Venous obstruction: An analysis of one hundred thirty-seven cases with hemodynamic, venographic, and clinical correlations

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One hundred thirty-seven limbs with venous obstruction were analyzed. The arm/foot venous pressure differential and reactive hyperemia tests were found to be useful techniques to diagnose and grade venous obstruction. Traditional techniques including venography and ambulatory venous pressure are inferior in this regard. The newer techniques have provided newer insights in venous obstruction which are detailed herein. The hand-held Doppler was surprisingly very sensitive in grade I as well as in more severe forms of obstruction. Neither anatomic locale of obstruction nor its extent determined hemodynamic severity. Extensive proximal lesions could be hemodynamically mild, and conversely distal crural obstructions and single segment lesions could be hemodynamically severe. Phlebographic appearance was a poor index of collateralization. The paradoxical venous pressure response to the reactive hyperemia test in grade IV obstruction was found to be due to suppression or delay of the reactive hyperemia response itself in the presence of severe venous obstruction. The pain of venous claudication may be related to this phenomenon. Skin ulceration in the presence of venous obstruction was related to the associated reflux rather than the hemodynamic severity of the obstruction itself. The Linton procedure was found to be useful in treating such skin ulcerations. After perforator disruption, obstruction did not become hemodynamically worse, but reflux as measured by the Valsalva test improved with ulcer healing. The improvement in reflux related to Valsalva offers for the first time a hemodynamic rationale for the Linton procedure.
(J Vasc Surg **1991;14:305-13.**)

Extensive literature exists on the postphlebitic syndrome dating back to the early part of the century. Yet good data with regard to chronic obstruction are not available because most authors have not made the necessary distinction between hemodynamic obstruction and reflux in characterizing their case material. The problem has been compounded by the fact that the traditional methods of assessing venous obstruction are deficient in many respects. Most centers continue to rely solely on ascending venography to diagnose and assess venous obstruction. Yet the technique provides anatomic, not physiologic information, which is necessary to correlate symptomatology with hemodynamic severity. Ambulatory venous pressure measurement, long considered the gold standard in physiologic venous testing, cannot differentiate obstruction from reflux, and it is unclear how the results of this test should be interpreted in the presence of combined obstruction/reflux. Plethysmography, a useful technique in venous obstruction, is infrequently used partly because of calibration and other problems that plagued early models of the instrument. A simple pressure-based technique to detect and grade venous obstruction has been in use in our laboratory for some time.[1] The technique is based on the principle that an arm/foot venous pressure differential denotes venous obstruction and that the adequacy of collateralization/recanalization can be assessed by monitoring venous pressure changes in the lower limb under the influence of reactive hyperemia. The techniques are reliable, easily accomplished in combination with ambulatory venous pressure measurement, and provide a range of information with regard to venous obstruction not

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Presented at the Fifteenth Annual Meeting of The Southern Association for Vascular Surgery, Palm Springs, Calif., Jan. 23-26, 1991.

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24/6/31016

available with other techniques mentioned above. The additional insights into venous obstruction obtained with these techniques in combination with the hemodynamic, venographic, and clinical correlations provide the basis of the current report.

MATERIAL AND METHODS

At the University of Mississippi Medical Center from 1981 through 1989, 1354 limbs were examined for venous insufficiency in the vascular laboratory. Three hundred eighty-five of these limbs (28%) were tentatively diagnosed as having chronic venous obstruction based on laboratory examination. One hundred thirty-seven of these limbs underwent further studies including invasive pressure measurements. One-hundred-twenty-seven venograms were available for correlation analysis. Because some hemodynamic techniques were introduced later than others, or for other reasons (e.g., failed venipuncture), the number of limbs analyzed for specific techniques may vary. The actual numbers are indicated under specific tables and figures.

