Chapter 3

Primary chronic venous disorders

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Primary chronic venous disorders, which according to the CEAP classification are those not associated with an identifiable mechanism of venous dysfunction, are among the most common in Western populations. Varicose veins without skin changes are present in about 20% of the population while active ulcers may be present in as many as 0.5%. Primary venous disorders are thought to arise from intrinsic structural and biochemical abnormalities of the vein wall. Advanced cases may be associated with skin changes and ulceration arising from extravasation of macromolecules and red blood cells leading to endothelial cell activation, leukocyte diapedesis, and altered tissue remodeling with intense collagen deposition.

Laboratory evaluation of patients with primary venous disorders includes venous duplex ultrasonography performed in the upright position, occasionally supplemented with plethysmography and, when deep venous reconstruction is contemplated, ascending and descending venography. Primary venous disease is most often associated with truncal saphenous insufficiency. Although historically treated with stripping of the saphenous vein and interruption and removal of major tributary and perforating veins, a variety of endovenous techniques are now available to ablate the saphenous veins and have generally been demonstrated to be safe and less morbid than traditional procedures. Sclerotherapy also has an important role in the management of telangiectasias; primary, residual, or recurrent varicosities without connection to incompetent venous trunks; and congenital venous malformations. The introduction of ultrasound guided foam sclerotherapy has broadened potential indications to include treatment of the main saphenous trunks, varicose tributaries, and perforating veins. Surgical repair of incompetent deep venous valves has been reported to be an effective procedure in nonrandomized series, but appropriate case selection is critical to successful outcomes. (J Vasc Surg 2007; 46:54S-67S.)

INTRODUCTION

Chronic venous disorders (CVD) include a spectrum of clinical presentations ranging from uncomplicated telangiectasias and varicose veins to venous ulceration. Chronic venous insufficiency (CVI) usually refers more specifically to the spectrum of skin changes associated with sustained venous hypertension. Manifestations of chronic venous disorders may result from primary venous insufficiency or be secondary to other processes, primarily acute deep venous thrombosis (DVT). This manuscript addresses the current state of knowledge with respect to primary chronic venous disorders.

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Lower extremity venous disease is common and in the United States, the number of afflicted individuals is equivalent to the entire population of the states of Texas, Florida, and Connecticut. Regardless of the underlying etiology, CVI is the seventh leading cause of chronic debilitating disease in the United States (U.S.).[1] Ten to 35% of the U.S. adult population has some form of CVI.[2] In industrialized nations, up to 1.5% of people will suffer from venous ulceration and in patients 65 years and older, the incidence increases to 4%.[1,3] Currently, more than 500,000 people suffer from venous stasis ulcers.[1,4] The lack of effective therapies and the recurrent nature of the disease place a heavy burden on the U.S. healthcare system. The population-based costs in the U.S. for treatment of CVI and venous ulcer care has been estimated at over one billion dollars a year.[5,6] The high incidence and increasing cost of CVI care has renewed interest in this disease process and much has been learned in the past decade.

Great progress has been made in understanding the pathophysiology and hemodynamics of chronic venous disorders. In primary chronic venous disease, this has led to a variety of new management tools that are frequently less invasive and more cosmetically acceptable than traditional extensive vein stripping.

Table I. CEAP classification of chronic venous disease

Clinical classification
- C_0: no visible or palpable signs of venous disease
- C_1: telangiectasies or reticular veins
- C_2: varicose veins
- C_3: edema
- C_{4a}: pigmentation or eczema
- C_{4b}: lipodermatosclerosis or atrophic blanche
- C_5: healed venous ulcer
- C_6: active venous ulcer
- S: symptomatic, including ache, pain, tightness, skin irritation, heaviness, and muscle cramps, and other complaints attributable to venous dysfunction
- A: Asymptomatic

Etiologic classification
- Ec: congenital
- Ep: primary
- Es: secondary (post-thrombotic)
- En: no venous cause identified

Anatomic classification
- As: superficial veins
- Ap: perforator veins
- Ad: deep veins
- An: no venous location identified

Pathophysiologic
- Pr: reflux
- Po: obstruction
- Pr,o: reflux and obstruction
- Pn: no venous pathophysiology identifiable

Adapted from Eklof B, Rutherford RB, Bergan JJ, et al. Revision of the CEAP classification of chronic venous disease. J Vasc Surg 2004;40: 1248-52.[8]

CLASSIFICATION OF CHRONIC VENOUS DISORDERS

In order to standardize the reporting and treatment of the diverse manifestations of chronic venous disorders, a comprehensive classification system (CEAP) has been developed to allow uniform diagnosis and comparison of patient populations. Created by an international ad hoc committee of the American Venous Forum (AVF) in 1994,[7] it has been promulgated throughout the world and is now the accepted standard for classifying chronic venous disorders. The fundamentals of the CEAP classification include a description of the clinical class (C) based upon objective signs; the etiology (E); the anatomical (A) distribution of reflux and obstruction in the superficial, deep, and perforating veins; and the underlying pathophysiology (P), whether due to reflux or obstruction.[7] Seven clinical categories are recognized including limbs without venous disease (class 0) and those with telangiectasias (class 1), varicose veins (class 2), edema (class 3), skin changes without ulceration (class 4a and 4b), healed ulcers (class 5), and active ulcers (class 6). (Table I) The underlying etiology can further be classified as congenital, primary, or secondary. Primary venous disorders are not associated with an identifiable mechanism of venous dysfunction. In contrast, secondary venous disorders result from an anteceded event, usually an episode of acute DVT. As discussed below, the underlying pathophysiology, whether due to reflux or obstruction, can be further localized to precise lower extremity venous segments (Table II).

Table II. Eighteen named venous segments (with number designations)

Superficial veins
- (1) Telangiectasias or reticular veins
- (2) Great saphenous vein above knee
- (3) Great saphenous vein below knee
- (4) Small saphenous vein
- (5) Nonsaphenous veins

Deep veins
- (6) Inferior vena cava
- (7) Common iliac vein
- (8) Internal iliac vein
- (9) External iliac vein
- (10) Pelvic: gonadal, broad ligament veins, other
- (11) Common femoral vein
- (12) Deep femoral vein
- (13) Femoral vein
- (14) Popliteal vein
- (15) Crural: anterior tibial, posterior tibial, peroneal veins (all paired)
- (16) Muscular: gastrocnemial, soleal veins, other

Perforating veins
- (17) Thigh
- (18) Calf

Adapted from Eklof B, Rutherford RB, Bergan JJ, et al. Revision of the CEAP classification of chronic venous disease. J Vasc Surg 2004: 40; 1248-1252. [8]

Designed to be a document that would evolve over time, CEAP underwent its first official review and revision by an international panel under the auspices of the AVF in 2004.[8] The revised document retains the basic CEAP categories, but improves the underlying details including terminology; divides the C4 class into a and b categories; and adds several descriptors to the E, A, and P categories. A new severity scoring system was adopted to replace the original.[9] Important details and conventions related to writing the CEAP classification, dating it, and denoting the diagnostic method used for the classification were defined.

