Evaluation of Methods for Detecting Venous Reflux

Perspectives in Venous Insufficiency

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• **Using 793 limbs with nonobstructive venous reflux, we evaluated a number of techniques used for the assessment of venous reflux. The venous Doppler examination was found to be a reliable screening tool with excellent sensitivity and good specificity. Photoplethysmography was 97% sensitive in patients with ambulatory venous hypertension; however, in milder forms of reflux, it was less sensitive. The major drawback of photoplethysmography was the large number of false-positive results obtained. Ambulatory venous pressure measurement and another pressure-based technique, Valsalva-induced foot venous pressure measurement, defined overlapping but different normal and abnormal limbs. Descending venography, when performed as described by Kistner et al, was found to be a reliable tool to assess reflux with more than a 90% sensitivity. The horizontal technique of performing descending venography and nucleotide descending venographies had unacceptably low sensitivity and were abandoned. Features of venous reflux as outlined by these modern technical tools are described.**

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Ambulatory venous pressure measurement has been the traditional "gold standard" for evaluating venous reflux. More recently, numerous other techniques, such as descending venography and photoplethysmography (PPG), have become popular alternative methods of analyzing venous insufficiency. In addition, it is possible to separate venous reflux more accurately from obstruction such that a more selective and "purer" material is available for analysis of venous reflux.[1] Not surprisingly, the newer technology has yielded newer perspectives. In some areas, such as the relationship between superficial and deep venous insufficiency or the etiologic role of perforator incompetence, it has yielded information contrary to long prevalent beliefs. This article presents an evaluation of several available techniques for detecting venous reflux, with emphasis on descending venography.

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MATERIALS AND METHODS

Materials

From 1978 to 1987 a total of 1421 limbs were screened for suspected chronic venous insufficiency in the Vascular Laboratory of the University of Mississippi Medical Center, Jackson. Of these, 793 limbs were determined to have nonobstructive chronic venous insufficiency based on laboratory examination and hemodynamic techniques previously described to rule out obstruction.[2] Several limbs were hemodynamically classified as "normal," as no abnormalities were detected by the various laboratory techniques. In addition, data from 30 healthy volunteers were also included as part of the control group of normal limbs. This experience forms the basis of this article. Statistical analysis was carried out using the Kruskal-Wallis method of analysis of variance by ranks.[3]

Methods

Clinical Classification.—Severity of venous reflux was graded clinically as recommended by the Committee on Venous Standards.[4]

Doppler Examination.—A detailed Doppler examination of both limbs, with examination of the femoral, popliteal, saphenous and posttibial veins, was carried out with the patient in the supine position.

PPG.—The technique of PPG for venous congestion was carried out as described by Barnes et al.[5] A tourniquet (30 mm Hg) was used below the knee to differentiate superficial from deep incompetence.

Venous Pressure Measurement.—*The Arm-Foot Venous Pressure Differential and Reactive Hyperemia Tests.*—The arm-foot venous pressure differential and reactive hyperemia tests exclude venous obstruction and have been detailed elsewhere.[1,2]

Ambulatory Venous Pressure Measurement.—Pressures in a dorsal vein of the foot were recorded with the patient standing still, followed by manual compression of the calf several times (usually six to 10 compressions) until the pressure reached a plateau and then recovered to levels recorded before simulated exercise. The efficacy of the manual calf compression technique was validated by comparing it with the traditional "toe-stand" technique (see "Results" section).

In the toe-stand technique, instead of manual compressions, the patient was asked to raise the heel repeatedly to exercise the calf muscles actively until the foot venous pressure reached a plateau.