Hemodynamic assessment

Doppler examination. Patients were examined with a 5 MHz hand-held Doppler for signs of obstruction (spontaneity, phasicity, and augmentation) as well as for reflux. More recently, the hand-held Doppler has been replaced by a duplex scanner, which in addition to giving the above data, yields color flow and scannable features of lower limb veins.

Ambulatory venous pressure measurement. This was measured in all patients before and after manual calf compression (simulated exercise) through a venipuncture in the foot as per technique previously described.[2] The technique is reproducible, avoids problems with patient cooperation, and yields results similar to the traditional toe-stand technique.

Arm/foot venous pressure differential and reactive hyperemia-induced foot venous pressure increase. These tests were used in combination to detect and grade venous obstruction.[1,3] In brief, the venous pressure differential between the arm and foot in the supine patient at rest is measured by separate venipunctures in the arm and the foot. Normal limbs with an unobstructed venous system have a differential of <4 mm Hg. A fraction of patients with phlebographic venous obstruction will have a pressure differential of over 4 mm Hg. The remainder will demonstrate a differential of <4 mm Hg as a result of recanalization/collateralization with normal hemodynamics at rest. Further information on the adequacy of recanalization/collateralization can be obtained by inducing reactive hyperemia while monitoring foot venous pressure in the recumbent patient. After a 2-minute ischemic cuff occlusion at 300 mm Hg, a foot venous pressure elevation not to exceed 6 mm Hg would be noticed within 5 seconds after cuff release in unobstructed limbs. An elevation beyond this level denotes residual obstruction under circulatory stress. Paradoxically a pressure elevation of <6 mm Hg is obtained in highly decompensated (grade IV) venous obstruction (see herein).

Grading of venous obstruction

By use of the above two tests in combination, it is possible to grade the severity of venous obstruction based on the adequacy of collateralization/recanalization. This classification is shown in Table I.

Valsalva foot venous pressure elevation

The dorsal foot venous pressure in the recumbent patient is monitored while the patient exerts a graduated Valsalva effort (40 mm Hg for 5 seconds). A pressure elevation over 4 mm Hg from resting levels is indicative of reflux.[2,4] The test is highly reproducible, has a clear separation between refluxive and normal limbs, and is useful in assessing the effectiveness of antireflux surgical procedures in the venous system.[2]

Ascending and descending venography

These techniques have been described in detail elsewhere.[5] On descending venography, significant reflux was considered to be present only when it could be demonstrated during the Valsalva maneuver.

Statistics

Student's *t* test for paired data (where applicable) was used. A computerized ANOVA program was used selectively for some data.

RESULTS

Accuracy of diagnostic techniques. The sensitivity and specificity data for the Doppler compared to venography in diagnosing venous obstruction was as follows: sensitivity - 89% for grade I obstruction (n = 55) and 82% for grades II, III, and IV obstructions (n = 59); specificity 92% (n = 50). Sensitivity data for Doppler are given separately for grade I obstruction and for higher grades because venographic signs of obstruction were often subtle in grade I obstruction (see "Discussion" section). Veno-

Table I. Grading of obstruction

		Arm/foot venous pressure differential (normal <4 mm Hg)	*Reactive hyperemia foot venous pressure elevation (normal <6 mm Hg)*
Grade I†	Fully compensated	<4 mm Hg	<6 mm Hg
Grade II	Partially compensated	<4 mm Hg	>6 mm Hg
Grade III	Partially decompensated	>4 mm Hg	>6 mm Hg
Grade IV	Fully decompensated	>4 mm Hg	<6 mm Hg*

*Paradoxical response (see text).
†Since pressure parameters for both tests are normal, accurate diagnosis depends on Doppler and/or venography (see text).

