Venous haemodynamics: What we know and don't know

F Lurie
Department of Surgery, John A Burns School of Medicine, University of Hawaii, 848 South Beretania Street, Suite 307, Honolulu, Hawaii 96813, USA

Abstract
The presence of haemodynamic abnormalities in chronic venous disease (CVD) has been well established. The relationships between these abnormalities and clinical manifestations, or natural history of CVD, are complex and remain to be investigated. Flow-mediated processes and mechanisms unrelated to blood flow may play an important role in the pathophysiology of CVD. Current state of knowledge makes questionable a possibility of building treatment strategies based on a single simplified model of the disease. As an example of such simplified approach, CHIVA introduces an opportunity to critically assess the gaps in knowledge in venous pathophysiology.

Keywords: varicose veins; haemodynamics; chronic venous disease; venous surgery; CHIVA

Publication of the *Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus* is considered by some to be the beginning of scientific medicine. The methodology of induction from careful observations and experimentation to a theoretical model followed by testing its predictions became essential to the progress of the biomedical sciences and scientific medicine. One of Harvey's experiments was the demonstration of unidirectional flow in normal veins. When Sir Benjamin Collins Brodie and Friedrich Trendelenburg demonstrated that this unidirectionality is disrupted in extremities with the varicose veins, it was logical to infer causality, and the haemodynamic paradigm of venous diseases was born. Surgical procedures have been designed and the outcomes of these treatments continue to provide support for this paradigm.

Causality of valvular incompetence that leads to the development of reflux remains to be determined and so too the mechanisms involved in the relationship between venous reflux and venous diseases. Theoretical models have been developed to explain this relationship. However, these models are based on multiple assumptions and, although they provide a valuable and necessary basis for the development of new and improvement of existing therapies, will evolve or even be rejected in the future. Critical analysis of evidence resulting from following each of these models, as well as deviating from them, is therefore an essential part of scientific progress. An example of an alternative avenue in the development of therapeutic approach is a concept often referred to as 'venous haemodynamics' also known as CHIVA.

Originated in France, CHIVA gained popularity in southern Europe and, although the number of practitioners adherent to its principals remain small, their reports continue to appear and draw attention on international meetings and in scientific journals. This lingering interest introduces an opportunity to critically assess the current state of knowledge in physiology and pathophysiology of venous circulation in lower extremities, and identify areas where new or stronger evidence is needed.

Correspondence: **Fedor Lurie MD PhD**, Vascular Surgeon, Kistner Vein Clinic, Clinical Professor, University of Hawaii. Email: flurie@kistnerveinclinic.com

Accepted 24 September 2008

Principles of venous haemodynamics

The principles of CHIVA treatment and their justification was presented in the most complete form by Franchesci[1] in his book. He postulated that the two

causes of varicose veins are changes in venous wall and hydrostatic pressure in standing position: 'Therefore it is necessary to treat effectively either the venous wall or the hydrostatic pressure. CHIVA acts by reducing the hydrostatic pressure,' and it is done by fractionating the column of blood. In addition, disconnecting veno-venous shunts disrupts re-circulation within the superficial system and preserves draining of superficial network. To achieve these goals, CHIVA requires: (a) preservation of saphenous vein and its first-order tributaries; (b) ligation of the great saphenous vein (GSV) at specific points – proximal to the groin tributaries at the saphenofemoral junction (SFJ), and distal to 're-entry' perforator, and (c) interruption of the veno-venous shunts by destruction of the second-order tributaries of the GSV.

The concept of 'draining', or low resistance flow from superficial veins into deep system, is the central idea of CHIVA, and makes it different from 'destructive' or surgical treatment, which by 'destroying drainage pathways favours recurrence'.[1] Therefore the aim and theoretical advantage of CHIVA is reduction of varicose vein recurrences, and the comparison between CHIVA and other approaches to treatment of varicose veins should use recurrence as a primary outcome measure.

