

Hemodynamic Saphenous Preserving Procedures in Chronic Venous Disease

Can, and should, we preserve the saphenous vein?

Editors:
Felipe Puricelli Faccini
Claude Franceschi
Stefano Ermini

Authors

Brazil

Alexandre Roth de Oliveira

MD/ MSc/ Professor of Anesthesiology at UNISINOS

Ani Arendt

Member and Ultrasound specialist of Brazilian Society of Angiology and Vascular Surgery.
Academic doctor at Grupo Hospitalar Conceição

Claudia Sathler-Melo

Member and Ultrasound specialist of Brazilian Society of Angiology and Vascular Surgery

Fanilda Barros

Member and Ultrasound specialist of Brazilian Society of Angiology and Vascular Surgery and
Fellow of the Vascular ultrasound by the Jobst Vascular Center - University of Michigan USA.

Felipe Puricelli Faccini

MD, M.Sc. Member of Brazilian Society of Angiology and Vascular Surgery. Vascular surgeon at
Instituto de Cardiologia em Porto Alegre. Founder of Instituto Pró-Safena and Pro-saphenous
Mentoring in Brazil. Member of the Global CHIVA Advisory Panel.

Ivia Binotto

Member of Brazilian Society of Angiology and Vascular Surgery

Joana Storino

Assistant professor of anatomy at CMMG and Member of Brazilian Society of Angiology and
Vascular Surgery.

China

Sophie Zhu

Attending doctor at Smile Medical Group, China. Member of the Global CHIVA Advisory Panel.

Colombia

Alberto Muñoz

Chair Vascular and Endovascular Unit
Colombia National University Hospital-Clinica Vascular de Bogota
Professor Surgery- Colombia National University

Andres Jimenez

Colombia National University.

France

Claude Franceschi

Developer of the CHIVA technique. Centre Marie Thérèse, Hôpital Saint Joseph Paris, and Hôpital
Salpêtrière, Paris, France.

Germany

Erika Mendoza

Venenpraxis Wunstorf, Germany

Italy

Fausto Passariello

Physicist and vascular surgeon, Editor in Chief of the Journal of Theoretical and Applied Vascular Research (JTAVR), Vasculab Foundation ONLUS, Naples, Italy. www.vasculab.it

Massimo Cappelli

Private Office, Firenze, Italy.

Roberto Delfrate

Surgery Unit, Figlie di San Camillo Hospital, Cremona, Italy

Stefano Ermini

Private practice. Veneinforma, Grassano, Florence, Italy

Spain

José Maria Escribano

Hospital Universitari Vall d'Hebron. Barcelona. Spain

Sergi Bellmunt

Hospital Universitari Vall d'Hebron. Barcelona. Spain

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PREFACE

When less is more. That is the feeling when I finished reading the book about saphenous preservation, written and organized by the colleague and friend Felipe Faccini. He was masterful to invite experienced authors to create a focused and concentrated book that will certainly change the comprehension of venous hemodynamics and the principles of CHIVA technique.

The human being has a natural resistance to changes and tendency to oppose new, unfamiliar things. This is particularly true in the case in which the problem to be solved already has several methods to deal with it. The treatment of the saphenous vein with reflux has several current treatment possibilities. The saphenous-stripping, thermal ablations (laser, radiofrequency), glue, foam, high-frequency ultrasound among others are commonly performed, and they all have one thing in common, the destruction of the saphenous vein. On the other hand, the disruptive technique CHIVA breaks the tradition of destroying the vein with a new concept of preserving the vein based on hemodynamic knowledge. Those of us that do surgeries have already needed a vein for a graft and there was no vein to do it. This is valid for limb salvage and also for coronary bypass and depicts the importance of the saphenous preservation.

In the first chapter, the book presents a valid question: Are we over treating the saphenous vein? The introduction of new techniques made the procedures less invasive and easy to do and recover, the answer is yes. This book presents a technique that is not new, but is not largely known and used. As the authors comment,

it needs study and a learning curve. Thus, the surgeon needs to believe in the benefit to the patients if he/she is about to change the current practice and spend time to learn the technique.

This book presents the pathway to change the current practice in an easy-to-understand and objective manner. The first chapter is a reflection of current practice and provokes the reader to prepare for the rest of the book. The rest of the book presents clearly and comprehensively hemodynamics and principles of saphenous preservation technique. The contents are suitable for the starter and also for knowledgeable specialists. The results are presented with scientific evidences and the book also gives us chapter about ASVAL, hemodynamic sclerotherapy and hemodynamic laser+ sclerotherapy. A book that teaches, updates and convinces.

I believe reading this book is pivotal to the colleagues who constantly seek the utmost objective of our profession, an excellence service to the patients. I invite the colleagues to think in an empathic manner when they are about to indicate the elimination of a saphenous vein. We should think if this procedure, independent on the technique used, is the best that we can offer to our patient.

I finish with the words I started, less is more. Less elimination of the saphenous vein, better and long-lasting results. I congratulate the authors for the excellent job. An easy, detailed and captivating book, indispensable for the good modern practice of vascular surgery, focused on the quality-of-life of the patients.

Bruno de Lima Naves, President of the Brazilian Society of Angiology and Vascular Surgery, SBACV 2020/2021.

1. Chronic Venous Insufficiency - A proactive approach.

Felipe Puricelli Faccini, Claudia Sathler-Melo and Claude Franceschi

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Key Points

Are we over treating the saphenous vein?

What are the consequences of saphenous elimination and overtreatment?

Is preserving the saphenous vein conceivable?

Approach to preserve the saphenous vein

The past and current treatment of varicose veins and venous insufficiency aims to eliminate all segments with reflux. If we see a vein with reflux that disrupts flow balance and creates symptoms, the reactive action is to eliminate it. If we see a perforator with reflux according to guidelines criteria, the reactive action is to eliminate it. Although this brings immediate relief, the body's counter reaction is certain and not predictable. The results of venous treatments are full of mishaps, recurrence, and relapses. We frequently see patients who underwent several interventions to treat varicose veins, sometimes under anesthesia. More than half of the patients who have the great saphenous vein eliminated have recurrent symptoms during their lives ¹.

A recent Phlebology editorial addressed the trade-offs of varicose vein surgery. The editorial starts with the following

statement: " The unprecedented range of treatments now on offer for varicose veins poses dilemmas, uncertainties, and incentives for both patients and practitioners" ². It is crystal clear for us that personal experience must play an important role to help the surgeon choose the best treatment for his patients. For example, a surgeon that performs stripping, phlebectomy and sclerotherapy for decades and has thousands of happy patients may be better off to keep going. Although, we might need a compass to guide us and help us reflect where we are going from time to time. In our opinion, we should pursue the real principles of medical treatment, instead of being kept in the middle of analyzing collateral endpoints (occlusion rates, for example). The recurrence, quality-of-life and incidence of complications seems to us as great principles to pursuit in Phlebology.

Are we eliminating the GSV too much?

A few years ago, the procedure to eliminate the saphenous vein comprised stripping the vein under general or spinal anesthesia. The recovery was not immediate, and most patients needed a few weeks until complete recovery after the operation. Most patients suffered post-operative pain and had to stay some time out of work. Both the patients and the surgeons usually thought a lot before performing an operation. Most patients undergoing venous procedures involving the saphenous vein were symptomatic, high-scaled at CEAP class and deeply affected regarding quality-of-life.

Modern procedures brought easier recovery and a softer threshold to eliminate the saphenous vein. We can now easily perform the procedures that once had hard recoveries. The

general anesthesia became local anesthesia, achieving immediate recovery, and low pain scores. Both endolaser venous ablation of the vein and foam sclerotherapy of the great saphenous vein are obvious examples of this statement. The number of saphenous veins eliminated is increasing along with the ease to do it. The NY Times has published an analysis about vascular procedures in which the venous procedures increased close to 150% from 2005 to 2013 in the USA ³. Later, this discussion has grown out of the newspaper and became a scientific discussion. The evaluation of venous procedures performed in the US between 1996 and 2014 shows an 4529% increase in the number of procedures, the increase starts after 2004 ⁴. The situation seems to be broader than a country's bias. A recent study has shown that in Belgian, the saphenous procedures rose by 0.83% a year from 2007 to 2017. The same study showed that patients with limited financial resources (preferential reimbursement) had significantly lowered intervention rates than usual system patients ⁵. Some may argue that the modern methods made it possible to treat patients early in the disease's course, but the possibility that we started over-treating patients is common sense. An editorial of the Society for Vascular Surgery official publication proposed the creation of a new vascular society, the SOS - Save Our Saphenous Society ⁶.

You know a man by the company he keeps. To depict the modern method versus over-treating paradigm, we should discuss the characteristic of over-treating centers and doctors. Vascular surgeons are responsible for less than 30% of saphenous ablations in the US ⁷. A study confirmed the increasing trend of doctors performing over two ablations per patient in the US between 2012-2015. The same study showed that several specialties are

performing these ablations without inter-physician analysis ⁷. Another study accounting for endovenous thermal ablation in Medicare beneficiaries showed that some centers/physicians had a clear tendency to do more ablations. These ablation outliers were of a nonvascular surgery specialty, have fewer years in practice, and have a higher overall venous ablation practice volume ⁸. Baber et al. compared rates of endovenous therapy performed by several specialties and providers in the USA. The study showed that physicians who do not traditionally treat CVD and high-volume providers are more likely to do endovenous therapy. The odds ratio was 9-times higher to have the saphenous vein treated in providers above the 75 percentile of procedures/year as compared to below 75 percentile providers ⁹.

A recent editorial of the Journal of Vascular surgery discusses the causes and solutions for this overtreatment ¹⁰. The authors suggested that physicians that over-ablate should examine their indications and vascular laboratory. Societies should reinforce information and education to help physicians meet standards. Insurers should inspect providers that perform several ablations in a single setting. The authors pointed out seven causes for the over ablation of the saphenous veins.

- 1) The medical training may cause overtreatment (nonvascular specialties not habituated might incorporate procedures without adequate training).
- 2) Disease complexity.
- 3) Inadequate Duplex Mapping
- 4) Physician may not be up-to-date with guidelines and literature

- 5) Billing mistake, charging every puncture instead of every vessel.
- 6) Many procedures in labs instead of hospitals - less oversight.
- 7) Hopefully rare, but fraud and reflux over diagnose may happen.

Recurrence - What happens when we remove a vein?

The recurrence of varicosities is a constant concern in patients undergoing venous operations and causes significant burden to patients in the long term. Studies have shown that the recurrence rates after stripping of the great saphenous vein can be as high as 60% in a 30-year follow-up ¹. Newer techniques to eliminate the saphenous vein do not have enough years of follow-up to address this matter. Although, newer techniques cannot show recurrence advantage even in shorter time range studies as compared to saphenous stripping ¹¹.

Recent studies are suggesting that excessive venous resection may cause more recurrence. Biochemical and animal studies showed that an increase in the pressure on veins and chronic shear stress of the vein wall cause venous remodeling and may lead to recurrence ^{12,13}. Matting and spider veins may develop soon after intervention as a reaction to venous modification ¹⁴.

Animal studies have shown that transcription factor activator protein 1 (AP-1) appeared to be a prerequisite for venous remodeling/proliferation and MMP-2 [matrix metalloproteases] expression. MMP-2 expression and venous proliferation follow the sudden interruption of the ear vein in rats ^{12,13}. A clinical study showed that the ligation of all the junctional saphenous tributaries causes a higher recurrence risk of varicose veins. This

study compared recurrence between two groups, high ligation of the saphenofemoral junction with and without ligation of all the tributaries. The group that had all tributaries ligated had a sevenfold increase in recurrence ¹⁵. These data suggest that an approach with less resection may help reduce recurrence.

Summarizing, we should remember that chronic venous disease is a lifelong disease and recurrence is a constant problem. Eliminating the venous capital of the patient all at once might not have the long-term effect that we desire. A recent editorial of Phlebology reminds us that patients must take part in the choice of treatment (including an understanding of the consequences of no treatment) ². We should remember that there is the possibility of not performing interventions (lifestyle, elastic stocking) and performing less destructive interventions, preserving venous capital.

What can we do to preserve the saphenous veins?

The principal purpose of this book is to offer alternatives to help the surgeon avoid saphenous vein elimination. Several chapters explain venous hemodynamics and all aspects of the CHIVA technique. We base the CHIVA technique on the hemodynamics of the leg and aim to correct flow disturbances with minimum venous resection. When we stop a reflux source, the veins wilt and most of them do not require resection. The hemodynamic surgery is a challenge that requires advanced knowledge of venous hemodynamics to fit all patients. The surgeons with excellent results in CHIVA often perform only saphenous sparing procedures. Poor planning of the procedure may end up in a superficial thrombophlebitis. Although, some

cases that do not involve a substantial length or ostium of the great saphenous vein are simple to do and might fit to any vascular practice.

We will divide the practice of CHIVA in two chapters, one for cases we consider simple (Physician non-specialist in hemodynamic), and another addressed to surgeons ready to go deeply into hemodynamics. If the reader likes saphenous sparing procedures and feels comfortable with simple cases, the chapter on hard cases brings additional insight on the technique. In the second case, we consider they should perform further training before putting these cases to practice. We will also discuss other techniques that aim to preserve the saphenous vein and venous capital, i.e. ASVAL.

The foam, laser or liquid sclerotherapy can also avoid saphenous elimination. We might use the opportunity of treating esthetic and low CEAP class patients and try to prevent venous deterioration of the leg. We hear much discussion if C1-C2 class patients should have a duplex mapping. If you inject or point a laser to a vein, why not make a duplex mapping? We may profit from the opportunity of treating esthetic/few symptoms patients to address the problem entirely. Obviously, that the rule of a patient's choice and explaining that the patients may do nothing still applies. However, society and patients demand esthetic treatments and if the specialist will not do it, unspecialized people will do it.

There are several cases in which the great saphenous vein is not the crucial source of reflux. In these cases, sclerotherapy aimed at the vein creating the reflux may correct the reflux and solve symptoms or solve symptoms without reflux reversion.

This approach is independent of the fundamental theories of reflux, ascending and descending. For instance, a case of a saphenous vein with reflux created by a collateral that has dilated over time along with its reservoir. Sclerotherapy of this collateral may solve the problem and end reflux. We can treat a case of saphenous vein reflux coming from a pelvic leak or perforator with sclerotherapy of the vein, and the reflux ends. We have solved with sclerotherapy several cases that had a previous indication of saphenous removal or ablation, keeping and even reverting flow of the saphenous vein. The long-term results of sclerotherapy procedures are surely less than ideal, and we may need new procedures. Although, the procedure is simple and 3.5 times cheaper than thermal ablation¹⁶. We consider that a hemodynamic-driven approach to sclerotherapy may improve results.

Last Comment

In conclusion, there are several saphenous sparing techniques that can add to the modern vascular surgeon armamentarium. The readers should decide which to include in their practice. The insurance companies are getting more aware of the overtreatment paradigm and are progressively hardening the policies. Our proposal is not a drastic change in the vascular surgeons' practice. We can use ultrasound to better understand the hemodynamic problem of the patient. This value our work to anyone who can understand the enormous benefit of such an approach. In our experience, many patients choose procedures that preserve the saphenous vein instead of other procedures if we inform them. We note this both in surgical procedures

(CHIVA versus endolaser) and sclerotherapy (“see, shoot” versus hemodynamic sclerotherapy).

Therefore, we have successfully included saphenous preservation in our practice with satisfactory clinical and financial results. One could consider including hemodynamic sclerotherapy for simple C1-3 patients, for example. Several cases with esthetic concern pay for their treatments, as insurances do not reimburse it. We offer hemodynamic sclerotherapy as an alternative to these patients. We destroy fewer veins and get excellent results with this approach. Another example, saphenous veins with small diameter (<5.5) and no venous disease complications^{17,18}, for which most insurance companies deny reimbursement. These patients sometimes have aesthetic reasons to ask for a procedure. We can offer hemodynamic sclerotherapy and/or CHIVA at lower cost and with much less vain vein destruction than if we were to do an ablation plus sclerotherapy. In the cases with no reimbursement, this lower cost is pivotal.

The financial aspects are also important. We consider them favorable to procedures that preserve the saphenous vein, both in the private sector and in the public sector. The first reason is that in our opinion there might be a significant number of unnecessary saphenous treatments nowadays. Another reason, the ablation procedures require use of disposable material that adds up cost to every procedure. This increases the fixed costs of the clinic, hospital and health care system. If the clinic can charge the same for a preserving procedure than for an ablation, in the year's end you will probably have a surprise. We asked about the annual clinic's spending with disposable material in ablation procedures to the participants of a conference. Several large numbers came

up. If the extra costs brought us better results, they would warrant it. However, the extra costs do not bring long-term hard end-point advantages like fewer recurrences¹⁹. Short-term results of saphenous preserving procedures under local anesthesia show fewer nerve damages and bruises than stripping, with very low complication rates. Long-term results show fewer recurrences than stripping at 10 years in randomized clinical trials. The number and profile of trials is still not ideal, as it is impossible to blind the doctors performing post-operative Duplex ultrasound (saphenous vein is still there)²⁰.

A significant advantage of saphenous sparing procedures is that surgeons need training in venous hemodynamics to perform it. This is an opportunity to strengthen our knowledge in venous disease and to get back all the patients treated by nonvascular doctors⁷. The opinion of the authors is that the patients receive better care from professionals highly specialized in the field than from a physician (or other healthcare professional) that does the procedures without in-depth involvement with the disease.

Decades ago, the CHIVA technique started in Europe, and many centers started doing it. Some centers had a significant incidence of superficial phlebitis²¹ while others had very little incidence²⁰. We consider that difficult CHIVA procedures need a learning curve. Fortunately, there is a substantial part of CHIVA procedures and ASVAL that are easier to perform. ASVAL is another saphenous sparing technique²². Surgeons have wonderful options at their discretion. We can treat the simpler cases with saphenous sparing procedures or even hemodynamic sclerotherapy. The harder cases are for surgeons after full hemodynamic training in CHIVA. May this book help the readers go further in excellent pathways at their own discretion.

References

1. Fischer R, Linde N, Duff C, Jeanneret C, Chandler JG, Seeber P. Late recurrent saphenofemoral junction reflux after ligation and stripping of the greater saphenous vein. *J Vasc Surg* [Internet]. 2001 Aug;34(2):236–40. Available from: <http://dx.doi.org/10.1067/mva.2001.115802>
2. Campbell B, Franklin IJ, Gohel M. The choice of treatments for varicose veins: A study in trade-offs [Internet]. *Phlebology: The Journal of Venous Disease*. 2020. p. 026835552092270. Available from: <http://dx.doi.org/10.1177/0268355520922708>
3. Creswell J, Abelson R, editors. Medicare payments surge for stents to unblock blood vessels in limbs [Internet]. Vol. A1. *The New York Times*; 2015. Available from: <https://www.nytimes.com/2015/01/30/business/medicare-payments-surge-for-stents-to-unblock-blood-vessels-in-limbs.html>. Accessed June 12, 2018.
4. Lawrence PF. “Better” (sometimes) in vascular disease management. *J Vasc Surg* [Internet]. 2016 Jan;63(1):260–9. Available from: <http://dx.doi.org/10.1016/j.jvs.2015.10.022>
5. Guillaume GM, Vuylsteke ME, Dalcq V, Van der Borgh L, Meeus P, de Maeseneer MG. Influence of reimbursement policies on phlebological surgical practice in Belgium between 2007 and 2017. *Int Angiol* [Internet]. 2020 Feb 20; Available from: <http://dx.doi.org/10.23736/S0392-9590.20.04305-9>
6. Samson R. Calling SOS -- Save Our Saphenous! *Vascular Specialist Online* [Internet]. 2013 Nov 21 [cited Accessed 04/25/2020]; Available from: <https://www.mdedge.com/vascularspecialistonline/article/84109/calling-sos-save-our-saphenous>
7. Crawford JM, Gasparis A, Almeida J, Elias S, Wakefield T, Lal BK, et al. A review of United States endovenous ablation practice trends from the Medicare Data Utilization and Payment Database. *J Vasc Surg Venous Lymphat Disord* [Internet]. 2019 Jul;7(4):471–9. Available from: <http://dx.doi.org/10.1016/j.jvsv.2019.01.066>

8. Mann M, Wang P, Schul M, Khilnani NM, Park A, Makary MA, et al. Significant physician practice variability in the utilization of endovenous thermal ablation in the 2017 Medicare population. *J Vasc Surg Venous Lymphat Disord* [Internet]. 2019 Nov;7(6):808–16.e1. Available from: <http://dx.doi.org/10.1016/j.jvsv.2019.06.019>
9. Baber JT Jr, Mao J, Sedrakyan A, Connolly PH, Meltzer AJ. Impact of provider characteristics on use of endovenous ablation procedures in Medicare beneficiaries. *J Vasc Surg Venous Lymphat Disord* [Internet]. 2019 Mar;7(2):203–9.e1. Available from: <http://dx.doi.org/10.1016/j.jvsv.2018.09.012>
10. Lawrence PF, Gloviczki P. Appropriate care for venous disease. *J Vasc Surg Venous Lymphat Disord* [Internet]. 2019 Jul;7(4):469–70. Available from: <http://dx.doi.org/10.1016/j.jvsv.2019.03.005>
11. Paravastu SCV, Horne M, Dodd PDF. Endovenous ablation therapy (laser or radiofrequency) or foam sclerotherapy versus conventional surgical repair for short saphenous varicose veins. *Cochrane Database Syst Rev* [Internet]. 2016 Nov 29;11:CD010878. Available from: <http://dx.doi.org/10.1002/14651858.CD010878.pub2>
12. Feldner A, Otto H, Rewerk S, Hecker M, Korff T. Experimental hypertension triggers varicosis-like maladaptive venous remodeling through activator protein-1. *FASEB J* [Internet]. 2011 Oct;25(10):3613–21. Available from: <http://dx.doi.org/10.1096/fj.11-185975>
13. Pfisterer L, König G, Hecker M, Korff T. Pathogenesis of varicose veins - lessons from biomechanics. *Vasa* [Internet]. 2014 Mar;43(2):88–99. Available from: <http://dx.doi.org/10.1024/0301-1526/a000335>
14. Timperman PE. Prospective evaluation of higher energy great saphenous vein endovenous laser treatment. *J Vasc Interv Radiol* [Internet]. 2005 Jun;16(6):791–4. Available from: <http://dx.doi.org/10.1097/01.RVI.0000165044.41012.C8>
15. Cappelli M, Lova RM, Giangrandi I, Ermini S, Giancesini S. Ligation of the Saphenofemoral Junction Tributaries as Risk Factor for Groin Recurrence. *Journal of Vascular Surgery: Venous and Lymphatic Disorders* [Internet]. 2018;6(2):290. Available from: <http://dx.doi.org/10.1016/j.jvsv.2017.12.030>

16. Lattimer CR, Azzam M, Kalodiki E, Shawish E, Trueman P, Geroulakos G. Cost and Effectiveness of Laser with Phlebectomies Compared with Foam Sclerotherapy in Superficial Venous Insufficiency. Early Results of a Randomised Controlled Trial. *Eur J Vasc Endovasc Surg* [Internet]. 2012 May 1;43(5):594–600. Available from: <http://www.sciencedirect.com/science/article/pii/S1078588412000755>
17. Gibson K, Meissner M, Wright D. Great saphenous vein diameter does not correlate with worsening quality of life scores in patients with great saphenous vein incompetence. *J Vasc Surg* [Internet]. 2012 Dec;56(6):1634–41. Available from: <http://dx.doi.org/10.1016/j.jvs.2012.02.065>
18. Navarro TP, Delis KT, Ribeiro AP. Clinical and hemodynamic significance of the greater saphenous vein diameter in chronic venous insufficiency. *Arch Surg* [Internet]. 2002 Nov;137(11):1233–7. Available from: <http://dx.doi.org/10.1001/archsurg.137.11.1233>
19. O'Donnell TF, Balk EM, Dermody M, Tangney E, Iafrati MD. Recurrence of varicose veins after endovenous ablation of the great saphenous vein in randomized trials. *J Vasc Surg Venous Lymphat Disord* [Internet]. 2016 Jan;4(1):97–105. Available from: <http://dx.doi.org/10.1016/j.jvsv.2014.11.004>
20. Bellmunt-Montoya S, Escribano JM, Dilme J, Martinez-Zapata MJ. CHIVA method for the treatment of chronic venous insufficiency. *Cochrane Database Syst Rev* [Internet]. 2015;(6). Available from: <https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD009648.pub3/abstract>
21. Mandolesi S, Ballo M, Galeandro I, Filippo S, Migaldi D, Spinelli F, et al. [The 1st national multicenter study of the CHIVA (Conservative Therapy and Hemodynamics in Venous Insufficiency in Outpatient Departments) method of treatment of varices. One-year follow-up]. *Ann Ital Chir* [Internet]. 1990 Jul;61(4):425–7. Available from: <https://www.ncbi.nlm.nih.gov/pubmed/2082780>
22. Chastanet S, Pittaluga P. Ten-Year Outcomes of Treatment of Varicose Veins by Ambulatory Selective Ablation of Varices Under Local Anesthesia (ASVAL) [Internet]. Vol. 6, *Journal of Vascular Surgery: Venous and Lymphatic Disorders*. 2018. p. 289. Available from: <http://dx.doi.org/10.1016/j.jvsv.2017.12.028>

2: Duplex anatomy of the leg veins.

