CrossMark

From the American Venous Forum

Journal of Vascular Surgery Venous and Lymphatic Disorders™

Quantifying saphenous reflux

Seshadri Raju, MD, FACS,[a] **Mark Ward Jr, MS,**[a] and **Tamekia L. Jones, PhD,**[b] *Jackson, Miss; and Memphis, Tenn*

Background: **Quantification of reflux is desirable in advanced chronic venous disease as clinical features are based on its adverse impact on ambulatory venous pressure (AMVP). Prior clinical observation suggests that reflux in a saphenous vein >5 mm is likely significant. On the basis of normal calf pump mechanics, we hypothesized that a reflux volume ≥30 mL was necessary to upset pump equilibrium.**

Methods: **Venous laboratory data in 119 limbs with isolated saphenous reflux were analyzed. Reflux volume was calculated by duplex ultrasound (area × velocity × duration). The relationship of reflux volume to saphenous size, calf pump function (air plethysmography, AMVP), flow resistance (Poiseuille equation), and clinical severity were examined.**

Results: **Saphenous size had a bimodal relationship to reflux volume. Reflux volume of ≥30 mL occurred mostly (97% of limbs) with saphenous size of ≥5.5 mm, but 51% of saphenous veins >5.5 mm had reflux volumes <30 mL. This is because saphenous veins invariably carried less than their maximum reflux potential indicated by their size (Poiseuille equation). Variable additional focal resistance across refluxive valve cusps and narrower re-entry perforators is not taken into account when only saphenous truncal size is used for resistance calculation. Furthermore, the association of AMVP with reflux was found not to be based on a set (≥30 mL) threshold but was variable, depending on existing calf pump mechanics, compensatory in some (12% of limbs) and aggravating reflux effects in others (26%). Calf pump abnormalities were found in 70% of refluxive limbs and in 44% (n = 16) of contralateral limbs without any reflux. Reflux volume was significantly higher overall in limbs with ulcer (C6), but the range overlapped with lesser clinical classes. Seven of 14 limbs with active ulcers had reflux volume >30 mL; six of seven limbs with active ulcers and reflux volume of <30 mL had calf pump abnormalities that would be poorly tolerant of reflux even at these smaller volumes.**

Conclusions: **Saphenous size alone cannot be used as an indicator of significant reflux. More than two thirds of the limbs with isolated saphenous reflux have calf pump abnormalities, which also occurred without reflux in the opposite limb—a novel finding. This means that in addition to quantification of reflux volume, calf pump assessment such as with air plethysmography and AMVP is desirable in clinical classes 3 and higher for proper assessment. (J Vasc Surg: Venous and Lym Dis 2015;3:8-17.)**

In the last decade, reflux-mediated microvascular injury has emerged as the central pathologic change of chronic venous disease.[1-3] At least two distinct pathophysiologic stages in the evolution of overt disease appear to be involved: (1) an initial venous dilation from shear stress-induced release of nitrous oxide and cytokines and (2) the later appearance of venous hypertension due to progressive increase in reflux and calf pump dysfunction that perpetuates shear stress-mediated injury.[4,5] The initial vasodilation may be reversible in early stages of the disease by saphenous ablation.[6] In CEAP classes 3 to 6 disease, clinical severity correlates with ambulatory venous hypertension.[7] Any benefit of saphenous ablation in this setting will depend on the quantity of reflux load eliminated from the calf pump to reduce ambulatory venous pressure (AMVP).

There have been several attempts to quantify reflux by many different technologies. Indirect methods such as photoplethysmography and air plethysmography (APG) gauge reflux by measuring refill time (after emptying) of a relatively small area of the superficial venous network and the whole calf, respectively. The photoplethysmography technique is prone to large changes in monitored capacitance from thermal and other influences. Because refilling depends on many such variables, including arterial inflow and reflux from elsewhere, these indices are considered only qualitative or at best semiquantitative indices of global reflux.[8-14] For quantifying reflux in individual vessels, a direct measurement with duplex ultrasound is preferable.[10,15] Clinical correlation with CEAP classes has been poor with both direct and indirect indices of reflux. Some authors have combined or modified these techniques in an attempt at better clinical correlation with some success.[10,16]

Duplex ultrasound can measure several components of reflux, such as vessel size, velocity, and duration as well as the reflux volume. There have been several attempts to use one or the other of these components as a surrogate for overall reflux severity to simplify the metrics. Reflux duration at a specific valve site can be reproducibly measured if standardized distal compression with pneumatic cuffs to elicit reflux is used.[17] Initial hopes of a quantitative role for valve closure times pioneered by van

From The Rane Center at St. Dominic Hospital, Jackson[a]; and the Departments of Pediatrics and Preventive Medicine, Children's Foundation Research Institute, University of Tennessee Health Science Center, Memphis.[b]

Author conflict of interest: S.R. has stock in Veniti and holds a U.S. patent for intravascular ultrasound diagnosis in veins.

Presented at the Twenty-sixth Annual Meeting of the American Venous Forum, New Orleans, La, February 19-21, 2014.