Furthermore, to encourage wider usage among clinicians, an abbreviated or "basic CEAP" was adopted as an alternative to the comprehensive CEAP. The basic CEAP eliminates some of the details of the full CEAP, as illustrated by the following example:

A patient with pain, varicose veins, and lipodermatosclerosis in whom duplex ultrasonography confirms primary reflux of the great saphenous vein and incompetent perforators in the calf would have the following "advanced" CEAP:

$C_{2,4b,S}$, E_p, $A_{s,p}$, $P_{r2,3,18}$

The new "basic CEAP" would be:

$C_{4b,S,}$ E_p, $A_{s,p}$, P_r

in which the clinical class is denoted only by the highest number ($_{4b}$) and precise localization of segmental reflux is eliminated. The ultimate simplification of using only the highest clinical class (C_{4b}) was discarded as inadequate for scientific interchange.

In addition to the classification itself, the date of the classification and the "Level" of diagnosis (L1 = office, LII

Table III. Prevalence of C0-C6 (CEAP) in the Bonn[21], Polish[20] and French[19] Studies

	Bonn Vein Study			Polish Study	French Study	
Design	Random sample			Cross-sectional	Cross-sectional	
Survey	General population			Consecutive primary Care patients	Telephone lists	
Investigators	Phlebologists			Primary care physicians	Vascular physicians	
CVI definition	C3 – C6			C1 – C6	Trophic skin changes	
Participants	3072			40,095	409	
Males	1350			6404	277	
Females	1722			33691	132	
Classification	All (%)	Male (%)	Female (%)	All (%)	Male (%)	Female (%)
C0	9.6	13.6	6.4	51.5		
C1	59.1	58.4	59.5	16.5		
C2	14.3	12.4	15.8	21.8	23.7	46.3
C3	13.4	11.6	14.9	4.5	1.1	2.2
C4	2.9	3.1	2.7	4.6	4.0	2.1
C5	0.6	0.6	0.6	1.0	1.4	0.7
C6	0.1	0.1	0.1	0.5	0.0	0.0

= noninvasive laboratory, L III = invasive investigations) should be added, as follows:

$C_{2,4b,S}$, E_p, $A_{s,p}$, P_r (2003-08-21, LII)

EPIDEMIOLOGY OF CHRONIC VENOUS DISORDERS

Early epidemiologic studies

Several epidemiological studies of chronic venous disease in various countries have been performed over the last several decades. Most of these have focused on varicose veins.[10-17] Earlier studies reported varicose veins to be present in 1% to 73% of females and 2% to 56% of males. The prevalence of CVI in these studies ranges from 1% to 40% in females and 1% to 17% in males.[10] However, the results have varied with geography and study methods. Varicose veins have a prevalence of 25% to 33% and 10% to 20% in Western females and males, respectively.[10,11,15,17] The annual incidence of varicose veins in the Framingham study was 2.6% in women and 1.9% in men.[18] The prevalence of skin changes varied between 3% and 13% in the population. The prevalence of active and healed ulcers varied between 1% and 2.7%. Established risk factors for chronic venous disease include older age, family history, female gender, multiple pregnancies, standing occupation, and obesity in females.[10,11,14,18]

However, the early data has several limitations including the use of different definitions for varicose veins and CVI, inclusion of different age groups, and frequently a failure to include a random sample of the general population. As the prevalence of chronic venous disease increases with age and is higher in females, the data has to be adjusted for age and gender. Furthermore, many studies have relied on amnestic data from questionnaires rather than clinical and duplex evaluation. Only a few recent studies have used the CEAP classification.[19-21]

Epidemiologic studies based on the CEAP classification

In recent years, three studies have been published based on the CEAP classification.[22] They differ with respect to mode of recruitment of the study population, age, and methods of investigation[19,20,22](Table III).

The Bonn Vein Study enrolled 3072 (1722 women, 1350 men) participants, 18 to 79 years of age, from a random sample of the population registers of Bonn and two rural townships.[21] All participants completed a standardized questionnaire and underwent a clinical and duplex examination by four trained phlebologists. The complete CEAP was used for classification.

Leg complaints consistent with venous disease (leg heaviness, subjective swelling) were present in 49.1% and 62.1% of German males and females, respectively. With respect to CEAP-classification, only 9.6% of the population (13.6% men, 6.4% women) showed no signs of venous disorders (CO); 59.1% (58.4 men, 59.5% women) showed only telangiectasias or reticular veins (C1). Varicose veins without edema or skin changes (C2) where present in 14.3% (12.4% men, 15.8% women); pretibial pitting edema (C3) in 13.4% (11.6% men, 14.9% women); skin changes (C4) including eczema, pigmentation, or lipodermatosclerosis in 2.9% (3.1% men, 2.7% women); and healed (C5) or active (C6) ulceration in 0.6% and 0.1%, respectively (Table III). The prevalence of stages C2 to C6 disease increased with age. Only in stages C2 and C3 was the prevalence significantly higher in females. The urban population showed a higher frequency of CVI (C3 to C6). In a multivariate analysis adjusted for age and region of living, risk factors for varicose veins included older age, female gender, pregnancy and obesity in women. Risk factors for CVI were older age, obesity, and urban residence.

In a cross-sectional, multicenter Polish study,[20] 40,095 adults were interviewed and clinically evaluated by 803 participating primary care physicians. Patients were classified by highest CEAP clinical severity and CVI was defined as stages C1 to C6. Leg complaints were present in 81% in patients with varicose veins and 35% of the varicose-free participants. C0 was found in 51.1% of the population, C1 in 16.5%, C2 in 21.8%, C3 in 4.5%, C4 in 4.6%, C5 in 1.0%, and C6 in 0.5%. Risk factors for CVI and varicose veins were similar.

A French cross-sectional survey evaluated a subpopulation of patients enrolled in a study of Raynaud's phenomenon.[19] All patients were evaluated using a standardized questionnaire and examination by a vascular specialist. C0 or C1 disease was present in 48.7% of patients; C2 was present in 23.7% and 46.3% of males and females, respectively; C3 was found in 1.1% and 2.2%, respectively; and C4 in 4.0% of the men and 2.1% of the women. Healed ulcers were found in 1.4% of the males and 0.7% of the females. No active ulcers were identified in this study. The main risk factors for varicose veins included family history, advanced age, pregnancy, and height in women and exercise less than once a week in men.

