New approaches to the diagnosis and treatment of venous obstruction

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Diagnosis of chronic venous obstruction has hitherto depended on phlebographic assessment alone. The pitfalls in this method are noted and two simple hemodynamic techniques for measurement of venous obstruction are described. The techniques are easily performed, have a high degree of sensitivity and specificity, and are particularly useful in assessing various therapeutic approaches to venous obstruction. Our experience with a variety of surgical procedures for venous obstruction is described. Two such new procedures, primary arteriovenous fistula and perforator bypass for peripheral venous obstruction, are described in detail. (J VASC SURG 1986; 4:42-54.)

Despite increasing interest in reconstructive venous surgery, a large number of patients in many clinics still languish under diffuse diagnostic labels such as "venous stasis ulceration" and "postphlebitic syndrome" without the benefit of further diagnostic evaluation. This situation is in part due to the lack of easily applicable diagnostic techniques to investigate venous dysfunction and in part to the perceived poor results of a surgical approach to these patients. The absence of suitable investigative techniques is particularly noticeable in chronic venous obstruction. Ambulatory venous pressure measurements and photoplethysmography are useful in venous reflux disease but are not helpful in venous obstruction beyond establishing the presence of venous hypertension. Ascending phlebography is usually required to establish the presence of obstructive venous disease. Unfortunately, the latter is an anatomic, not hemodynamic, technique and thus is prone to misinterpretation, especially if used as the sole basis for therapeutic decisions. For example, patients with demonstrated phlebographic obstruction may have normal hemodynamic function because of profuse collateralization. Conversely, we have seen patients with patent but recanalized main venous channels, which are well visualized with phlebography, demonstrate significant hemodynamic abnormality because of residual obstruction. A hemodynamic technique is clearly necessary for precise quantification of obstruction, for therapeutic decisions with regard to surgical correction, and for objective follow-up of these patients in the postoperative period. Hemodynamic techniques developed in our laboratory and currently in use for these procedures are detailed herein. Several new surgical approaches to the difficult problem of venous obstruction are also described, with preliminary results.

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MATERIAL AND METHODS

Hemodynamic techniques

A complete Doppler venous examination was performed as described previously.[1] A standard ambulatory venous pressure study was also part of the evaluation to establish the presence of ambulatory venous hypertension. In addition, the following two techniques specific for venous obstruction were performed.

Arm/foot venous pressure differential. With the patient in the supine position, venous pressures in the dorsum of the foot and hand were simultaneously measured through venous transducers and recorded.

Foot venous pressure elevation with reactive hyperemia. Through the same venipuncture in the foot used for the previous measurement, resting venous pressure was recorded on a strip chart. Inflow occlusion with a thigh cuff pumped to 300 mm Hg was maintained for 3 minutes and released. It was important to prevent blockage of the venipuncture needle by reflux of blood during this phase of the procedure. After release of the thigh cuff, the foot venous pressure changes induced by the reactive hyperemia were dynamically monitored on the strip chart. After an initial rise, the curve stabilized at a higher level of the initial resting pressure. The differences were recorded in millimeters of mercury. Since the presence of an abnormal arm/foot venous pressure differential appeared to influence the foot venous pressure elevation induced by reactive hyperemia, the two techniques should always be performed and evaluated in conjunction with each other.

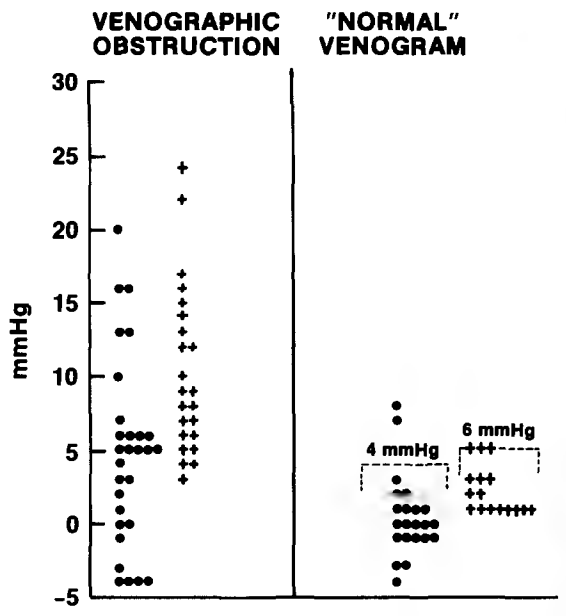

Fig. 1. Differential of arm/foot venous pressure and increment of foot venous pressure induced by reactive hyperemia in group of patients whose phlebograms were normal or showed venous obstruction. Note higher arm venous pressure in a few patients with negative arm/foot venous pressure differential. *Closed circle* = arm/foot differential; *plus sign* = reactive hyperemia increment.

Fig. 2. Patient with previous inferior vena cava ligation had developed large collaterals, some as large as vena cava itself. But he was hemodynamically obstructed, nevertheless. (Arm/foot venous pressure differential, 6 mm Hg; reactive hyperemia, 8 mm Hg elevation in venous pressure.)

Validation of the hemodynamic techniques. The validity of these hemodynamic techniques was established by comparing their results in a group of phlebographically normal control subjects and a group of patients with proven phlebographic obstruction. Some, but not all, of the patients in the latter group underwent surgical correction and are thus included in the Surgical Case Material section.