Theoretical model

The unidirectional blood flow in the veins of lower extremities is secured by the presence of multiple valves. Malfunction of these valves can cause unwanted haemodynamic and biological sequelae that are poorly understood and are subjected to on-going investigation. The two major concepts proposed as an explanation of association between valvular incompetence and clinical manifestations of chronic venous disease are venous hypertension and re-circulation. Both of these concepts are frequently mentioned when the results of conventional treatment of varicose veins are discussed and when the principles of 'venous haemodynamics' or CHIVA approach are justified.

Measurements of the blood pressure in veins of the foot showed that during ambulation it decreases in normal individuals.[2] It was proposed that this pressure drop is due to the emptying of the deep veins by the muscle pump. Although an increase in blood flow during exercise is indisputable, a simple mechanical explanation based on changes in pressure may not be as accurate as it was thought to be, at least with regard to flow changes in superficial veins. Direct simultaneous measurements demonstrated that dramatic increase in i.m. pressure during movements causes no change in popliteal vein pressure, and slight increase of the pressure in distal GSV.[3,4] Use of more sophisticated technology confirmed these observations. The decrease of the pressure in the dorsal foot veins does not relate to the changes in pressure in the popliteal vein, and the latter can increase, decrease or remain unchanged with response to exercise.[5] Despite the absence of similar pressure changes, substantial increase in blood flow in reaction to foot movement occurs not only in deep, but also in saphenous veins.[6] This increase in saphenous flow cannot be explained by the action of muscle pump as the flow should be directed from superficial veins through perforators into the calf veins.[7,8] Well-designed, controlled experiments on isolated muscles failed to solve this controversy, and indicate that the muscle pump has only a small direct effect on muscle blood flow.[9,10]

The concept of recirculation was introduced by Trendelenburg, who described 'private circulation', when blood returns from the CFV to the GSV through incompetent junction and then into the deep system via perforating veins. This phenomenon unquestionably exists and has been confirmed experimentally[11] and by direct sonographic observation. The inferences deducted from this concept include drawing a 'flow map' and planning selective interventions aimed to re-direct the blood flow.

Apart from an obviously questionable cause–effect relationship between recirculation and venous disease, these inferences introduce several important questions. Is information regarding competency of the valve always valid? If a valve is incompetent, how often does reversed flow occurs? At which circumstances reflux happens and how much blood is refluxing? Most importantly, how this recirculation relates to other pathophysiological mechanisms involved in the development and progression of chronic venous disease (CVD)?

Prolonged standing, for example, is associated with progression of venous disease and its symptoms. Recirculation, however, is an unlikely event during standing. A gravitational force equally applies to arterial and venous vessels, and does not change pressure gradients and direction of flow. The only effect of the increased hydrostatic pressure is pooling of volume in compliant vessels. The increase of pressure in the deep veins during muscle contraction is also not a universal phenomenon.[5,12] It appears that while recirculation of blood in the venous system sometimes happens, its pathophysiological role, and the use of it as a therapeutic target, are highly questionable.

Current clinical testing of venous function is based on duplex ultrasound and utilizes reflux-provoking manoeuvres, such as Valsalva or rapid compression–decompression of the extremity. Such haemodynamic events rarely occur during normal life and should not be confused with the physiological patterns of blood flow in veins. The provoking manoeuvres test the ability of valves to close and do not indicate whether the valves actually close, or how often reflux exists during normal physical activities. Even when reflux is present over considerable time intervals, its haemodynamic impact cannot be estimated by duplex ultrasound. Therefore, the information on valve function obtained by duplex ultrasound cannot be used as guidance for drawing a 'flow map' of blood flow in the veins. In addition, the accuracy of ultrasound in identifying small veins and the flow abnormalities in them is highly questionable. This results in unknown status of the largest portion of the venous system of extremity even when the most detailed ultrasound examination has been performed.