SUMMARY

Chronic venous disorders are among the most frequent in western populations. Venous symptoms such as heaviness of the legs, swelling, and pain during standing are correspondingly frequent complaints. Although there are differences between recent studies, some generalizations are possible. Varicose veins without skin changes are present in about 20% of the general population, slightly more frequent in women. The exact prevalence of C3 remains uncertain due to lack of standardized definition. Only the Bonn Vein Study precisely defined pitting edema. This may have caused differences in the prevalence of C3, varying between 1.1% and 14.9%. The prevalence of more advanced CVI in the studies is similar – the prevalence of signs such as eczema, pigmentation, and lipodermatosclerosis or venous ulceration reaching about 5% in men and women. C4 varied between 2.1% in France and 4.6% in Poland. The highest prevalence of healed ulcers was found in French men (1.4%) and the lowest in the German population (0.6%). Active venous ulcers were found in between 0.0% and 0.5% of the population. The main risk factors for varicose veins are advanced age, female gender, pregnancy, and family history. Obesity seems to play a more important role in CVI than in varicose veins.[19-21]

PATHOPHYSIOLOGY OF CHRONIC VENOUS DISORDERS

Varicose veins

Despite advances in our understanding of varicose veins, the underlying etiology remains uncertain. Early theories presumed that varicose veins arose from the effects of valvular incompetence and venous hypertension and arose in a descending fashion from valvular incompetence at the saphenofemoral or saphenopopliteal junction. Unfortunately, there is little evidence of a constitutive valvular abnormality in primary venous disease and these theories cannot explain why truncal varicosities are often found below competent valves, why normal valves are often seen between those exhibiting varices, or why dilation often precedes valvular incompetence.[23,24] Rather than being initiated at the saphenofemoral junction, both detailed studies of surgical specimens and ultrasound observation suggest that primary valvular incompetence is a multicentric process that develops simultaneously in discontinuous venous segments.[25]

Recent theories have focused on intrinsic structural and biochemical abnormalities of the vein wall, hypothesizing that varicose veins develop because of underlying connective tissue defects and altered venous tone.[26-28] Varicose veins demonstrate diverse histologic abnormalities, including irregular thickening of the intima, fibrosis between the intima and adventitia, atrophy and disruption of elastic fibers, thickening of individual collagen fibers, and disorganization of the muscular layers that are heterogeneously distributed throughout the great saphenous vein and its tributaries.[29-34]

The histological changes suggest that varicose veins have reduced contractility and compliance. Varicose saphenous veins show an increased collagen and reduced elastin content.[35] Saphenous smooth muscle content, as well as total protein content, is reduced and effective contraction may be further compromised by fragmentation of the muscle layers.[33,36] Similar findings in limbs without varices but at risk for their development and in the forearm veins of varicose vein patients suggest that abnormalities in vein wall architecture precede the development of both overt varicosities and valvular incompetence.[26,28]

It remains unclear whether these structural changes are primary or result from other pathologic processes. Proposed mechanisms have included hypoxia induced endothelial changes; downregulated apoptosis; changes in enzyme activity associated with decreased energy metabolism and increased lysosomal activity; and underlying defects in venous tone associated with a loss of vascular reactivity.[29,33,37-39]

Chronic venous insufficiency

Microscopic alterations. Over the past century, numerous theories regarding the etiology of venous stasis ulceration have been proposed. The earlier theories are of historical interest only and recent attention has focused on inflammation and the events regulating it.[40] Our current knowledge indicates that venous hypertension causes extravasation of macromolecules (ie, fibrinogen and α_2-macroglobulin) and red blood cells (RBCs) into the dermal interstitium resulting in a persistent or chronic injury stimulus.[40-44] RBC degradation products and interstitial protein extravasation are potent chemoattractants and presumably represent the initial underlying chronic inflammatory signal responsible for leukocyte recruitment. It has been assumed that these cytochemical events are responsible for the increased expression of ICAM-1 (intercellular adhesion molecule-1) on endothelial cells of microcirculatory exchange vessels observed in CVI dermal biopsies.[45] ICAM-1 is the activation dependent adhesion molecule utilized by macrophages and lymphocytes for diapedesis. Both these cells have been observed by immunohistochemistry in the interstitium of dermal biopsies.[45] However, a recent morphometric assessment of the dermal microcirculation identified macrophages and mast cells only and questioned the role of lymphocytes in CVI dermal pathology.[46] The exact role of leukocytes in the pathogenesis of CVI is unknown, however, the presence of mast cells suggests a role in cytokine activation, tissue remodeling, or ulcer formation.

Extracellular matrix (ECM) alterations. Once leukocytes have migrated to the extracellular space, they localize around capillaries and postcapillary venules. The perivascular space is surrounded by extracellular matrix (ECM) proteins, forming a perivascular "cuff".[41,43-45,47] This perivascular "cuff" and the accompanying collagen deposition are the sine qua non of CVI tissue damage. The role of the cuff and its cell of origin are not completely understood. The cuff was once thought to be a barrier to oxygen and nutrient diffusion. However, recent evidence suggests that cuff formation is an attempt to maintain vascular architecture in response to an increased mechanical load.[48] Immunohistochemical analyses have demonstrated transforming growth factor-β_1 (TGF-β_1) and α_2-macroglobulin in the cuff interstices.[43] It has been suggested that these "trapped" molecules are abnormally distributed in the dermis leading to altered tissue remodeling and fibrosis.

Cytokine regulation and tissue fibrosis. Leukocyte recruitment, ECM alterations and tissue fibrosis are characteristic of chronic inflammatory diseases caused by alterations in TGF-β_1 gene expression and protein production. TGF-β_1 has been demonstrated to be present in pathologic amounts in the dermis of patients with class 4, 5 and 6 CVI. The intense tissue fibrosis clearly is caused by the excess amounts of TGF-β_1. Whether or not TGF-$\beta_1$is involved in ulcer development is currently unclear. Other cytokines such as vascular endothelial growth factor (VEGF) and platelet derived growth factor (PDGF) have been identified in dermal biopsies of CVI patients but their role in the pathophysiology of the disease is unclear.

