%) ± MMT (35%)

CEAP, clinical, etiologic, anatomic, and pathologic classification; *MMC,* medial middle calf; *MMT,* medial middle thigh; *MLC,* medial lower calf; *PMC,* posterior middle calf; *LLC,* lateral lower calf.

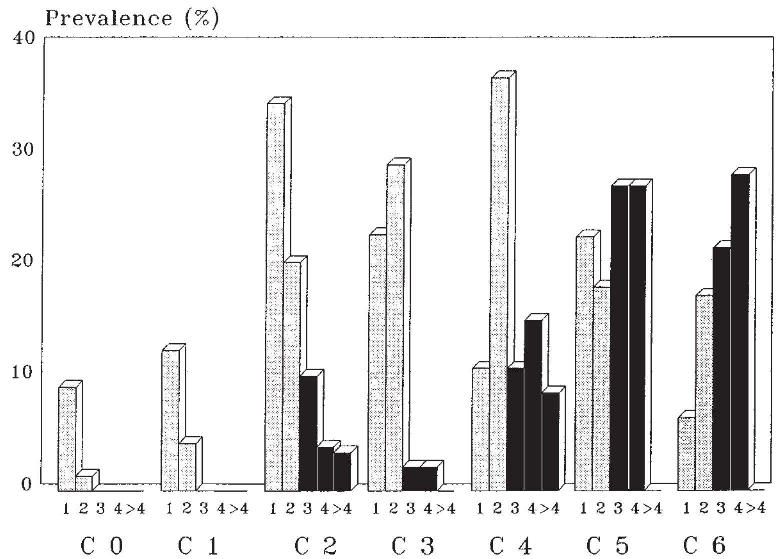


Fig 5. Prevalence of limbs with 1, 2, 3, 4, or more incompetent perforating veins in different clinical classes (CEAP). There are no limbs with 3 or more incompetent perforating veins in classes 0 to 1. Ratio of limbs with 3 or more incompetent perforating veins to limbs with 1 to 2 incompetent perforating veins increases significantly with clinical severity (r = .9, P < .01).

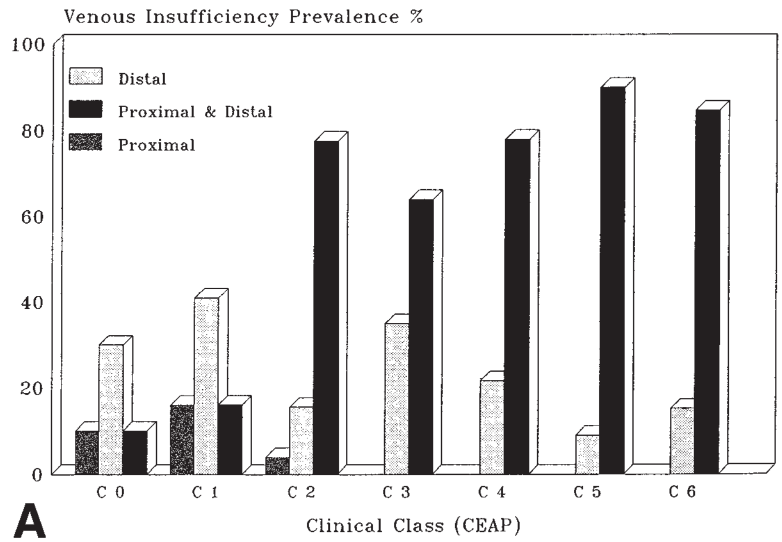
reflux (S + PV, S + D, D + PV, S + PV + D) along the clinical spectrum of CVI is shown in Fig 7. Incompetence involving all systems increases significantly with the grade of disease (r = .9, P < .01).