Fanilda Barros, Cláudia Sathler-Melo, Joana Storino

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***“Variability is the law of life”
Sir William Osler***

History

The anatomy of the venous system is the base of Phlebology and is crucial to perform correct evaluation and treatment of venous disorders. It is important to know that there is great variability in venous anatomy, and this variability should be studied and systemized.¹

The knowledge about venous physiology and physiopathology expanded, which led to nomenclature problems and confusion.³ “The difficulty in information exchange internationally could impair the therapeutic management of patients.³ The anatomical nomenclature is essential to communication and sharing findings with all the international scientific community.²

In 1998, The International Federation of Anatomists (IFFA) and the Federative Committee of Anatomical Terminology (FCAT) created a consensus to standardize internationally human anatomy and addressed the venous system. The development of Duplex Ultrasound (DU) and its use in clinical practice made the previous terminology incomplete.³

Terminology

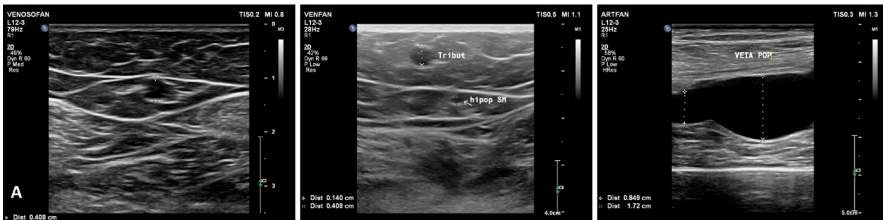
A systematic and homogeneous use of anatomical terminology is the basis for an adequate language in Phlebology. The proper use of anatomical terms is essential to the scientific and clinical approach to venous diseases.¹

There is a great variability among individuals regarding the caliber of their veins, and abnormal development may cause great variation in different vein segments in the same individual. The terms used to describe calipers are not uniform due to slight differences in changing terms and adjectives used to describe various development characteristics of an organ. Below, we present the main names according to the most accepted medical dictionaries³:

- Agenesis indicated complete absence of a vein segment.³
- Aplasia indicates lack of development of a vein segment. The vein is present, but its size is minimal, comparable to its embryonic size³.
- Hypoplasia indicates an incomplete development of a vein segment or vein. It is less severe in degree than aplasia, but it has a caliber reduction when compared to a normal structure.³

The daily ultrasound practice should use these terms correctly and describe the structures according to the findings of ultrasound. The routine scan with adequate probes (8-10 MHz for superficial and 3.5-5 MHz to deep veins) can show absence (Agenesis), embryo remnant (Aplasia) or smaller than 50% normal caliber of a segment (Hypoplasia).³

- Dysplasia indicates a complex abnormality in the development of a vein or group of veins that are greatly different from their normal sizes, architecture, and connections.³
- Atrophy indicates a smaller size of a normally developed vein due to a degenerative process. The changes in the vein wall vary according to the degenerative process.³
- Venous aneurysm indicates localized dilatation of a venous segment, with >50% increase in diameter compared to normal.³
- Venomegaly refers to a diffuse dilation greater than 50% enlargement compared to a normal vein.³



³ **Figure 1.** Anatomic terms according to caliper of the saphenous vein: (a) Normal caliber, (b) hipoplasia (arrow) e (c) venous aneurysm.

Main Concepts

The lower extremity veins include a great variety of veins from capillaries to the common femoral vein, and they drain the venous blood of the leg. Concerning their position in terms of distance from the superficial skin, there are 3 vein levels: Dermal, hypodermal and deep veins.⁴

The dermal veins comprise mainly two horizontal plexus: subpapillary plexus lies on the papillary dermis (it may be superficial

or deep papillary) and the deep dermal venous plexus in the reticular skin.⁴ The subcutaneous tissue (hypodermis) contains the subcutaneous venous plexus that drain in superficial veins and includes saphenous veins and collaterals. Subfascial venous plexus belong to the deep system and may be intramuscular (gastrocnemius and soleal veins) or intermuscular (tibial and fibular veins). Perforators connect this plexus to both dermal and hypodermal superficial plexus.⁴ These veins are named because they “perforate” the muscle fascia. The term “ communicating veins ” is used to describe veins that connect veins from the same system, thus perforators are not communicating veins.¹ The clinical, etiological, anatomical and physio pathological (CEAP) classification of chronic venous disease includes terms from the explained characteristics of leg veins. Telangiectasia and reticular veins belong to the Dermal plexus, Saphenous veins and other non-saphenous veins belong to the hypodermis and deep veins and muscular veins belong to the subfascial plexus.⁴

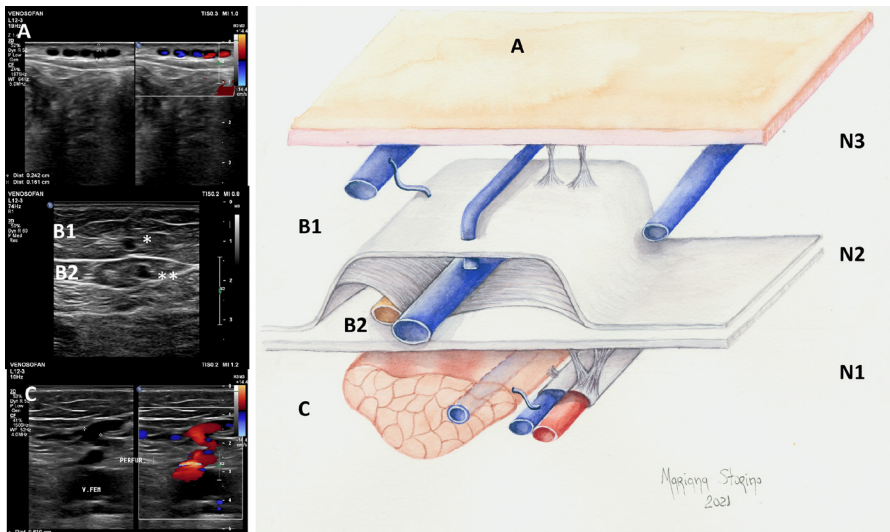


Figure 2. Venous compartments of the leg:(A) Dermis, dermic veins. (B) Subcutaneous, B1 (collaterals and accessory veins *) - N3 in CHIVA terminology and B2 saphenous vein and nerve (**) - N2 in CHIVA terminology. (C) Deep venous system (N1 in CHIVA Terminology). Adapted from Caggiati et al, 2002

The veins of the lower limbs are divided in 3 main systems: The superficial, the deep and the perforator systems. These systems are located in two main compartments: superficial and deep.¹ The deep compartment is inner from the muscle fascia and includes the deep veins. The superficial compartment boundaries are the muscle fascia below and dermis on its most superficial portion.¹ The subcutaneous tissue contains the saphenous vein and its tributaries, accessory and communicating veins. The superficial compartment has a separate saphenous compartment that is evidenced during duplex and anatomical evaluation. The saphenous compartment is deep to a hyperechogenic fascia and superficial to the muscle fascia. The saphenous fascia is the membranous layer of the subcutaneous tissue that covers the saphenous vein and its origins (marginal foot veins and dorsal foot arch). The saphenous compartment contains the saphenous veins and its arteries and nerves. Accessory, tributaries, collateral and communicating veins are external to it.¹

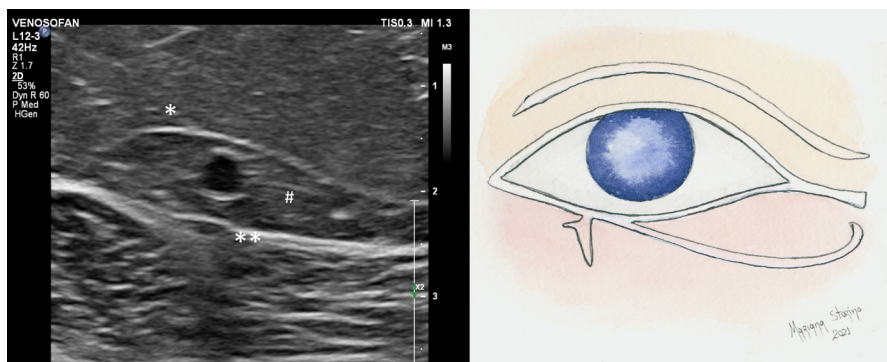


Figure 3a. Saphenous compartment “Egyptian eye” is the transverse view of the saphenous vein between the saphenous fascia (*) and deep fascia (**), anchored by its (#).

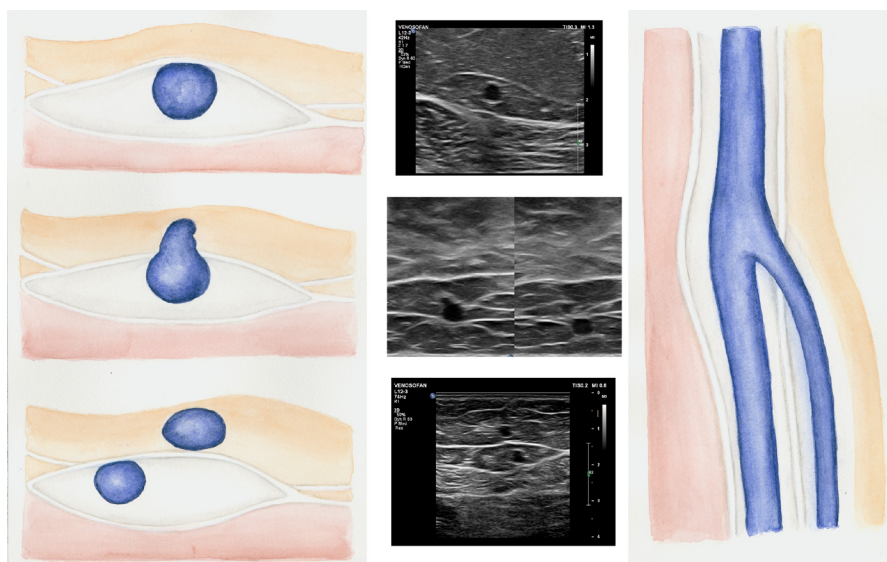


Figure 3b. Tributaries, accessories, collaterals and communicating veins are external to saphenous compartment.

The use of the “saphenous eye” or “Egyptian eye” to identify the saphenous vein is a major advance in Phlebology.⁶ Ricci et al. (2017) described the “E”asy point where the great saphenous vein is free from other structures and is covered only by a superficial fascia. This point is easily identifiable 3 to 5 cm below the saphenous junction, where the saphenous vein lays over the long abductor muscle for 1-2 cm. This anatomical point is important because most tributaries drain proximal to this valve of the great saphenous vein and an empty E point corresponds to aplasia or hypoplasia of the saphenous vein and dominance of the AASV (anterior accessory saphenous vein).⁶ The AASV dominance is not rare (11% prevalence) and should be noted because this vein is the main junction drainage in these cases. Thus, the E point is an easy assessment of the saphenous dominance, completing the conventional evaluation of the duplex.⁶

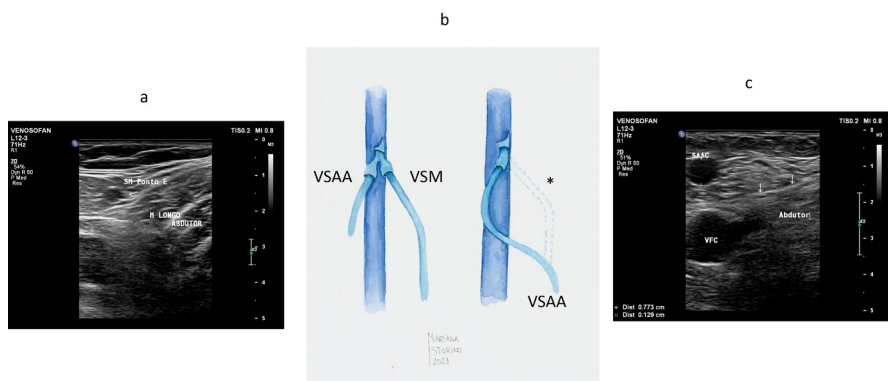


Figure 4. Point E. (a) Anatomic point 3-5 cm from SFJ, posterior boundary long adductor muscle, the GSV (SM in picture) is free of the tributaries. (b) GSV at Point E (VSM in the picture). At the right, dominance of the AASV (VSAA in the picture) due to saphenous hipoplasia called a Negative Point E. (c) US image of a Negative Point E with hipoplasia of the GSV and dominance of the anterior accessory (AASV or VSAA in Portuguese). The femoral vein appear in the image as VFC (CFV in English).

The accessory saphenous veins are venous segments ascending paralleled to the saphenous vein, and they can be anterior, posterior or superficial to the main saphenous trunk. This term names all the collateral that represent parallel alternative flow pathways.¹

The term saphenofemoral junction, saphenopopliteal junction and its valves are included in the official anatomical terms because they are anatomically and clinically appropriate. The meaning of junction corresponds to the connection of the saphenous vein and deep veins, including the valve that is usually at this position. The junction terminal valves prevent reflux from the femoral and popliteal deep veins into the superficial vein. These valves can also be presented distal to the opening of the junction, in this case called subterminal valve.³

Both classical and recent studies regarding anatomy, physiology and physio pathology of the junction suggest that it may be important to consider also 3 to 5 cm distal to the junction itself as a junctional area. The pre-terminal valve may be up to 5 cm distal to the junction

and is distal to the tributaries. This valve is important to prevent reflux from the tributaries to the saphenous vein when it closes.³

The proximal level of the junction corresponds to the supra-saphenous valve, and it is located proximal to the saphenous open in the deep vein. This valve has a pivotal role in the hemodynamics of the venous system. The distal limit of the junction in the deep vein is not thoroughly established. Some authors propose to consider the infra-saphenous valve (distal to the open) and its role in the venous hemodynamics is still uncertain.³ The anatomic-clinical concept of junction includes the opening of the tributaries that drain to the saphenous trunk between the terminal and preterminal valves. This portion is commonly called saphenous cross, derived from the french term “crosse”³

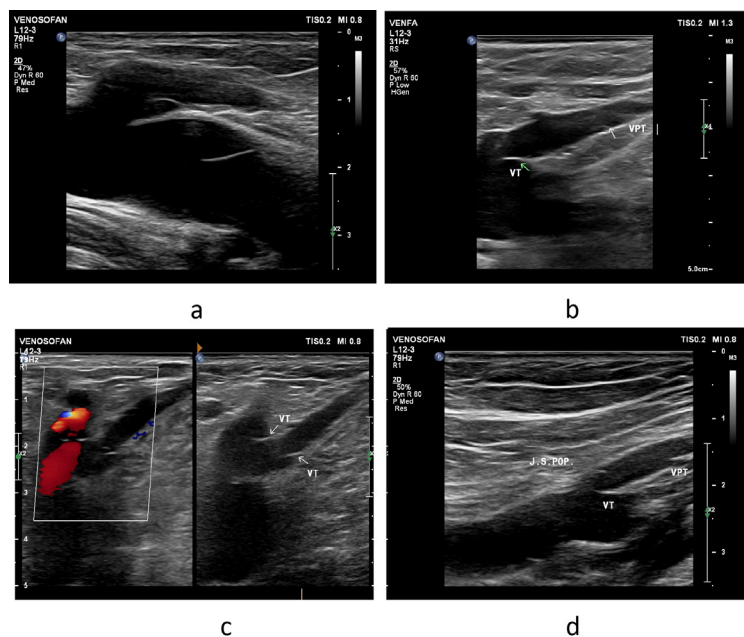


Figure 5. Ultrasound image of the terminal and pre-terminal valves. A: B mode demonstrates the valve leaflets. . B. Terminal and distally pre-terminal valves. C: SFJ with 2 entrances and separated valves. D. SPJ with the terminal valve of the small saphenous vein. These segments are called “Crosse” from French.

It is important to highlight that the classification N1, N2, N3 that is adopted to describe shunts in this book describes the venous networks (N). The deep compartment is N1, saphenous trunks N2 and tributaries N3 (Fig.2) .⁸

Superficial Venous System

Great Saphenous Vein System

Great Saphenous Vein - GSV

This is the longest vein in the body. It is usually formed by the confluence of the dorsal venous arch of the foot and the first digital dorsal vein of the foot (drains the toe dorsally). The GSV runs proximally in its compartment through the medial aspect of the foot and passes anterior to the medial malleolus. It ascends to the groin in the medial leg and thigh, and the tributaries and accessories flow to it.⁴

The GSV passes the knee medially and continues medially until it perforates the fascia lata at the saphenous hiatus (“fossa ovalis”) and drains to the femoral vein at the femoral canal. The saphenous vein has intimate relation to the saphenous nerve from the point of superficialization of the nerve at the distal thigh to the foot.⁴ The caliper of the GSV is 3-4 mm , and it may present from 10 to 20 valves, most of them in the leg. The saphenous trunk may be duplicated , but data on this is very scarce. The discrepancies in the literature are caused by the imprecise definition of duplication and lack of analysis before the ultrasound. A “true duplication”, two GSV in the same compartment, is presented in about 1% of patients.⁴

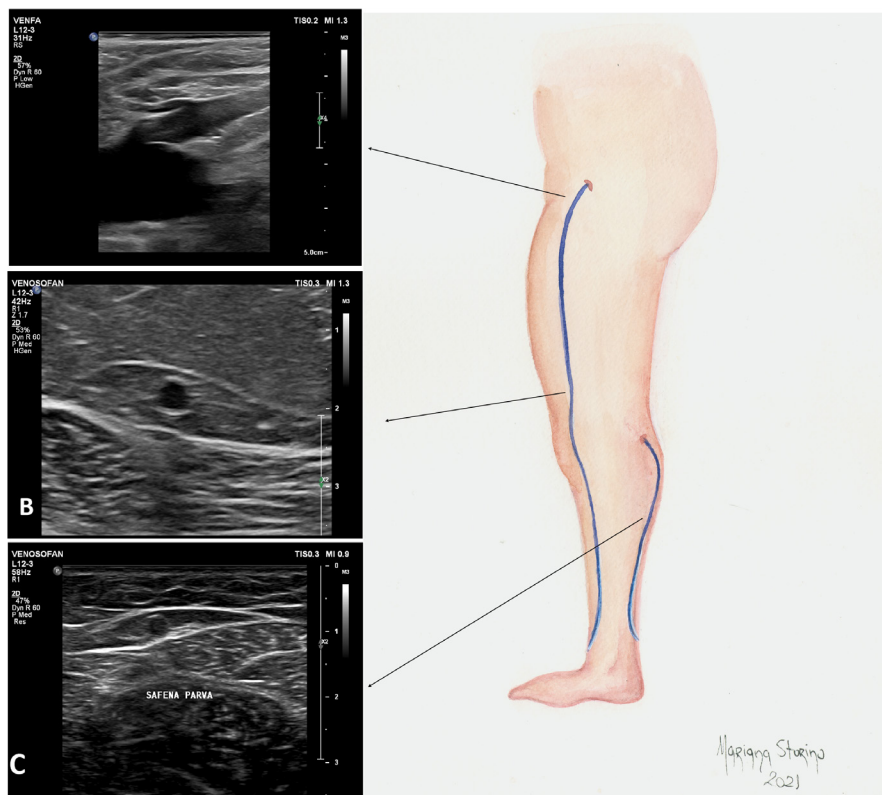


Figure 6. Ultrasound correlation of atrophic saphenous veins and compartments. (A) Saphenofemoral Junction - longitudinal section. (B) Great Saphenous Vein in the thigh. (C) Small saphenous vein in the leg. The ultrasound shows that the saphenous veins are involved by 2

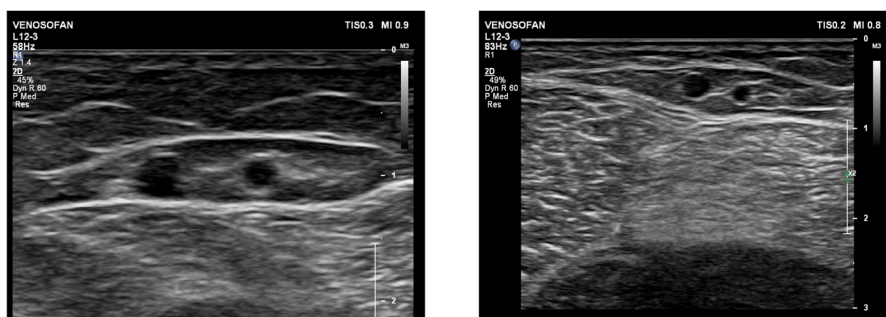


Figure 7. Duplication of atrophic saphenous vein: Two vein inside the compartment.