Role of matrix metalloproteinases (MMPs) and their inhibitors in venous ulcer healing. The signaling event responsible for the development of a venous ulcer and the mechanisms responsible for prolonged wound healing are poorly understood. Wound healing is an orderly process that involves inflammation, re-epithelialization, matrix deposition, and tissue remodeling. Tissue remodeling and matrix deposition are processes controlled by MMPs and tissue inhibitors of matrix metalloproteinases (TIMPs). In general, MMPs and TIMPs are not constitutively expressed, but are induced in response to exogenous signals such as various cytokines or growth factors, cell-matrix interactions and altered cell-cell contacts. TGF-β_1 is a potent inducer of TIMP-1 and inhibitor of MMP-1. Several studies have demonstrated that prolonged and continuous TGF-β_1 production causes tissue fibrosis by stimulating ECM production and inhibiting degradation through its effects on MMP and TIMP. In patients with active ulcers, increases in MMP activity from ulcer exudates and decreased expression of TIMP-1 in keratinocytes have been reported.[49] These observations suggest that excessive proteolysis may be responsible for the decreased healing rates seen with venous stasis ulcers.

Summary. CVI is the result of venous hypertension caused by venous valvular incompetence. Prolonged exposure to venous hypertension causes extravasation of macromolecule and RBCs, which in turn leads to microvascular endothelial cell activation, leukocyte diapedesis, ECM alterations, and intense collagen deposition. The changes in the dermal microcirculation and interstitium are partially mediated by increased levels of TGF-β_1. TGF-β_1 causes increased ECM and collagen production and altered tissue remodeling by affecting MMP and TIMP production. The exact cause of ulcer formation remains unknown, however, the presence of mast cells suggests that they may play an important regulatory role.

DIAGNOSTIC EVALUATION OF CHRONIC VENOUS DISEASE

The diagnostic evaluation of chronic venous disease has advanced from a clinical impression based upon physical examination to an objective image-based process similar to that followed for arterial disease. It is comprised of clinical and laboratory elements that address the presenting features, underlying etiology, distribution, and mechanism of disease. In doing so, it provides the essential elements of the CEAP classification.

The complete diagnosis includes both clinical and laboratory elements and can be achieved with a single office visit and a noninvasive vascular laboratory examination that consists of a focused hand-held Doppler examination and an erect venous duplex scan supplemented when necessary by plethysmography. In the minority of venous cases in which deep venous reconstruction is considered, a more invasive examination with ascending and descending venography or venous pressure studies may be needed. Since the ultrasound examination is painless, safe, and affordable, this objective image-based workup of CVD is practical and constitutes the standard of practice.

Clinical evaluation

The clinical evaluation determines the nature and the severity of the underlying venous problem and its impact on the patient's quality of life. In this phase, the presenting symptoms and signs are assessed and assigned to a hierarchy of categories including telangiectasias, varicose veins, venous edema, skin changes, and ulceration. The disease classification,[8,50] severity, and effect on the patient's quality of life determine the degree of investigation required to guide treatment.

Laboratory evaluation

The laboratory evaluation of chronic venous disease defines the cause of the problem as congenital, primary, or secondary; the anatomic location of the problem in the superficial, perforator, or deep systems; and the pathophysiologic mechanism as pure reflux, reflux with obstruction, or dominant obstruction. The pathophysiologic mechanisms are localized to 18 defined segments from the calf to the inferior vena cava (IVC).

Duplex ultrasonography. Duplex ultrasonography, using an erect venous reflux protocol, is an essential component of the evaluation of chronic venous disorders. The duplex examination required for chronic venous disorders differs substantially from that used to exclude deep venous thrombosis. It is optimally performed in the standing position and includes an assessment of both reflux and obstruction in the deep, superficial, and perforating veins from the IVC to the calf veins. Based upon the clinical evaluation, a more or less detailed scan may be adequate. When the problem is limited to telangiectasias (clinical class 1), ultrasound scanning of the deep and perforator veins is of minimal importance and can be omitted or substituted with a continuous wave Doppler examination. For class 2 (varicose veins) and 3 (venous edema) disease, a complete scan is warranted to identify reflux and obstruction in the deep and perforating systems. In advanced venous insufficiency (clinical classes 4 to 6 and selected class 3), a full and detailed examination of all of the segments is necessary when the treatment alternatives might include interventions involving perforator or deep veins. If intervention has been ruled out (eg, reasons of risk or inactivity) the utility of a full scan is limited to assisting with prognosis or intensity of medical management.

Duplex ultrasonography is required for determination of the etiologic, anatomic, and pathophysiologic elements of the CEAP classification. It is possible to distinguish congenital, primary and secondary causes of CVD in the majority of cases. The valvular reflux and varicose changes in primary disease are readily distinguished from the luminal scarring and obstructive pattern of post-thrombotic disease, even though the post-thrombotic vein may also show significant reflux. Problems can arise in differentiating primary from completely recanalized post-thrombotic disease, which may also present as pure reflux. Anatomically, although the identification of reflux and obstruction in the superficial and deep veins is accurate, some aspects of the perforator examination are controversial. Although most perforating veins are not visualized, ultrasonic detection of abnormal perforators rivals or exceeds venographic methods.[51] Limitations are that the assignment of reflux and obstruction to precise venous segments may be both operator- and equipment-dependent, and detection of subtle degrees of post-thrombotic partial obstruction and early valve reflux may be difficult.

Physiologic noninvasive tests. In contrast to the precise segmental information provided by ultrasound, measurement of volume or pressure changes with guided manipulation of the extremity provides reliable global information about venous function. The quantitative estimate of venous reflux provided by air plethysmography (APG), specifically the VFI, has proven useful pre- and postoperatively in assessing the results of therapy.[52,53] However, some limitations of these physiologic measurements have been expressed.[54,55] Pressure measurements are occasionally necessary in the evaluation of obstruction prior to or following deep vein reconstruction.[56] The practical application of the physiologic tests has been diminished by the widespread availability of duplex ultrasonography and treatment decisions seldom require these tests.

Venography. Although largely replaced by ultrasound scanning for initial definitive diagnosis, venography retains a critical role in the evaluation of advanced CVI prior to and perhaps after venous reconstruction.[57] Ascending venography provides an overall anatomic map of the lower extremity veins and pathways of venous return. Manipulation of patient position from horizontal to vertical, combined with tourniquets at various levels, can reveal important physiologic data about partial and complete segmental obstruction. Descending venography is the standard for analyzing sites of venous valves, distinguishing primary valve disease from secondary, and estimating severity of reflux. It may also provide further information regarding patent venous channels in obstructive disease. Computed tomographic (CT) and magnetic resonance (MR) venography will likely have an increasingly important role in the future.