DISCUSSION

Despite the substantial number of studies on the anatomy[1-7] and the hemodynamic importance of PVs in CVI,[9-11] their exact role has remained unclear because there is no definitive test that evaluates their specific contribution to venous hypertension.[8,17] The advent of CFDI has changed the methodology of lower limb vein evaluation.[28-31] Duplex scanning is not unpleasant, can be repeated without risk, and, compared with venography, provides information that is more detailed hemodynamically[21,32,33] and is almost as good or better anatomically (depending on the operator). The technique has become an indispensable tool for documenting the presence and the nature of venous disease in clinical trials and for monitoring patient progress. Comparing duplex scanning with descending phlebography (standardized Valsalva's maneuver) in the assessment of venous reflux in patients with healed ulcers caused by CVI, Baker et al[21] demonstrated that the former is more sensitive in detecting both deep and superficial venous reflux below the knee and isolated segmental and SSV reflux, which is not possible with the latter. In comparison with the findings at surgical exploration (modified Linton's procedure), Pierik et al[7] reported that duplex scanning is 79.2% sensitive and 100% specific in the detection of IPVs in patients with venous ulceration. Perforators were missed as a result of the following: (1), their anatomical proximity to the ulcer bed, which may have hampered the transmission of the U/S beam; (2), their anatomical proximity to the tibial crest; and (3), their small size (<1 mm). In a study that evaluated duplex imaging as a means of assessing IPVs compared with ascending venography and intraoperative findings (Rob procedure) in 11 patients with long standing venous stasis ulceration, Hanrahan et al[34] reported that duplex scanning enabled the detection of 71 PVs (26 IPVs) and venography of 51 PVs (35 IPVs) in a total of 99 PVs (35 IPVs) that were identified during surgery.

Several studies have shown that the duration of reflux on duplex scanning correlates significantly with its plethysmographic determination.[21,35,36]

To date, there are no established criteria for the assessment of the hemodynamics of PVs. Their classification as incompetent mainly depends on reflux times accepted for the truncal veins. In normal veins, reflux can occur briefly before the valve leaflets close. The presence of bidirectional or outward flow with reverse component exceeding 0.5 seconds, which is



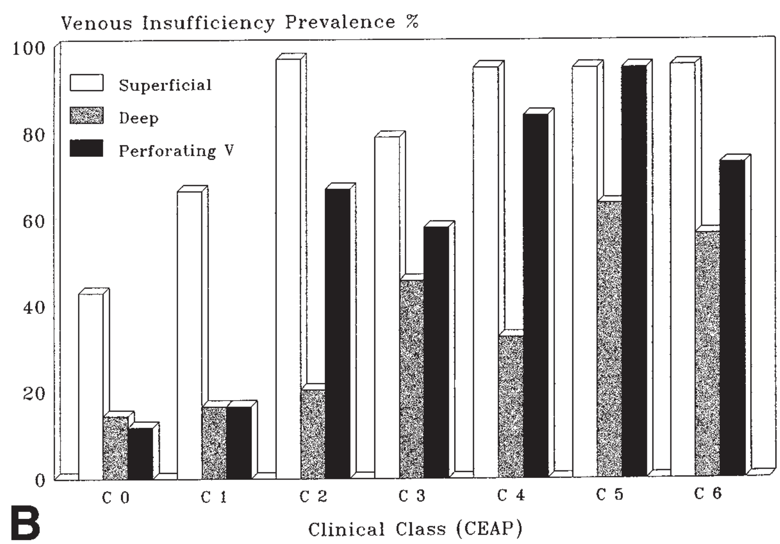


Fig 6. A, Prevalence of proximal (Prox), distal (Dist), or P + D (Prox + Dist) incompetence in different clinical, etiologic, anatomic, and pathologic classifications. Reflux in classes 2 to 6 involves both P and D segments. **B,** Overall prevalence of superficial, deep, or perforating vein incompetence across clinical spectrum of chronic venous insufficiency. Prevalence of perforating vein ($r = .86$, $P < .01$) and deep vein incompetence ($r = .9$, $P < .01$) increase with clinical severity. Prevalence of superficial vein incompetence changes little with clinical class (clinical, etiologic, anatomic, and pathologic classifications, 2 to 6).

the 95% confidence interval for the normal reflux time,[33] is considered abnormal.