Anterior Accessory Saphenous Vein - AASV

The term “anterior accessory saphenous vein” is used to represent any venous segment that ascends parallel to the saphenous vein and is located anterior, both in the leg and in the thigh.¹ It can be easily identified as it runs anterior to the GSV and superficial to the deep vein and artery.³

The difference between the AASV and GSV is that the AASV is more superficial, but it may run in the saphenous compartment in the proximal segment. A lymph node is commonly found at the angle where the AASV drains to the GSV.⁴ The AASV drains to the GSV 1 cm distal to the junction in 41% of cases. One or more accessory saphenous veins are present (not hypoplastic) in 67% of the cases with 2-5 mm of diameter.⁴

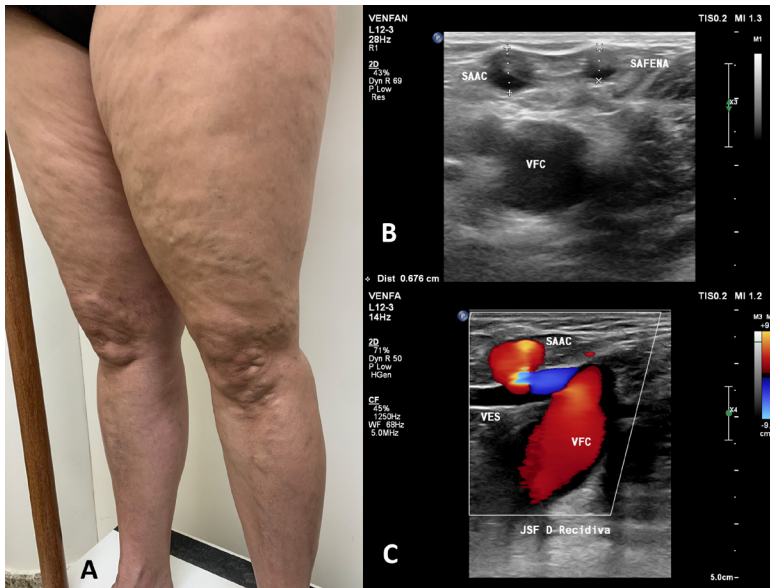


Figure 8. (A) The anterior accessory saphenous vein (AASV) in the thigh. (B) AASV or (SAAC in the image) with diameter greater than the GSV (safena in the image) at a lateral position. (C) Reflux draining from the removal vein (VFC in the image) to the AASV.

Posterior Accessory Saphenous Vein - PASV

The term “posterior accessory saphenous vein” is used to represent any venous segment ascending parallel to the saphenous vein and posterior both at the leg and the thigh¹. Its posterior leg segment usually drains to the saphenous vein distal to the knee and is also called Leonardo vein or posterior arch vein.¹ This vein is important due to its close connection to the saphenous vein.⁴

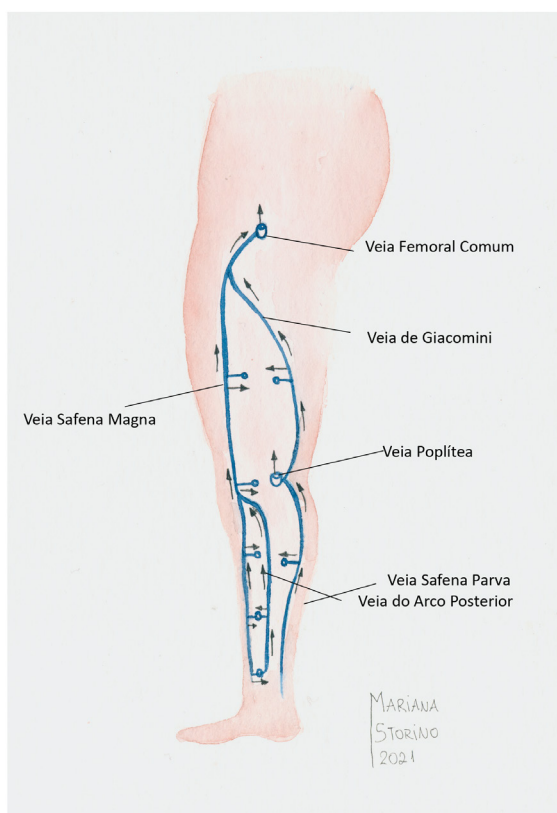


Figure 9. Schematic representation of the tributaries of the saphenous veins, tributaries and perforators. The common femoral above. The Giacomini vein connecting the SSV to the GSV. The posterior arch vein in the leg and its close relation to the GSV and perforators. Femoral comum - Common Femoral, Safena magna - GSV, Poplíteal - Popliteal, Safena para - SSV, Arch posterior - Posterior arch or Leonardo Vein.

Confluence of inguinal superficial veins - Saphenofemoral Junction - SFJ

The GSV drains to the femoral vein at the saphenous of the fascia lata at the proximal portion of the femoral hiatus. It is called saphenofemoral junction and is located 3-4 cm lateral to the pubic tubercle.⁴

The term “subinguinal venous confluence” has been recently introduced to describe the great saphenous vein between the first two valves. The proximal part of the saphenous vein has the terminal valve (incorrectly called junctional or ostial) that is the last valve of the GSV before entering the deep system. This valve is presented by 94-100% of the individuals. The distal valve is the preterminal valve (incorrectly called subostial, pre-ostial, subterminal or preterminal) that is 3-5 cm distal to the first terminal valve.⁴

This area borders the supra-saphenous valve (presented by 81% of individuals) in the common femoral vein proximal to the SFJ. Other boundaries are the pre-terminal valve of the GSV and the infra-saphenous valve at the common femoral vein. The tributaries that drain to the saphenous vein are also part of the confluence (listed below). These tributaries are responsible for the centripetal drainage of the thigh, groin, abdominal wall, external genital organs, including lymph nodes of this region.⁴

The confluence (SFJ) lies at the inguinal's ligament reflection and receives several tributaries, namely:

- Superficial epigastric vein;
- Superficial circumflex iliac vein;
- Superficial external pudendal vein;
- Accessory saphenous veins (sometimes join the saphenous vein distal to this area);
- Anterior circumflex femoral vein (sometimes join the saphenous vein distal to this area).⁴

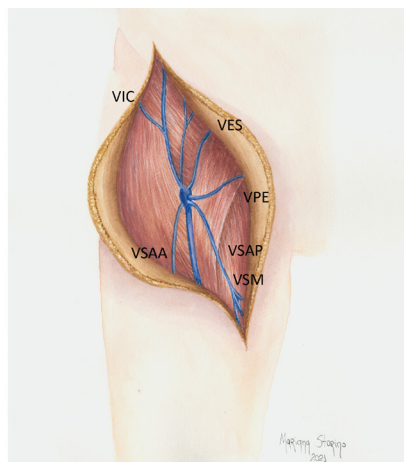
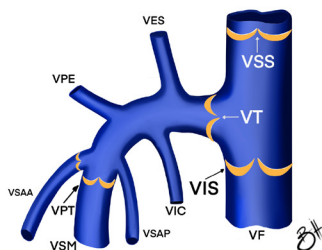


Figure 10a. Intervalvar segment of the GSV with the tributaries. VF: Femoral Vein VSM: GSV or greater saphenous vein; VSAA: AASV anterior accessory saphenous vein; VSAP: PASV (posterior accessory saphenous vein; VPE: EPV (External pudendal vein); VES: SEV (superficial epigastric vein; VIC: CIV (Circumflex iliac superficial vein); VIS: Infra-saphenic valve; VT: Terminal Valve; VPT: Pre-terminal valve; VSS: Supra-saphenic valve. Adapted from Gillot et al, 2007.

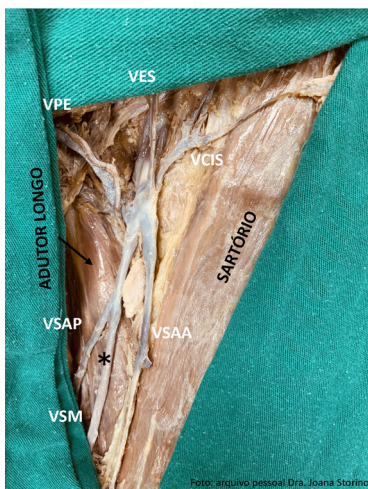


Figure 10b. Femoral trigonus left limb. The Point E (*) is the point where the GSV passes above the long adductor muscle (arrow) and is more superficial and in close contact with lymph nodes. This point usually harbors the pre-terminal valve. Usually all tributaries drain proximal to this point to the GSV.

JSF: SFJ Saphenofemoral junction.

VSM: GSV - Great Saphenous vein

VSAA: AASV Anterior accessory saphenous vein.

VSAP: PASV Posterior accessory saphenous vein.

VPE: PEV pudendal external vein.

VES: SEV Superficial Epigastric Vein.

VCIS: CISV Circumflex iliac superficial vein.

A terminal arch of the saphenous vein receiving all these collaterals occurs in 75% of patients. A common trunk of collaterals or direct drainage of a collateral to the femoral vein or accessory saphenous vein appear in 25% of patients.⁴

Anatomical variations of the GSV may be responsible for recurrence after varicose vein treatments. The incomplete ligation of tributaries of the SFJ may perpetuate the reflux from the GSV arch and cause recurrence.⁷

Anatomy textbooks usually describe the arch tributaries as a venous “star” with five main tributaries. Some books describe only three tributaries⁷. The classical textbooks rarely describe the anatomic variations of the tributaries and that the number of tributaries is very variable.⁷ The common description of an arch receiving 5 “star” tributaries presents only in 5.9% of the patients.⁷

The ultrasound evaluation of these anatomical diversities is pivotal for saphenous preservation. The complete understanding of the reflux beginning and pathway is the mainstay of CHIVA.⁷

Cirocchi et al. (2019) published a meta analysis of 16 studies and described the prevalence of SFJ variations:

- Duplication of the GSV (one junction) in 9.6% of cases;
- Duplication of the GSV (separated junctions) in 1.7% of cases;
- Ectasia of the SFJ (type 1: 2%; type 2: 1, 2%; type 3: 1.7%);
- Number of tributaries: 4 in 35.7% of cases.

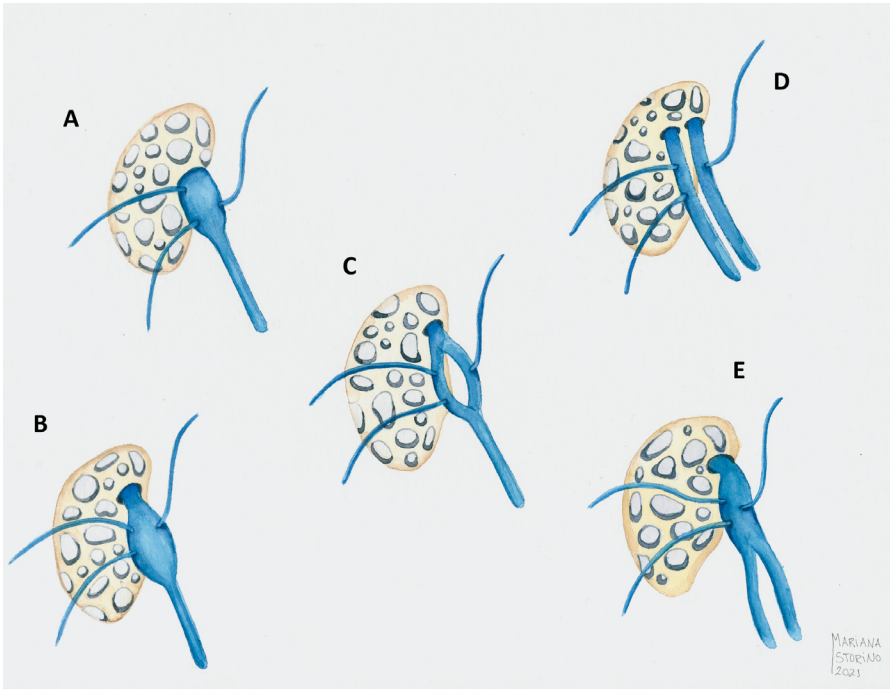


Figure 11. Main variations of the saphenofemoral junction. Ectasia of the junction. Type 1 (A), type 2 (B), and type 3 (C); Duplication of the SFJ: 2 separated entrances (D) and bifid junction (E). Adapted from Cirocchi et al, 2019.

Small Saphenous Vein System

Small Saphenous Vein - SSV

It is the second larger superficial vein of the limb, and originates from the dorsal lateral part of the foot arch veins. It ascends at the lateral portion of the foot as the marginal lateral vein and passes posterior to the lateral malleolus, running at the posterior leg. Furthermore, it has a close relation with the sural nerve at the lower third and the cutaneous medial sural nerve at the two upper thirds. The SSV ascends until it perforates the crural/popliteal fascia, where it becomes subfascial. At this point, it usually (60% of the cases) drains to the popliteal vein from 2-7 cm above the

popliteal fossa. In about 30% of cases it drains to the deep system through communicating veins to the GSV and in 10% of cases it drains to the deep system in perforators or gastrocnemius veins.

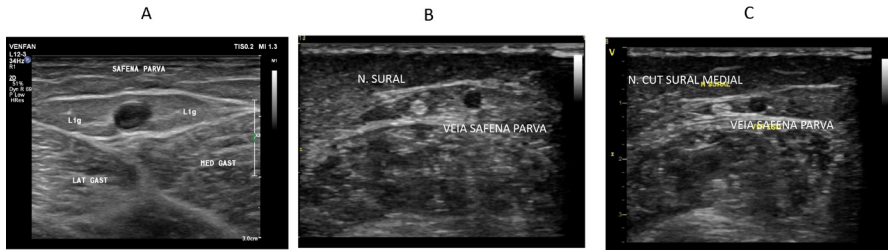


Figure 12. Ultrasound image showing the Small saphenous vein (SSV) inside its compartment. (A) SSV proximal third related to lateral and medial heads of the gastrocnemius muscle. (B) SSV ascends the posterior leg together with the sural nerve. (C) SSV with the medial sural nerve in the upper third of the leg.

Caggiati et al. reported that 62% of cases the SSV drains directly to the popliteal vein, 14% of cases drain in gastrocnemius vein, 24% drain cranial to this point. The cases draining proximal to this point further divide in another draining points: 15% to the GSV - “Giacomini vein”, 5% to perforators and in 0.06% it can ascend as proximally as in the inferior gluteal vein ⁴.

The SSV often has 3 mm of diameter and 7-13 valves, the last valve at the saphenopopliteal junction. It is closely accompanied by the “small saphenous artery”. The knowledge about this artery is relevant as the injection in this artery may be a complication of sclerotherapy (Schadeck, 2004).⁴

The veins in the popliteal fossa include the SSV, popliteal vein and their tributaries. Dodd observed that the tributaries of the popliteal fossa typically belong to the system of perforators and are seen in 40% of dissections. These popliteal fossa veins may be a unique varicose tributary or a junction of tributaries, and may enter

the popliteal vein in a central or lateral position. In half of the cases, they join the SSV, but they can also join the gastrocnemius veins⁴.

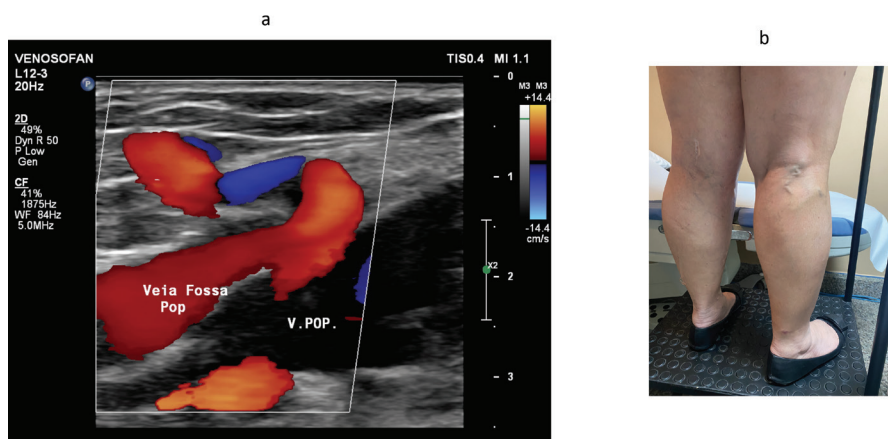


Figure 13. (a) Ultrasound image of popliteal fossa vein and (b) location of the correlated varicose veins.

Saphenopopliteal junction - SPJ

The drainage of the SSV into the popliteal vein is deep to the popliteal fascia. Just below the junction is the position of the terminal valve. From 3 to 5 cm distal to this point there is a second valve called pre-terminal valve. The significant anatomical variation of the junction and its close relation to nerves including a motor nerve (tibial nerve, cutaneous medial sural nerve), makes the knowledge of the anatomy important to perform procedures⁴.

We can summarize the anatomy and divide the types of junctions in 5 main categories. The presence (A and B) or absence (C, D and E) of a saphenopopliteal junction includes most cases⁵.

- Type A: Normal SPJ and up to 5 cm from the popliteal crease (83%)

- Type A1: No common trunk with medial gastrocnemius veins (62%)
- Type A2: With common trunk with medial gastrocnemius veins (21%)
- Type B: High SPJ, higher than 5 cm above the popliteal crease (6%)
- Type C: No SPJ, SSV continues as Giacomini vein (5%)
- Type D: No SPJ, SSV ends in the leg (1%)
- Type E: No SPJ, SSV ends in the deep plexus or perforators of the thigh (5%).⁵

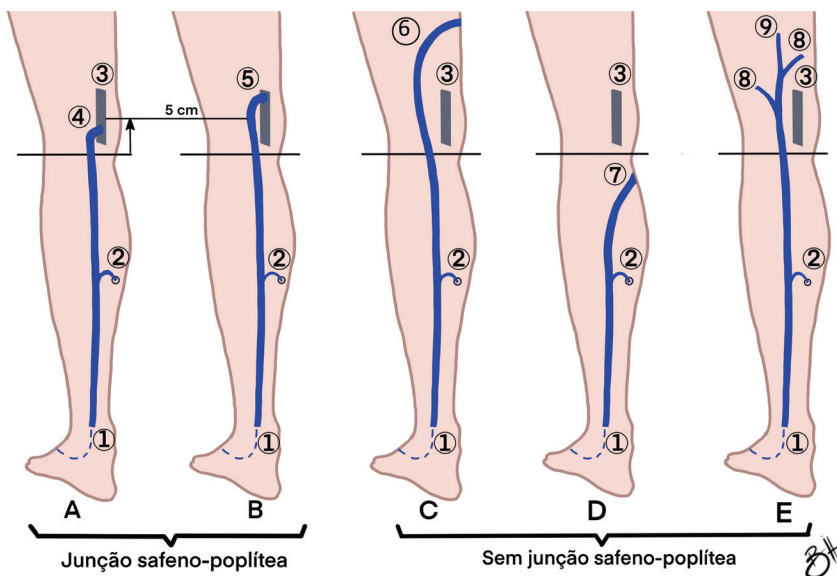


Figure 14. Five different types of small saphenous vein ending. With saphenopopliteal junction (A e B) and without junction (C, D e E). (1) Small saphenous vein (2) leg perforator (3) popliteal vein (4) normal arch of the small saphenous vein (5) high saphenopopliteal junction (6) communicating vein (7) thigh perforators (8) cranial and dorsal extension (9) gluteal extension. Adapted from Gillot et al, 2007.

Cranial extension of the SSV

This vein is a proximal extension of the SSV and originates in the superficial portion of the popliteal fossa between the terminal and pre-terminal valves of the SSV. It ascends between the semimembranosus and femoral biceps and above lays between the femoral biceps and semitendinosus muscles, close to the posterior cutaneous femoral nerve. The course of this vein is variable, it may reach the gluteal region to the gluteal veins, may reach a posterior femoral perforator or the muscle plexus. It may also remain superficial, drain to the Giacomini vein to the GSV. The cranial extension is present in 9.5% of cases. The term “femoropopliteal vein” was first used by Joseph Hyrtl in 1864, and a full description of this anatomy is depicted in the paper by Sagoo et al⁴. The term cranial extension is not totally correct because it creates some misunderstanding of proximal distal relations. The correct term might be “femoral extension” giving a more precise anatomic and function description. The terms derived from the Latin “*extensio cranialis venae safenae parvae*” is the term more commonly used⁴.

Carlo Giacomini first described a superior anastomotic tributary in 1873. He stated that this vein separates from the SSV and ascends from the popliteal fossa to end in the GSV or posterior saphenous accessory⁴. From an anatomic view, it is a communicating vein and works as a post junction extension of this SSV vein and continues as a posterior circumflex femoral vein. It drains to the GSV and is named Giacomini vein to honor the first description of the vein. This vein connects the SSV and GSV and is considered an intersaphenous vein ³.

The posterior circumflex vein of the thigh is a tributary of the GSV (or posterior accessory) that ascends transversal in the

posterior aspect of the thigh. It may originate in the SSV, in the upper extension of the SSV or in the lateral venous system. It is the remnant of the embryonic marginalis lateralis¹.

One or more small veins with transverse course interconnect the GSV and SSV. The usual flow direction is from the SSV to the GSV in these intersaphenous veins. The Giacomini vein is the posterior circumflex femoral vein that connects the SSV to the GSV or its posterior accessory. The caliber of the Giacomini vein is usually 3 times smaller than the GSV. The SSV draining via Giacomini to the GSV is present in 53% of individuals. Zierau observed an incidence is 2.5% of phlebographies. The incidence among patients with chronic venous disease changes, and it has been found in 55-80% of patients, depending on the severity of reflux⁴.

Small saphenous accessory vein

This vein ascends parallel to the SSV, but is more superficial and external to the saphenous fascia. It drains proximal to the small saphenous vein. The true duplication of the SSV is rare¹.

Lateral Venous System

A venous network is found at the lateral aspect of the thigh and leg as a remnant of the embryonic lateral marginal vein that is replaced by the saphenous veins in the embryo. The abnormal development of this venous system may appear related to certain syndromes, as Klippel-Trenaunay and Parkes-Weber. The flow usually directs from the proximal thigh lateral to drain in the lateral knee and leg perforators. The veins from the lateral perforator system drain to the muscular thigh and leg perforators (indirect

drainage) and lateral gastrocnemius perforator (direct drainage) and thus drain to the deep system. The circumflex femoral vein interconnects this system and the GVS. In advanced Chronic Venous Disease, this system receives reflux from knee perforators that drain reflux to the lateral system⁴.

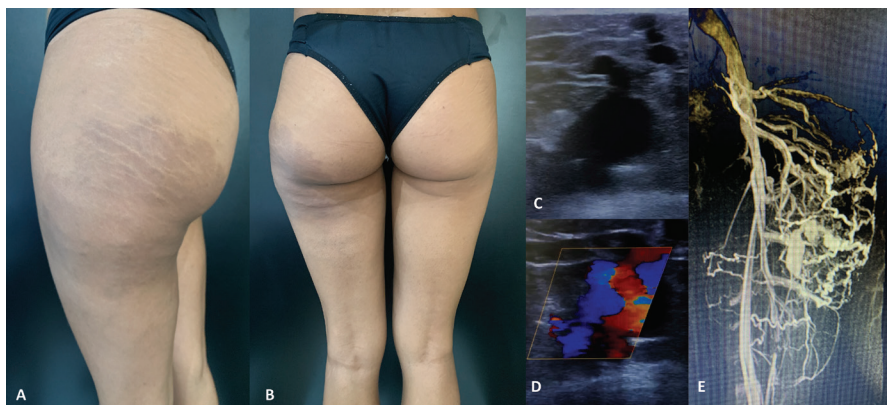


Figure 15. Abnormal remnant of the embryonic lateral marginal vein in Parkes-Weber. (A, B): Port wine stains at the lateral thigh and hypertrophy of the region accompanied by arterio-venous malformation on ultrasound (C, D) and angioMRI (E).

Foot veins

Current consensus considers all veins at the dorsal foot as superficial veins, and these veins should be specified according to the exact topographic location. It is important to notice that the dorsal venous arch and marginal and medial marginal veins of the foot are positioned in the same layer as the saphenous compartment⁴.

Blood from the hypodermis of the dorsal foot is collected by superficial digital dorsal veins to the superficial metatarsal dorsal veins (non-valved) and by the dorsal foot venous arch to both saphenous veins⁴.

The profunda femoris veins originates from the union of the posterior and lateral thigh muscle regions (profunda communicating veins). These communicating veins accompany the arteries that originate in the profunda femoris artery. The term perforating, sometimes used in these veins, should be avoided because this term is reserved for the real perforators ¹.