Valsalva-Induced Foot Venous Pressure Elevation.—The pressure in the dorsal vein of the foot was recorded in the supine patient at

Table 1.—Evaluation of Techniques Used to Detect Venous Reflux

Technique Being Evaluated*	Technique Used as Reference ('Gold') Standard for Evaluation*: Descending Venography by Kistner et al[7] n	% Sensitivity	% Specificity	Doppler n	% Sensitivity	% Specificity	AVP RT, <16 s n	% Sensitivity	% Specificity	Valsalva-Induced FVP, >4 mm Hg n	% Sensitivity	% Specificity	Presence of Stasis Ulcer n	% Sensitivity	Strip Test During Surgery n	% Sensitivity
Doppler	208	92	73	...	...	...	360	93	54	360	93	42	87	100	107	89
PPG	208	74	37	814	85	62	389	97	57	315	96	48	87	90	...	...
AVP RT																
<16 s	174	83	77	389	76	81	...	...	...	333	67	73	112	77	...	...
<50% Drop	96	86	78	...	...	...	...	...	...	...	...	...	113	78	...	...
Valsalva-induced FVP, >4 mm Hg	104	74	85	300	86	70	333	66	76	...	...	...	60	87	...	...
Descending venography																
Kistner et al[7]	...	...	...	130	98	89	277	92	60	96	95	45	60	100	107	89
Thomas et al[9]	...	...	...	44	54	89	...	...	...	...	...	...	...	...	...	...
Nucleotide	104	41	71	140	43	74	...	...	...	...	...	...	45	47	...	...

*PPG indicates photoplethysmography; AVP RT, ambulatory venous pressure recovery time; and FVP, foot venous pressure.

rest and with the patient exercising a graduated Valsalva's maneuver to 40 cm of water pressure.[5] The *rise* in foot venous pressure (expressed in millimeters of mercury) with Valsalva's maneuver was the relevant factor for the test.

Ascending Venography.—Ascending venography was performed with the patient in 60° partially erect position with a tourniquet above the patient's ankle.

Descending Venography.—*Descending Venography by Kistner et al.*—Descending venography was performed according to the technique described by Kistner et al.[7] The patient was placed at 60° partially erect position and asked to perform Valsalva's maneuver by blowing against a mercury manometer at 30 to 40 mm Hg. Reflux observed during the Valsalva maneuver was graded according to Kistner's classification as follows: 0, no reflux; 1, reflux of the upper thigh; 2, reflux up to the popliteal; 3, reflux up to the calf veins; or 4, reflux up to the ankle. A different classification[8] based on the number and level of venous systems involved was also evaluated. In the latter method, reflux was classified as involving single level/single system, single level/multiple systems, or multiple level/multiple systems.

Descending Venography by Thomas et al.—In 44 limbs, a supine technique of descending venography recently described by Thomas et al[9] was also evaluated. Reflux was monitored and filmed while the patient executed a Valsalva maneuver in the horizontal position.

Nucleotide Descending Venography.—Technetium Tc 99m albumin colloid was injected via a femoral vein catheter. The technique for eliciting reflux and gradation was similar to that employed for descending venography.

Strip Test for Reflux During Surgery.—The presence of valve reflux can be detected during surgery by performing a strip test.[6] A bulldog clamp is placed on the vein 3 to 4 cms below the valve. Tributaries draining into this segment are either ligated or controlled by silk loops. The venous segment between the valve and the clamp is digitally stripped empty and refilling is observed. A competent valve will prevent retrograde refilling of the emptied venous segment. Reverse Trendelenberg's position of the patient during the maneuver is helpful.

RESULTS

Evaluation of Techniques

The sensitivity and specificity varied according to the "gold standard" utilized for comparison. When stasis ulceration was utilized as a "gold standard" (Table 1), all of the techniques not surprisingly exhibited good to excellent sensitivity. Because stasis ulceration was always associated with reflux, specificity data are lacking under this column. Of course, venous reflux can be present in a milder form without stasis ulceration. A number of techniques, including Doppler, descending venography, ambulatory venous pressure, and Valsalva-induced foot venous pressure elevation, are usable techniques in this context. Unfortunately, there is no agreement as to which of these can be considered a "gold standard." Almost all suffer from shortcomings (see "Comment" section). Table 1, therefore, provides a measure of accuracy for a given technique when a variety of other techniques are used as a "gold standard." For such a comparison, both the technique being evaluated and the referenced "gold standard" should have been performed on the refluxive limb. For a variety of technical and nontechnical reasons, not all techniques were performed on every limb evaluated in the laboratory. The number of limbs tested, therefore, has varied for the various comparisons detailed in Table 1. The number of limbs tested are shown under *n* for calculating sensitivity and specificity data for a given technique.