Arm/foot venous pressure differential in phlebographically "normal" and obstructed patients is shown in Fig. 1. The foot venous pressure was often lower than that of the arm in several patients, yielding a negative differential. A positive differential of less than 4 mm Hg was considered to be within normal limits. A higher differential was present in approximately 50% of patients with obstruction seen with phlebography. The remainder had apparently adequate collateralization at rest, yielding a normal differential at rest. A reactive hyperemia test was required to evaluate the adequacy of these venous collateral pathways during periods of increased flow.

Foot venous pressure elevation induced by reactive hyperemia from resting levels is shown for normal as well as phlebographically obstructed patients in Fig. 1. A venous pressure increment of up to 6 mm Hg was obtained in normal controls. Therefore, a value of 6 mm Hg or above was considered abnormal. Patients with phlebographically demonstrated obstruction showed four types of response to reactive hyperemia, which was related to the prevailing arm/foot venous pressure differential, as well as to the extent of collateralization (Table I). Two patients had a normal arm/foot venous pressure differential and reactive hyperemia–induced venous pressure increment. These patients had normal hemodynamic function, despite phlebographically demonstrated obstruction, because of adequate collateralization. A second group of patients with phlebographic obstruction had normal arm/foot venous pressure differential but an abnormal reactive hyperemia response, indicating the presence of collaterals that were adequate at rest but were insufficient during states of increased flow. The next gradation of venous obstruction was seen in a few patients who had an abnormal arm/foot venous pressure differential at rest but also had an abnormal reactive hyperemia response. Finally, the most serious hemodynamic situation was seen in a few patients in whom the resting foot venous pressure was high, but the reactive hyperemia-induced venous pressure increase was absent, indicating total decompensation even at rest. Therefore, a pattern of increasing hemodynamic severity from fully compensated to total decompensation with partial stages in between could be perceived. Since an abnormal venous pressure increment induced by reactive hyperemia could be absent at

Table I. Varying degrees of severity of venous obstruction

Grade of venous obstruction	*No. of patients*	*Arm/foot venous pressure differential**	*Reactive hyperemia–induced venous pressure elevation†*
Grade I Fully compensated	2	–	–
Grade II Partially compensated	8	–	+
Grade III Partially decompensated	8	+	+
Grade IV Total decompensation	3	+	–

*Plus sign = greater than 4 mm Hg.
†Plus sign = greater than 6 mm Hg. For details see text.

Table II. Diagnostic accuracy of techniques used to detect venous obstruction

	*Arm/foot venous pressure differential** (%)	*Reactive hyperemia venous pressure elevation†* (%)	*Both techniques combined* (%)	*Doppler examinations‡* (%)
Sensitivity	65	80	90	84
Specificity	91	96	93	79
Positive predictive value	89	94	95	76
Negative predictive value	91	85	94	86

NOTE: Twenty limbs had phlebographically demonstrated obstruction and 24 limbs had normal phlebograms.
*Obstruction = greater than 4 mm Hg.
†Obstruction = greater than 6 mm Hg.
‡Data available for only 19 limbs with phlebographically demonstrated obstruction and 24 normal limbs.

either end of the spectrum, it was important to interpret this technique in conjunction with arm/foot venous pressure differentials, which helped to clarify these extremes of hemodynamic severity.

The sensitivity and specificity data for these techniques in a group of normal persons and patients with phlebographically demonstrated obstruction are presented in Table II. Comparable data for the Doppler method in the same group of subjects are also shown.

Surgical case material

The current report comprises 28 cases of venous obstruction proved by phlebography, evaluated by hemodynamic techniques described, and treated by a variety of surgical methods to relieve obstruction. In one case bilateral venous obstruction was treated. In three cases second surgical procedures were carried out on a single limb after the first procedure had failed. Consequently, the case material represents 26 limbs with venous obstruction in 25 patients. A total of 28 surgical procedures were carried out. The latter figure was used for various data calculations presented in this report. Follow-up hemodynamic data and postoperative phlebographic assessment on a selective basis were available for evaluation. The cause of the obstructive venous disease was presumed to be occlusive deep venous thrombosis in 25 instances, iliac vein web occlusion of uncertain origin in two instances, and previous gunshot injury in one instance. The primary indication for operation was pain in only 1 of 28 cases, skin ulceration and stasis dermatitis in 14 cases, and swelling in 13 cases. Patients in this group often had a combination of symptoms of pain, ulceration, and swelling.

Diagnosis of venous obstruction was often suspected during Doppler and venous pressure examinations in the laboratory before phlebography. Phlebography was carried out before operation, in all instances, to confirm the diagnosis, delineate the anatomy, and choose the appropriate surgical procedure. On the basis of phlebographic appearance, 19 of the 28 cases were judged to have segmental venous occlusion and nine others to have venous occlusion at multiple sites. In one case in this series, bilateral venous occlusion was present (multiple level in both sides). Fifteen of the 19 segmental venous occlusions involved the iliofemoral venous segment with occasional extension to the vena cava. In one of these (Fig. 2), the occlusive process extended on to the inferior vena cava, because of prior vena cava ligation. The remaining 4 of 19 segmental occlusions involved the popliteal and/or adjoining posterior tibial vein. The nine limbs with multilevel disease had