The popliteal vein originated in the distal margin of the popliteal muscle as an extension of posterior tibial veins. The popliteal vein runs close to the popliteal artery, superficial to it and inside the same fibrous sheet. The upper part of the popliteal vein is the adductor hiatus, where it changes name to become the femoral vein ¹.

The sciatic vein is the main trunk of the embryonic deep venous system. It has close relation to the sciatic nerve and may assume an important role as a collateral flow to the femoral vein¹.

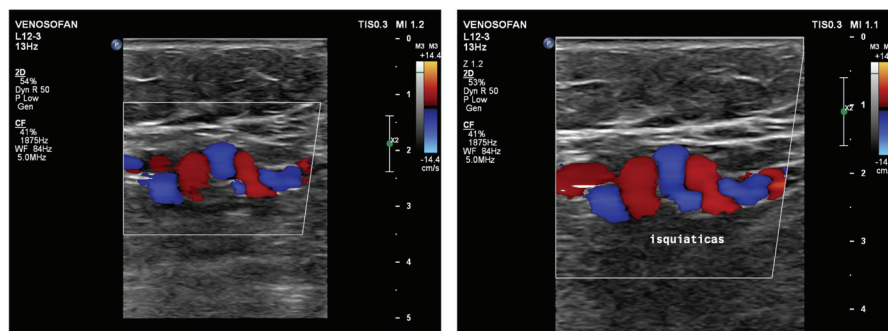


Figure 17. Sciatic vein. Embryonic remnant. Subfascial course in the posterior thigh.

The term “sural veins” is inadequate to describe the complexity of the calf veins. The soleus veins and gastrocnemius veins are the calf veins. The gastrocnemius veins are divided in medial, lateral and intergemmelus. The intergemmelus vein ascends between the heads of the gastrocnemius muscle, just below the SSV¹.

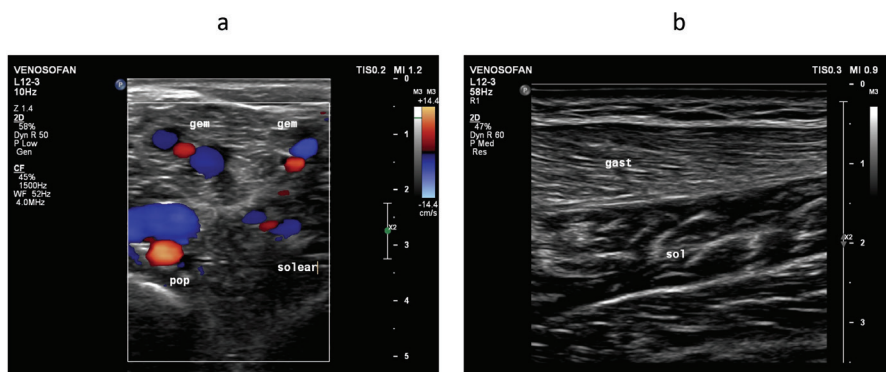


Figure 18. Ultrasound image of muscle vein of the leg: (a) Transverse section of the gastrocnemius veins (gem), solear veins and popliteal vein. (b) Gastrocnemius muscle and soltar muscle can be differentiated by the opposite direction of muscle fibers.

The term “geniculate venous plexus” should be used instead of geniculate vein. The veins at the knee are not branches of the popliteal vein, they are a complex plexus with several interconnections¹.

The deep veins of the foot are the medial plantar, lateral plantar, deep plantar arch, deep metatarsal veins (plantar and dorsal), deep digital veins (plantar and dorsal) and dorsal vein of the foot. These veins are usually pairs of veins and run along with the arteries inside the muscle fascia¹.

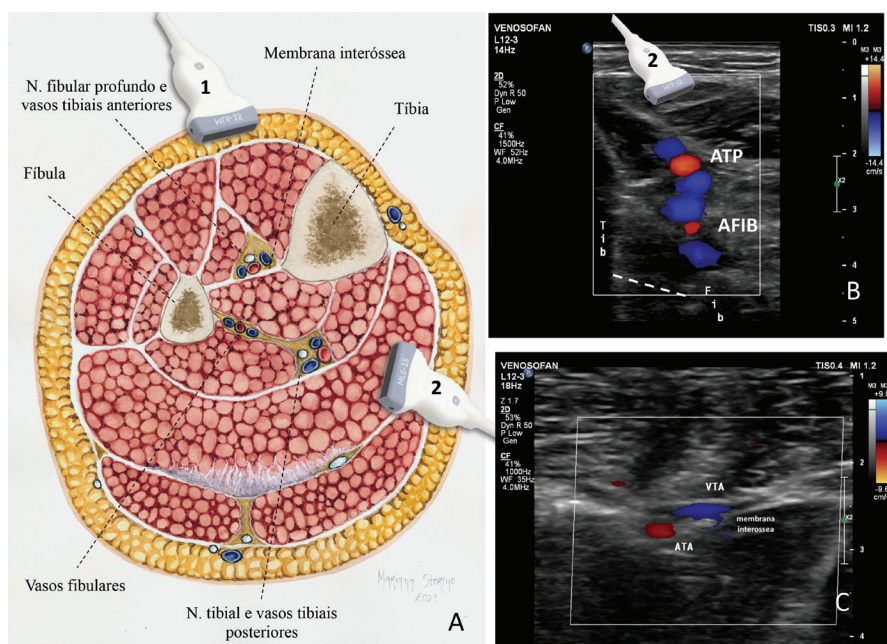


Figure 19. Ultrasound and anatomy of veins. A: Leg compartment in the middle calf transverse section. B: Relation of the posterior tibial vessels and more posterior the fibular vessels through a medial window (Probe 2). C: Anterior tibial artery (ATA) and vein (VTA in the image) related to the interosseous membrane - membrana interóssea in the image (probe 1).

Perforators

Hemodynamic principles

The hemodynamic level theory explains why perforators are closely related to muscle veins. In fact, muscle veins are the most important veins of the leg due to its contraction and relaxation and its effects in flow⁵. The location of perforators is constant and locates close to the veins that aspirate the blood to the deep system. Perforators are also closely related to the GSV, SSV and communicating veins and their main valves. There are other hemodynamic levels of perforators, mainly in the leg, and they may reflect a symmetrical “mirror” of medial and lateral veins⁵. This book has a chapter to discuss hemodynamic of perforators.

Perforators

Historically, many physicians use eponyms to describe perforators. The location is commonly used to describe the perforators more recently, as the position is more clearly defined.² The perforators are numerous and very variable regarding connections, size and distribution.¹

The foot perforators are the dorsal (with intercapitular veins), medial, lateral and plantar foot perforators¹.

The ankle perforators are denominated according to their position, as medial, lateral and anterior ankle perforators¹.

The leg perforators are divided in 4 main groups. The medial perforators are also called posterior tibial perforators or para tibial perforators. The para tibial connect the tributaries and GSV at the medial aspect of the tibia and are also called Sherman (distal 2 thirds) and Boyd (upper third). The posterior tibial perforators connect the posterior accessory saphenous vein with the posterior tibial deep vein and are called Cockett perforators. These posterior tibial perforators are divided in upper, middle or lower perforators¹.

The anterior perforators enter the anterior compartment and connect anterior GSV tributaries with the anterior tibial deep vein. The lateral perforators connect veins of the lateral subcutaneous plexus with the fibular deep vein¹. The posterior leg perforators are called according to the muscle they drain to (medial and lateral gastrocnemius, intergemmelus (SSV to gemellus muscle also called May). Finally, the knee perforators are also divided according to their location as medial, supra-patellar, lateral, infra-patellar and popliteal fossa¹.

The thigh perforators are denominated according to their location. The medial thigh harbors the femoral canal perforators (Dodd)

and inguinal perforators that connect the GSV and tributaries to the femoral vein ¹. The anterior thigh perforators enter the deep system in the quadriceps muscle. The lateral thigh perforators penetrate the deep system in the lateral muscles. The posterior perforators may be medial posterior (perforate abductor muscles), sciatic perforators (posterior midline pathway close to the sciatic nerve), posterior lateral perforators (femoral biceps ans semitendinosus muscle - Hach perforators) and pudendal perforators ¹.

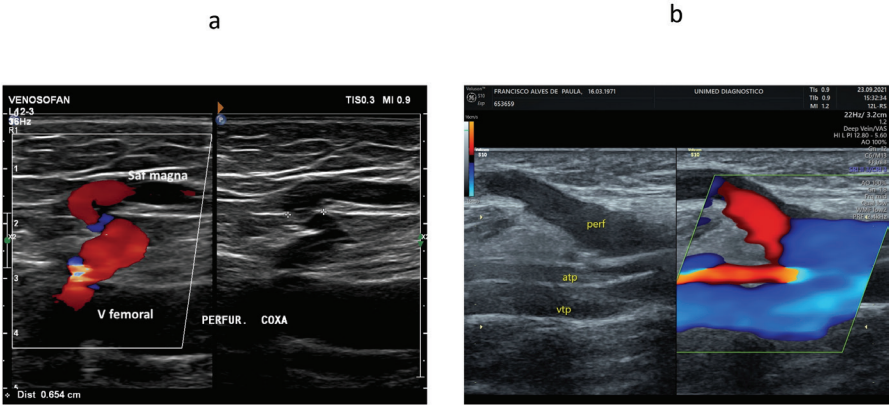


Figure 20. (a) Direct perforator communicating the femoral vein and the great saphenous vein. (b) Indirect perforator communicating the posterior venous arch of the leg to the tidal posterior vein.

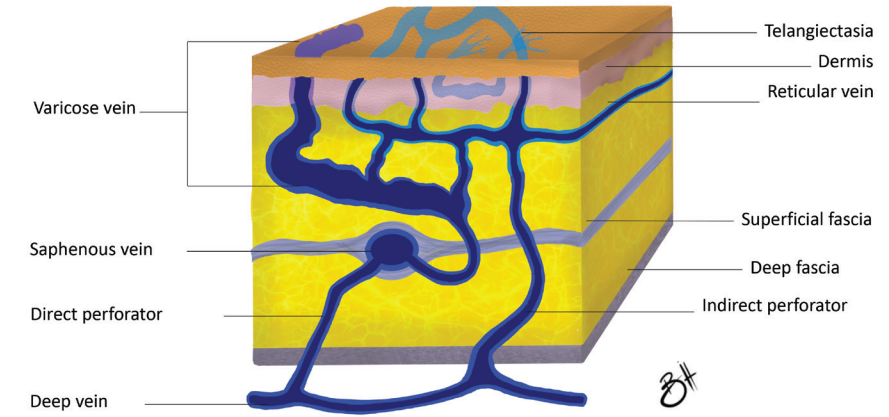


Figure 21. Schematic representation of leg veins and its levels.

Microvalves

For more than forty years, Braverman has studied microvessels in the skin, relating them with diseases like psoriasis, hereditary telangiectasias and angiokeratomas⁹. The microscopic analysis of full-thickness pieces of skin showed vessels with 70-120 micrometers at the dermal-subcutaneous junction having valves and not having a well-developed internal elastic lamina, characterizing venous micro channels. Such microvalves were structurally identical to those of the heart and leg veins. Braverman pointed out errors in textbooks of histology, assuming the absence of elastic fibers in veins lesser than 200 micrometers. In fact, elastic fibers are found in veins with 120 micrometers in diameter.¹⁰

Caggiati found evidence of the existence of microvalves and its role, pointing out the wrong assumption by anatomy textbooks that veins smaller than 2 mm were non-valved. The pathophysiology of the chronic venous disease is related to the macro valves and to the micro valves as well. The valves in the microveins are generally bicuspid and present in the collecting veins. In the lower leg, they are present in veins above 20 micrometers and have the same structure, location and orientation. There are some evidences of their relevance in attenuating the venous hypertension and their role in skin changes, if there is failure of the proximal macrovalves. Capillaroscopy, high-frequency ultrasound, microfiber angioscopy and laser Doppler can help in the future comprehension of the microvalves and their participation in the venous disease¹¹.

Lately, Vincent et al. studied the venous anatomy of amputated legs without venous insufficiency and legs with varicose veins and ulcers. The aim of the study was to determine

the role of the valves in the microveins to prevent reflux and skin changes. All legs were scanned with Doppler ultrasound to detect or exclude reflux in the saphenous veins. The retrograde filling was demonstrated in the “normal” (CEAP 0,1) members, even if the saphenous and tributaries valves were competent. Six generations of valves were depicted, besides the great saphenous vein. The incompetence of macrovalves associated with the incompetence of the microvalves were linked to more advanced disease and skin changes. Other than Franceschi’s concept of five venous (N1-N5) nets in three compartments (AC1-AC3), Vincent et al.¹² suggested a fourth one (AC4), with the fifth net (N5), inside the skin. Microvalves failure has been related to ulcer risk and adverse effects after sclerotherapy.

As depicted by Braveman et al., we consider that the association of microvalves and chronic venous disease exists, and its study may add to the improvement of patient care. Faccini et al. have recently published a paper reminding us that the saphenous vein may reverse the reflux when we treat the reflux of tributaries and their subcutaneous venules. This points out to the fact that small vein reflux may be the cause and not only a consequence in chronic venous disease.¹³

The role of microvalve insufficiency in the development of chronic venous disease is important, although further scientific research is needed to clarify its real participation in the pathophysiology of the disease.

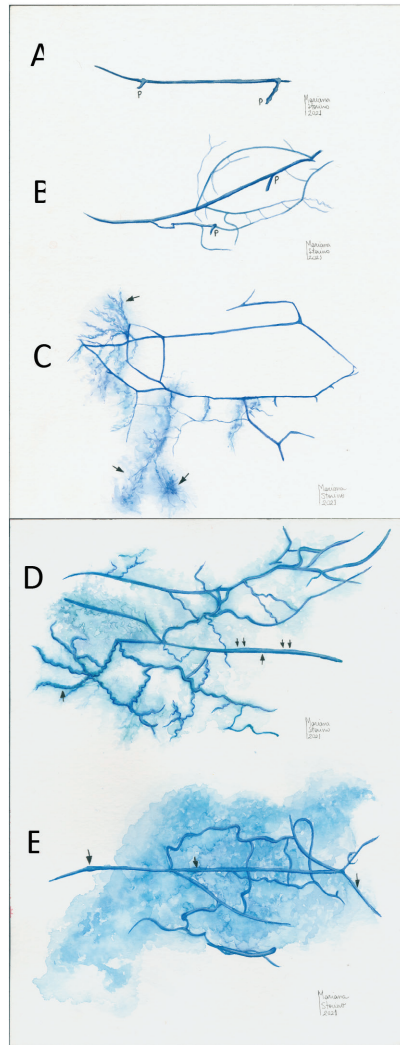


Figure 22. Variable patterns of resin venous filling in normal legs. A, No incompetent valves and no saphenous reflux. B, Filling of accessory vein larger than 300 micra. C, Filling of small net veins (half arrow) and varicosities (arrow). D, Multiple territories filling a net of small veins and tortuous veins (arrow). The GSV was intact and competent and valves present (half arrow). E, Extense filling of the superficial venous network with straight and valved GSV (between 2 arrows) and competent valves (half-arrow). We should observe the great variability of superficial small veins filling in limbs without reflux. Proximal to the right in the images. Adapted from Vincent et al, 2011.

References:

1. Caggiati A, Bergan J, Gloviczki P, et al. Nomenclature of the veins of the lower limbs: an international interdisciplinary consensus statement. *J Vasc Surg* 2002; 36:416-22.
2. Kupinski, A M et al. Venous Nomenclature. *Journal of Diagnostic Medical Sonography* 2019, Vol. 35(4) 352-353.
3. Caggiati A, Bergan JJ, Gloviczki P, Eklof B, Allegra C, Partsch H: Nomenclature of the veins of the lower limb: extensions, refinements and clinical application. *J Vas Surg* 2005; 416:719-724.
4. D Kachlik et al. Superficial venous system of the lower extremity. *Phlebology*. 2010 Jun;25(3):113-23.
5. Uhl JF, Gillot C. Embryology and three-dimensional anatomy of the superficial venous system of the lower limbs. *Phlebology*. 2007;22(5):194-206.
6. Ricci, S et al. The E point: a new echographic great saphenous identification sign in specific anatomical variants and applications. *Phlebology*. 2017 Mar;32(2):120-124.
7. Cirocchi, R et at. Systematic review and meta-analysis of the anatomic variants of the saphenofemoral junction. *J Vasc Surg Venous Lymphat Disord*. 2019 Jan;7(1):128-138.e7.
8. Giancesini S, Occhionorelli S, Menegatti E, Zuolo M, Tessari M, Spath P, Ascanelli S, Zamboni P. CHIVA strategy in chronic venous disease treatment: instructions for users. *Phlebology*. 2015 Apr;30(3):157-71.
9. Yen A, Braverman IM. Ultrastructure of the human dermal microcirculation: the horizontal plexus of the papillary dermis. *J Invest Dermatol*. 1976 Mar;66(3):131-42.
10. Braverman IM, Keh-Yen A. Ultrastructure of the human dermal microcirculation. IV. Valve-containing collecting veins at the dermal-subcutaneous junction. *J Invest Dermatol*. 1983 Nov;81(5):438-42.

11. Caggiati A, Phillips M, Lametschwandtner A, Allegra C. Valves in small veins and venules. *Eur J Vasc Endovasc Surg.* 2006 Oct;32(4):447-52.
12. Vincent JR, Jones GT, Hill GB, van Rij AM. Failure of microvenous valves in small superficial veins is a key to the skin changes of venous insufficiency. *J Vasc Surg.* 2011 Dec;54(6 Suppl):62S-9S. e1-3. doi: 10.1016/j.jvs.2011.06.085. Epub 2011 Sep 13. PMID: 21917406.
13. Faccini FP, Sathler-Melo CC. Elimination of saphenous reflux after tributary sclerotherapy: report of two cases. *J Vasc Bras.* 2021 Jun 11;20.

3 - Fluid mechanics for the non-specialist. with application to venous ultrasound investigations

Fausto Passariello

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Abstract

The same physical and chemical laws which hold for the inanimate world are still valid for the biological organisms. A set of simplified definitions are provided in order to give a global view of the arterial as well as of the venous hemodynamics. Finally, a short description follows of a few methods for practical bedside daily measurements.

Keywords

Biophysics, Fluid mechanics, Pressure, Flow, Viscosity.

Introduction

In the last decades venous hemodynamics experimented the progressive trend to neglect the quantitative approach in favor of qualitative data collection. The strong angle dependence of Doppler velocity values lead people to rely mainly on the direction of flow and on its changes after solicitation manoeuvres.

In addition, quantitative evaluations are generally time consuming and require a greater effort of the ultra-sonographer.

It is possible instead to add a quantitative approach to daily ultrasound venous examinations and to get also several data for the observational research work.

Biological organisms have several physical and chemical laws in common with the inanimate objects, but according to a never defeated prejudice in Biological Sciences, many people think that biological phenomena do not share the same physical and chemical laws of the inanimate world.

Let me remind as a clear counter-example the Gibbs Free Energy (XIX century), which governs the thermodynamics transformations at constant temperature of the inanimate objects as well as the biochemical reactions of cell metabolism of living organisms¹.

In Venous Hemodynamics the criticism about Fluid Mechanics was a great obstacle to the comprehension and nowadays still slows down the advance of knowledge.

I will synthetically remind several definitions of great interest for venous hemodynamics and then I will describe their application to a few hemodynamic measurements.

Definitions

Pressure

Given a surface S , the pressure p is the force F exerted per unit area A

In an operational manner², p is the quantity measured by a manometer.

¹ Lehninger AL. Biochemistry, Worth Publishers, Inc., New York, 1970.

² Bridgman PW. The Logic of Modern Physics. MacMillan, New York, 1927.

Pressure can be also defined in a differential form as the **variation of energy per unit volume**.

An arbitrary **zero pressure definition** is generally adopted at the Lewis angle, which matches the **right atrium level**.

Bernoulli equation

In a stationary condition, the Bernoulli equation holds, where the constant sum of the 3 terms is the energy density E/V divided by the volume V .

$$E/V = p + rgh + (1/2)rv^2 = K$$

Where r is the density, g the gravitational acceleration, h the height, v the velocity and K is a constant.

The Young-Laplace law and the container geometry

The Laplace Law (1805) was originally discovered and published one year earlier by Thomas Young (1804), also well known for the Young modulus in elasticity theory: we will refer to it as the Young-Laplace Law.

The law is able to treat **two curvatures**, but for a thin wall cylinder vessel, the **simplified well known formula** holds.

The Young-Laplace Law is a special case of the constitutive equation for the **Hookean elastic solid**.

Compliance

The **stress-strain** (deformation) graphic representation is common in Mechanics, while in Physiology generally the graph is

drawn in the opposite format strain-stress or **volume-pressure** or as a % **volume** variation³.

The slope of the curve is the **compliance** value.

Using the %Volume variation the dimension of the compliance is the inverse of a pressure

Compliance measurements require the knowledge of the **transmural pressure**

- the **external pressure** in tissue/surrounding structures is generally unknown.
- using the **intravenous pressure** instead of **transmural pressure** can be a useful approximation in normal conditions.

A **low intravenous pressure** is generally found when the compressible vein loses its circular contour, changing to an **elliptic or infinite-sign-like contour** (∞).

Flow

Flow is the volume of fluid which passes through an orthogonal (normal) section in 1 s.

Using an indirect method, arterial or venous flow can be computed approximately from the mean velocity and the BMode area measure.

The Poiseuille law

In the **Poiseuille** law the variation of the radius **a** is greatly predominant to viscosity according to the fourth power of a.

³ Passariello F. Compliance: physical and biological features. Acta Phlebol. 2013;14:9-13.

$$\dot{Q} = -\frac{\pi a^4}{8\eta} \frac{dp}{dx}$$

Note the minus sign as the downstream pressure is lower than the upstream one.

In addition, the length of the conduit is already included into the pressure gradient.

Laminar flow

In a laminar flow the laminae of fluids slide without mixing each other.

We can consider the velocity of the lamina, the velocity gradient between laminae (shear rate) and the tangential force between laminae interface (shear stress τ).

In a cylindrical tube the laminae are cylindrical areas and the shear rate is defined as the gradient of the axial velocity in the radial direction.

Definition of viscosity

There is a linear relationship between the shear Stress and the shear Rate, where the constant linear coefficient m by definition is simply the **viscosity**, otherwise called the **absolute** or the **dynamic viscosity** of the fluid.

Fluids which follow the Newton formula are called **Newtonian fluids**, as water and approximatively plasma.

Non-Newtonian fluids

Non-Newtonian fluids as blood instead exhibit a great variety of behaviors. Viscosity in a **non-Newtonian fluid** is the apparent viscosity, with a shear rate point by point variability.

Viscosity can increase (**shear thickening**) or decrease (**shear thinning**) as the shear rate increases.

Plotting the shear stress against the shear rate in a shear thinning fluid like blood, the curve lays below the tangent in the origin. The tangents in the other points become progressively smaller.

Bolus flow

A **Bingham plastic** is a fluid which behaves like a solid at low shear stress while behaves like a viscous fluid at high shear stress.

At very low shear rate, the flow can become a **bolus flow**. This corresponds to a threshold called **yield stress τ_y** , which corresponds to the transition between elastic deformation and viscous flow.