Doppler Examination.—The Doppler examination was sensitive irrespective of the reference standard used for comparison. The Doppler examination can detect reflux even at a single valve level. Reflux may not become hemodynamically important until multiple valve sites become refluxive. The Doppler examination, therefore, can be considered a highly sensitive technique for detection of even early disease.

PPG.—Photoplethysmography was moderately sensitive when compared with descending venography or Doppler examination. Sensitivity was excellent when tested in patients with abnormal pressure measurements, but PPG had a uniformly low specificity, regardless of the reference standard used. A normal PPG test, therefore, generally signifies the absence of advanced reflux with pressure changes. The number of false-positive results in "normal" limbs is high, and this test may miss a number of limbs with minor forms of reflux.

Table 2.—Clinical Severity of Venous Insufficiency* and Associated Hemodynamics (Mean ± SD)

	PPG RT, s†	AVP†		Valsalva-Induced FVP, mm Hg
		% Drop	RT, s	
Class I (n)	9.6 ± 4.2 (48)	36 ± 12 (23)	15 ± 3.4 (41)	4.9 ± 3.3 (35)
III (n)	7.0 ± 4.9 (84)	28 ± 9 (49)	10.5 ± 5.5 (68)	7.9 ± 4.9 (60)
P	NS	NS	<.002	<.1

*Classification by Venous Standards Committee.[4]
†PPG indicates photoplethysmography; RT, recovery time; AVP, ambulatory venous pressure; FVP, foot venous pressure.

For these reasons, perhaps it should not be used as the sole screening device in the vascular laboratory.

Ambulatory Venous Pressure Measurement.—The manual calf compression technique was compared with the traditional toe-stand technique in 44 limbs. No difference was seen in the mean recovery time (15 vs 15 seconds, respectively). Variations in mean postexercise pressure were less than 6 mm Hg (50 vs 56 mm Hg for manual compression and toe stands, respectively). The manual calf compression avoided difficulties with patient cooperation and eliminated exercise-induced reactive hyperemia, sometimes seen with the traditional toe-stand technique.

Compared with descending venography, ambulatory venous pressure (recovery times, <16 seconds) was 83% sensitive. Sensitivity of postexercise pressure drop (<50%) was slightly better. Ambulatory venous pressure was somewhat less sensitive when compared with venous Doppler examination, probably because reflux at multiple valve sites is required for the generation of abnormal ambulatory venous pressure. A small, but significant, percentage of patients with stasis ulceration have "normal" ambulatory venous pressure measurements.[6]

Tourniquet Test to Differentiate Superficial from Deep Reflux.—In 14 limbs (11%) of 124, a below-the-knee tourniquet completely normalized ambulatory venous pressure recovery times, suggesting "pure" superficial disease. In 12 of these 14 limbs, descending venography was performed and showed reflux in the deep system.

In another group of limbs (n = 66), the tourniquet test showed significant (>3 seconds) improvement of ambulatory venous pressure recovery times in 18 limbs, suggesting combined superficial and deep disease. In 11 (61%) of these 18, combined disease was confirmed on descending venography. Superficial (saphenous) reflux was not found in the remaining seven limbs (39%) on descending venography. In 48 limbs, tourniquet application resulted in no change in ambulatory recovery times. However, 13 of these limbs had significant saphenous (and deep) reflux on descending venography, apparently missed by the tourniquet test (false-negative results of 27%). These data suggest that the tourniquet method may be unreliable in separating superficial from deep disease.