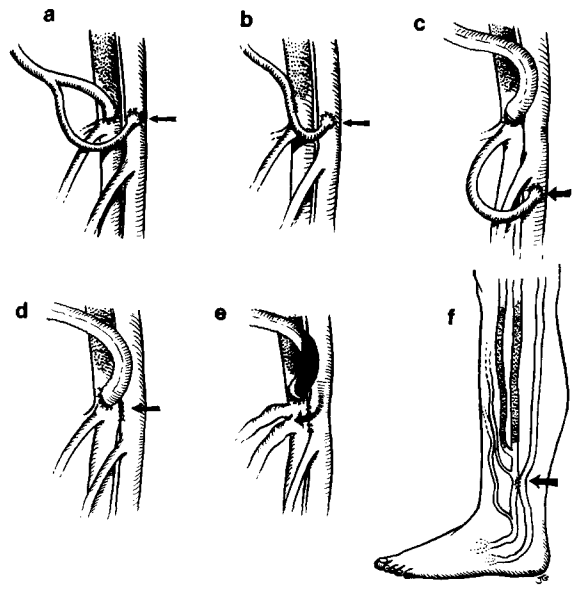

Fig. 3. Differing types of arteriovenous fistula *(arrow)* used. Branch of saphenous crossover graft used for fistulization *(a)*; end of crossover graft to artery fistula *(b)*; end-to-side saphenous femoral fistula in prosthetic bypass *(c)*; side-to-side fistula in prosthetic bypass *(d)*. When the prosthetic bypass became occluded, the fistula was allowed to persist to dilate existing venous collaterals *(e)*; peripheral arteriovenous fistula used as primary procedure to dilate collaterals in presence of obliterated deep venous system *(f)*.

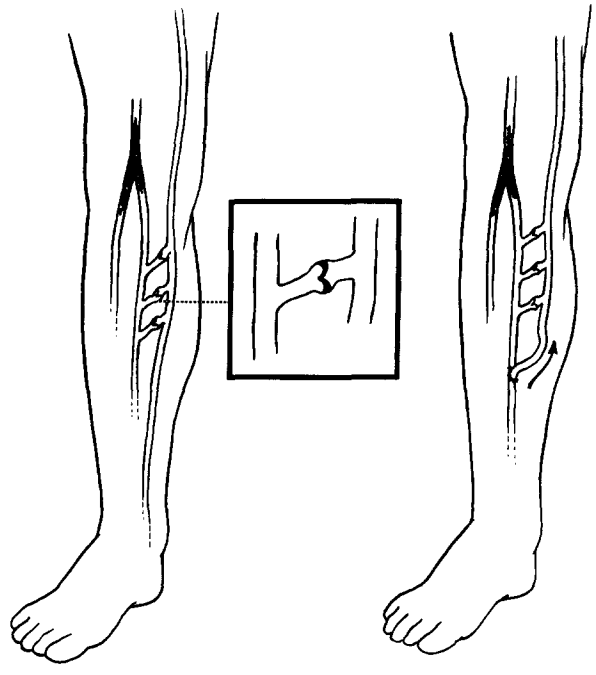

Fig. 4. Dilated perforator collaterals in presence of tibiopopliteal venous obstruction. Collateral flow is inefficient, as it is impeded by valves *(inset)*. Saphenotibial anastomosis bypasses inefficient collaterals (perforator bypass).

the following distribution: iliofemoral venous segment and superficial femoral vein in the thigh, four limbs; iliofemoral venous segment and popliteal vein, one limb; and superficial femoral vein in the thigh with popliteal and calf vein involvement, four limbs.

Hemodynamic classification. Preoperative hemodynamic data were available in 21 of 28 cases. Arm/foot venous pressure differential and/or reactive hyperemia was diagnostic for venous obstruction in 20 of these 21 cases (95% sensitivity). In contrast, Doppler examination suggested obstruction in only 21 of 27 cases examined with this technique (78% sensitivity). Because the technique of reactive hyperemia was introduced later than the measurement of arm/foot venous pressure differential, both measurements were available in only 15 of these 28 cases. According to the classification described in Table I, these 15 cases were distributed as follows: grade I, one; grade II, six; grade III, six; and grade IV, two.

Choice of surgical procedure. The choice of a particular type of operation was strongly dictated by phlebographic findings. With proximal disease involving the vena cava, iliac vein, or the common femoral vein, either the Dale procedure or bypass graft with externally supported Gore-Tex was considered. Normal contralateral venous outflow was essential to perform the Dale procedure. In instances of bilateral disease, the externally supported Gore-Tex bypass was the most appropriate bypass to be considered. In two instances before the externally supported Gore-Tex became available, a primary arteriovenous (AV) fistula at the midthigh level was performed. In 10 instances of popliteal and infrapopliteal disease, the initial choice was peripheral AV fistula (primary AV fistula) to dilate existing venous collateral pathways. More recently, the preference has been to perform the perforator bypass (three cases). In the two instances of iliac web obstruction, primary resection of the web was carried out.