Casson equation

At very low shear stresses, the Newton formula can be substituted by the **Casson equation**, where h is the **Casson viscosity coefficient**, i.e. is approximatively the apparent viscosity at a very high shear rate⁴.

$$\sqrt{\tau} = \sqrt{\eta} \sqrt{\dot{\gamma}} + \sqrt{\tau_y}$$

⁴ Casson M. (1959) In Rheology of Disperse Systems, Mills, C.C. (ed.). Pergamon, Oxford, pp. 84-104.

Whole blood is a non-newtonian, shear thinning and also a Bingham plastic fluid, owing to the yield stress present at low shear rates⁵.

Viscosity estimate

Both the yield stress and the apparent viscosity can be estimated, the latter being computable by at each shear rate. For instance, the regression equation is shown below for the linear estimate⁶ of the whole blood apparent viscosity **μ** from the hematocrit **Hct** and the total plasma proteins concentration **TPP** at a shear rate of 208 s⁻¹.

$$\mu = 0.12 Hct + 0.17 TPP - 2.07$$

The truncated parabola

The bolus flow is present in arterial as well as venous vessels, changing the velocity profile from the well-known parabola to a **truncated parabola**, with a null shear rate in the center of the vessel.

Oka equation

This modified profile can be effectively described by the **Oka equation**⁷

⁵ Milnor WR. Hemodynamics. Williams & Wilkins, Baltimore, 1989.

⁶ de Simone G, Devereux RB, Chien S, Alderman MH, Atlas SA, Laragh JH. Relation of blood viscosity to demographic and physiologic variables and to cardiovascular risk factors in apparently normal adults. Circulation. 1990 Jan;81(1):107-17. doi: 10.1161/01.cir.81.1.107. PMID: 2297818.

⁷ Oka S. (1965) In Symposium on Biorheology, Copley, AL (ed.). Interscience, New York, p. 89.

$$\overbrace{\dot{Q} = -\frac{\pi a^4}{8\eta} \frac{dp}{dx} \mathcal{F}(\xi)}^{Poiseuille}$$

$$\underbrace{\hspace{10em}}_{Oka}$$

which is based on a complicated function of a **parameter** **x**, defined as dependent on the **pressure gradient** and the **yield stress**. In a simplified and elegant way, the Oka equation was rearranged as the original Poiseuille equation multiplied by a correction factor **F(x)**⁸.

$$\mathcal{F}(\xi) = 1 - \frac{16}{7}\xi^{\frac{1}{2}} + \frac{4}{3}\xi - \frac{1}{21}\xi^4$$

$$\xi = \frac{2\tau_y}{a} \left(\frac{dp}{dx} \right)^{-1}$$

The use of the Oka equation is reserved to detailed research studies.

For this important theoretical result in hemodynamics **Prof. Syoten Oka** was assigned the Jean-Leonard-Marie Poiseuille Award in 1975 by the International Society of Biorheology.

⁸ Fung YC. Biomechanics, Mechanical properties of living tissues. Springer Verlag New York inc., 1981.

Practical bedside measurements

Caliber

Ultrasound devices provide facilities to measure distances. The vessel caliber is got placing the cursors at the internal walls.

Cross sections can visualize both the anterior/posterior and medial/lateral walls. Ultrasound reflection gives a better resolution for the superficial and deep walls, while the visualization has a lower quality for the lateral walls. In longitudinal sections just the superficial and deep walls are detectable, with an uncertainty due to a non-centered section.

In standing position, generally veins are distended by the hydrostatic pressure and the cross section is almost circular, thus a single measurement of diameter (passing through the center of the lumen) will be enough for all subsequent computations.

In supine position instead the vein is subjected to a variable range of pressures, thus its shape changes accordingly:

1. Very low pressure - the shape like a dumbbell or like the ∞ math symbol.
2. Intermediate pressure - elliptic shape;
3. High pressure - circular shape.

As regards the elliptic shape, the cross-section area is worth

$$\pi ab = \pi \frac{d_1 d_2}{4} = \pi \frac{d_{eq}^2}{4}$$

where a and b are the major and minor semi-axes, d_1 and d_2 the corresponding diameters and d_{eq} the equivalent diameter, defined as

$$d_{eq} = \sqrt{d_1 \cdot d_2}$$

i.e. the diameter of the circle with the same area. The use of the equivalent diameter simplifies significantly all computations.

Any cross-section, whatever its shape, has its equivalent circle (and diameter), though the above formula holds just for elliptical shapes.

Veins can have an uniform caliber along their length or instead a variable one, depending on the site of measurement, even in physiological conditions. For instance, the caliber of the greater saphenous vein (GSV) changes considerably, for instance at the junction (where the shape of the arch can have several variations), at 2 cm upstream from the junction or in the trunk at mid-thigh.

In diseased veins, incompetent or thrombotic ones, the caliber changes according to the severity of the pathology. Localized dilatations or stenoses provide a great variety of cases. The best solution is to report the caliber, declaring also the site of measurement.

Mean velocity

There are several types of mean velocities

1. The mean value is computed for each small sample (Mean) and can be reported in real time as a curve vs. time on the device display.
2. Considering an interval of the original signal (for instance the cardiac cycle), it is possible to compute the mean value of a measure, thus also the mean value of the Mean. We will refer to this last value as the Mean velocity (v_{Mean}).

A quick hand-made computation provides an inaccurate but useful value for v_{Mean} . In analogy with the quick mean pressure estimate

$$v_{\text{Mean}} \simeq V_{\text{min}} + \frac{\Delta v}{3}$$

where V_{min} is the minimal value and Δv is velocity range in the considered period.

Flow

The equation for flow (ϕ) is

$$\phi = v \cdot A$$

where A is the area of the vessel cross section and v the velocity.

Using the equivalent diameter the equation can also be written as

$$\phi = \pi \cdot v \cdot \frac{d_{eq}^2}{4}$$

As the flow does not depend on the site of measurement, it is better to search for the most regular cross-section in order to make measurements. In addition, most venous measurements are performed in standing position, when the hydrostatic pressure is high and the section shape is almost circular. Thus the single diameter measurement can be adopted as the equivalent diameter.

Conclusion

The current text is just a short guide to the fundamentals of biophysics and fluid mechanics applied to the venous circulation. It is intended to be an encouragement to start a deeper research study⁹.

⁹ Passariello F, Beach KW, Franceschi C, Allegra C, Labropoulos N. Basic science in venous hemodynamics. *Acta Phleb* 2016 August;17(2):37-51.

4 - Reflux patterns and Types of shunts

Felipe Faccini, Stefano Ermini and Claude Franceschi

<https://doi.org/10.5281/zenodo.6490674>

Key Points

Not all reflux saphenous vein needs intervention

Discussion of Reflux theories

Explanation of Shunts (basis for CHIVA operations)

Waveform analysis

The good understanding of reflux theories and the origin of the flow problem of each patient is important to surgeons that perform procedures preserving the saphenous vein. This chapter is probably the most important chapter of this book. Once the reader can see the reflux from a Shunt point of view, it turns the saphenous preserving mentality on. Franceschi et al. published the concept of shunt in 1988¹. A venous shunt considers the anatomical compartments (N1-deep, N2 - saphenous, N3 - collateral). There is a usual flow direction and volume in every vein, they follow the venous hierarchy. A shunt is a break in this hierarchy.

The shunt usually has 3 characteristics, (1) an exit - escape point, (2) pathway - involved veins with reflux and (3) a re-entry for the blood. Thus, the escape point is the “short circuit” that provides pathological deviated blood to overload the involved veins. The veins that carry this overloaded blood are the pathway. Finally, the re-entry is the vein that carries the blood back to the right track. The re-entry is as important as the other parts of the

shunt, and sometimes forgotten. I would like the reader to imagine what would happen if the blood left the deep system, ran through an extensive set of veins in the leg and did not have a way back to the deep system/heart. I can only imagine a superficial thrombosis happening on the first day. So, when you think of a shunt, always think of the escape, the pathway and the re-entry.

Reflux is a complicated subject, and there is no single cause to blame for it. Its origins and classification are very debatable. This shunt theory includes most cases of varicose patients, but we often see cases of reflux that did not have an obvious escape point from the deep system. For example, varicose veins that occur after dilation of subcutaneous veins that get together to create a reservoir and overflow creates reflux.

We will discuss the shunts one by one in this chapter. We present now one simple example of shunt to entice the memory. The great saphenous vein at the femoral junction has important reflux (escape point) from the junction to the low-thigh and drains to a dilated collateral (pathway). This collateral after a few centimeters of dilations drains its blood to a perforator that drains its reflux (re-entry). The perforator drains to the tibial vein, and the blood goes back to where it belongs.

Reflux Theories

This book has a chapter about physics and hemodynamic principles. The knowledge of a few principles is pivotal and will be briefly presented. The gradient is the difference of energy between 2 recipients (or venous systems). If there is a communication - no valve - the energy tends to go from the high energy to low energy

until it is equal in both sides. The energy depends on the gravity and the size of the blood column. Bernoulli stated that the flow velocity creates a differential pressure because of the difference in the lateral pressure on the vessel. The faster the flow, the smaller the lateral pressure and the easier for the blood to go from one vein to the other. This is important, if the vein dilates, the velocity decreases and the lateral pressure increases, making it more difficult for the blood to get in that vein. Venturi described a tendency for faster flow in a stenosis, to help blood get inside a vessel. Poiseuille stated that turbulence creates dilation of the vein (why do venous grafts dilate less in a high-pressure arterial bypass than in a lower pressure venous system?). The thoracic abdominal pumps and calf muscle create a constant turbulence in leg veins. The veins are compliant, which means they increase the blood reservoirs before an increase in pressure. The smaller the vein, the higher the compliance and capacity to become a reservoir of blood and dilate. The Laplace law states that the higher the radius, the higher the pressure in the wall of a vein.

There are two basic theories on the origin of reflux. The ascending theory considers that the varicose veins dilate at the epifascial veins or smaller ones ². This increases the compliance of these veins and, according to the Venturi effect, these veins present turbulent flow. Oscillatory turbulent flow is one of the major causes of venous deterioration ^{3,4}. Studies have also shown that even micro-veins have valves, and these relate to the skin degeneration of chronic venous insufficiency ⁵. This theory relates to the cases in which we observe a reflux only at the superficial system. The descending theory considers that the distinct pressures between compartments (deep-superficial, saphenous-

epifascial) creates unbalances and consequently a gradient. This gradient sends flow from one system to another in certain circumstances. The abdominal-thoracic pump forces blood down during Valsalva maneuver, and the leg muscles pump blood up during contraction (systole). If an abnormal connection (valveless saphenous junction, perforator, pelvic leak or other source) is present, the pumped blood will search to fill the gradient of the system with less pressure.

Both theories explain part of the cases, and the authors consider that ascending and descending theories are complementary. We see patients with superficial-only varicose veins, unrelated to the deep system or saphenous system. For example, patients with lateral thigh collaterals and telangiectasias that descend laterally and drain its reflux to a perforator or the distal saphenous vein. Evidence suggests that the micro-veins have valves and relate to reflux and skin alterations of chronic venous disease^{5,6}. Patients that activate a pelvic shunt after pregnancy are a typical example of the descending theory.

Is Reflux Always Pathologic? No.

The widespread use of duplex scan has created many diagnoses of reflux. The effect of this was that we turned people into patients. We can provoke flash reflux in many people with normal legs. Following the guidelines for duplex evaluation avoids wrong reflux diagnosis, i.e. patient standing during examination. Many patients with leg pain search for help with vascular surgeons. There are several diseases that cause leg pain mimicking the pain of venous disease, i.e. orthopedic, neurologic, rheumatic and so on. If a rushed medical interview and clinical examination misses

the other disease and the patient has an asymptomatic reflux in the duplex scan, the practitioner might perform an unnecessary procedure. Unfortunately, this is much more common than we desire. Even in those cases, with minor symptoms or esthetic complaints related to a reflux, we should remember that an intervention is not the only way. There are at least two recent editorials of important vascular/Phlebology journals in Europe and America that address the overtreatment situation ^{7,8}. Lawrence and Gloviczki addressed the overtreatment situation deeply and proposed that the medical societies should educate its members and that insurers should increase their oversight ⁷. Campbell et al. suggests we should provide the patient a well-informed choice (including an understanding of the consequences of no treatment) ⁸. We need to remember that not all reflux relates to a venous disease, and that not all symptoms in the leg relate to venous reflux.

Classification of Shunts

Open versus Closed Shunts and Mixed Shunts.

The classification of shunts proposed by Franceschi bases on the characteristics of the escape point, pathway and reentry point. The shunt is closed if it recirculates in a closed circle. For instance, the reflux escapes at the saphenous-femoral junction, making its way through the saphenous vein until it gets to a perforator and enters the deep system. The blood passes at the femoral junction again. Basically, the closed shunt re-circles at the same vein where it started. We consider the shunt open if it does not re-circle in the same vein before it goes to the heart. An

example of open shunt would be a Palma bypass, the flow escaping at the left saphenous-femoral junction goes to a collateral pathway and finally re-enters at the right saphenous-femoral junction. The blood will not re-circle its origin, being considered an open shunt. Mixed shunts are those that have an open shunt and a closed shunt that share the escape point and part of the pathway. As an example, let us add up the examples before. The patient with a left-right Palma bypass after iliac obstruction develops dilation and reflux at the left saphenous vein in the compensation process. This patient will have a mixed shunt, one open and one closed with the escape point at the saphenous-femoral junction and part of the left saphenous vein in common.

The Concept of Vicarious and Derived Shunts

The Vicarious shunts are the shunts that divert blood from an obstruction (deep thrombosis, trauma) to compensate it. The term vicarious shunt was used to describe a bypass shunt, a bridging circulation or a circulation by proxy. This shunt has an obstruction and expresses usually by systolic flow. The leg muscles pump the blood up to the heart and the blood finds an obstruction, then it directs to the proxy circulation to finish its pathway. The development of superficial varicose veins and telangiectasia after saphenous ablation or saphenectomy is also a vicarious shunt; we destroy the pathway of the blood, whether it is up to the junction or down to a perforator. The reaction is to develop increased pressure and create new collaterals.

The derived shunts (deviation or detour shunts) deviate the flow from the escape point to the pathway and re-entry points. The derived shunt is the consequence of valve incompetence at

an anatomical position that allows gradient pressure reversion to enter the shunt. These shunts have diastolic reflux predominantly. This means that after muscle contraction that increases pressure on the leg veins comes the relaxation that decreases it. This relaxation allows reflux to go back through the escape point and nurtures the derived shunt. The concept of systole and diastole and inward and outward flow is essential and will come later in this chapter. If we see an outward systolic flow automatically, we should think of deep disease and evaluate the case in its complexity.

The Phases of Reflux (Waveform Analysis).

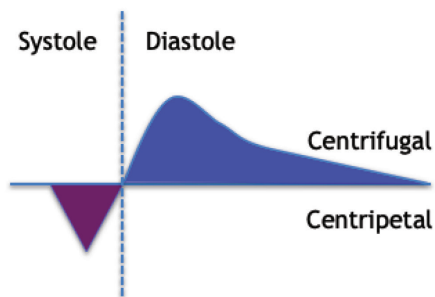
The pulsed wave of color Doppler can help us understand the physiology and pathology of the flow. We need to observe the usual aspects most readers already know about, upward versus downward flow. This means the time and speed of flow/reflux. All guidelines discuss the time of reflux we need to consider reflux pathologic. The speed is also obvious, and most doctors recognize that a higher speed means worse reflux. The model of time of reflux is to define pathologic reflux is not perfect. The time depends on the dynamics of the maneuver, the greater the emptying of the leg, the greater the reflux (see dynamic maneuvers in this chapter).

The knowledge of venous compartments is essential to understand venous disease. It is important to know from where to where the blood is moving to comprehend the pathologic mechanism involved and treat it. We should analyse the inward and outward flow between compartments, besides upward and downward. When there is a connection of two compartments, i.e. N1 (Deep) with N2 (Saphenous Vein), we should profit from the opportunity and go beyond measuring speed and velocity.

Looking at the wave of reflux, we can understand the direction of flow and correlate with the stimuli that is creating that flow.

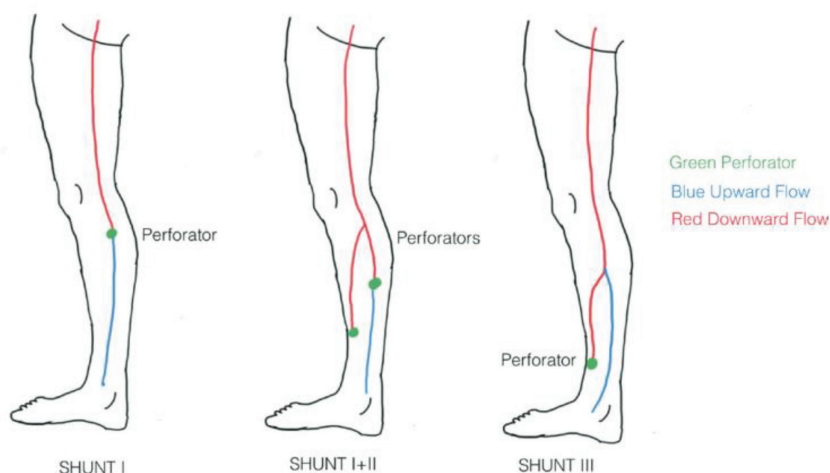
The Valsalva maneuver forces blood out of the abdomen. The systolic phase (blowing out) increases abdominal pressure, and the diastolic phase (breathing in) decreases it. During the systole it forces the blood down to the leg and to the pelvic veins unless valves stop it, and during the diastole it aspirates the blood back to the abdomen. The contraction of calf muscles does the opposite. The systole of this maneuver forces blood into the abdomen, and the diastole aspirates blood back to the leg unless valves stop it.

The characteristics of the flow can help us understand the disease and provide adequate hemodynamic treatment. If you analyze the flow at the waveform figure during a maneuver, you will have the systole, diastole and according to the transducer position, you can infer if the flow is centrifugal or centripetal. For example, if you consider a dynamic maneuver contracting the calf muscles, the figure will represent the following: 1) The systole (muscle contraction) creates flow from the leg to the heart. 2) The diastole (muscle relaxation) creates flow/reflux from the heart to the leg.



The Classification of Shunts and Types of Shunts

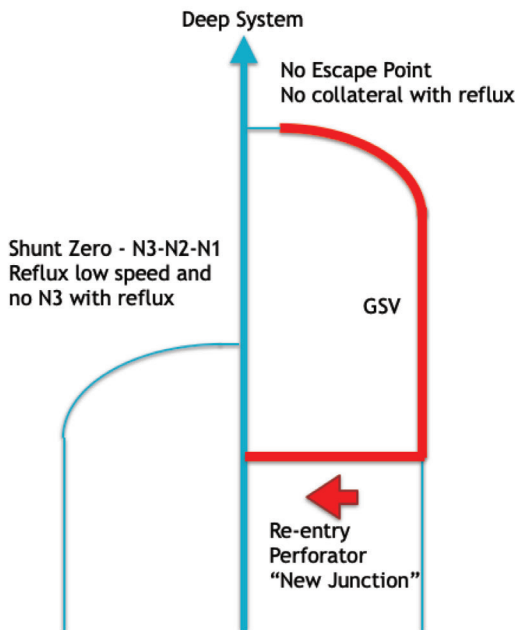
There are basically 3 types of shunts according to draining perforators. Shunt type I perforator drains reflux directly from the saphenous vein. Shunt type II is collateral to perforator. Shunt type I+II has a perforator draining the saphenous vein and another draining the collateral. Shunt type III has saphenous reflux that does not have a saphenous perforator, it drains to a perforator in a collateral. The last type poses difficulty to simple CHIVA procedures. The figure shows the easy to memorize shunt to guide the first approach. Later we show the complete shunt classification of CHIVA.



We present the full classification of closed shunts below. It divides the closed shunts according to Escape point, pathway and re-entry. The most important aspect you should observe is the re-entry, whether it is in a perforator from the saphenous veins or a perforator from a collateral N3.

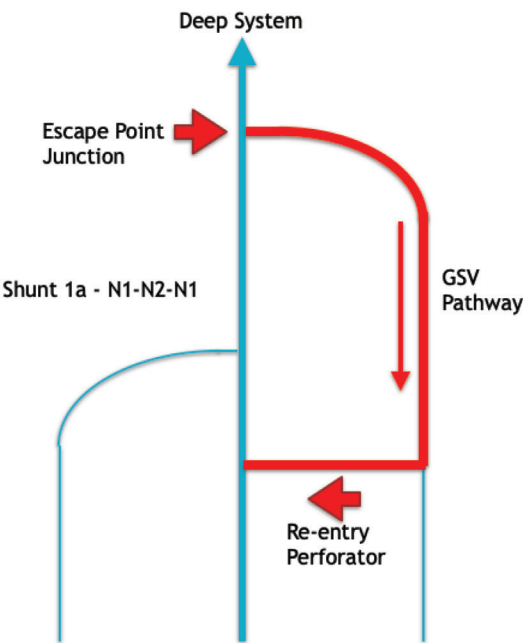
Shunt Type Zero

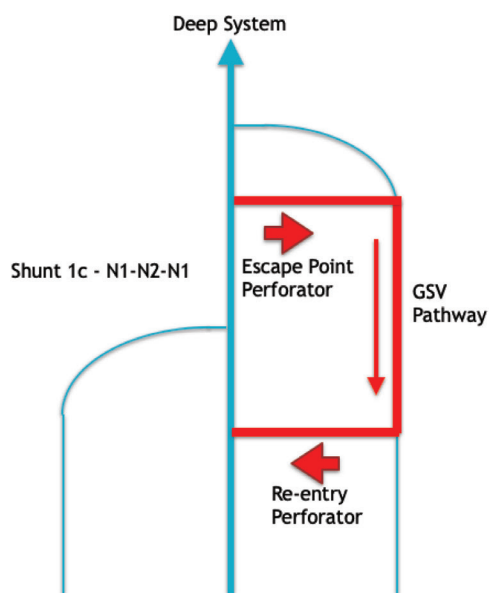
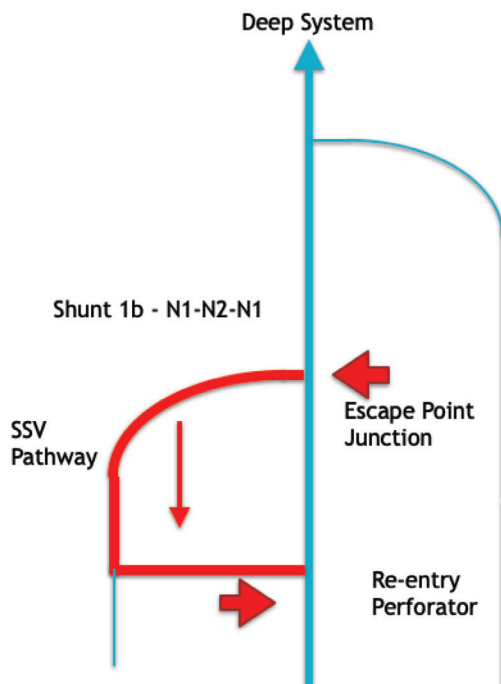
The concept of Shunt zero is pivotal. It is the ultimate result of a well done CHIVA operation or a physiologic reflux that does not need treatment. Shunt zero is a centrifugal flow at the saphenous vein characterized by “reflux” at the duplex scan. The flow has low speed and drained to a perforator. If a N3 collateral presents significant reflux it is not a shunt zero. The flow does not change the compartment N2. This shunt is the final result of CHIVA when the saphenous flow cannot be reversed. This concept is also important for surgeons of other non-preserving techniques, as this physiologic flow should not be treated. Unfortunately, we have seen many patients with shunt zero reflux having their saphenous veins ablated.