Recent investigations demonstrated that presence of reflux or turbulent flow produces a cascade of reactions involved in pathophysiology of venous disease.[13] These studies provide the basis for a hypothesis that the key events are initiated by the presence of few flow disturbances with or without such major haemodynamic sequelae as venous hypertension and recirculation.

It is clear that factors other than mechanical play an important role in the regulation of blood flow in the veins of extremities. While many flow-related phenomena can occur only in diseased veins, our understanding of venous flow mechanics is far from the point when it can be effectively used for the development of therapeutic strategy.

Treatment outcomes

The modern conventional treatment of primary CVD combines patient-centred and evidence-based approaches. The treatment goal is patient-specific and can range from improvement of appearance, to symptoms relief, to facilitating of ulcer healing and prevention of ulcer recurrences. The selection of treatment options is based on the evidence of achieving the desirable outcome and reaching the treatment goal. Historical evidence of treatment of many thousands, if not millions, of patients, and results of scientific studies including control randomized trials, consistently indicate that elimination of reflux provides the best result. In most cases, treatment of all incompetent veins is impossible, but the fewer refluxing veins that remain untreated, the better the outcome is.

Natural history studies showed that untreated disease progresses with the development of more refluxing segments and deteriorating the existed incompetent veins leading to more severe stages of venous disease.[14–17] Leaving in place an incompetent saphenous vein after high ligation is associated with the same process of disease progression manifested by appearance of recurrent varicose veins.[18] Evidence exists that elimination of reflux in veins alters this natural history and prevents disease from progression. It is virtually impossible to find a patient with primary disease who was treated in early stages (C2) by surgical or thermal ablation of incompetent saphenous veins and later developed venous insufficiency (C4–C6) without recurrence. It has been shown by a randomized trial, that even in the most severe cases of combined deep and superficial venous insufficiency, more complete correction of reflux provides better prevention of disease progression.[16]

Recurrences of varicose veins that need surgery happens in 7.5–25% of extremities after conventional treatment. This undesirable outcome continues to be a subject of investigation.[19] Some of these recurrences have been attributed to technical imperfection of initial treatment. Angiogenesis or neovascularization has been suggested as another factor in the development of recurrent varices.[20–24] In some cases, especially long after the initial treatment, development of new varices may be an unavoidable result of the natural history of CVD.

Proponents of the 'venous haemodynamics' approach argue that recurrences result from 'destroying drainage pathways' by conventional treatment, and could be eliminated, or significantly decreased in the incidence by preserving these pathways.[1]

However, the results of a randomized trial showed that the recurrent varices were present in 18% of limbs after CHIVA treatment. Interestingly, there was no difference between CHIVA and stripping-in the incidence of recurrences originated from groin tributaries, and in all CHIVA recurrences there were recurrent veins originating from incompetent GSV, which was left in place. This is despite that fact that the selection of patients for this trial was biased in the direction favouring CHIVA.[25] The authors of this randomized trial estimate that such patients represent only 30–35% of patients with varicose veins.[26,27] This trial clearly demonstrated that treatment employed in CHIVA group can be effective in selected patients.

However, even in such a selective group with identical haemodynamic scenarios, factors leading to recurrences remain unknown. Unfortunately, the cited report[25,26] is the best available publication of CHIVA outcomes, one of a very few reports on CHIVA that meet current methodological standards.

General considerations

Development of a new treatment approach is always exciting news. When this new approach challenges the established treatment options, it introduces the opportunity to critically review our state of knowledge, and identify the gaps that need to be addressed by future studies. In the case of CHIVA, such comparison is challenging because the real difference is philosophical in nature. CHIVA is based on deductive reasoning with a number of logical inferences derived from a general theoretical model of venous physiology. The theoretical model utilized by CHIVA reduces the complex biological nature of the venous system to a mechanical aspect of the blood flow in veins, and the physics on which the model is based is mainly applicable to an idealized flow of Newtonian fluid in a rigid tube with fixed geometry.