Valsalva-Induced Foot Venous Pressure.—The technique was highly reproducible. The coefficient of variation on repeated tests was 4% (n = 27). Mean (± SD) Valsalva-induced foot venous pressure in normal limbs was 2.9 ± 1.1 mm Hg (n = 24). In refluxive limbs, a mean value of 7.9 ± 5.1 mm Hg (n = 63) was obtained. This difference was significant ($P<.0001$). Patients with stasis symptoms undergoing valve reconstruction had somewhat higher values (9.2 ± 5.3 mm Hg, n = 41) which significantly improved after surgery (4.2 ± 2.5 mm Hg, n = 41; $P<.004$ vs preoperative values). The technique is highly sensitive in stasis ulceration (Table 1) and only 3% of the patients were asymptomatic in the presence of an abnormal test (n = 168). It was roughly similar to ambulatory venous pressure measurements in sensitivity and specificity values. However, the two techniques apparently define slightly different normal and abnormal populations. Each technique is abnormal only about two thirds (66% to 67%) of the time when the other technique is abnormal. A normal reading by each technique is obtained in only about three fourths (73% to 76%) of the limbs so tagged by the other technique (Table 1). This indicates that related, but different, values are being measured by the two pressure-based techniques.

Strip Test to Detect Valve Reflux During Surgery.—Only 89% of the patients determined to have reflux preoperatively by detailed studies, including the Doppler examination and descending venography, demonstrated valve insufficiency by the strip testing intraoperatively. In the other 11% of patients, the vein undergoes contraction from surgical manipulation. Contraction of the valve ring by this mechanism results in intraoperative valve competence.[6]

HEMODYNAMIC BASIS FOR CLINICAL GRADATION OF REFLUX

Table 2 shows the correlation between gradations of clinical severity (recommended by the Committee on Venous Standards[4]) and the corresponding PPG, Valsalva-induced foot venous pressure, the ambulatory venous pressure test results. Photoplethysmography, a qualitative test, shows little gradation with increasing clinical manifestation of disease. Such a gradation seems to be present with the other two pressure-based, semiquantitative techniques. Postexercise pressure drop (percentage) did not show a significant difference even though a suggestive trend was present. Despite the presence of an abnormal test indicating venous reflux, 8%, 13%, 5%, and 3% of limbs tested by Doppler, PPG, ambulatory venous pressure, and Valsalva foot venous pressure techniques, respectively, were clinically asymptomatic.

Ascending Venography: Calf Varicosities

The presence of calf varicosities on ascending venograms was often noted by the interpreting radiologist. The presence of calf varicosities (n = 77) was associated 100% with deep venous disease on descending venography. Seventy-four of 77 of these limbs also had ambulatory venous hypertension. *Therefore, calf varicosities are a sign of deep valve disease.*

Descending Venography

The sensitivity of descending venography in detecting valvular reflux was excellent when compared with other techniques, including direct observation (strip test) at the time of surgery (Table 1). Descending venography was also specific using the venous Doppler examination as the reference standard. Specificity of descending venography was low when ambulatory venous pressure or Valsalva-induced foot venous pressure was used as the reference. This is a reflection of the fact that descending venography is sensitive to even milder

forms of venous reflux, whereas ambulatory venous pressure and Valsalva-induced foot venous pressure become abnormal only with more extensive disease.

The Horizontal Technique for Descending Venography

Descending venography when performed in the horizontal position as described by Thomas et al[9] was poorly sensitive (54%) with venous Doppler as the reference standard. The specificity was 89%. Because of the high false-negative rate (46%), it has since been abandoned.

Bilaterality

Reflux is predominantly bilateral. This is emphasized by the detection of bilaterality by various techniques, including descending venography (Table 3).

Superficial and Deep Venous Insufficiency

From descending venography, venous reflux can be identified as "pure," superficial (saphenous reflux only), pure deep reflux, or a combination (saphenous plus deep veins). The incidence of pure superficial reflux is diminutive (<1% [1/232]). Deep reflux either alone (71% [164/232]) or in combination with superficial reflux (29% [67/232]) was the predominant pathologic feature.

HEMODYNAMIC BASIS FOR GRADING REFLUX BY DESCENDING VENOGRAPHY

Reflux detected by descending venography was examined by two methods of classification: the Kistner classification[7] (based on the distal extent of reflux) and our classification[8] (based on the number of venous systems involved in reflux).