SURGICAL TREATMENT OF VARICOSE VEINS

Individuals seeking treatment for varicose veins find them to be unsightly, but the inquiring physician finds that nearly all are symptomatic with aching pain, heaviness, swelling, eczema and itching being the most prominent symptoms.[58] Since reflux at the saphenofemoral junction is commonly present, the traditional approach to treatment has been removal of the great saphenous vein after ligation and division of the saphenofemoral junction.[59] Many patients undergoing the modern surgical approach of proximal ligation, division, and stripping of the saphenous vein do so with little downtime, however, some suffer extensive bruising, hematoma, and pain, especially when large varicose veins have been treated. Furthermore, it is disappointing that one-third of patients will develop further varicose veins after such treatment.[60]

Surgical treatment of varicose veins consists of two components.[61] One is to remove the saphenous vein from the circulation and the second is to remove varicose veins from their sources of venous hypertension. The patient's perspective is that it is the varicose veins that need treatment. The treating physician's perspective is similar but he believes that in order to prevent recurrence, the refluxing saphenous vein must be removed from the circulation.

Saphenous ablation

Surgical methods of removing the great saphenous vein from the circulation have included proximal ligation alone, proximal ligation with ankle to groin stripping, and proximal ligation with knee to groin stripping. It is generally agreed that ligation alone, without removal of the saphenous vein, is inadequate[62] as the patent vein in the thigh continues to reflux. The stripping operation has durable results because the saphenous vein is permanently removed. The groin dissection itself may have favorable long-term consequences but its immediate effect is prolonged soreness and tenderness.

Despite the acknowledged limitations of surgery and the negative patient perception of vein stripping, there are advantages to operative treatment of varicose veins. The operation can be performed as a single procedure and when done in a well-equipped operating room with effective anesthesia, all of the pathologic veins can be dealt at one time. Both saphenous extirpation and phlebectomy can be done at one sitting with no need for immediate retreatment. There are several modern ways to diminish morbidity,[5] but there is always some downtime. Because of this, attempts have been made to minimize postoperative discomfort and yet maintain the benefits of saphenous vein extirpation.

Great saphenous vein stripping

Groin-to-knee stripping of the saphenous vein is generally considered in every patient requiring surgical intervention. Although the decision may be against saphenous stripping, removal of the varicose clusters via stab avulsion or some form of sclerotherapy is an absolute requirement in nearly all patients.

Properly performed preoperative marking serves to document the extent of varicose vein clusters and identify the clinical points where control of varices is required. As a rule, incisions in the groin and at the ankle should be transverse and placed within skin lines. The groin incision should be high enough to permit identification of the saphenofemoral junction. The best cosmetic results in the thigh and leg are generally obtained with vertical incisions. Transverse incisions are used in the region of the knee, and oblique incisions are appropriate over the patella when the incisions are placed in skin lines.

The practice of identifying and carefully dividing each of the tributaries to the saphenofemoral junction has been dominant for over 90 years. The rationale for this has been the perceived inadvisability of leaving behind a network of anastomosing inguinal tributaries. The importance of these efforts has been underscored by descriptions of residual inguinal networks as an important cause of varicose vein recurrence.[63] However, this central principle of varicose vein surgery is currently under challenge, on the grounds that groin dissection can lead to neovascularization and subsequent recurrence of varicosities.

After exposure of the saphenofemoral junction, a disposable plastic Codman stripper can be introduced from above downward. Although plastic disposable vein strippers and their metallic equivalents were designed to be used with various-sized olives to remove the saphenous vein, an inversion technique in which the vein is tied to the stripper below its tip, inverted into itself, and removed distally is more efficient and reduces tissue trauma in the thigh. Alternatively, an Oesch stripper can be employed.

Passage of the stripper from above downward to the ankle serves to confirm the absence of functioning valves, and stripping of the vein from above downward is unlikely to cause nerve damage. In exposing the saphenous vein at knee level, the superficial fascia must be incised because the vein lies between this structure and the deep fascia of the thigh. If the stripper passes unimpeded to the ankle, it can be exposed with an exceedingly small skin incision placed in a carefully chosen skin line. At the ankle, the vein should be carefully dissected to free it from surrounding nerve fibers. If this is not done, saphenous nerve injury will result, and the patient will experience numbness of the foot.

Subcutaneous extravasation of blood during and after saphenous vein stripping is a major cause of discomfort and occasional permanent skin pigmentation. Use of high volume, dilute tumescent local anesthesia will minimize extravasation. Applying a hemostatic tourniquet after Esmark exsanguination of the limb can also minimize such extravasation. If a tourniquet is not used, the entire operation can be performed with the limb elevated 30 degrees. To decrease oozing into the venectomy tract, a 5 cm roller gauze soaked in a 1% lidocaine-epinephrine solution can be attached to the stripper using the ligature fastening the saphenous vein to the stripping device. The hemostatic pack, which lies within the saphenous vein, can be pulled into the tract with minimum tissue trauma; when it is not inverted into the vein itself, it can act as an obturator to facilitate removal of the saphenous vein without tearing. As the vein is removed by inversion, the gauze is left in place for hemostasis.

Incisions to remove varicose clusters vary according to the size of the vein, the thickness of the vein wall, and the degree of adherence to perivenous tissues. Except in areas where skin lines are obviously horizontal, vertical incisions 1 to 3 mm in length are appropriate and successive incisions are spaced as widely as possible. Varicosities are exteriorized by means of hooks or forceps. Dissection of each perforating vein at the fascial level is not required and may in fact be cosmetically undesirable. There is no need to ligate or clip the ends of each varix. The combination of leg elevation, trauma-induced venospasm, and direct pressure ensures adequate hemostasis.

Neovascularization after saphenous vein stripping

The advent of minimally invasive techniques, such as radio-frequency and laser ablation of the great saphenous vein, has focused attention on neovascularization in the groin as a potential cause of recurrent varicose veins after saphenous stripping. Neovascularization is commonly seen following the traditional stripping procedure[64] and is thought secondary to "frustrated" venous drainage from the abdominal wall and perineum.[65] Regardless of the mechanism, the result is recurrent reflux in thigh or lower leg veins.

Although the phenomenon had been previously described,[66] neovascularization was only a clinical curiosity until venous ultrasound became widely available for postoperative surveillance of patients.[67] It must now be accepted that this condition is more common than previously realized.[68] Neovascularization has been demonstrated by a variety of imaging techniques including phlebography corrosion casts. Histologic study has confirmed that the vessels seen as regrowth of veins at the saphenofemoral junction are truly new vessels.[69] Many now believe that neovascularization is a major cause of recurrent groin reflux after varicose vein surgery.[70]

Table IV. Efficacy of VNUS closure of the saphenous vein

	1-year	*2-year*	*3-year*	*4-year*	*5-year*
Number	458	240	119	107	37
Reflux free	90%	88%	87%	87%	84%
Varicose vein recurrence	14%	16%	14%	21%	22%

Adapted from Merchant RF, DePalma RG, Kabnick LS. Endovascular obliteration of saphenous reflux: a multicenter study. J Vasc Surg 2002;35:1190-6.[77] VNUS Medical Technologies, Inc, San Jose, Calif.