Unlike CHIVA, the conventional approach is historically and methodologically based on the inductive reasoning. Clinical observations and results of experimental studies have served as a basis for generalization and synthesis of theoretical models. This includes, but by no means is limited to mechanical aspects of circulation. Within the inductive framework, the question of whether the theoretical basis of the treatment is true or false is not epistemically privileged, and this theoretical model changes when new knowledge becomes available. In other words, it is not so important if the GSV stripping or ablation works because it interrupts the column of blood and reduces the hydrostatic pressure, or because it disrupts recirculation, or because it eliminates the reflux, or because of some other mechanism unknown to us. What is important is that these procedures give patients a desirable outcome. When a new treatment becomes available we can compare the outcomes and, if they are better, accept the new treatment. Analysis of why the new treatment works better generates new knowledge and modifies our theoretical model, which in turn provides the basis for the development of even better treatments. An example of such process is the understanding of the role of groin tributaries in recurrence of varicose veins, which is changing after thermal ablation of the GSV became available.

On the contrary, when deductive reasoning is employed, the validity of the theoretical model becomes extremely important, and the model itself caries with it an epistemic privilege of indubitability and incorrigibility. If the model is false, the whole system collapses. The success of the CHIVA treatment confirms the validity of the theoretical basis, but failure of such treatment should be attributed to a failure to carry out a correct treatment, or to other external factors. Such an approach can still produce a new knowledge, particularly by the identification of cases when CHIVA produces acceptable outcomes and analysing their common features. The limitation is that analysis of failures cannot be performed within the CHIVA concept. The illustrations of this is a selection bias of the randomized trial comparing CHIVA and conventional treatment[25,26] in which only cases previously identified as likely to result in the best CHIVA outcomes were included. We also tried to demonstrate, that the validity of the theoretical model of 'venous haemodynamics' has been challenged by multiple experiments and observations.

The opportunity to improve treatment outcomes introduced by the success of CHIVA should not be overlooked. However, the existing information on 'haemodynamics' is limited and not sufficient to estimate the validity and practicality of this approach. In everyday practice, the physician's responsibility for the well-being of the patient must take precedence over the responsibility to generate knowledge. It is a current consensus that the treatment must be selected based on the best available evidence, and selection of an alternative treatment constitutes *de facto* research and should follow appropriate guidelines. As a treatment, CHIVA definitely falls into a research category and should be continued as such until sufficient evidence of its validity is generated.

References

1 Franceschi C. *Theory and Practice of the Conservative Haemodynamic Treatment of Incompetent and Varicose Veins in Ambulatory Patients*. France: Precy-sous-Thil & Eacuteditions de l'Armancon, 1993

2 Pollack AA, Wood EH. Venous pressure in the saphenous vein at the ankle in man during exercise and changes in posture. *J Appl Physiol* 1949;**1**:649–62

3 Alimi YS, Barthelemy P, Juhan C. Venous pump of the calf: a study of venous and muscular pressures. *J Vasc Surg* 1994;**20**:728–35

4 Hojensgard IC, Sturup H. Static and dynamic pressures in superficial and deep veins of the lower extremity in man. *Acta Physiol Scand* 1952;**27**:49–67