It recently has been reported that a subfascial PV diameter of >3.9 mm (95% confidence interval, 3.4, 4.4 mm) tends to be associated with incompetence. However, almost a third of IPVs have a subfascial diameter of <3.9 mm, and, irrespective of competence, PVs located at the lower thigh, knee, ankle, and anterior calf have a smaller diameter than those at the medial middle thigh or calf.[37] Therefore, the diameter cannot be used as a sole diagnostic criterion of incompetence. In addressing the controversial subject of flow direction in medial calf PVs in CVI, Sarin et al[38] demonstrated outward flow in 15% of the PVs in the healthy limbs on venous outflow enhancement when no reflux was present (in the

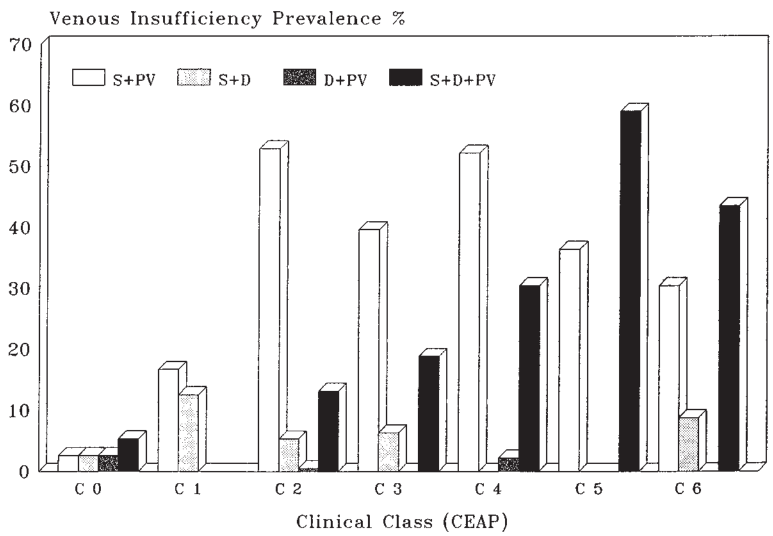


Fig 7. Prevalence of complex patterns of vein incompetence (superior + proximal [S + PV], superior + deep [S + D], D + PV, S + D + PV) in different clinical classes (CEAP) of chronic venous insufficiency. Incompetence involving all systems (S + D + PV) increases significantly with clinical severity ($r = .9$, $P < .01$).

PV) during compression/release. They maintained that a PV is pathologic when flow is present in it during the relaxation phase, and this is invariably associated with CVI. Labropoulos et al[37] found that the vast majority of IPVs have outward flow only (77%), whereas bidirectional flow (inward and outward) is more frequently found in IPVs than in controls ($P = .048$).

This study has shown that, although IPVs can be encountered in limbs at any clinical stage of CVI, their presence is extremely unlikely in classes 0 and 1. In legs with varicose veins (class 2), an average of 1 IPV should be expected per examined limb, but the prevalence becomes almost 2-fold when skin changes are present and more than 2-fold in limbs with active ulceration. When we looked at the prevalence of limbs with 1, 2, 3, 4, or more IPVs across the clinical spectrum, we found a significant change ($P < .01$) in the pattern from limbs with 1 or 2 IPVs in classes 0 to 2 to limbs with 3, 4, or more IPVs in classes 4 to 6. Our findings support previous work[24] that showed that IPVs occur mainly in patients with skin changes (48.8%) or ulceration (60.8%). Our results also agree with Lees et al,[22] who reported an overall incidence rate of PV incompetence of 23% in patients with CVI without skin changes (CEAP classes 1 to 3) and of 65% in those with skin changes and ulcers (CEAP classes 4 to 6). Hanrahan et al[5] have reported that PV incompetence is present in 63.2% of the limbs with venous ulceration. We have presented data that show that IPVs are rare in symptom-free subjects.[23]

The present study has shown that IPVs, irrespective of clinical classification, are mainly located medially, most frequently in the middle third of calf, followed by the lower third of the calf and the middle third of the thigh. This is in agreement with previous work.[2,4] The data of Townsend et al,[4] which are based on interosseous venograms, show that 44% of the IPVs in the calf occur in the medial middle third, 20% in the medial lower third, and 6% in the posterior middle third if analysis assumes 9 calf fields. The data are also in agreement with Pierik et al[7] who showed that the medial middle calf followed by the medial lower calf are the fields with the highest incidence rate of IPVs. Using CFDI, Sarin et al[38] isolated 163 medial calf PVs that were located mainly in the zone between 12 to 24 cm above the malleolus, which represents the middle third of the calf in our study.