Surgical techniques

Dale procedure. The saphenous vein from the unobstructed limb with an intact saphenofemoral junction was used as a crossover femorofemoral venous bypass. The technique was as described previously by Dale,[2] except that an adjunctive AV fistula was used.[3]

Reinforced polytetrafluoroethylene (Gore-Tex) venous bypass. The vena cava at the confluence of common iliac veins was exposed through a ret-

Table III. Demographic and hemodynamic data, surgical procedure and outcome

Patient	*Age/sex (yr)*	*Symptoms, duration*	*Site of obstruction seen on phlebogram*	*Hemodynamics* (*Arm/foot pressure differential* / *Reactive hyperemia pressure elevation*) *Preop*	*Early postop (<3 mo)*	*Late postop (3-6 mo)*	*Duration of follow-up (yr)*
Dale procedure (8 cases)							
J.N.	24/F	Ulcer, swelling; 10 yr	Ileofemoral and popliteal	N.D.	N.D.	N.D.	2.4
V.P.	41/F	Swelling, pain; 5 yr	Iliac vein	N.D.	1 / N.D.	0 / N.D.	3
B.W.	46/F	Swelling, pain; 3 yr	Iliac vein and SF vein	N.D.	N.D.	N.D.	2
M.W.	44/F	Swelling, pain; 5 yr	Iliac vein	0 / N.D.	2 / N.D.	1 / 3	2
M.H.	34/M	Ulcer, swelling, and pain; 4 yr	Iliac vein	26 / N.D.	5 / N.D.	N.D. / N.D.	1
M.M.	38/F	Swelling, pain; 5 yr	Ileofemoral segment	10 / N.D.	5 / N.D.	5 / 5	2
A.B.	53/F	Ulcer, swelling, and pain; 4 yr	Iliac vein	0 / N.D.	0 / 3	0 / N.D.	3
V.H.	54/F	Swelling, pain; 8 yr	Iliac vein	14 / N.D.	19† / N.D.	1 / N.D.	2.8
Iliac web resection (2 cases)							
M.H.	51/F	Swelling, pain; 5 yr	Iliac vein	5 / 2.5	1 / 4	N.D. / N.D.	1.6
A.W.	28/F	Swelling, pain; 3 yr	Iliac vein	N.D.	N.D.	N.D.	2
Stented Gore-Tex (8 cases)							
S.P.	35/F	Swelling, pain; 2 yr	Ileofemoral segment	3 / 9	0 / 0	0 / 3	2
M.M.	40/F	Swelling, pain; 7 yr	Iliac vein	5 / 8	0 / 2	4 / 8	2.5
M.C.	37/F	Ulcer, swelling, pain; 2 yr	Ileofemoral segment	6 / 8	14† / 4	N.D.	1.2
C.A.	42/M	Ulcer, swelling, pain; 2 yr	Ileofemoral segment	7 / 17	0 / 3	6 / 12	1
E.T.	42/F	Ulcer, swelling; 2 yr	Iliac vein, extending to vena cava also	0 / 4	0 / 10	0 / N.D.	1.5
M.M.	35/M	Swelling, pain; 2 yr	Ileofemoral segment	5 / 6	0 / 2	4 / 8	1.6
J.C.	32/M	Ulcer, swelling, pain; 5 yr	Iliac vein and SF vein	1 / 6	N.D.	N.D.	1.4
C.J.	41/M	Ulcer, swelling, pain; 5 yr	Vena cava–iliac vein segment and left SF vein	5 / 9	2 / N.D.	0 / 1	2
Primary AV fistula (7 cases)							
M.C.	29/M	Ulcer, pain; 5 yr	Popliteal and SF	4 / 4	N.D.	N.D.	1

N.D. = not done; AV = arteriovenous; SF = superficial femoral.
*Determined by phlebographic or hemodynamic method.
†AV fistula effect.

Postop phlebogram and date	*Current patency* and postop symptoms*	*Fate of primary/secondary AV fistula*	*Comments/complications*
Bypass occluded 2.3 yrs; recanalization of iliac vein	Occluded; recurrence of ulcer	Surgical closure	Noncompliant patient
Bypass open at 2 yr	Open; swelling, pain better but residual symptoms with open bypass	Surgical closure	—
N.D.	Occluded; transient improvement for 3 mo, then recurrence of symptoms	Surgical closure	—
Bypass occluded at 2 yr with collaterals	Occluded; marked relief of symptoms for 4 mo then recurrence	Spontaneous closure at 3 mo	—
Bypass occluded at 6 mo; collaterals decreased	Occluded; moderate symptom relief for 3 mo, then gradual recurrence	Surgical closure	—
Bypass occluded at 2 yr	Occluded; marked relief for 3 mo, then gradual recurrence	Surgical closure	Later underwent stented Gore-Tex bypass
N.D.	Open; near total symptom relief; occasional swelling	Surgical closure	
N.D.	Open; near total symptom relief	Surgical closure	AV fistula open
N.D.	Open; marked improvement in swelling		
N.D.	Probably closed; recurrence of symptoms after 3 mo		
Open 1 mo postop	Open; total symptom relief; working, skiing	Still open	
N.D.	Closed at 6 mo; recurrence of symptoms	Spontaneous closure	Retroperitoneal hematoma from anticoagulation requiring exploration, mild compression, neuropathy
Open at 4 mo by CT scan with contrast	Open; ulcer did not heal until AV fistula closed 4 mo postop; total symptom relief; working full time	Surgical closure	With AV fistula
Closed 1 mo postop	Occluded; symptoms unchanged from preop	Spontaneous closure	
Open 3 mo; closed 1 yr	Occluded; ulcer initially healed with symptom relief	Spontaneous closure	Superficial wound infection
Open 3 mo	Occluded; relief of symptoms for 6 mo, then recurrence	Surgical closure	
Open 5 mo	Occluded 6 mo with recurrence of ulcer	Surgical closure	Superficial wound infection
Open 1 mo	Occluded 6 mo with recurrence of ulcer after initial healing	Spontaneous closure	Bilateral procedure; other limb asymptomatic; amputation required for left ulcer at 2 yr
Occluded at 8 mo	Occluded at 6 mo with recurrence of pain; ulcer never healed	Spontaneous closure	Later underwent perforator bypass

Continued on p. 48

Table III. Cont'd.