Reprint requests: Seshadri Raju, MD, FACS, The Rane Center, 971 Lakeland Dr, East Tower, Ste 401, Jackson, MS 39216 (e-mail: rajumd@earthlink.net).

The editors and reviewers of this article have no relevant financial relationships to disclose per the Journal policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

2213-333X

http://dx.doi.org/10.1016/j.jvsv.2014.07.005

Table I. CEAP clinical class of diseased limbs with isolated superficial reflux

CEAP clinical class	*N = 119*
0-1	8
2	19
3	30
4	38
5	2
6	20
No data	2

Bemmelen et al were not realized, and the measure is only qualitative.[17,18] Reflux duration now survives as a useful threshold to define reflux.[19] The size of the saphenous vein has been used as an index of reflux severity with fair correlation to clinical severity as well as to plethysmographic parameters.[20-22] A significant correlation between APG measures of reflux and size of refluxing veins at the knee as well as diameter of veins below the knee (weak to moderate, respectively) has been shown.[23] Our initial objective in this retrospective analysis was to relate reflux volume to saphenous size in the expectation that reflux volume will be more accurate. As the analysis progressed, it became clear that saphenous size had a bimodal correlation to reflux volume, and reflux volume in turn affected AMVP variably, depending on prevailing calf pump mechanics that could either buffer or magnify the effect of reflux. The aim of this study was to present the parameters of this complex calf pump pathophysiology.

METHODS

Patients. A total of 119 limbs with *isolated* reflux in the greater saphenous vein (reflux in no other venous segment) during an 11-year period were analyzed. All patients with an adequate data set (APG, AMVP) were included. Patients with combined superficial and deep reflux have been excluded to simplify analysis. The CEAP clinical classification of the study participants is shown in Table I.

AMVP measurement. AMVP was measured by standard technique through a needle in a dorsal foot vein. Measured parameters are percentage drop and venous filling time (VFT). Fig 1 illustrates the pressure dynamics that occur. Although it is referred to as a calf pump, it includes both superficial and deep compartments with a 10% to 20% and 80% to 90% volume split, respectively.[24] When the calf pump contracts, simultaneous ejection occurs in both the great saphenous vein and the deep veins, lowering the pressure in both. The major pressure drop in the saphenous vein occurs during the first step.[25] During calf diastole, reflux occurs through the saphenous vein, refilling both compartments through perforators until they are full.[26,27] The numerous (≈150) perforators, many with bidirectional flow, ensure pressure equivalence between the superficial and deep veins when filling is completed (Pascal law).[28-30] When forward flow resumes, pressure differences due to local flow conditions in the valved system may be present.[31,32]

VFT is a more sensitive parameter than percentage drop as it is more often associated with reflux and C6 disease, has a better resolution, and reflects not only the initial pressure drop but also the calf pump elastance component during pressure recovery.[14] VFT is preferentially used in this analysis.

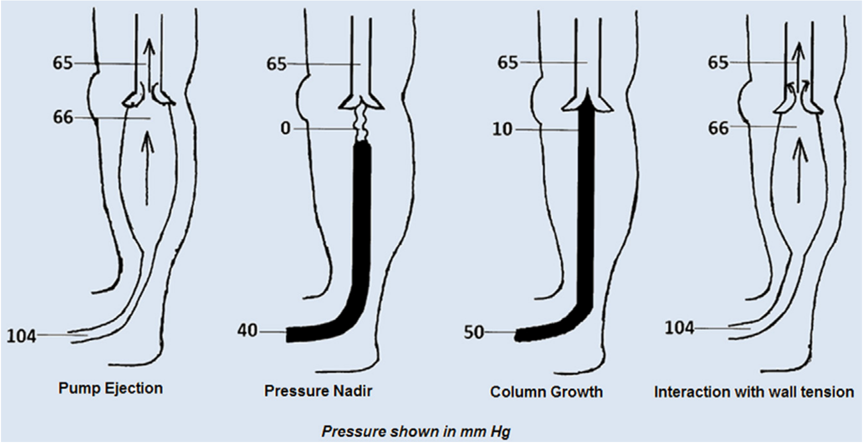

Fig 1. Pressure changes in the calf pump. The resting pressure of ≈104 mm Hg at the foot level declines to 40 mm Hg with ejection. Note the fully distended state of the calf pump veins before ejection. After ejection, the popliteal valve closes, the veins below collapse, and the pressure at the top of the residual venous column is zero. The pressure above the closed popliteal valve is ≈65 mm Hg. The calf pump begins to fill with inflow from the arterial side. As the blood column grows and touches the popliteal valve, the infrapopliteal veins are full but not stretched; the pressure will be relatively low within the calf pump (≈10 mm Hg) at this stage, and the popliteal valve will continue to remain closed. Continued arterial inflow slowly distends the calf pump veins. This "stretching" of the venous wall is necessary to create enough pressure (>65 mm Hg) adequate to open the popliteal valve and to restore flow.