Table II. Actual values for hemodynamic tests of obstruction

Hemodynamic grade	*No.*	*Arm/foot venous pressure differential mean mm Hg ± SD*	*Reactive hyperemia foot venous pressure increase mean mm Hg ± SD*
Grade I	57	1.8 ± 1.1	2.4 ± 1.4
Grade II	36	2.7 ± 1.1	7.8 ± 3.4
Grade III	17	8.8 ± 4.1	9.1 ± 5.4
Grade IV	27	7.8 ± 4.6	1.8 ± 0.9

graphic appearance was more definitive for obstruction in grades II, III, and IV. Doppler was thus sensitive in grade I obstruction and in higher grades as well. The arm/foot-reactive hyperemia techniques when used in combination had excellent sensitivity and specificity at 91% (n = 92) and 91% (n = 24), respectively, when venographically obvious obstruction was used as the gold standard.

The distribution of the 137 limbs among the four grades of obstruction was as follows: grade I, 42%; grade II, 26%; grade III, 12%; and grade IV, 20%. It should be noted that the arm/foot venous pressure differential was elevated in only 32% of cases (grades III and IV). In the remaining 68%, the arm/foot venous pressure differential was normal (grades I and II). Conversely, the reactive hyperemia pressure response was "normal" in 62% of limbs (grades I and IV). Forty-two percent of cases, or less than half, were fully compensated (grade I) both at rest and reactive hyperemia. Mean values for arm/foot venous pressure differential and reactive hyperemia for the four grades of obstruction are shown in Table II. A progressive increase in these parameters was seen for grades I through III. By definition, a paradoxical decrease in reactive hyperemia pressure was seen from grades III to IV.

Forty-eight percent of all obstructions were pelvic, 25% were femoral, and 27% were crural in location per phlebographic appearance. Fig. 1 depicts anatomic distribution of the case material among the four grades of obstruction. When the obstruction involved multiple anatomic levels, the highest point of obstruction was used in determining its placement within the classification.

Twenty-six percent of the obstructions involved a single anatomic segment, whereas the remainder involved multiple segments per venography. Nineteen percent of all obstructions involved multiple segments in a contiguous fashion, whereas 55% involved multiple segments with intervening skip areas. Fig. 2 shows the distribution of the case material when classified in this fashion among the four hemodynamic grades.

The size and number of collateral vessels seen in the presence of obstruction were tabulated and classified according to hemodynamic grades. The incidence of deep femoral collateral vessels in the four grades was as follows: grade I, 50%; grade II, 64%; grade III, 78%; and grade IV, 68%. The mean size of deep femoral collateral vessels was 3 mm. In 43% the deep femoral collateral vessel size was >4 mm. Pelvic collateral channels were present in 28%, 45%, 67%, and 44% in the four grades, respectively. An average of four collateral vessels were present per patient. The average size of a pelvic collateral vessel was 4 mm. No correlation was found between either channel size or number and the hemodynamic grade of obstruction.

Fig. 3, A and B shows photoplethysmography tracing of digital arterial pulsations before and after

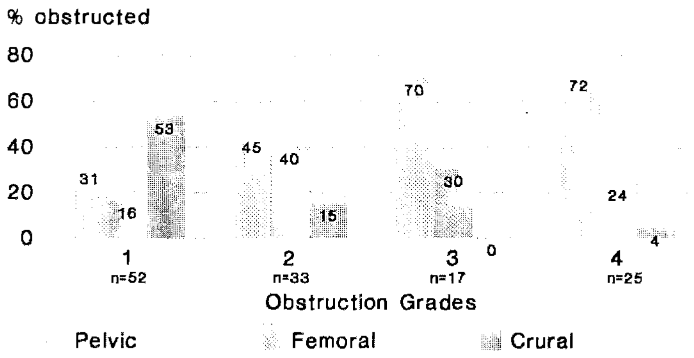

Fig. 1. Anatomic distribution of venous obstruction. Venograms for analysis were available in 127 of 137 limbs studied.