Endovascular Management of Varicose Veins

Lower extremity varicose vein disease is most often associated with truncal venous insufficiency involving the saphenous system; the great saphenous vein, the small saphenous vein, and/or incompetent major tributaries or perforator veins. As discussed above, varicose vein disease has historically been treated with stripping of the saphenous vein, and interruption and removal of the major tributary and perforator veins.[71] However, endovenous ablation procedures have more recently been reported to be safe and effective methods of eliminating the proximal portion of the great saphenous vein, the small saphenous vein, and even tributary and perforator veins from the venous circulation, with faster recovery and better cosmetic results than stripping.[60,72-74] The three currently available methods to achieve ablation of diseased veins are: the Closure procedure using a radio-frequency (RF) catheter and generator (VNUS Medical Technologies, Inc, Sunnyvale, Calif); the endovenous laser ablation procedure using a laser fiber and generator (various manufacturers); and endovenous chemical ablation with ultrasound guided foam sclerotherapy (either injected or catheter-directed). The first two methods use electromagnetic energy to destroy the vein in situ; the latter utilizes a foamed chemical detergent (Polidocanol or sodium tetradecylsulfate). As with stripping, portions of the great and/or small saphenous vein, perforator veins, and varicose tributaries remaining after these endovenous procedures must be treated with either injection sclerotherapy or phlebectomy.

Endovenous thermal ablation

Prolonged exposure of tissues to high frequency energy results in total loss of architecture with disintegration and carbonization. Clinical observation suggests that these minimally invasive procedures do destroy the saphenous vein and ultimate results are quite acceptable and comparable to stripping of the saphenous vein. However, patients experience minimal discomfort and time lost from work.

Clinical trials evaluating RF ablation of the great saphenous vein have demonstrated success rates equivalent to or better than historical results for stripping.[73,75] These findings were confirmed in a prospective, randomized study comparing RF ablation with stripping.[76] Several reports, some with follow-up as long as 5 years, have confirmed the safety and efficacy of RF saphenous vein ablation[65,77] (Table IV). Ablation rates of 90% or more have been routinely demonstrated.[78]

Following the introduction of RF ablation, reports appeared demonstrating an unprecedented rate of successful great saphenous vein ablation using laser energy.[79] The original clinical trials, and 3-year follow-up data, confirm the high success rate reported earlier.[80,81] Other centers have similarly reported high rates of successful ablation.[74]

The details of heat ablation of the truncal veins have been described elsewhere.[65] In brief, after ultrasound localization of the truncal vein, it is accessed either directly through a micro incision or percutaneously under ultrasound guidance, at a suitable site near the knee or higher. A sheath followed by the RF catheter or laser fiber are inserted into the truncal vein and advanced to the most superior point of treatment. Following injection of ultrasound guided, dilute local anesthetic into the saphenous sheath, the generator is activated and the vein is ablated during withdrawal of the catheter/fiber.

Patient selection

Inclusion criteria should include: symptoms and physical signs of venous insufficiency; duplex ultrasonography, performed by a fully qualified sonographer, documenting a patent vein with reflux greater than 0.5 seconds; patent deep venous system; vein conducive to catheterization; and full patient mobility. Exclusion criteria include arteriovenous malformations; restricted ambulation; and deep venous obstruction. As a practitioner's experience with endovenous ablation expands, relative exclusion criteria may be relaxed, and patients with deep venous reflux, previous venous treatment, large diameter veins, or those on chronic anticoagulant therapy or hormone replacement therapy may be safely and successfully treated.

Complications

Intraoperative and postoperative complications occur infrequently, and are generally well tolerated and short-lived. Intraoperative complications include: difficult device access or advancement and treatment interruption (RF only). Postoperatively, patients may encounter bruising and pain (more often with laser);[82] paresthesia; thermal skin damage; superficial thrombophlebitis; lymphedema; and DVT. The risk of the most clinically significant of these, DVT, is generally reported to be less than 1%,[78] usually in calf veins. Paresthesias have been reported in 2% to 16% of patients following RF ablation and are usually transitory.[83] In a report of patients followed carefully in one center, the incidence of DVT and paresthesia was essentially equivalent with laser and RF ablation.[84]

Notably, as discussed above, there is a relative absence of neovascularization after thermal ablation of the great saphenous vein.[77] Endovenous ablation of the great saphenous vein deliberately leaves the superficial epigastric vein intact, which, it is believed, has resulted in few reports of neovascularization at the 5-year interval.

Follow-up

The risk of incomplete ablation and recanalization of the treated vein as well as the need for adjunctive treatment of the distal great saphenous vein, refluxing tributaries, and small saphenous vein mandate careful follow-up after vein ablation. Color-flow Doppler ultrasound, interviews, and physical examinations at appropriate intervals are needed to achieve successful treatment. It is not appropriate to merely ablate the proximal vein and expect the patient's symptoms and varicosities to resolve. Unless one is committed to careful follow-up and adjunctive treatment, the practitioner and the patient will be left with unsatisfactory results.

There is considerable confusion in the literature regarding the definition of successful treatment, the means used to detect treatment failures, and the reporting of results. Recent advancements in ultrasound technology have allowed more critical evaluation of clinical results than were possible in the past. Duplex examination after vein ablation should include grey-scale, compression, and color flow Doppler modalities. Identification of treatment failure is dependent on the sensitivity of the ultrasound equipment used, the expertise of the sonographer, and the vigor with which the examination is conducted.

The development of foam sclerotherapy has further called into question even the most critical examination techniques. Because foam is an excellent ultrasound contrast medium, injection into distal vein segments, tributaries, and incompetent perforators will sometimes reveal an incompletely treated vein that is occluded by all other duplex criteria. Whether these minimally patent segments will become clinically significant is currently unknown. However, patients complaining of localized pain in the area of a previously ablated vein deserve very careful examination to identify incompletely ablated segments.

It has been reported that most incompletely ablated veins will be seen in the first few months after treatment.[80] However, patients with recurrent symptoms and partially patent segments have been identified more than 3 years following apparently successful ablation. Thus, it is necessary to perform careful follow-up of these patients for 1 year, and then yearly, or certainly when recurrent symptoms occur.