Shunt Type 1

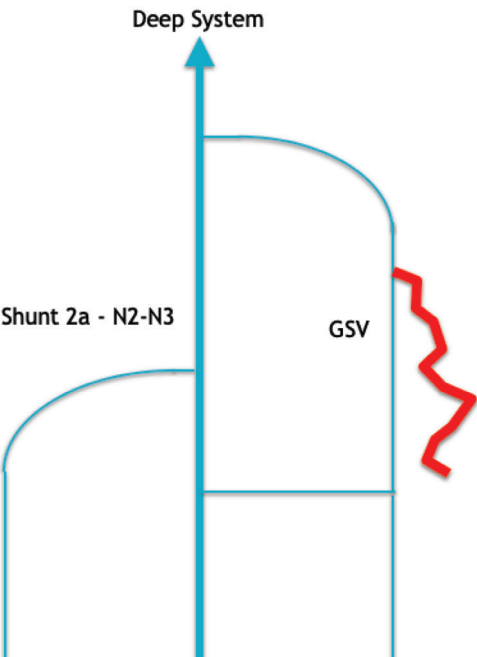
The escape point is located at a junction or perforator straight to the saphenous vein (Saphenofemoral, perforator or saphenopopliteal), the pathway is exclusively saphenous and the drainage (re-entry) is a perforator directly from the saphenous vein involved. These cases have no reflux at N3 collaterals.

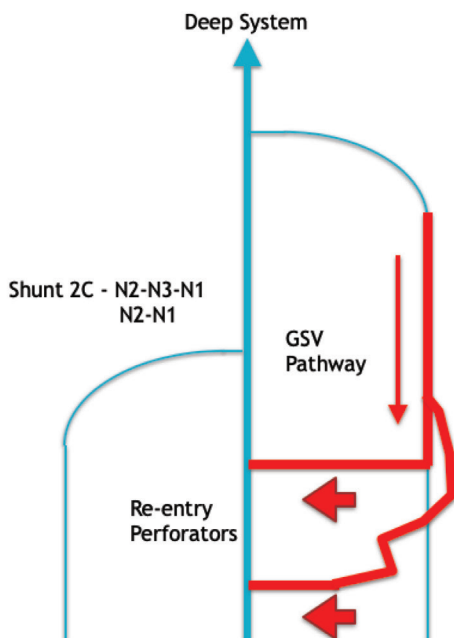
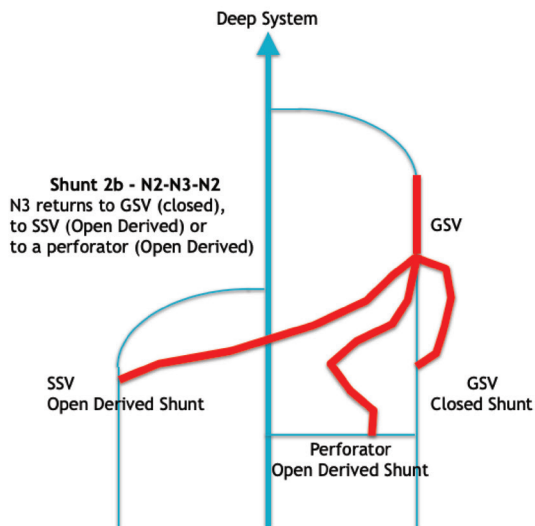




Shunt Type 2

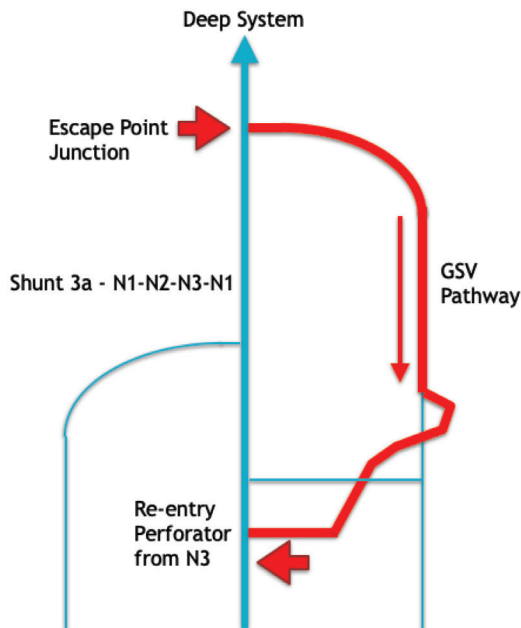
There is no definite escape point from the deep system. The change of compartment is from N2 saphenous vein to N3 collateral vein. The pathway is a collateral and the re-entry may be at the saphenous veins or a perforator.

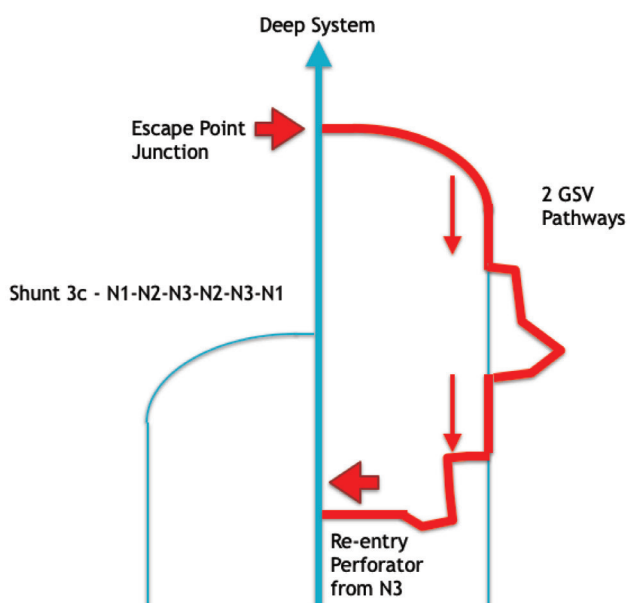
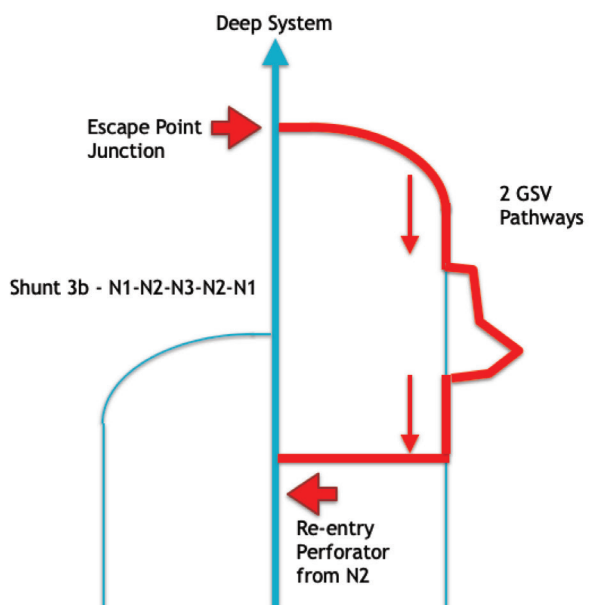


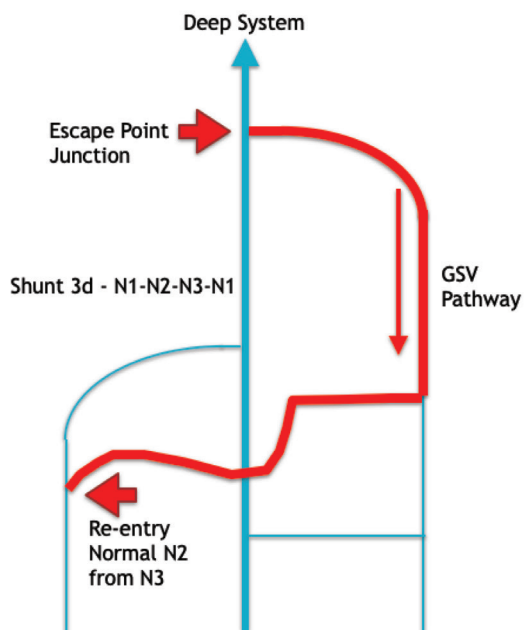


Shunt Type 3

There is an escape point from the deep system (junction) and the pathway includes the saphenous vein and a collateral. The re-entry is a perforator or the other normal saphenous vein. There is no perforator directly connected to the saphenous vein with reflux, the perforator is connected to the collateral only or to the other saphenous vein (for example, great saphenous vein with reflux, reentry at the small saphenous vein).

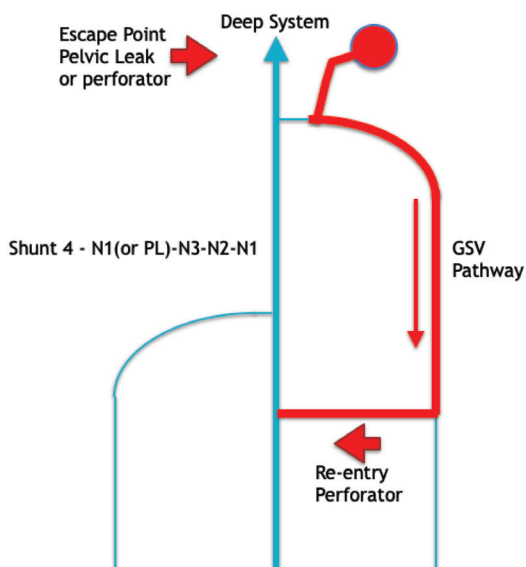






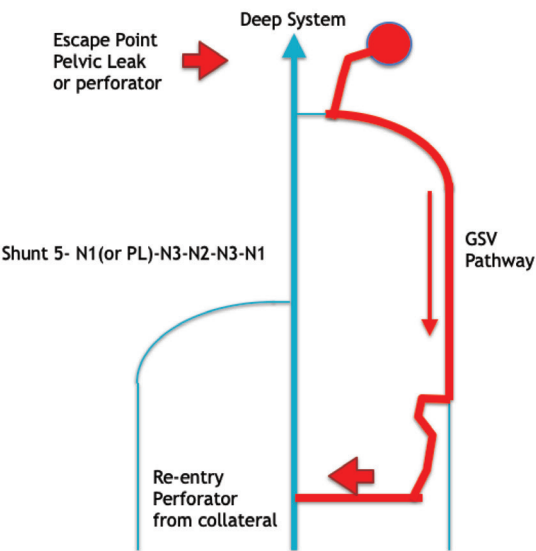
Shunt Type 4

The escape point is a pelvic leak or a perforator that uses the saphenous vein as a pathway. The first saphenous valve must be without reflux. The re-entry point is a perforator directly from the saphenous vein to the deep system.



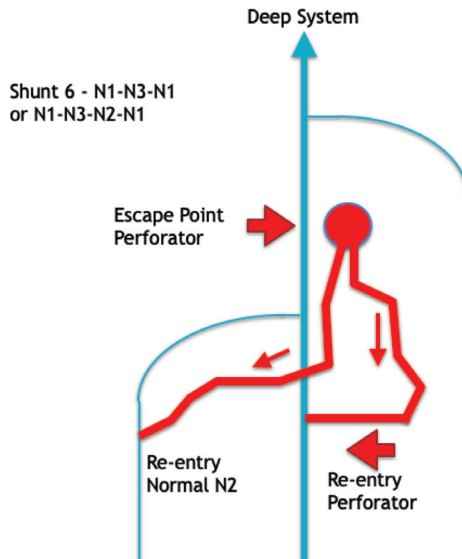
Shunt Type 5

The escape point is a pelvic leak or a perforator that uses the saphenous vein as a pathway. The first saphenous valve must be without reflux. The re-entry point is a perforator from a N3 collateral to the deep system.



Shunt Type 6

The escape point is a perforator draining to a collateral. This collateral N3 is the pathway and drains to another perforator or a normal saphenous vein without reflux.



Dynamic evaluation of reflux

There are two basic tests for reflux considering the effects of breathing and leg muscles in the venous system: The Valsalva and the calf squeezing maneuvers. The squeezing test is made by distal compression of the calf, achieved by manual or cuff compression^{9,10}. This maneuver has some flaws that make us look for better and more physiological alternatives. Patients with leg edema and pain usually get uncomfortable during the examination. Patients with large calves, ulcers and doctors with smaller hands also present as problems to examine reflux adequately. The compression created manually or cuff is not physiological and might create undesirable breaking of the flow in non-physiological compartments (you

may press one muscle harder than another). This may mislead us sometimes when we think we have produced flow in a specific area and in reality we have not. The lack of a standardized method for compression makes reproducibility difficult ¹⁰. Thus, we consider new and more physiological alternatives to the squeezing are desirable.

The Parana Maneuver creates a physiological upward flow by simultaneous contraction of most leg muscles. This effect is achieved by a push or pull at the waist, depending on the patient's position towards the examiner ¹¹. This maneuver creates a higher flow than squeezing and contracts all muscles physiologically. It is widely used in venous hemodynamic examinations. The Parana Maneuver is easy to perform when the patient's back is facing the examiner. When the patient is facing the examiner the maneuver is a push at the waist that is not comfortable for the doctor. We developed another maneuver easier to do in this position, but the validity is not published yet. Thus, our discussion in this chapter focuses on Parana Maneuver. There is another maneuver constantly used that mimics calf contraction and is sometimes easier to perform than the Parana maneuver. The Knee bending maneuver was created by Stefano Ermini during a temporary physical difficulty to perform Parana. The physician pulls the leg to force calf contraction with one hand and performs the duplex with the other. This maneuver makes it easier to finger press and close a collateral during the maneuver and test reflux, it also avoids compression at the leg that is favorable for patients with painful edema. This maneuver is currently under validation by the authors of this chapter.



QR code to Knee Bending maneuver.

The Paranà Maneuver moves 68% more blood than the Squeezing Maneuver, it doubles the time of diastolic phase in patients with incompetence of saphenous vein and triples in perforators ¹¹. All the chapters discussing hemodynamic reflux and treatments in this book consider Paranà and Valsalva. We perform squeezing tests in the hemodynamic evaluation of our patients to external validity of our reports according to guidelines.



QR Code Parana Maneuver

References:

1. Franceschi C. Theory and practice of the conservative haemodynamic cure of incompetent and varicose veins in ambulatory patients, translated by Evans J. Précy-sous-Thil, France: Editions de l'Armançon. 1988;
2. Labropoulos N, Giannoukas AD, Delis K, Mansour MA, Kang SS, Nicolaides AN, et al. Where does venous reflux start? J Vasc Surg [Internet]. 1997 Nov;26(5):736–42. Available from: [http://dx.doi.org/10.1016/s0741-5214\(97\)70084-3](http://dx.doi.org/10.1016/s0741-5214(97)70084-3)
3. Bergan JJ, Schmid-Schönbein GW, Smith PDC, Nicolaides AN, Boisseau MR, Eklof B. Chronic venous disease. N Engl J Med [Internet]. 2006 Aug 3;355(5):488–98. Available from: <http://dx.doi.org/10.1056/NEJMra055289>
4. Lee BB, Nicolaides AN, Myers K, Meissner M, Kalodiki E, Allegra C, et al. Venous hemodynamic changes in lower limb venous disease: the UIP consensus according to scientific evidence. Int Angiol [Internet]. 2016 Jun;35(3):236–352. Available from: <https://www.ncbi.nlm.nih.gov/pubmed/27013029>
5. Govind D, Thomas KN, Hill BG, van Rij AM. Microvenous Reflux in the Skin of Limbs with Superficial Venous Incompetence. Ultrasound Med Biol [Internet]. 2018 Apr;44(4):756–61. Available from: <http://dx.doi.org/10.1016/j.ultrasmedbio.2017.11.014>
6. Vincent JR, Jones GT, Hill GB, van Rij AM. Failure of microvenous valves in small superficial veins is a key to the skin changes of venous insufficiency. J Vasc Surg [Internet]. 2011 Dec;54(6 Suppl):62S – 9S.e1–3. Available from: <http://dx.doi.org/10.1016/j.jvs.2011.06.085>
7. Lawrence PE, Gloviczki P. Appropriate care for venous disease. J Vasc Surg Venous Lymphat Disord [Internet]. 2019 Jul;7(4):469–70. Available from: <http://dx.doi.org/10.1016/j.jvsv.2019.03.005>
8. Campbell B, Franklin IJ, Gohel M. The choice of treatments for varicose veins: A study in trade-offs [Internet]. Phlebology: The Journal of Venous Disease. 2020. p. 026835552092270. Available from: <http://dx.doi.org/10.1177/0268355520922708>

9. Sarin S, Sommerville K, Farrah J, Scurr JH, Coleridge Smith PD. Duplex ultrasonography for assessment of venous valvular function of the lower limb. *Br J Surg* [Internet]. 1994 Nov;81(11):1591–5. Available from: <http://dx.doi.org/10.1002/bjs.1800811108>
10. De Maeseneer M, Pichot O, Cavezzi A, Earnshaw J, van Rij A, Lurie F, et al. Duplex ultrasound investigation of the veins of the lower limbs after treatment for varicose veins - UIP consensus document. *Eur J Vasc Endovasc Surg* [Internet]. 2011 Jul;42(1):89–102. Available from: <http://dx.doi.org/10.1016/j.ejvs.2011.03.013>
11. Ermini S, Passariello F, Vasculab F. The Paraná Manoeuvre [Internet]. 2017. Available from: <http://dx.doi.org/10.24019/2017.parana>

5 - Perforators: Hemodynamic viewpoint

Felipe Faccini and Stefano Ermini

<https://doi.org/10.5281/zenodo.6490732>

Key Points

Be careful before you blame leg perforators for the venous disease.

Perforators with reflux may be pathologic, but not necessarily the source of the disease. They may be the drainage.

The history of the perforators is full of uncertainty and misunderstandings. When the “Blow-out” syndrome was described in 1953 ^{1,2} the vascular diagnosis armamentarium was weak and several concepts might have been mistaken. The evaluation of both the deep and superficial systems was not precise. For example, the Cockett and Jones’s important study about the effect of perforators tested both deep and superficial venous disease together. By the knowledge on hemodynamics we have today, the old venographic studies cannot understand the complexity of leg flow and reflux. Thus, we consider that a great rethinking of pathology of perforators is warranted.

From that time on, we kept ligating perforators at the leg of patients without evaluation of results for many years. Alternative methods came to treat these perforators, which failed to demonstrate an advantage over clinical management and old procedures. Subfascial ligation (SEPS) has been advocated as

advantageous, but its results do not appear to improve results of the usual varicose vein surgery without perforator treatment ³. Some advocates radiofrequency, laser and foam, but their results to date only analyze the closure of the vein, not the clinical outcome ^{4,5}. There are no clinical trials proving its efficacy in venous disease. The shunt theory we discussed in the reflux chapter gives us a hint of why the perforator treatment does not work as we might imagine. According to this theory, the perforators at the leg are commonly the re-entry of the flow that escaped above in the thigh, gluteus or perineum.

There are a few anatomical aspects we need to review before deepening the discussion about perforators. First, we should remember that the distribution of venous valves in the leg is not uniform. The deep system has only a few venous valves above the knee, and several valves per vein below the knee. This is important if we consider that the height of the blood column above a perforator is several centimeters in the thigh and only 1-2 centimeters in the leg ⁶. Another aspect that people confuse about perforators is the idea that all perforators have valves. A study has shown that the absence of valves in perforators of normal individuals is common, but more common in individuals with reflux⁷. Thus, normal perforators may have no valves. The association of perforator reflux with venous disease lacks a causality proof. Is the perforator the cause of disease or the physiologic re-entry of superficial reflux? We should consider that the shunt might activate these perforators and its reflux relates to overflow.

Types of Perforators

The flow at a vein is basically dependent on two parameters: Valve function and Direction of the gradient. If there is no valve to stop the blood, the flow goes along with the pressure gradient. The gradient has basically two driving forces.

1. Systolic gradient happens with muscle contraction, creating a centripetal flow. Calf muscle may create 140 mmHg of pressure during contraction and create centripetal flow independently of valve status and continence.
2. Diastolic gradient occurs with relaxation of the calf muscles due to gravitational pressure created by the hydrostatic pressure at the column of blood. The pressure at the deep venous system decreases after the end of contraction to as low as 7-8 mmHg. At this point, the presence and continence of valves is an important factor.

Thus, the flow goes with the gradient unless valves stop it. As we can infer from the anatomical discussion, the perforators in the leg are better drainers than thigh ones (less deep column because of more valves and powerful muscle emptying). The perforators are also frequently valveless even in normal subjects, what suggests a more intrinsic connection between deep and superficial venous flow than we might consider. The procedures preserving the saphenous vein had taught us that rarely a perforator is the source of reflux. The most common situation is the perforator being a draining pathway of the superficial reflux. We should avoid destroying perforators that are not the source of reflux.

We should analyze the behavior of the perforator during systole and diastole to define the situation. The Doppler study should be performed with patient standing, and we should use maneuvers to mimic calf pump activation (Compression, Paranà, Knee bending).

Perforators and superficial venous insufficiency

Reentry perforator of varicosities (terminal perforator):

These perforators are usually in the lower leg and are the drainage from the hypodermis of the region. They are typically dilated and are not continent, presenting reflux.

The hemodynamic behavior of these perforators during systole is unequivocal. It depends on the gradient pressure/speed that occurs in the deep system and location of the perforator relating to the calf muscle pump. The beginning of the systole has high-pressure and low speed of the column of blood. This creates a cutipetal flow in these perforators (to the skin). The superficial column of blood with incontinence opposes this flow. The angle of the entrance of the perforator in the deep system facilitates “reflux” in this phase, as we see when the entrance of the perforator in the deep system is lower than its position in the superficial system.

The diastolic phase starts when the calf pump stops and the deep pressure is lower, close to 7-8 mmHg. The drive of the blood to re-entry the deep system will depend on the size of the incontinent column of blood in the superficial system. If there are 70 cm of saphenous vein for example, we will have 70 cmh₂O of column. This is equivalent to 51.4 mmHg, thus the blood will

create cutifugal (from the skin) reflux until superficial pressure diminishes, or a muscle contraction increases the 7-8 mmHg of the deep system. To sum up, the diastole presents a gradient superficial to deep that will create re-entry reflux at the perforator during the time needed to equalize pressures and end the gradient. The time needed to equalize pressures depends on the emptying of the superficial system at the deep and also on the refilling of the venous system. The usual distinction of short and long duration reflux lacks hemodynamic and physiological-pathological. The importance of standardized results is pivotal, but lacks a relation of duration and gravity of venous disease.