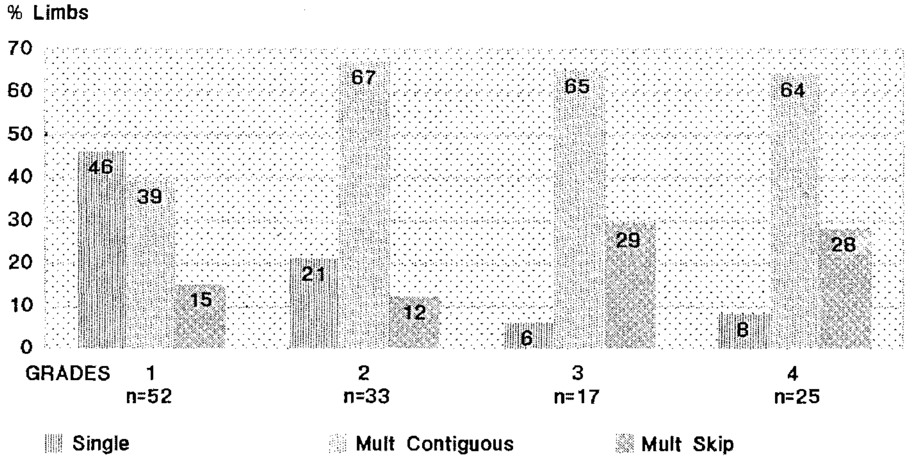

Fig. 2. Distribution of venous obstruction according to the number of venous segments involved; 127 venograms were available for analysis.

ischemic cuff occlusion while the reactive hyperemia test was performed in two patients with grade I and grade IV obstruction, respectively. Although a classic reactive hyperemia arterial response with doubling of the photoplethysmography amplitude is present in the limb with grade I obstruction, this was absent in the patient with Grade IV obstruction. This explains the basis for the paradoxical venous pressure response seen in patients with grade IV obstruction. Restriction of the reactive hyperemia response in grade IV obstruction has been confirmed also by pneumoplethysmographic data. For example, in the same patient with grade I obstruction in one limb and grade IV in the opposite limb pneumoplethysmography was used to monitor the reactive hyperemia response bilaterally. After ischemic cuff occlusion for 2 minutes, the limb with grade I obstruction demonstrated an arterial inflow of 10.4 ml/sec, whereas the opposite limb with grade IV obstruction showed an inflow of only 5.5 ml/sec (data obtained with the help of Peter Neglen, MD). Thus the reactive hyperemia response appears to be muted or considerably delayed in limbs with grade IV obstruction. Poor arterial inflow from arterial occlusive disease seemed unlikely in these limbs based on ankle pressure measurements and clinical examination.

Postexercise pressure was abnormal in all groups (Fig. 4). No difference was observed in ambulatory venous pressure between the various grades of obstruction except for grade III with small numbers, which was higher than either grades III or IV ($p < 0.05$). Thirty-one skin ulcers were seen in this group of 137 limbs with venous obstruction. The incidence of skin ulceration and swelling, respectively, within each hemodynamic grade is shown in Table III. An increased incidence of ulcer or swelling with increasing hemodynamic severity of obstruction, as one might expect, does not occur. Reflux