CONCLUSIONS

Endovenous ablation is generally safe. Intraoperative and postoperative complications are infrequent and generally less morbid than with traditional surgical procedures. Differences in methods of follow-up and definitions of successful ablation may explain differences in results between published reports. Only long-term follow-up will demonstrate where these minimally invasive methods belong in the therapeutic armamentarium of the treatment of chronic venous disease of the lower extremity. While some surgeons have expressed the view that none of these techniques have yet been shown to better conventional surgery in the long term, the patient's perception has uniformly been that minimal invasion is better.

Sclerotherapy of Varicose Veins

Sclerotherapy is a well-accepted treatment modality not only for varicose veins of the lower or upper extremities, but also for vascular malformations such as small hemangiomas and varicose veins associated with the Klippel-Trenaunay syndrome, where surgery may not be indicated. Sclerotherapy is considered the treatment of choice for cosmetic nuisances such as spider veins or telangiectasias and venous lakes. Advances in imaging technology have also extended the use of sclerotherapy to treatment of reflux in areas such as the saphenofemoral and saphenopopliteal junctions. Some of the "new" techniques are being evaluated and more representative results should become available within a few years.

Clinical evaluation

After the initial interview, physical examination determines the type of varicose veins and the most appropriate type of treatment. An extensive noninvasive evaluation is not required in patients with mild telangiectasias. However, the durability of sclerotherapy in the presence of severe reflux is often limited and patients with more extensive disease require an assessment of deep and superficial reflux with Doppler and duplex ultrasound examinations.

Indications for sclerotherapy

Sclerotherapy is clearly indicated in the following situations: Telangiectasias and venous lakes, usually 1 mm or less in diameter; varicosities between 1 to 3 mm in diameter without connection to refluxing main trunks; residual or recurrent varicosities without obvious connection to incompetent main venous trunks; congenital malformations of venous predominance such as small hemangiomas; and some diffuse congenital malformations where surgery is contraindicated. Hemorrhage due to variceal rupture can also be effectively treated with sclerotherapy. Sclerotherapy may also enhance the venous ulcer healing in some situations. This is a temporary measure while definitive treatment is planned. Finally, the introduction of foam sclerotherapy has widened the indications for sclerotherapy to include the main great and small saphenous trunks, varicose tributaries, and perforating veins.

Sclerotherapy is not indicated in elderly and sedentary patients afflicted by arthritis or medical conditions that prevent active mobilization. Relative contraindications may include the presence of severe systemic diseases such as diabetes, cardiac or renal insufficiency, emphysema, collagen diseases, and malignancies; arterial insufficiency documented by an ankle brachial index below 0.7; a history of asthma or strong allergic conditions that may predispose to anaphylaxis; a body surface index >26 where compression is difficult to apply; and the use of anticoagulants, which may be associated with a risk of large hematomas or ecchymosis.

Sclerosants

Sclerosants are classified according to their mode of action as osmotic agents, detergents and chemical or corrosive agents. Osmotic agents include hypertonic sodium chloride (23.4%), 65% glucose and sodium salicylate; the detergent agents are sodium tetradecyl sulfate, polidocanol and sodium morrhuate; and corrosive or chemical sclerosants include sodium and potassium iodide, chromglycerine, and absolute alcohol. Only the detergent agents, sodium tetradecyl sulfate, sodium morrhuate, and ethanolamine oleate are approved by the United States Food and Drug Administration. The most commonly utilized agents in this country are sodium tetradecyl sulfate and hypertonic sodium chloride (the latter not FDA approved as a sclerosant).

All currently available sclerosants cause irreversible molecular damage to the venous wall, permanently deactivating the vein and producing a destructive endosclerosis. They specifically affect lipids on the endothelial cell surface, softening the endothelium and causing the endothelial cells to detach and fall apart in plaques. Deeper layers, including the media, are affected and spasm is regularly seen with ultrasound during treatment. Few severe side effects have been reported with foam sclerotherapy, but local side effects, including hyperpigmentation and mild superficial thrombophlebitis may occur.

Sclerosant concentration depends on the size of vein to be treated. In general, dilute sclerosants are used for small veins and higher concentrations for larger veins. Telangiectasias (1 mm or less) are usually treated by injecting 0.125% to 0.25% sodium tetradecyl sulfate or 0.5% polidocanol. Veins 3 to 6 mm respond well to 0.5% to 0.75% sodium tetradecyl sulfate or 0.75% to 1.0% polidocanol. Veins larger than 6 mm diameter require 3.0% sodium tetradecyl sulfate or 2.0% to 3.0% polidocanol.[85]

Foam sclerotherapy

The liquid form of sclerotherapy was universally used in the past. The "air-block" technique[86] has been used in small venules, where displacement of the blood column by microbubbles can be observed. This method was modified by Cabrera[87] to produce a thicker, larger mass of sclerofoam. The action of foam sclerosant differs from that of the liquid; foam forming a coherent mass that displaces the blood column and allowing controlled, prolonged contact with the venous endothelium. The development of foam sclerotherapy has extended its utility to include the ultrasound-guided treatment of large venous trunks and bulky, deeply seated congenital vascular malformations of venous predominance.

Only detergent based sclerosants, such as polidocanol and sodium tetradecyl sulfate, can be used as a foam. Sclerofoam is produced by mixture of a well-tolerated, physiologic gas and a relatively small amount of the detergent sclerosant. Oxygen, CO_2, and room air have all been successfully utilized. Although many methods of producing foam have been described, the easiest may be that reported by Tessari, using two syringes connected by a three-way stopcock.[69] Two syringes are connected by a three-way stopcock, creating foam by alternatively moving the syringe pistons up and down. Such foam persists for a few minutes and can be injected into tributary varicosities and the saphenous veins. Depending on the vein size, Frullini[88] recommends total volumes of 3 to 5 mL of 1% to 1.5% sodium tetradecyl sulfate or 2% to 3% polidocanol. Telangiectasias are successfully treated with 0.10% to 0.25% polidocanol foam. The higher concentrations are used for large truncal veins less than 9 mm in diameter. In treating the saphenous trunks, sclerosing foam may be directly injected or delivered by means of an indwelling catheter, sometimes with an occlusive balloon just below the saphenofemoral junction. Others have described duplex controlled catheter injection of sclerosing foam in a bloodless field using controlled-ischemia.[89]