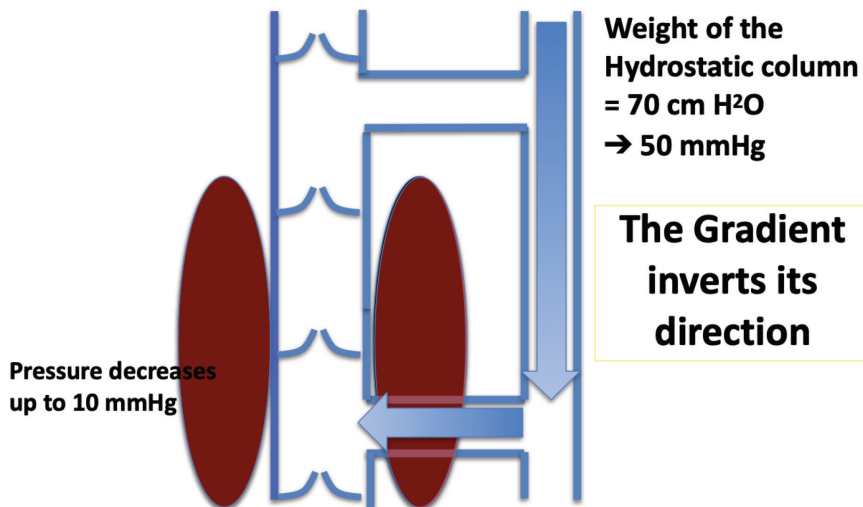
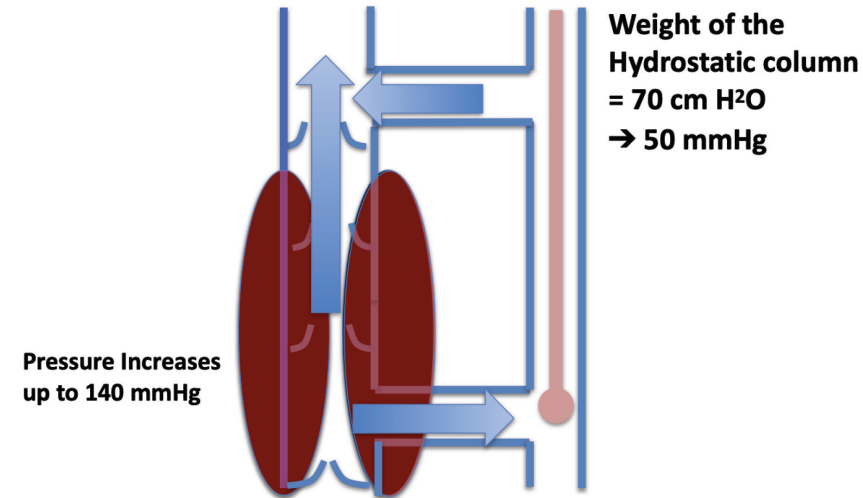
A calf muscle contraction may interrupt anytime the re-entry flow of a perforator. The PW Doppler analysis shows cutipetal systolic flow (deep>superficial) and important and longer cutifugal diastolic flow (superficial>deep). The hemodynamic characteristic of re-entry perforators is the function of a diastolic entry of blood to the deep system. This expresses the continence and function of the deep system valves.

Non-terminal perforators (re-entry but not the end of reflux):

Non-terminal perforators occur mainly at the superior portion of the leg. A refluxive superficial venous axis proximal and distal to its origin characterizes them. The behavior of the perforator depends on the speed of the blood in the deep system, while systole the speed of blood in a normal deep system creates flow from the superficial to the deep system (cutifugal flow). During diastole, the speed of the blood in the superficial veins aspirates blood from the deep system (cutipetal flow). These perforators have superficial→deep aspiration

or no flow is systole and deep→superficial flow during diastole. The importance of the reflux depends on the distance and magnitude of the distal veins without continence.

The schematic representation shows the systole and the diastole of the muscle pump and its effects on the perforators.



Perforators in post-thrombotic syndrome

The post-thrombotic syndrome may occur due to 2 basic ways.

1. Complete recanalization of the deep axis and valve destruction.
2. Partial recanalization of the axis and its fibrotic obliteration.

These two conditions may happen simultaneously at the same leg, and the predominant situation may vary according to the case and time.

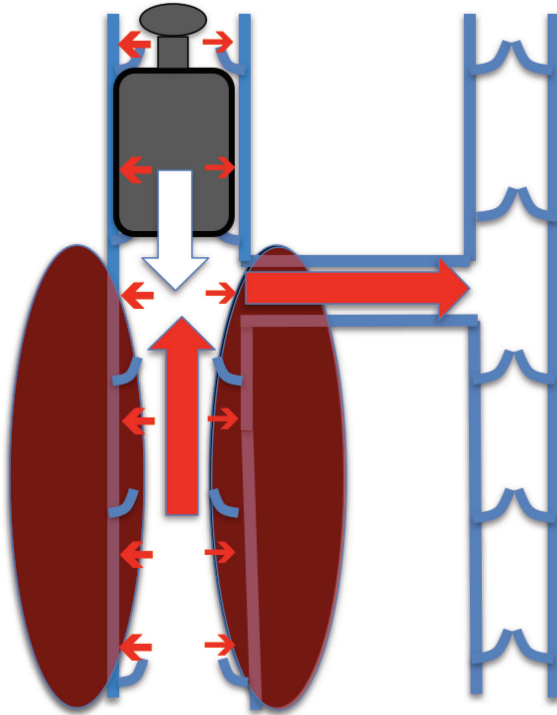
1. Valve destruction and recanalization

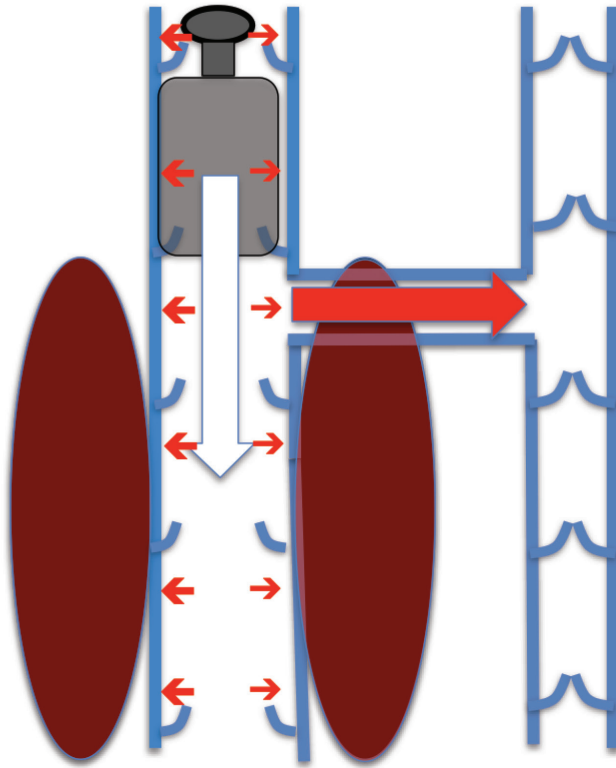
The malfunction of valves in the deep system creates a lack in physiological fractionating of the column of blood / hydrostatic pressure. The muscle contraction drives the blood column against a high pressure hydrostatic column of blood (longer due to lack of valves). This creates a low-speed flow and increases the lateral pressure, mainly if this occurs in the lower leg. The lower leg is where most perforators with important cutipetal flow present.

When the calf muscles relax, the weight of the hydrostatic column worsens the situation in the lower leg (if valves are not working). The same perforators that presented cutipetal reflux during systole now present cutipetal reflux during diastole. The leg perforators in post-thrombotic syndrome with valve destruction

present cutipetal (deep to superficial) during systole and diastole.

The schematic representation shows the flow effect of systole and diastole in perforators when the deep system presents obstruction and reflux.



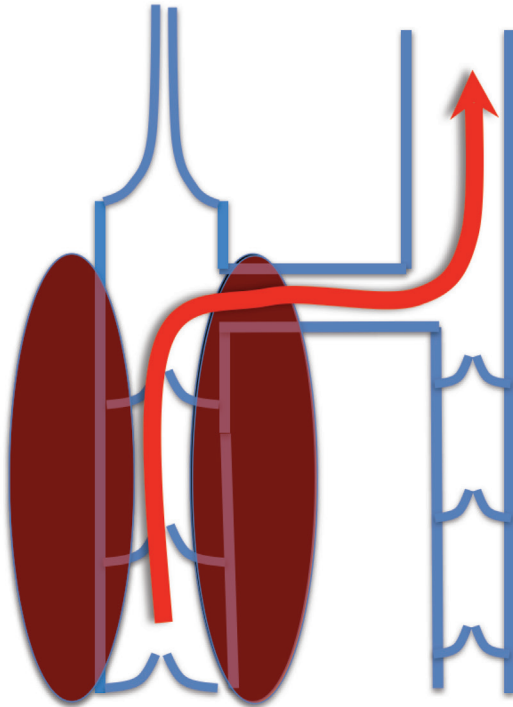


2. Obstructive post-thrombotic syndrome

This situation poses an obstacle to the flow during calf muscle systole. The low speed of flow increases the lateral pressure and creates important systolic cutipetal (deep to superficial) reflux in the leg perforators. Calf diastole has limited reflux because the obstruction in the deep system reduces hydrostatic pressure and the column of blood. The obstruction fractionates the column of blood. The diastole presents cutifugal (superficial to deep) that depend on the magnitude of superficial veins.

The different hemodynamic characteristics of obstructive versus nonobstructive post-thrombotic syndrome are the fractionating of the column of blood made by the obstruction, and the full column of blood in the valveless deep system of non-obstructive cases. The differences in the clinical presentation in the obstructive versus nonobstructive may be related to this hemodynamic behavior. The abrupt change in lateral pressure in the change from systole to diastole may help create skin manifestations.

The schematic presentation represents the outflow of a perforator happening due to deep total obstruction with no recanalization.



Perforators as origin of by-pass (vicarious shunts):

The presence of deep obstruction may cause perforators to drive flow from the deep to the superficial veins, creating a collateral pathway for the blood. These perforators present cutipetal (deep to superficial) flow during muscle contraction systole and usually no flow in diastole. The same situation happens in the venous axis, participation in the vicarious shunt returning the blood. This vicarious return axis may comprise leg collateral veins, saphenous vein, and veins above the leg. We usually see an increase in size of these veins to cope with the flow. This superficial axis rarely has centrifugal reflux during diastole because of the high deep pressure that remains. The maneuver to create flow should be as close to the physiological blood drive as possible, we use dynamic maneuvers to evaluate these cases. Sometimes the dilation of the superficial pathway creates an additional centrifugal way to the blood (See CHIVP chapter for further discussion). We should consider that the increase in the caliber of these superficial veins dampens the valve function. Thus, the main factor keeping centripetal flow in these veins is the difference between the muscle pump pressure and the size of the column of blood in the superficial system. As an example, if we have a deep pressure of 140 mmHg in the venous deep system of a post-thrombotic patient and a 70 cmh₂o of superficial hydrostatic pressure. During systole the deep pressure may rise to 190 cmh₂o (1 mmHg is aprox. 1,36 cmh₂o) and the column pressure is 70 cmh₂o with the patient

standing. This drives the blood up the superficial system. We use the dynamic maneuver in these cases because the gradient shown above is dependent on the volume dislocated during muscle contraction. If we create an irregular or insufficient muscle compression (squeezing), we may see the refill of the partial muscle contraction as a reflux and destroy the vicarious shunt that was diminishing the patient's problem. The schematic presentation below shows the hemodynamic effect of muscle contraction in the deep system with obstruction and the effect on perforators.

Perforators creating a systolic derivative shunt:

A derivative systolic shunt is different from a vicarious bypass shunt because it aims to overcome a functional stenosis of the deep system. We find this condition in popliteal perforators and saphenous popliteal junction. The flow of these perforators arrive to the Giacomini vein, creating centripetal flow. This centripetal flow at the Giacomini vein usually has 2 destinations:

1. It may go to the greater saphenous vein and thus to the femoral vein. In these cases, we see centripetal flow during muscle systole and no flow during muscle diastole.
2. It may create a collateral with centrifugal flow, and this flow will reenter the deep system lower from its exit point. This case presents centripetal flow during muscle systole and also during diastole. The origin of this diastolic flow is the siphon effect - the exit of the collateral from the

popliteal-giacomini is upper, and relates to the re-entry is a perforator or saphenous vein in the leg.

The hemodynamic behavior described at item 1 is the same found in perforators that are the origin of a vicarious shunt. We can differentiate one from the other by closing the Giacomini vein with finger compression. If the popliteal flow remains, we have a derivative shunt. If it ends, we have a vicarious shunt.

Considerations:

We cannot consider systolic reflux in a perforator as pathogenic if it drives blood up to the heart during muscular contraction. Anatomic characteristics of the patient may make it easier for the blood to go up this way (in addition to the deep system). Even in cases with deep obstruction (pathogenic) causing gradient during calf contraction and forcing the blood to return via the superficial system. If the blood returns only towards the heart, we should consider it a bypass reaction of the venous system.

The Valsalva maneuver forces blood away from the thorax and abdomen, thus the drive of the blood is the opposite from muscle contraction. If we see systolic reflux during a Valsalva, we can infer that the flow is going the wrong way, making the perforator pathogenic.

The venous muscle diastolic reflux is always against its normal flow. Thus, we should consider it as part of a pathologic process, not necessarily pathogenic. This does not mean that the pathology is the perforator itself and that we should sacrifice it when it is the re-entry.

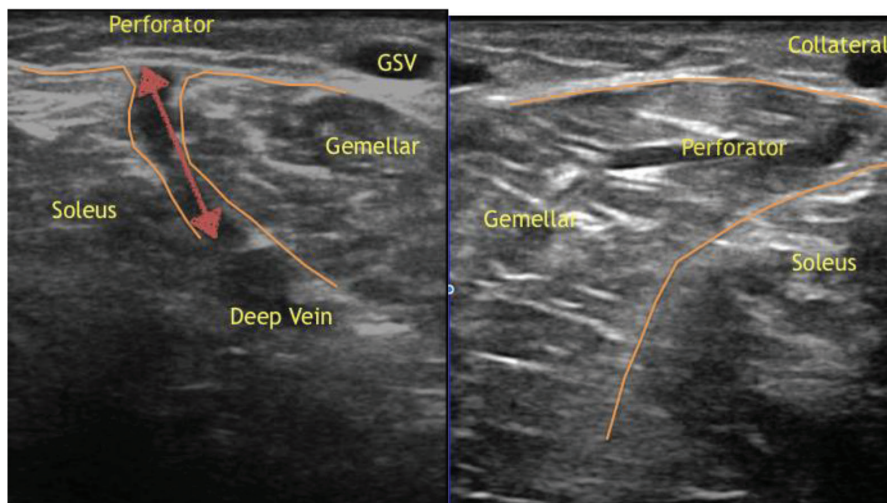
Quality of a perforator

If we depend on a perforator to keep the flow of a saphenous vein to preserve it, the assessment of the perforator's capacity to drain is pivotal. There are cases when we need to ligate a collateral with reflux, but the reflux goes directly into a perforator through this collateral. If the saphenous vein does not have another perforator to drain the small postoperative reflux, it will probably thrombose. The bigger the saphenous vein, the higher the quality of the perforator needed.

The closure test evaluates the re-entry perforator. It measures reflux up in the saphenous vein while the collateral is finger pressed and compares it to a measure at the same place with the collateral open. The calf contraction/muscle contraction and Valsalva are used to provoke reflux. We perform it up in the saphenous vein to avoid confusion caused by Hunter perforators. If the vein maintains a small reflux, the perforators draining it will probably suffice. The Perthes test makes the patient walk with a rubber band pressing the thigh veins. We observe the wilting of veins (saphenous included) predicting the result after treatment. These tests evaluate the perforators and deep system quality.

A study has shown that the results of CHIVA depends mostly on the saphenous drainage ⁸. If we ligate too much of the saphenous drainage and do a crossotomy, the result may be thrombosis and neoformation of veins and telangiectasia (much like an unintentional ablation). There are some characteristics associated with increased drainage of a perforator, namely: 1) Size, 2) deep vein it goes to, 3) Flow capacity and 4) intra versus inter-muscle. The large perforator veins with good flow, going to a

large deep vein without passing inside a muscle, usually are more reliable. The perforator that connects straight to the saphenous vein is better than a perforator through a collateral. Concerning the size of the perforator, ideally a perforator should be close to half the size of the saphenous vein it drains.



References:

1. Dodd H. THE ANKLE BLOW-OUT SYNDROME [Internet]. Vol. 261, The Lancet. 1953. p. 142. Available from: [http://dx.doi.org/10.1016/s0140-6736\(53\)90859-9](http://dx.doi.org/10.1016/s0140-6736(53)90859-9)
2. Cockett FB, Elgan Jones DE. THE ANKLE BLOW-OUT SYNDROME A NEW APPROACH TO THE VARICOSE ULCER PROBLEM [Internet]. Vol. 261, The Lancet. 1953. p. 17–23. Available from: [http://dx.doi.org/10.1016/s0140-6736\(53\)92512-4](http://dx.doi.org/10.1016/s0140-6736(53)92512-4)
3. Lin ZC, Loveland PM, Johnston RV, Bruce M, Weller CD. Subfascial endoscopic perforator surgery (SEPS) for treating venous leg ulcers. Cochrane Database Syst Rev [Internet]. 2019 Mar 3;3:CD012164. Available from: <http://dx.doi.org/10.1002/14651858.CD012164.pub2>

4. Hager ES, Washington C, Steinmetz A, Wu T, Singh M, Dillavou E. Factors that influence perforator vein closure rates using radiofrequency ablation, laser ablation, or foam sclerotherapy. *J Vasc Surg Venous Lymphat Disord* [Internet]. 2016 Jan;4(1):51–6. Available from: <http://dx.doi.org/10.1016/j.jvsv.2015.08.004>
5. Dumantepe M, Tarhan A, Yurdakul I, Ozler A. Endovenous laser ablation of incompetent perforating veins with 1470 nm, 400 µm radial fiber. *Photomed Laser Surg* [Internet]. 2012 Nov;30(11):672–7. Available from: <http://dx.doi.org/10.1089/pho.2012.3351>
6. Caggiati A. The venous valves of the lower limbs. *Phlebology* [Internet]. 2013 Apr 9 [cited 2019 Jul 20];20(2):87–95. Available from: <https://www.phlebology.org/the-venous-valves-of-the-lower-limbs/>
7. Sarin S, Scurr JH, Smith PD. Medial calf perforators in venous disease: the significance of outward flow. *J Vasc Surg* [Internet]. 1992 Jul;16(1):40–6. Available from: <https://www.ncbi.nlm.nih.gov/pubmed/1619723>
8. Cappelli M, Lova RM, Ermini S, Turchi A, Bono G, Bahnini A, et al. Ambulatory conservative hemodynamic management of varicose veins: critical analysis of results at 3 years. *Ann Vasc Surg* [Internet]. 2000 Jul;14(4):376–84. Available from: <http://dx.doi.org/10.1007/s100169910064>

6 - Pelvic leaks

Roberto Delfrate

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Varicose veins of pelvic origin are a reality to consider. They may affect mainly women, but also men can be involved. Several studies based on various assessments (clinical, ultrasound, venography) consider around 10% of pelvic leaks in women varicose where the number of multiparous are 4 times more frequent than in nulliparous ¹⁻⁴. A high percentage of recurrences after stripping were related to pelvic venous reflux and evaluated as 17% but not specifically anatomically defined and not specifically treated ^{5,6}. Claude Franceschi first described the existence of six well-defined parietal points for each side through which a pelvic reflux can be transmitted to the lower limb and be responsible for varicose veins of the lower limbs in mono and multiparous women ⁷⁻⁹. Reflux from a pelvic leak can spread either in the ipsilateral as well as contralateral lower limb thanks to the existence of avalvulated subcutaneous perineal as well as inguinal venous plexuses. The reflux can spread peripherally, involving the N2 axes or exclusively non-saphenous collectors. When involved, the N2 axes may represent an anatomical terminal re-entry structure as in the shunt 4 or shunt 4+2 (figure 1), as well as an interposed re-entry structure as in the shunt 5 (Teupitz shunt classification coherent with the original classification reported by Franceschi ¹⁰⁻¹²).

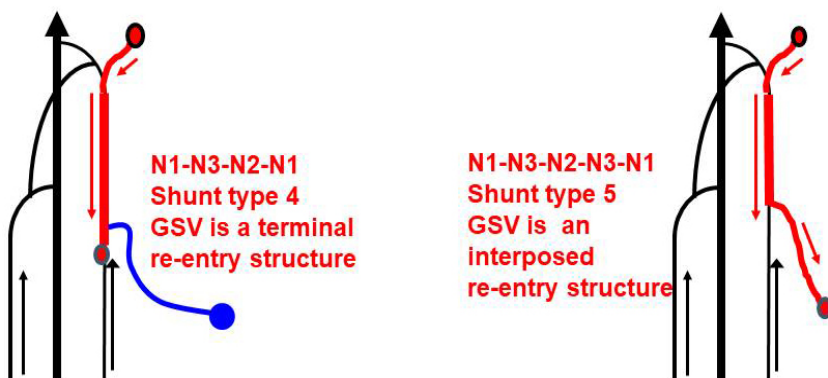


Figure 1 - The impact of pelvic escape point is significant: 8.3% of all the escape point treated in personal experience. They represent the escape point of shunt type 4 (on the left), characterized by a direct re- entry perforator located on an N2 axes and shunt type 5 (on the right) where the re-entry point is an indirect perforator. A shunt type 2 can be added to a shunt 4 (blue line)

Pelvic venous unit

The pelvic venous system is a complex network of venous vessels (figures 2-3) and venous plexuses of different embryological origin with the characteristic of draining and interconnecting different anatomic areas: pelvic viscera, front and back parietal structures, the lower limbs and particularly the inguino-crural and perineal regions, but also the back area of the thigh and through it the popliteal fossa ¹³⁻¹⁷. The pelvic venous system is composed by different vessels:

- avaluolated main venous trunks (iliac common vein, external iliac vein, hypogastric vein)
- inconstantly valved visceral veins (ovarian veins) or rarely valved visceral veins (uterine veins)

- generally valved parietal collectors (obturator vein, internal pudendal vein, superior and inferior gluteal veins, round ligament veins)
- non-valved venous plexuses, connecting vertically and horizontally every pelvic viscera and the pelvic wall.

This vascular network represents the functional pelvic venous unit. A distinctive characteristic of the pelvic venous system is the absence of pumps. The venous flow takes place according to the pressure gradient existing with the right heart and according to the residual pressure. We are now aware that well-defined parietal anatomic points of interconnection between the pelvic and parietal vessels exist (figures 2-3). They represent points of significant surgical interest as reported by Franceschi and others ¹⁸. During pregnancy, a valvular damage may occur in parietal as well as visceral collectors because of the increase in pelvic vein peripheral resistances and consequently of venous transmural pressure. Due to the valve damage, a venous reflux can be transmitted to the lower limb, passing through the Parietal Leak Points (PLPs) ¹⁹. Misunderstood pelvic escape points may cause a relapse of varicose veins, especially chaotic in case of ablation of the GSV. For this reason, all the hemodynamic diagnostic assessments for varicose veins of the lower limbs must look for refluxing PLPs.