Patient	*Age/sex (yr)*	*Symptoms, duration*	*Site of obstruction seen on phlebogram*	*Hemodynamics: Arm/foot pressure differential / Reactive hyperemia pressure elevation* — *Preop*	*Early postop (<3 mo)*	*Late postop (3-6 mo)*	*Duration of follow-up (yr)*
Primary AV fistula cont'd.							
M.U.	36/F	Ulcer, swelling; 4 yr	Popliteal	6 / 0	N.D. / N.D.	16 / 3	1.3
A.P.	39/M	Swelling, pain; 1 yr	Popliteal and femoral	0 / 12	0 / 2	0 / 2	2
C.L.	57/F	Ulcer, pain; 1.5 yr	Popliteal	6 / N.D.	N.D. / N.D.	0 / 9	2
P.B.	54/F	Swelling, pain; 10 yr	Iliac vein and SF vein	5 / 24	1 / 24	4 / 8	2
E.L.	50/M	Ulcer, swelling; 5 yr	Popliteal and femoral	5 / N.D.	N.D.	N.D.	1
M.C.	73/F	Swelling, pain; 1 yr	Ileofemoral segment	20 / N.D.	N.D. / N.D.	N.D. / N.D.	1 mo
Perforator bypass (3 cases)							
M.C.	30/M	Ulcer, pain; 6 yr	Popliteal and SF occlusion	N.D.	N.D.	N.D.	1.5
C.L.	58/F	Ulcer, pain; 1 yr	Popliteal	0 / 9	1 / 2	N.D. / N.D.	1
R.M.	37/M	Swelling, pain; 3 yr	Femoropopliteal segment	0 / 17	6 / 4	0 / 2	1

roperitoneal approach, via a right transverse incision at the level of the umbilicus. The common femoral vein on the affected side was exposed through a groin incision and a retroperitoneal tunnel between the two incisions was created by blunt digital dissection. A 16 mm reinforced Gore-Tex graft was anastomosed to the vena cava and common femoral vein by standard technique, with the use of 5-0 Prolene continuous suture under systemic heparinization. The last reinforcing ring was incorporated in the suture line at each end to keep the anastomosis open. In instances of bilateral venous obstruction, separate vena caval anastomoses were performed for each side so that thrombosis of the graft would not jeopardize the opposite conduit.

Adjunctive AV fistula. This procedure was performed in all cases when reinforced Gore-Tex graft or the Dale procedure was used. Four types of adjunctive AV fistulas were used under differing circumstances (Fig. 3). In most instances the fourth technique, a side-to-side superficial femoral AV fistula, was the only satisfactory choice available, especially when reinforced polytetrafluoroethylene bypass was used. In all instances, the surgeon attempted to create an AV fistula that measured approximately 4 mm in diameter.

Closure of adjunctive AV fistula. The AV fistula was electively closed after 4 to 12 weeks in 10 of 16 cases. Because a severe desmoplastic reaction occurred in all such instances, closure was technically difficult. This difficulty and the absence of symptoms caused by AV fistula per se mandated in six instances the indefinite persistence of the AV fistula until either spontaneous closure or provocation of symptoms occurred. In five instances, the AV fistula was allowed to persist even after the bypass became occluded, in an effort to dilate existing collateral branches.

Primary AV fistula. (Fig. 3, *f*.) This technique

Postop phlebogram and date	*Current patency* and postop symptoms*	*Fate of primary/secondary AV fistula*	*Comments/complications*
Occluded at 9 mo	Occluded at 6 mo; ulcer healed for 2 mo and then recurred	Spontaneous closure	Later underwent Linton procedure
Open at 9 mo	Occluded after 12 mo with recurrence of swelling; swelling improved only moderately; less severe symptoms than before	Spontaneous closure	Hemodynamics have improved to normal
Closed at 5 mo	Complete healing of ulcer for 5 mo, then recurrence; symptoms less severe than before	Spontaneous closure	Later underwent perforator bypass
N.D.	Occluded at 3 mo; temporary improvement for 3 mo, then recurrence	Spontaneous closure	
Open 5 days postop	Occluded 3 mo; ulcer healed then recurred; symptoms less severe than before	Spontaneous closure	
N.D.	—	—	Patient died 7th postop day of massive myocardial infarction
N.D.	Open? Poor follow-up; ulcer had healed since operation		
Open 3 mo	Open; ulcer had healed		
Open 1 yr	Open; swelling markedly less; no pain		

was performed in seven cases deemed unsuitable for autogenous or prosthetic bypass. Five of these patients had infrapopliteal disease with near-total obliteration of the deep venous system; the venous outflow was being carried almost entirely by the saphenous vein and the superficial venous system. The creation of a peripheral AV fistula was intended to dilate this functioning venous collateral system.