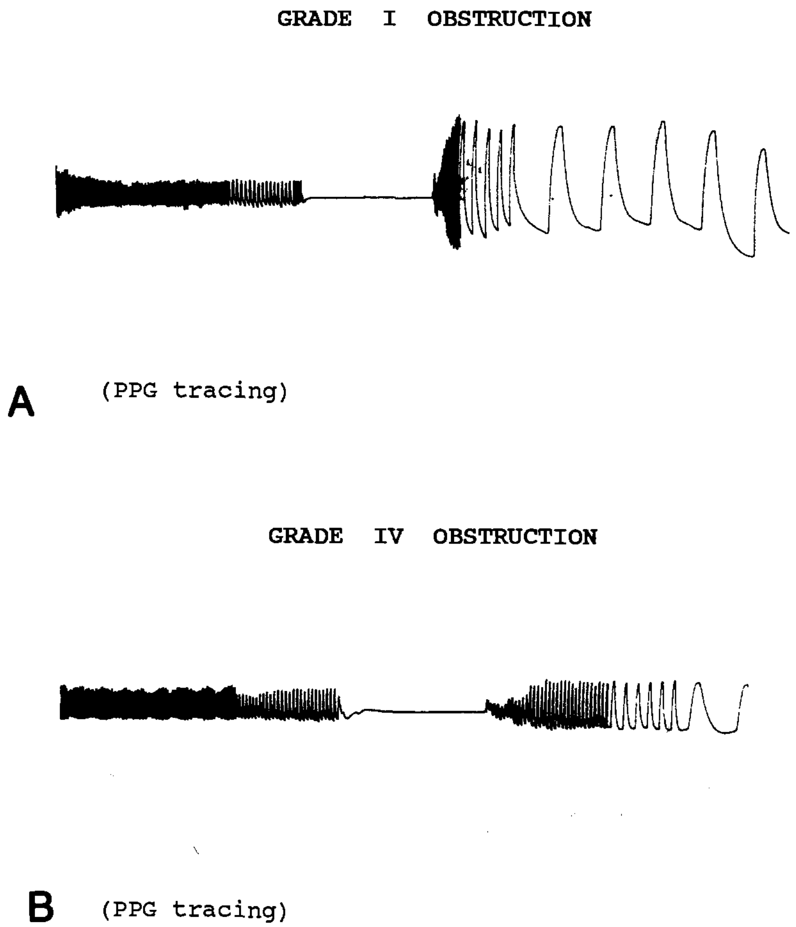

Fig. 3, A and B. Photoplethysmography tracing of digital arterial pulsations in a limb with grade I obstruction and another with grade IV obstruction, respectively. Classic reactive hyperemia response is evident in the former after release of ischemic cuff occlusion. This is absent in the latter.

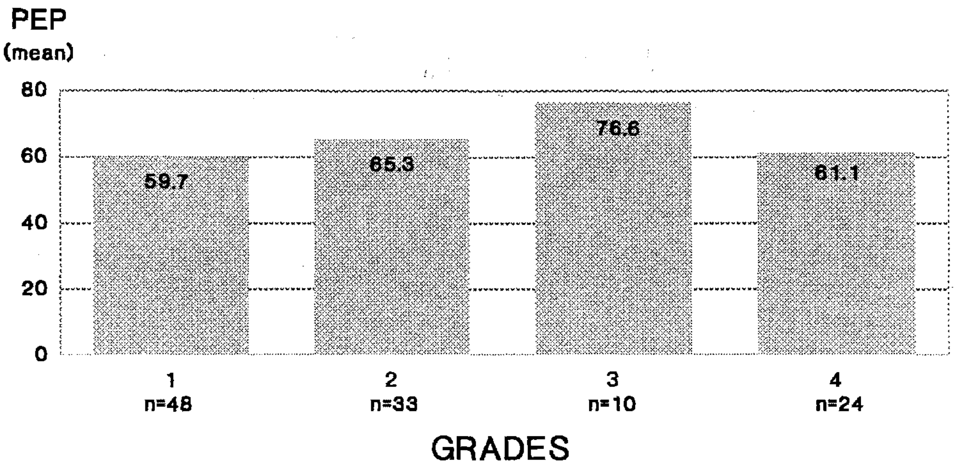

Fig. 4. Postexercise pressure in venous obstruction was elevated in all groups. No difference between the four grades of obstruction was present except for grade III with small numbers (see text).