Table 3.—Incidence of Bilaterality of Venous Reflux

Technique Used as Reference*	n	% of Reflux	
		Bilateral	Unilateral
Descending venography	96	91	9
AVP RT	76	95	5
Valsalva-Induced FVP	54	85	15
Doppler	562	89	11

*AVP RT indicates ambulatory venous pressure recovery time, and FVP, foot venous pressure.

Hemodynamic data and stasis ulcer incidence for these two systems of classification are given in Table 4. There is little correlation between hemodynamic values and the distal extent of reflux (Kistner classification). The other classification based on the number of venous systems involved in reflux was somewhat better in this regard; as more systems become refluxive, hemodynamic abnormality and stasis ulcer incidence correspondingly increased.

NUCLEOTIDE DESCENDING VENOGRAPHY

Nucleotide descending venography was originally introduced by us in the hope that the isobaric medium would eliminate artifactual reflux from downward streaming suspected to occur with hyperbaric contrast. The sensitivity and specificity of nucleotide descending venography were poor as compared with contrast descending venography or Doppler examination (Table 1). Nucleotide descending venography has also been abandoned.

COMMENT

As yet, there is no single "perfect" technique to assess venous reflux. The venous Doppler examination is, indeed, a reliable screening tool, but is qualitative and highly subjective. Even in experienced hands, reflux in closely proximate veins, such as the short saphenous and popliteal, may be confused with each other. Duplex scanners incorporating color-coded Doppler scans may solve most of these deficiencies. A scientific evaluation of this exciting new technique as compared with older techniques is awaited. Photoplethysmography has become popular because of its simplicity and totally noninvasive nature. However, it is moderately sensitive compared with descending venography and has a high false-positive rate compared with almost all other techniques in use.

Ambulatory venous pressure, even though considered the traditional "gold standard," cannot by itself differentiate obstruction from reflux or a combination of the two. In general, a correlation exists (Tables 2 and 4) between reflux hemodynamic disturbance and stasis changes in the skin. However, there is a wide range in these values and other factors, such as velocity of reflux, local tissue status, and variations in regional and local venous congestion, as suggested by Melville Williams, MD (oral communication, November 12, 1987), may be equally pertinent. In an analysis detailed elsewhere,[6] it was

Table 4.—Descending Venography: Classification and Associated Hemodynamics*

Classification	PPG/s	AVP		Valsalva-Induced FVP	Stasis Ulcer Incidence, %
		With Tourniquet RT, s	% Drop		
Venous system involved (n)					
Single level/single system	10.1 (25)	13.5 (20)	42.2 [1] (19)	3.4 [1] (14)	24 [1]
Single level/multiple system	10.3 (56)	14.1 (47)	34.9 [2] (44)	6.4 [2] (42)	52 [2]
Multiple level/multiple system	11.8 (105)	13.2 (85)	33.5 [3] (87)	6.3 [3] (7)	92 [3]
P	...	...	[1&2], [1&3]†	[1&2], [1&3]†	[1&2], [1&3]†
Kistner et al[7] classification, grade (n)					
1	8.1 [1] (24)	13.4 (17)	36.0 (18)	5.9 (16)	14
2	11.4 [2] (60)	14.1 (53)	38.0 (46)	6.2 (41)	41
3	11.5 [2] (60)	13.4 (54)	34.3 (50)	5.4 (39)	55
4	11.4 [2] (30)	11.6 (21)	34.7 (21)	7.7 (19)	27
P	[1&2]	NS	NS	NS	...

*PPG indicates photoplethysmography; AVP, ambulatory venous pressure; and FVP, foot venous pressure.
†Indicates significant.

shown that there was significant incidence of stasis ulceration even when postexercise pressures were below 50 mm Hg. Not surprisingly, the successful results of valve reconstruction have not correlated well with ambulatory venous pressure measurements postoperatively.[6]

Valsalva-induced foot venous pressure seems to correlate well with symptoms and seems to be especially sensitive to multivalvular venous reflux, which is most commonly associated with stasis ulceration.[6] It has proved to be a more reliable tool than ambulatory venous pressure for assessing the outcome of valve reconstruction surgery. Even though considerable overlap is present, Valsalva-induced foot venous pressure seems to define a population (both "normal" and "abnormal") somewhat different from ambulatory venous pressure measurement.