Perforator bypass. Since the long-term patency of primary AV fistula in infrapopliteal venous occlusions was unsatisfactory, other approaches to improve the functional capacity of superficial venous collaterals were considered. Extensive occlusion of the deep venous system was noted in three instances, but substantial collateralization occurred through the perforator veins into the saphenous system (Fig. 4). Phlebography showed some of these perforator collateral branches to be very large. Nevertheless, the foot venous pressure at resting levels was extremely high, suggesting that the retrograde flow through the perforator collaterals was inefficient, presumably because of the presence of valves against the direction of flow. In all three instances, the saphenous vein was mobilized and directly anastomosed to a patent segment of the posterior tibial vein to bypass the inefficient perforator collaterals (Fig. 4). Continuous heparinization throughout the surgical procedure and the postoperative period is probably important to achieve successful patency of these peripheral, small venous bypass anastomoses.

Iliac web resection. The obstructive lesion was thought to be a web in the left iliac vein in two instances. The obstructing web was at the caval bifurcation in one patient, whereas in the other it was more distal, near the common iliac bifurcation. In both instances, the accompanying iliac artery appeared to be the agent of compression and was intimately adherent to the area in which the web was

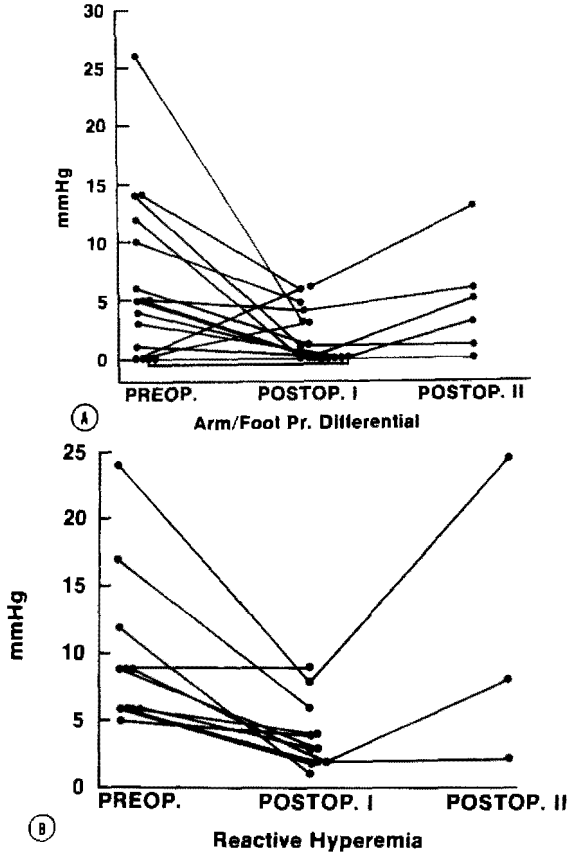

Fig. 5. A and **B.** Arm/foot venous pressure differential and foot venous pressure increase induced by reactive hyperemia are graphically presented in a group of patients before and after corrective surgery. *Postop I* and *II* refer to study intervals commonly at 2 and 6 months, respectively, after surgery.

found. The web was exposed through a phlebotomy and simply excised. No attempt was made to transpose the artery,[4] except to free it up extensively in an attempt to remove the vein from the area of perceived compression.

Anticoagulation. The intraoperative heparin management has varied as our experience has increased. Initially, intraoperative heparin was completely neutralized at the end of the surgical procedure, with warfarin started on the third postoperative day. Later, intraoperative heparin was partially neutralized and continued at mini-dose levels in the immediate postoperative period to be later converted to warfarin. More recently, intraoperative heparin has been left unneutralized to be continued at moderate levels (partial thromboplastin time, one and one-half times the control value) in the immediate postoperative period, with conversion to warfarin anticoagulation around the third to fifth postoperative day. Closed suction drainage of the wound is necessary with this protocol.

Regardless of the type of venous reconstructive surgery, all patients were instructed to stay on long-term warfarin anticoagulation under the supervision of their local physicians.

Follow-up. The hemodynamic profile was repeated on or about the fifth postoperative day, and at 6-month intervals as feasible thereafter. A combination of phlebographic techniques, including ascending phlebography, digital subtraction angiography, and computed tomography with intravenous contrast, were selectively used in many patients with varying intervals to determine graft and AV fistula patency in the postoperative period.

The details of case material, including demographic and hemodynamic data, surgical procedure, and outcome, are presented in Table III.

RESULTS

A total of 28 surgical procedures for venous obstruction were performed (Dale procedure, eight; stented Gore-Tex, eight; primary AV fistula, seven; perforator bypass, three; and iliac web resection, two). There was no apparent correlation between the anatomic site of obstruction and the particular type of symptoms, such as ulceration. Both proximal and distal venous obstruction satisfying the hemodynamic criteria for obstruction produced serious symptoms. The effect of surgery on hemodynamic parameters is graphically presented in Fig. 5 (arm/foot differential and reactive hyperemia).