Table III. Incidence of skin ulceration and swelling in venous obstruction

Obstruction grade	*No.*	*Incidence of stasis ulcer*		*Incidence of swelling*	
I	57	31%	NS	75%	NS
II	36	27%		80%	
III	17	5%		64%	
IV	27	30%		77%	

Table IV. Valsalva foot venous pressure elevation in obstructed limbs including those undergoing the Linton procedure

Obstruction	*No.*	*Valsalva foot venous pressure elevation mean mm Hg ± SD*	*p value*
Grade I	54	4.8 ± 4.2	NS
Grade II	34	3.9 ± 2.7	NS
Grade III	11	4.7 ± 1.9	NS
Grade IV	22	7.2 ± 3.8	NS
Linton procedure for skin ulcers (25)			
Healed group (19)			
Preoperatively		7.8 ± 6.9	<0.001
Postoperatively		3.9 ± 2.3	
Nonhealed group (6)			
Preoperatively		10.0 ± 4.6	NS
Postoperatively		9.0 ± 4.5	

occurred in association with obstruction, especially when skin ulceration was present. The incidence of reflux as measured by the Valsalva foot venous pressure elevation and by descending venography is shown in Table IV. Reflux measured by these techniques did not appear to be influenced by the hemodynamic individual grade of obstruction. However, a significant increase in reflux occurred among limbs with skin ulceration compared to those without skin ulcers within individual hemodynamic grades and the entire group as a whole (Fig. 5). Forty-seven descending venograms were available for analysis in obstructed limbs; 21 of these had skin ulceration. Thirty-five percent of limbs without skin ulceration (9/36) had reflux on descending venography with reflux confined to the thigh in all (average, grade <II). Seventy-seven percent of ulcerated limbs (16/21) had reflux by this technique with reflux beyond the knee or farther (average, grade III).

Twenty-five patients underwent modified Linton procedure for skin ulceration associated with venous obstruction. These patients were distributed according to the four hemodynamic groups as follows: grade I, 14; grade II, 5; grade III, 1; and grade IV, 5. After operation, with an average follow-up of 15 months (range, 8 to 23 months), 14 ulcers had completely healed, 5 were smaller, and 6 remain unhealed. No worsening of the hemodynamic grade of obstruction occurred after operation in any of the patients. Thus disruption of perforator collateral vessels did not result in worsening the grade of obstruction. The Valsalva foot venous pressure elevation as an index of reflux in this selected group of patients undergoing the Linton procedure is shown in Table IV. Patients who healed or whose ulcer size was reduced had a significant improvement in reflux as measured by the Valsalva test after the Linton procedure. In surgical failures this reflux parameter was unchanged.

DISCUSSION

A simple hand-held Doppler can be a reliable tool for the diagnosis of venous obstruction. In our laboratory excellent sensitivity was obtained for grade I as well as for more severe forms of obstruction. However, the Doppler instrument does not provide quantitative information, and operator training is required because diagnostic interpretation is subjective. The addition of tests for arm/foot pressure differential and reactive hyperemia pressure increase has provided for increased confidence in the diagnosis and grading of venous obstruction; the tests are based on objective pressure criteria free of operator interpretation. These hemodynamic tests have excellent sensitivity and specificity compared to venography and are conveniently carried out in combination with