Our study has shown that IPVs are exceptionally uncommon in the lateral aspect of the thigh, the medial upper and posterior lower thigh, and the posterior upper and lower calf. This is in agreement with previous work.[4,39] The study has also shown that the increasing prevalence of IPVs with the clinical severity of CVI is associated with a significant increase in the prevalence of reflux involving all venous systems (S, D, and PVs; $P < .01$). This is in agreement with previous work.[5,22,24,26] Lees et al[22] reported multisystem vein incompetence (S + D + PV) in 36% of the limbs with skin changes and in 6% of the limbs with CVI in the absence of skin changes (CEAP classes, 1 to 3). Hanrahan et al,[5] who looked at the distribution of valvular incompetence in 95 extremities (78 patients) with venous stasis ulceration with duplex scanning, reported multisystem incompetence (S + D + PV) in 31.6%, PV incompetence in 63.2%, isolated deep reflux in 2.1%, and isolated superficial incompetence in 17% of the limbs. According to Labropoulos et al,[24] combined patterns of reflux (S + PV, S + D, PV + D, PV + S + D) were most often seen (>65%) in classes 2 and 3 (old classification; $P < .0001$). Welch et al[26] found that reflux that involved both the superficial and the deep systems from 14% in class 1 (varicose veins and edema) increased to 22% in class 2 (skin changes) and reached 37% in class 3 (preulcerative skin changes or ulceration; old classification).[40]

The overall prevalence of deep vein incompetence also increases with the severity of CVI. In contrast, the overall prevalence of superficial vein incompetence is virtually unchanged between CEAP grades 2 to 6 ($P > .05$). In the limbs with IPVs, the (S + D)/S ratio of incompetence increases significantly across the clinical spectrum ($P < .01$). Also, the calf-to-thigh IPV ratio increases with the severity of CVI ($P < .01$). These findings indicate a strong relationship between deep vein incompetence and PV incompetence—although the latter may be present in the absence of the former—that may be characteristic of advanced CVI but may also be suggestive of the etiologic role of the deep system in the pathogenesis of IPVs. This is in support of the work by Neglen et al,[41] Weingarten,[42] van Rij,[43] and Myers,[44] who have also emphasized the role of deep vein incompetence in severe CVI.

We identified certain anatomical patterns of IPVs in symptomatic classes of CVI (Table I). In classes 2 to 6, the limbs with 3 or more IPVs had predominantly an incompetent medial middle perforator associated with a medial middle thigh IPV (classes 2 to 3) or a medial lower calf IPV (classes 4 to 6). This pattern was also associated with a posterior middle calf IPV (classes 3 to 5) or a lateral lower calf IPV (class 6). It appears that the higher the grade of disease the less the likelihood of an anatomical IPV pattern involving a thigh perforator.

We found that CEAP classes 2 to 6 are invariably associated with reflux involving both the proximal and distal lower limb venous segments with insignificant differences across this clinical spectrum ($P > .1$). This is in agreement with previous work.[5,24]

In conclusion, this study has shown that the prevalence of IPVs and their calf-to-thigh ratio increase linearly with the clinical severity of CVI. Both the prevalence of deep vein incompetence and the ratio of superficial and deep to superficial [(S + D)/S] also increase linearly with CEAP class. These findings support the significant relationship between deep venous reflux and PV incompetence, although the latter may exist in the absence of the former. IPVs predominately are located in the medial aspect of the lower extremity, more often in the middle third of the calf, followed by the lower calf and middle thigh. In CEAP classes 2 to 6, reflux is invariably proximal and distal. Incompetence involving all systems (S + D + PV) increases in prevalence with the severity of CVI.

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