Descending venography has been practiced for some decades, but the technique has varied and has been subject to numerous artifactual and interpretational errors. Kistner et al[7] have standardized the technique and emphasized that reflux is significant only if it is present with the patient performing Valsalva's maneuver at a 60°-erect position. This point is amply underscored by our poor experience with the horizontal Valsalva technique for descending venography. The method described by Kistner et al seems to have eliminated most of the previous difficulties and is reliable if performed as they described. It is, however, deficient in infrafemoral disease in the presence of a competent femoral valve, as the dye is introduced into the system above the femoral valve. Thus, popliteal valve reflux below a functional femoral valve will be missed by this technique. Color-coded Doppler scan may be more precise in detecting such regional reflux. It remains to be seen whether the favorable expectations for this new modality are proved by the experience being gathered by many centers.

Nucleotide descending venography was introduced by one of us (S.R.)[10] in the hope of avoiding some of the streaming artifactual errors sometimes obtained with descending venography. It was expected that the isobaric nature of the nucleotide medium would avoid this difficulty. Because of unacceptably low sensitivity, the technique has been abandoned.

There is extensive literature on reflux venous insufficiency, some dating back to the early part of the century. Much of the case material invariably includes postthrombotic limbs with recanalization. Because reliable hemodynamic techniques to detect obstruction were not available, it seems highly likely the material consisted of a mixture of obstruction, reflux, and a combination. The material presented herein consists only of limbs with refluxive pathologic features. Examination of this material with multiple techniques, including liberal use of descending venography, allows the characterization of venous reflux in general terms. This perspective is different from the traditional view in several significant aspects. The major points may be summarized as follows: venous reflux is predominantly bilateral and the major etiological mechanism is cryptogenic in origin. Postthrombotic reflux is probably not the predominant cause and likely represents a minority of cases selected for pure reflux as outlined. Reflux overwhelmingly involves the deep system, which seems to be the basis for symptoms of pain, swelling, and ulceration. Combined superficial and deep reflux occurs in approximately one third of these patients (29% in this series). Isolated superficial (saphenous) venous reflux is distinctly uncommon, the incidence being less than 1% in this study. There seems to be a rough correlation between venous hypertension and stasis symptoms. There is a large SD, however, suggesting that factors other than venous hypertension play a part in the generation of symptoms. Patients with symptoms commonly have multiple valves at multiple levels involved in reflux (58% in this series). Even when reflux is confined to the thigh, stasis symptoms, including ulceration, can occur when multiple systems, ie, saphenous, superficial femoral, and profunda, become refluxive. The hemodynamic severity of reflux seems to correlate with the increasing number of venous systems that become refluxive. There is a high incidence (73%) of perforator incompetence in symptomatic limbs. Of these, 97% were of the secondary variety associated with deep valve reflux. Primary perforator incompetence could be identified in only 3% of these limbs. The presence of prominent calf varicosities noted on ascending venography usually accompanies the presence of deep valve reflux.

The small incidence of pure superficial reflux (confined to the saphenous system only) as determined by descending venography in this series is in stark contrast to the much higher incidence generally reported in the literature utilizing the tourniquet method to differentiate superficial from deep reflux. In our laboratory, there was poor correlation between the two techniques. Significant false-positive and false-negative results occurred when the tourniquet technique was compared with descending venography. This needs further clarification as this issue has important theoretical implications regarding the etiology of superficial varicosities and its relationship to deep venous reflux.

For screening purposes the venous Doppler examination (preferably Duplex scanner) seems to be superior to PPG. In symptomatic patients requiring therapy, pressure studies as outlined are indicated to assess hemodynamic severity and to rule out the presence of obstruction. All three of the described pressure studies (arm-foot venous pressure differential, ambulatory venous pressure, Valsalva-induced foot venous pressure elevations) can be carried out at a single sitting using the same venipuncture in the foot. Until the utility of Duplex scanners becomes more fully established, descending venography (Kistner's technique) remains the standard in assessing patients for valve reconstruction surgery.

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