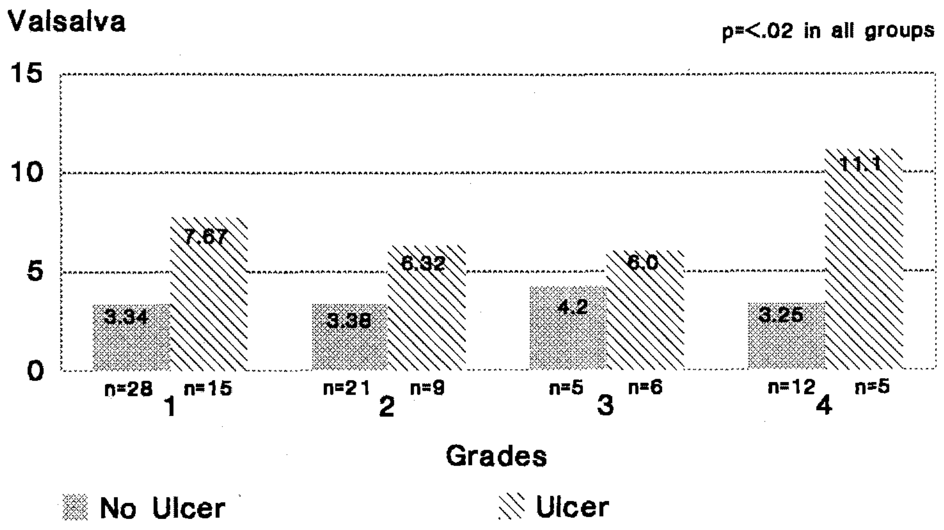

Fig. 5. Valsalva foot venous pressure elevation in venous obstruction with and without stasis ulceration. For the entire group ulcerated limbs had a mean Valsalva pressure elevation of 7.6 ± 4.4 mm Hg and nonulcerated limbs 3.4 mm Hg ± 2.0, $p < 0.001$.

ambulatory venous pressure measurements through the same venipuncture in the foot. The quantitative information provided by the tests allows for grading venous obstruction from mild to severe in hemodynamic terms. In grade I the hemodynamic obstruction pressure criteria for the two tests are normal, and diagnosis primarily depends on Doppler or venographic criteria or both. Venous Doppler was surprisingly sensitive (89%) in this context. Phlebographic signs of previous thrombosis under these circumstances can sometimes be subtle because of excellent resolution/recanalization of the previous thrombosis. However, radiologic features such as irregularities of the vein wall, persistence of collateral channels, presence of residual thrombi in calf veins, or an "empty calf" appearance with the reduction in the calf vein complement provide clues to previous thrombosis.

Nicolaides and Sumner[6] have recently demonstrated excellent correlation between the hemodynamic techniques (arm/foot pressure-reactive hyperemia) and the air plethysmography method in grading venous obstruction. The utility of the hemodynamic tests has been demonstrated in enhancing the diagnostic accuracy of phlebography, as an aid in the selection of patients for venous bypass surgery, and as a follow-up tool in assessing the outcome of such surgery.[1] We have found the tests to be quite useful in following patients with deep venous thrombosis, especially in selecting the strength and duration of anticoagulation based on hemodynamic data obtained (unpublished data). It is clear that both techniques, that is, arm/foot pressure differential and reactive hyperemia pressure increase, must be used in combination to obtain acceptable accuracy, as only one of the two tests is abnormal in 46% (grades II and IV) of limbs. This would result in a high false-negative rate for either test when used alone. In grade IV obstruction, the hyperemia test is paradoxically negative, that is, a significant venous pressure increase is not obtained despite the presence of high-grade obstruction. The reactive hyperemia response was found to be either muted or delayed in these limbs, suggesting the basis for the phenomenon. It is postulated that the severe grade IV obstruction in the venous system results in the fixed venous outflow severely restricting or delaying reactive hyperemia response characterized by increased inflow. The reactive hyperemia response as a physiologic phenomenon is generally considered a powerful and primordial response to temporary ischemia. It was, therefore, a surprising observation that it was diminished in grade IV obstruction. The authors speculate that this observation may be the basis of venous claudication or venous pain or both associated with severe venous obstruction. The classic explanation for venous claudication is ascribed to the elevation of foot venous pressure to supranormal levels with the onset of exercise.[7] We ourselves have not observed such supranormal pressures in chronic venous insufficiency in more than 13 years of venous testing, suggesting that this latter mechanism occurs very rarely, if at all.

Crural obstructions are generally hemodynami-

Fig. 6, A and **B.** A large collateral vessel connecting the profunda femoris and popliteal veins in two different cases. This is frequently seen after femoral vein obstructions **(A).** Occasionally such a connection is present as a congenital anomaly even when the femoral vein is open and unobstructed **(B).** The large bore connection to the popliteal vein may suggest a putative embryologic connection (see text).