Primary and adjunctive AV fistulas. There was a high incidence of spontaneous closure of both primary and secondary AV fistulas. All seven primary AV fistulas closed spontaneously a few days to several months after surgical creation. Spontaneous closure occurred in 5 of the 16 adjunctive AV fistulas used with the Dale or Gore-Tex bypass procedures. Only one of these still remains open; 10 were closed electively by surgical treatment. Transient improvement was observed in most patients during the patent period of the fistula; however, with spontaneous closure of the primary AV fistula, six of seven patients have reverted to their preoperative level of symptomatology. One patient appears to have been improved with treatment.

Bypass procedures. With the follow-up ranging from 6 months to 6 years, the results of various types of surgery for venous obstruction are detailed in Table III. Without exception, failure of the surgical procedure resulted in recurrence of symptoms in this group of patients, but patency shown by phlebog-

raphy did not always assure total symptomatic relief. The latter disparity was particularly noteworthy with the Dale procedure. Seven of eight of these bypasses were open up to 6 months and three of eight at 12 months, but relief of symptoms was present in only three of eight at 6 months and none of eight at 12 months when the bypasses were open. The possible reasons for this disparity are discussed later. The short-term patency of reinforced Gore-Tex graft was surprisingly good, with 75% remaining patent up to 6 months. A steep decline in patency rate was seen thereafter, coincident with discontinuation of anticoagulation by several patients on their own. Only two patients in this group currently maintain patent grafts at 11 and 18 months postoperatively. These patients, both of whom had segmental iliac occlusion, were young women taking birth control pills, which were stopped after deep venous thrombosis developed. The continued patency of the prosthetic grafts in these two patients could be related to the transient state of hypercoagulability, which reverted to a normal level when the pill was discontinued. These two patients also had limited segmental occlusions, unlike others in the group with more extensive disease. Two patients with prosthetic bypasses had superficial wound infection but deep infection did not occur and all thrombosed and patent grafts have remained free of infection.

The early results of perforator bypass have been encouraging. There has been symptomatic improvement with resolution of stasis ulceration or swelling in all three patients, coincident with normalization of venous hemodynamic function in two patients in whom these data were available.

Iliac vein web resection. One of the two patients is nearly relieved of the painful edema experienced preoperatively. Symptoms have recurred in the other patient and presumably obstruction has recurred.

DISCUSSION

It is generally recognized that postphlebitic syndrome may have a varied pathophysiologic basis of either obstruction, reflux, or a combination of the two. Stasis from either obstruction or reflux can and does result in ulceration. Since surgical correction is available for both obstructive[2,3] and refluxive venous disease,[5-7] detailed study of patients with postphlebitic syndrome is worthwhile to identify the specific cause. The techniques used to identify venous obstruction described herein are relatively simple and easily applied in a modestly equipped vascular laboratory. With ascending phlebography used as a "gold standard," the techniques carry a high degree of sensitivity and specificity. In fact, some of the so-called false negative results with these techniques may be a result of the fact that no hemodynamic obstruction exists, despite the appearance of venous blockage on phlebography.

Fig. 6. High iliac vein obstruction and transpelvic collaterals (*arrow*). An earlier venogram was interpreted as "normal," because collaterals were not visualized. However, hemodynamic obstruction was present (arm/foot differential, 5 mm Hg).

Ascending phlebography is the only technique used in most centers to assess suspected venous obstruction. Although invaluable for anatomic delineation, technical and interpretational errors (Fig. 6) with this technique are quite common; our experience indicates that the hemodynamic techniques described can help to reduce these errors, often providing additional physiologic insights into the disease process not available with phlebography alone (Figs. 2, 6, 7, and 8).[8]

The advantages of the hemodynamic techniques over phlebography alone in venous obstruction are clear. (1) Some quantification of the venous obstruction, with gradations from mild to severe, can be recognized (Table I). (2) The hemodynamic techniques allow serial follow-up of patients and are

Fig. 7. Patient with patent, but recanalized, venous channels had obstruction demonstrated by hemodynamic testing. (Arm/foot venous pressure differential, 6 mm Hg; reactive hyperemia, 12 mm Hg elevation.)

Fig. 8. Patient with femoral vein obstruction had good collateralization with the profunda system. He was well compensated at rest (arm/foot differential, 0 mm Hg) but had a reactive hyperemia pressure elevation of 8 mm Hg. Since he was mostly sedentary, valve repair in the profunda system for reflux was carried out with healing of stasis ulceration.

particularly useful in a continuing assessment of therapeutic modalities such as anticoagulation and surgery. Symptomatic improvement should be corroborated by hemodynamic improvement. For instance, phlebography showed a patent graft in a patient who had residual symptoms after the Dale procedure was performed. However, hemodynamic testing revealed incomplete relief of obstruction, presumably because of the smallness of the graft (arm/foot differential was 0 mm Hg, but reactive hyperemia elevation was 9 mm Hg). (3) In patients with substantial functional overlay, an objective hemodynamic measure of obstruction is obtained, regardless of the symptoms projected by the patient at a particular moment. (4) Among patients having both reflux and obstruction as sequelae of previous phlebitis, the relative severity of each can be adequately assessed by the hemodynamic techniques (Fig. 8). We have identified patients in whom phlebography indicated obstruction but who had normal hemodynamic function. We have carried out valve repair to correct reflux in three of these patients with resolution of stasis ulceration. (5) The effectiveness or the inadequacy of collateral branches seen on phlebography can be gauged by the hemodynamic techniques. Our experience indicates that phlebography can be misleading in this regard (Fig. 3). We have learned that some large and impressive-looking collateral pathways seen on phlebography can be hemodynamically inadequate, probably because of the presence of valves, stenoses, or high resistance areas not readily seen with phlebography.