Ultrasound guided foam sclerotherapy for saphenous trunks with patent deep venous junctions remains investigational in the U.S., although clinical trials are either in progress or planned for the near future. However, numerous reports from Europe have demonstrated excellent results using foam sclerosants for ablation of the saphenous veins.[72] Successful ablation has been reported in greater than 90% of patients.[90] Others have shown long-term (5 years) fibrosis in up to 81% of treated veins. A 98% rate of great saphenous occlusion was reported in 65 extremities followed for up to 31 months using the bloodless field technique described by Trinidad.[89]

Despite the promise of foam sclerotherapy, previous experience with liquid sclerosants must be kept in mind when treating the junctions. Waugh[91] reported recurrence rates of nearly 60% at 5 years using sclerotherapy either alone or in combination with high ligation for the treatment of primary varicose veins. In the modern era, randomized studies performed from England, Sweden, and North America have documented that "liquid sclerotherapy", used as a single form of treatment, for all types of varicose veins has a very high incidence of recurrence.[92,93] The introduction of these new techniques has opened new avenues of investigation. Careful evaluation and large randomized trials comparing liquid vs foam sclerotherapy with and without saphenous ablation will provide new insights into the true value of sclerotherapy as a method of treatment for varicose veins.

Consensus recommendations

Consensus recommendations regarding foam sclerotherapy were generated during the Second International European Symposium on Sclerotherapy.[94] The following is a summary of the consensus conclusions.

1. The indications and contraindications for foam and liquid sclerotherapy are similar. However, thicker foam is recommended for large veins and thinner, less viscous foam for smaller veins. The Monfreux method[95] produces thicker foam than Tessari's or Cabrera's. Possible new indications for sclerofoam are: pelvic varices, varicocele, hydrocele, venous angiodysplasias, and Baker cysts. Patients should be well informed of the advantages, limitations and complications of foam sclerotherapy.
2. An important advantage of sclerofoam is its echogenicity. Duplex ultrasound control of the procedure is particularly important when treating large veins, perforators, veins in the flexion (knee, groin) areas, and recurrent varices. Catheter control sclerofoam techniques may improve the safety and effectiveness of the procedure.
3. The majority of participants recommended elevation of the extremity during treatment and avoiding the erect position shortly after the procedure.
4. The effects of sclerofoam at a given concentration are greater than for liquid sclerotherapy (contact of the agent is direct and more prolonged that with the liquid form). It was recommended that in C-1 varices (reticular veins and telangiectasias) be treated with a maximum of 0.5 mL of foam per site and a total volume of 6 to 8 mL using the Tessari method. Some participants have used up to 14 mL of foam per session. For C-2 varices, a maximum volume of 6 to 8mL of 3% polidocanol per session, prepared by the Monfreux method, was recommended. The majority of participants recommended beginning with the most proximal point of insufficiency and proceeding downwards to the distal varicosities.
5. The indications for compression are similar for liquid and foam sclerotherapy. Compression of telangiectasias is controversial. In larger veins, compression should be applied for a week or longer.

SURGICAL REPAIR OF INCOMPETENT VENOUS VALVES

Surgical repair of incompetent venous valves is a clinically effective procedure with several series reporting 65% to 80% actuarial healing of stasis ulcers at 5 years and some even at 15 to 20 years.[96-109] Yet, it has remained the niche of only a small coterie, likely due to a very steep learning curve, lack of the dedicated resources required for the comprehensive management of venous disease, and indifference by most training programs. The scientific validity of the procedure has been questioned as well; the best evidence coming from non-randomized series of selected patients. However, many currently effective surgical procedures are based on similar evidence. As for other such procedures, case selection is the key to successful outcomes.

Despite its utility, the advent of venous stent technology is likely to further diminish the use of deep venous reconstruction. About two thirds of patients with venous stasis ulceration heal their ulcers following stent placement; a much easier, minimally invasive procedure likely to enjoy widespread adoption. Yet a third of the cases, still a very large number in absolute terms, will have recalcitrant ulcers and be candidates for valve reconstruction. Reconstruction is certainly an attractive alternative to life long Unna boot regimens.

Reflux and venous stasis

Venous skin changes in general and venous ulceration in particular are traditionally attributed to reflux rather than obstruction. However, the experience with venous stents clearly demonstrates that the pathogenesis involves a poorly understood, complex interaction between reflux and obstruction.[101] Although the vast majority of post-thrombotic cases involve both obstruction and reflux, the frequent presence of May-Thurner type obstructive lesions in "primary" disease has only recently been recognized. In such cases, symptoms may improve following stent placement alone without correction of the reflux component. Raju and Neglen have hypothesized that the obstructive lesion is an often silent, permissive condition predisposing to symptoms once additional pathology such as reflux develops.[101] In common with other well known permissive conditions such as hyperacidity and peptic ulcer, obesity and diabetes, correction of the permissive condition alone is often curative.

Measurement of reflux

Venous filling time (VFT) determined by ambulatory venous pressure measurement and the venous filling index (VFI_{90}) measured by air plethysmography are reliable quantitative global indices of venous function of which reflux is a dominant and reversible component.[96] Improvements in VFT and VFI90 have been documented after valve reconstruction. VFT improves by at least 4 seconds, often more, but seldom normalizes following valve reconstruction. This is partly due to the multiple factors that determine ambulatory venous pressure and the outstation nature of valve reflux. Ulcers will fail to heal if VFT persists below 5 seconds following valve repair.

Duplex has replaced descending venography as the preferred technique to identify reflux at specific sites and has the potential to be used quantitatively. As of now, it is only qualitative.[100] Initial enthusiasm for valve closure time to quantify reflux has proved disappointing. A related parameter, calculation of reflux volume has proved unreliable as well. Peak reflux velocity has been shown to be of value statistically, but the variance is such that it is not clinically useful.

Unfortunately, there is still no reliable quantitative measure to guide the optimal site for valve repair; to prioritize the relative importance of superficial, perforator and deep interventions; or to assess outcome. For this reason, controversy regarding the optimal valve site for repair (femoral vs popliteal "gatekeeper") still persists. Raju prefers the femoral site only because it is technically easier. Fortunately, venous reflux, as most venous pathologies, responds clinically to partial correction at least in the short term.

Techniques of valve reconstruction

The oldest and most durable repair in ultrasound terms, is internal valvuloplasty.[98,99,102] External and transmural techniques are faster, allowing multiple single stage valve reconstructions, and can be used even in smaller caliber veins.[103] The latter techniques deteriorate faster in duplex terms but this is not reflected in clinical outcome. All techniques, including the internal valvuloplasty, show alarming degrees of deterioration by ultrasound.[106] The cause of such deterioration remains unknown. There is no clinical evidence that multiple valve reconstructions are better than single repairs in "primary" disease.

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