5 Neglen P, Raju S. Ambulatory venous pressure revisited. *J Vasc Surg* 2000;**31**:1206–13
6 Lurie F, Ogawa T, Kistner RL, Eklof B. Changes in venous lumen size and shape do not affect the accuracy of volume flow measurements in healthy volunteers and patients with primary chronic venous insufficiency. *J Vasc Surg* 2002;**35**:522–6
7 Almen T, Nylander G. Serial phlebography of the normal lower leg during muscular contraction and relaxation. *Acta Radiol* 1962;**57**:264–72
8 Arnoldi CC. On the conditions for the venous return from the lower leg in healthy subjects and in patients with chronic venous insufficiency. *Angiology* 1966;**17**: 153–71
9 Laughlin MH, Schrage WG. Effects of muscle contraction on skeletal muscle blood flow: when is there a muscle pump? *Med Sci Sports Exerc* 1999;**31**:1027–35
10 Naamani R, Hussain SN, Magder S. The mechanical effects of contractions on blood flow to the muscle. *Eur J Appl Physiol Occup Physiol* 1995;**71**:102–12
11 Bjordal RI. Circulation patterns in incompetent perforating veins in the calf and in the saphenous system in primary varicose veins. *Acta Chir Scand* 1972;**138**:251–61
12 Neglen P, Raju S. Differences in pressures of the popliteal, long saphenous, and dorsal foot veins. *J Vasc Surg* 2000;**32**:894–901
13 Bergan JJ, Schmid-Schonbein GW, Smith PD, Nicolaides AN, Boisseau MR, Eklof B. Chronic venous disease. *N Engl J Med* 2006;**355**:488–98
14 Labropoulos N, Giannoukas AD, Delis K, *et al.* Where does venous reflux start? *J Vasc Surg* 1997;**26**:736–42
15 Labropoulos N, Leon L, Kwon S, *et al.* Study of the venous reflux progression. *J Vasc Surg* 2005;**41**:291–5
16 Makarova NP, Lurie F, Hmelniker SM. Does surgical correction of the superficial femoral vein valve change the course of varicose disease? *J Vasc Surg* 2001;**33**:361–8
17 Sarin S, Shields DA, Farrah J, Scurr JH, Coleridge-Smith PD. Does venous function deteriorate in patients waiting for varicose vein surgery? *J R Soc Med* 1993;**86**:21–3
18 Dwerryhouse S, Davies B, Harradine K, Earnshaw JJ. Stripping the long saphenous vein reduces the rate of reoperation for recurrent varicose veins: five-year results of a randomized trial. *J Vasc Surg* 1999;**29**:589–92
19 Perrin MR, Guex JJ, Ruckley CV, *et al.* Recurrent varices after surgery (REVAS), a consensus document. REVAS group. *Cardiovasc Surg* 2000;**8**:233–45
20 Kostas T, Ioannou CV, Touloupakis E, *et al.* Recurrent varicose veins after surgery: a new appraisal of a common and complex problem in vascular surgery. *Eur J Vasc Endovasc Surg* 2004;**27**:275–82
21 Bergan JJ. Regarding neovascularization: an innocent bystander in recurrent varicose veins. *J Vasc Surg* 2007; **46**:177–8
22 Jones L, Braithwaite BD, Selwyn D, Cooke S, Earnshaw JJ. Neovascularisation is the principal cause of varicose vein recurrence: results of a randomised trial of stripping the long saphenous vein. *Eur J Vasc Endovasc Surg* 1996;**12**:442–5
23 Labropoulos N, Bhatti A, Leon L, Borge M, Rodriguez H, Kalman P. Neovascularization after great saphenous vein ablation. *Eur J Vasc Endovasc Surg* 2006;**31**:219–22
24 van Rij AM, Jones GT, Hill GB, Jiang P. Neovascularization and recurrent varicose veins: more histologic and ultrasound evidence. *J Vasc Surg* 2004;**40**:296–302
25 Ricci S. Letter to Editor re: Varicose Vein Stripping vs. Haemodynamic Correction (CHIVA): a Long Term Randomised Trial. *Eur J Vasc Endovasc Surg* 2008;**36**:118–9
26 Carandina S, Mari C, De PM, *et al.* Varicose vein stripping vs. haemodynamic correction (CHIVA): a long term randomised trial. *Eur J Vasc Endovasc Surg* 2008;**35**:230–7
27 Zamboni P. La correzione emodinamica dell'IVC con strategia conservativa – CHIVA. In: Agus GB, ed. *Chirurgia delle varici*. Italy: EDRA Milano Publisher; 2006:281