With the techniques described herein, central as well as peripheral venous obstructions were found to produce hemodynamic derangement at the foot level; all levels of obstruction in the lower limb from the vena cava to the popliteal venous segment are detectable by the described techniques. Because serious sequelae, such as stasis ulceration, were associated with both peripheral and central obstructive lesions, it may be concluded that the hemodynamic result rather than the anatomic site of obstruction deter-

mines the outcome. In cases of obstruction at multiple levels, measurement of femoral venous pressure may be useful in addition to the techniques described in exploring therapeutic choices. At least in our hands venous Doppler examination has been less sensitive than the pressure-based techniques in detecting venous obstruction (Table II), possibly because of the subjective interpretation required with the Doppler method. Doppler-derived signs of venous obstruction are often subtle and the diagnosis of obstruction is frequently tentative; often only one of the three Doppler characteristics for obstruction (spontaneity, phasicity, or augmentation) is present. Of course, like phlebography, Doppler signals cannot assess the adequacy of collateralization. The arm/foot pressure differential and reactive hyperemia techniques appear to be less subjective and more quantitative than venous Doppler examination in venous obstruction.

Several technical and nontechnical aspects of venous bypass surgery, such as choice of bypass material, role of adjunctive AV fistula, and the schedule of anticoagulation, still remain unsettled. Modifications in these areas may influence the long-term outlook for venous bypass surgery. Because of these factors, results described herein should be interpreted cautiously. With this caveat, certain general and specific observations may be noted. Patients with multilevel venous obstructions have not fared well. Patients with relatively localized obstructions, especially when associated with transient hypercoagulation states with birth control pills, appear to have done better. Our limited experience with iliac web obstruction indicates that this is a real obstructive pathologic entity, as demonstrated by hemodynamic techniques. Surgical correction of this entity can provide symptomatic and hemodynamic relief. The eight patients treated with reinforced Gore-Tex graft had a surprisingly high patency rate of 75% up to 6 months, but many subsequently suffered occlusion. Only two remain open to date. Similar results have been reported by others.[9] The Dale procedure had the best patency rate (38% at 1 year) in this group of patients. Despite demonstrated patency, these patients remained partially symptomatic, because of inadequate hemodynamic relief; this was presumably related to the smallness of the saphenous vein bypass graft. Continuing pain from involvement of peripheral nerves in the phlebitic inflammatory process is also a possibility.

The role of adjunctive AV fistula with the Dale procedure and with stented Gore-Tex graft, as well, is controversial.[9,10] Dale[2] himself does not advocate usage of the temporary fistula and reports excellent patency rates of approximately 70% without it. Vollmar[3] has been the main proponent of the temporary fistula, which is closed 2 to 3 weeks later. The purported benefit is the increased patency rate of the vein bypass that he reports. Besides preventing thrombosis of the graft through increased flow during the critical perioperative period, an additional argument could be made for an adjunctive fistula on the basis of incomplete symptomatic and hemodynamic relief with the Dale procedure, as noted in our experience. An adjunctive AV fistula may be helpful in dilating the Dale bypass and render it more adequate for venous outflow. For this purpose the adjunctive AV fistula should probably remain in place for several months, much longer than the period advocated by others who have focused mainly on perioperative graft patency rather than size. There is controversy about the type of adjunctive fistula to be used with prosthetic and venous bypass procedures. An end of vein–to–side of artery fistula is preferred by some to a side-to-side AV fistula.[4] The latter is said to cause distal venous hypertension more often than the end-to-side type. A major problem with all temporary AV fistulas that are programmed for deliberate closure at a set time is the dense desmoplastic reaction that develops around them. This renders planned closure technically difficult. An ingenious method has been described by Edwards to overcome this difficulty and to effect a safer and less tedious closure of the fistula.[11]

The use of primary fistula for obstructive venous disease was briefly reported by the author previously. Another independent detailed report has since appeared.[11] However, our long-term experience with both primary and adjunctive AV fistulas that were allowed to remain open in an effort to dilate venous collaterals has been disappointing. Spontaneous closure of these fistulas was the rule. The presence of a hypercoagulable state in these patients with venous thrombosis and the obstructive venous hypertension that reduces AV fistula flow could be explanations for the spontaneous closure. Except in patients with a hypocoagulable state (e.g., chronic renal failure), it has been generally difficult to maintain small iatrogenic AV fistulas for long periods of time.[12,13]

The cases of distal venous obstruction detailed herein present challenging and difficult clinical problems. Severe forms of symptomatology, such as stasis ulceration, can and do occur in this group. Since the bypassable vessels are small, prosthetic substitutes are

excluded. Our dismal experience with primary AV fistula to dilate collateral branches in this disease has already been outlined. However, some patients appeared to obtain temporary relief and healing of their stasis ulceration for a period of time. The perforator bypass described herein is an attempt to provide a solution to this difficult clinical problem. Although our initial experience with this procedure is encouraging, long-term patency and hemodynamic relief from the perforator bypass remain to be established.

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