cally mild but can occasionally result in grade IV obstruction (Fig. 1). As the hemodynamic severity progresses, pelvic lesions become more dominant in relative distribution; pelvic obstructions can be either hemodynamically mild or severe. Single level lesions were usually shown to be hemodynamically mild, but occasionally resulted in grade IV severity (Fig. 2). Some extensive lesions involving multiple levels on venography were surprisingly mild in hemodynamic terms. The information in Figs. 1 and 2 can be generalized by the statement that neither the anatomic location nor the extent of an obstructive lesion seen on venography is a reliable guide to hemodynamic severity. In addition, no correlation was observed between the size and number of collateral vessels seen on phlebography and the hemodynamic severity of the obstructing lesion. This observation does not repudiate the obvious fact that the extent and degree of collateralization governs the hemodynamic outcome of an obstructing venous lesion, but only indicates that venography is an unreliable tool for assessing the extent and adequacy of collateralization. This point has been amply illustrated previously.[1,8] In this context the practice of performing venous bypass on the basis of venographic appearance without accompanying hemodynamic testing should be decried. Ominous looking lesions can be hemodynamically well compensated despite the phlebographic appearance. A venous bypass performed in the absence of a resting pressure gradient (grades I and II) does little to improve the hemodynamic situation and in the authors' view is unlikely to remain patent in the long term. Venous bypasses performed to relieve high-grade venous obstruction should yield a demonstrable improvement in hemodynamics after operation. The saphenous vein used in Palma bypass may be too small to provide hemodynamic relief in some patients.[3] Long-term arteriovenous fistulas (up to 4 to 6 months) may help to enlarge the saphenous conduit, even though infection of such long-term fistulas remains a potential threat.[3,8]

A constant finding in the presence of femoral obstruction was the association of a collateral vessel arising from the profunda system connecting to the popliteal vein (Fig. 6). In 43% of patients with femoral vein obstruction, this vessel measured more than 4 mm in size. The large bore connection between this collateral channel and the popliteal vein suggests the presence of a putative embryologic connection between the two systems that opens up easily when femoral vein obstruction is encountered. Occasionally, a large connection (presumably congenital) between the profunda femoris and popliteal veins is present even when the femoral vein is open and unobstructed (Fig. 6, *B*). Embryologically, the profunda vein connects to the popliteal vein through the axial vein, which later becomes segmented.

The basis of stasis ulceration as seen in association with venous obstruction is an enigma. The incidence of stasis ulceration is not significantly different between the various grades of obstruction (Table III). The ambulatory venous pressure is not greatly different among the four grades of obstruction, even though postexercise pressure is generally elevated in all of these four groups (Fig. 4). A significant difference in ambulatory venous pressures is observed between ulcerated limbs and those without ulceration when the entire group of venous obstructed limbs is considered. It is more important to note that a significant difference exists within each grade of obstruction between ulcerated and nonulcerated limbs with regard to the presence of associated reflux (Fig. 5). There also appears to be a correlation between ulcer healing and improvement in reflux, as measured by the Valsalva test, after the Linton procedure (Table IV). All healed or improved ulcers showed a significant improvement in this parameter, whereas ulcers that remained unhealed after the Linton procedure showed no improvement. The Linton procedure is a controversial treatment for stasis ulceration because recurrences are high and the procedure has little effect on ambulatory venous pressure.[9,10] It has been pointed out recently that the Valsalva foot venous pressure elevation may be superior to ambulatory venous pressure as an index of venous reflux.[2] The significant improvement in Valsalva foot venous pressure associated with ulcer healing after Linton procedure provides for the first time a hemodynamic rationale for the procedure itself. We initially used the Linton procedure in the presence of venous obstruction with some anxiety lest the obstruction be made worse by disruption of functional perforator collateral vessels. These initial fears proved groundless, however, as the Linton procedure was well tolerated, even in patients with high-grade obstruction, and in none of the patients was the hemodynamic severity of the obstruction exacerbated by the procedure. Thus the Linton procedure may have a role in selected patients with stasis ulceration associated with venous obstruction.

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Submitted Mar. 7, 1991; accepted May 15, 1991.