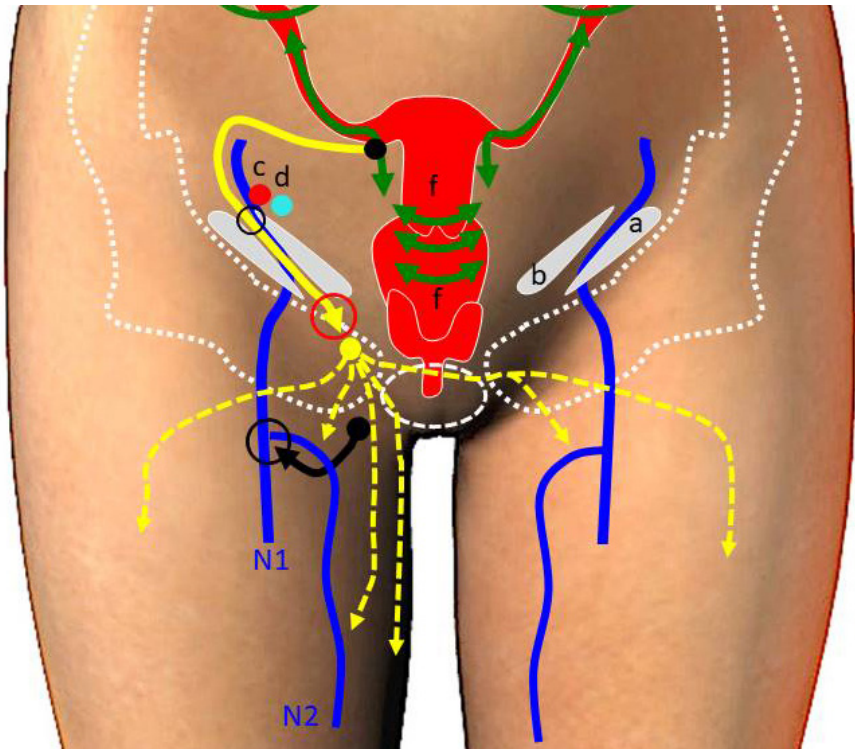


Figure 2 - Front view of the pelvis. The white dotted lines represent the bones of the pelvis. The white dashed line represents the pubis. Fascia of the abdominal external oblique muscle: a. Fascia transversalis: b. Inferior epigastric artery: a. Inferior epigastric vein: d. The yellow line represents the venous plexus of the round ligament and the vein of the round ligament. The flow of the subcutaneous plexuses of the mons veneri and of the inguino-crural area passes through the superficial ring of the inguinal canal (red circle) and reaches the venous plexus of the round ligament, then passes through the internal ring of the inguinal canal (black circle) and through the vein of the round ligament joins the uterine veins (the green lines represent the veins of the uterine tube and the uterine vein) at the angle between the body of the uterus and the uterine tube (black point). The medial circumflex muscular vein is represented by the black arrow an the OP is the black circle The external iliac vein (blue line above the inguinal canal) is deeper than the internal ring of the inguinal canal, and also a little bit laterally to the inferior epigastric vessels. The yellow dashed lines represent the possible reflux paths during the systole of the valsalva manoeuvre: reflux may spread directly into the ipsilateral or contralateral GSV arch as well as into a non saphenic paths toward an indirect re-entry point or an upstream N2. The ovary and the ovarian vein. Venous path composed by avaluated venous plexuses (f) connecting vertically and horizontally generally valvulated parietal and visceral collectors, as well as front and back visceral structures.

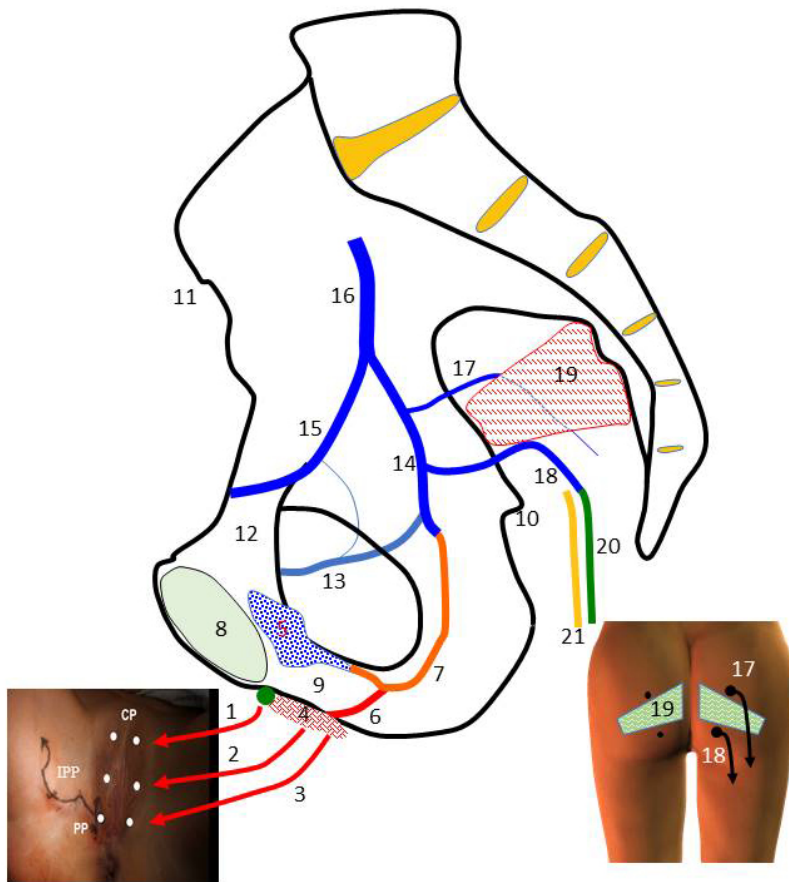


Figure 3 - Internal view of the pelvis and of the venous collectors and plexuses involved in pelvic leaks. 1, the venous path joining the external pudedal vein and the anterior labial vein to the deep dorsal clitoris vein (is the venous path of the Clitoris Point CP) in female, and in male the Male C Point path (MCP) connecting the superficial and deep dorsal vein to the pudendal vein; 2, the intermediate labial vein; is the venous path of the Intermediate Perineal Point IPP); 3, posterior labial veins; is the venous path of the classic Perineal Point PP; 4, venous labial plexus; 5, pudendal plexus; 6, perineal vein ; 7, internal pudendal vein; 8, pubis; 9, inferior pubic ramus; 10, ischial spine; 11, anterior superior iliac spine; 12, superior pubic ramus; 13, obturator vein (this vein usually joins the hypogastric vein but it can even directly reach the external iliac vein); 14 internal iliac vein; 15, external iliac vein; 16, common iliac vein; 17, superior gluteal vein (it's the venous path of the Superior Gluteal Point SGP); 18, inferior gluteal vein (it's the venous path of the Inferior Gluteal Point IGP); 19, piriformis muscle; 20. Sciatic vein (the reflux through it reaches the SSV and the posterior region of the leg); 21, sciatic nerve.. In the photo in the left lower angle you can see the perineum and the anatomical position of the CP, IPP, PP. The image in the left lower angle shows the topographical position of the SGP and IGP

PLPS Anatomy

The P Point (PP) represent the 60% of all the PLP personally treated in women. The subcutaneous plexuses of the perineal region converge into the posterior labial vein which passes through the superficial perineal fascia hole, located **posterior-**laterally to the labia majora about 1 cm in respect to the origin of the frenulum of labia minora; the posterior labial veins drain into the vulvar plexus. The vulvar plexus drains into the perineal vein that crosses the perineal muscle to reach the internal pudendal vein into the Alcock's canal(fig.3). The internal pudendal is one of the origins of the hypogastric vein. Thin nervous fibers may lie close to the posterior labial vein. The diameter of the posterior labial vein ranges from 1.8 to 3 mm in my experience. An intermediate labial vein may also exist 1 cm anteriorly and may represent the ***Intermediate Perineal Point (IPP)***. In case of valvular incompetence, the reflux follows the same pathway in the opposite direction, from the deep to the surface and dilation of perineal superficial veins may occur (fig.4). Furthermore, reflux can also extend to the ipsilateral or contralateral saphenous network (GSV or SSV) through superficial perineal plexuses and others incompetent venous paths.

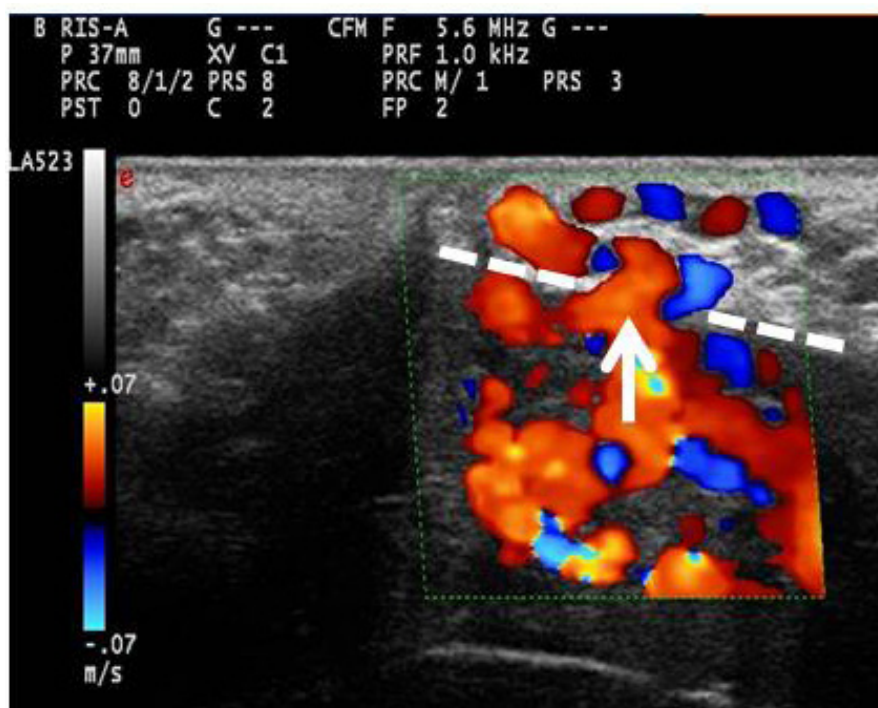


Figure 4 - Surgical anatomy of the the PP. The subcutaneous veins of the perineal region converge into the posterior labial vein which passes through a hole of the vulvar fascia into the vulvar venous plexus. Thin nervous fibers may lie close to the vein. The white arrow shows the PP. Clear systolic Valsalva reflux. The white dashed line represents the vulvar fascia.

The I Point (IP). Represent the 36% of all the PLP personally treated. The IP is the superficial ring of the inguinal canal (fig.5) crossed by the mons veneris veins, draining the superficial perineal and inguino-crural areas. In case of valvular incompetence reflux from the pelvic venous plexuses passing through the round ligament venous plexus can feed ipsilateral and also contralateral vulvar or perineal varicose veins, but also lower limbs varicose veins thanks to branches of the superficial perineal venous network (fig.2). Moreover, reflux in the round ligament vein may itself be fed by any incontinent ipsilateral and contralateral upstream genital, visceral, iliac, or ovarian vein and by the inferior venae cava.

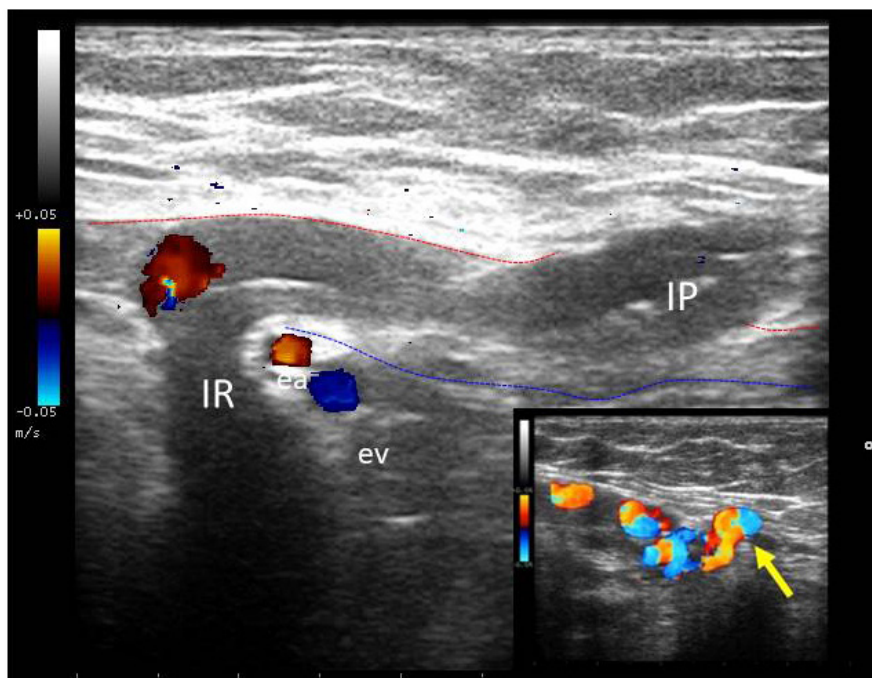


Figure 5 - Anatomy of the inguinal canal. The red line represent the oblique external muscle fascia, with the superficial ring of the inguinal canal clearly detectable medially: the IP. The blue line represents the transversalis fascia. The internal ring (IR) lies medially to the epigastric artery (ea) and the epigastric vein (ev). The venous plexuses of the round ligament is detectable between the two fascias. Valsalva systolic reflux in the inferior left angle

The Clitoris Point (CP). The CP is the anastomotic plexus between the bulbar vein and the superficial dorsal clitoris vein, through which the external pudendal vein and dorsal clitoris vein connect to the internal pudendal vein (fig.6). Veins from the clitoris area also pass through a hole in the superficial subcutaneous fascia to reach the inguino-crural area. Reflux can feed ipsilateral or contralateral perineal and anterior labial veins and or the lateral pudendal external, then the GSV.

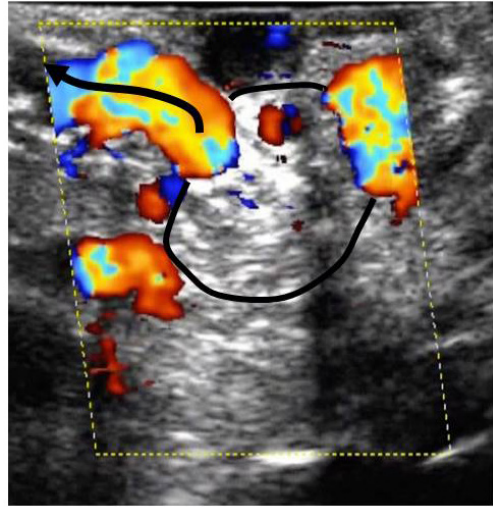
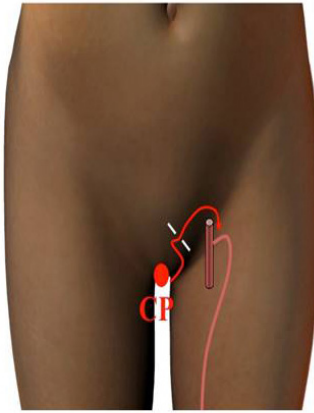


Figure 6 - Valsalva reflux through C point. The clitoris is the hyperechoic image inside the black line. The black arrow highlights the reflux from the deep into the subcutaneous veins during the systole of the Valsalva manoeuvre. The CP is the anastomotic plexus between the bulbar vein and the superficial dorsal clitoris vein through which the flow reaches the external pudendal vein

Superior Gluteal Point (SGP) and Inferior Gluteal Point (IGP). The superior and inferior gluteal veins drain into the hypogastric vein. The inferior gluteal vein drains the venous plexus of the sciatic nerve and enters into the pelvis passing below the piriform muscle (IGP), while the superior gluteal vein passes above it (SGP) (fig3). The venous plexus of the sciatic nerve can be detected posteriorly in the thigh around the hyperechogenic image of the sciatic nerve (fig.7).

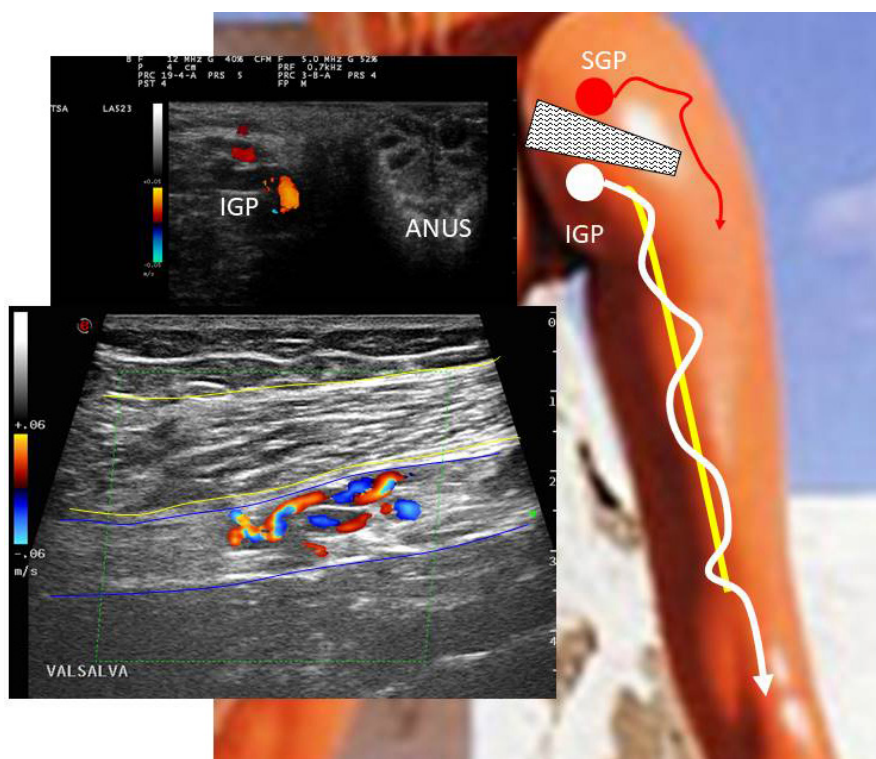


Figure 7 - SPG in red above the piriformis muscle, and IGP in white below the muscle. The yellow line represents the sciatic nerve with the veins of the sciatic plexus (white line) around it. In the inferior US image the yellow lines highlight the sciatic nerve while the blue lines the sciatic venous plexus surrounding the nerve. The reflux during the systolic phase of the Valsalva manoeuvre is detectable on the left in the two duplex scan images

Obturator Point (OP). Is the confluence of the anterior muscular

circumflex vein into the confluence between the saphenous arch and the femoral vein (fig.2). The anterior muscular circumflex vein represents the anterior origin of the Obturator vein, that passing through the obturator channel reaches the hypogastric vein. The anterior muscular circumflex vein passes between the pectineus muscle and fascia and reaches the SFJ immediately below or above the terminal valve (fig.8-9). It represents a female

but also a male escape point. This escape point can be associated both with the incompetence or competence of the terminal valve.

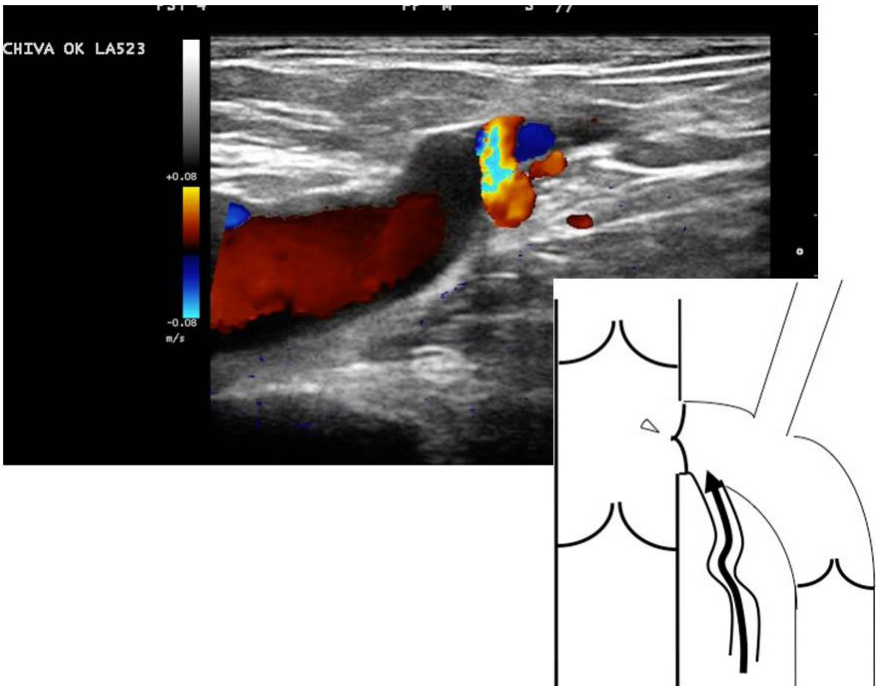


Figure 8 - The obturator escape point: confluence of the medial circumflex muscular vein into the SFJ immediately upstream to the competent terminal valve. The goal is the elimination of the reflux, preserving the physiological flow through the competent terminal valve.

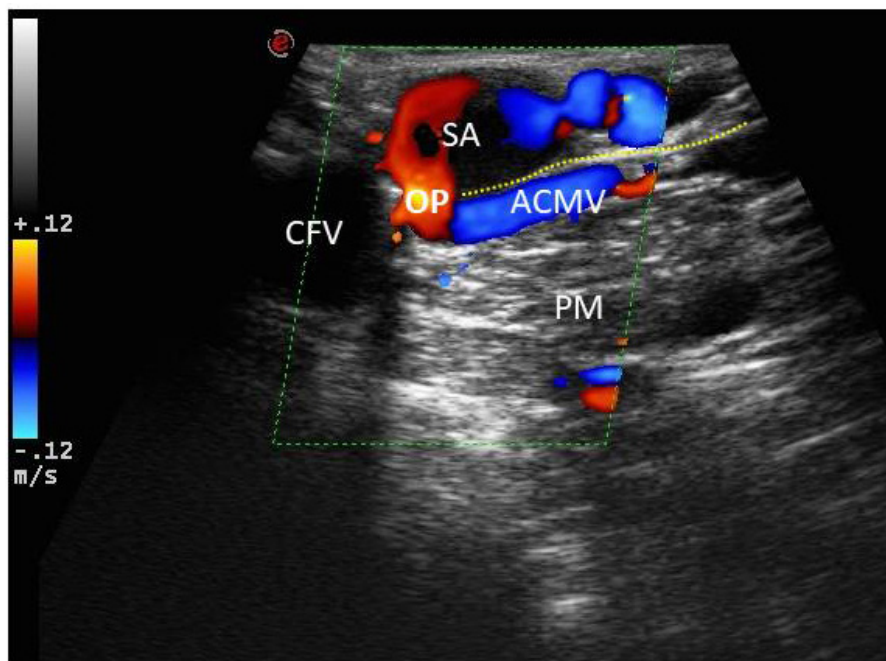


Figure 9 - The obturator point (OP) is the point where the anterior muscular circumflex vein joins the confluence between the saphenous arch and the femoral vein. The anterior muscular circumflex vein represents the anterior origin of the Obturator vein, which reaches the hypogastric vein through the obturator channel. In presence of valvular incompetence of the obturator vein a reflux can be transmitted into the GSV arch and trunk. The anterior circumflex muscular vein (ACMV) runs in the pectineus muscle (PM) immediately below his fascia (yellow dotted line); CFV, common femoral vein; SA, saphenous arch. The Obturator Point reflux is clearly detectable during the valsalva manoeuvre.

Male I Point (MIP) and Male C Point (MCP). The veins of the pampiniform plexus communicate with the superficial veins of the region through a venous collector that cross the hole of the subcutaneous fascia (MIP) near the pubis in the inguinal region to reach directly the saphenous arch or with the intermediate of the superficial epigastric veins. Two different venous paths but a venous collector that cross the subcutaneous fascia hole (MIP), clearly detectable with a B-mode evaluation, and easy to reach with a surgical dissection (fig.10). Most rarely the GSV reflux is fed by the dorsal plexus of the penis which refluxes throughout an EP located at subcutaneous fascia: the MCP (fig.11). As for

the female IP and CP, there is a wide possibility of transmitting the reflux from one side to the other thanks to the superficial and deep dorsal veins and plexuses surrounding the urethra and penis, and also scrotal veins. In the penis, there is a superficial and a deep venous network. The subcutaneous penile venous path drains mainly the skin and the subcutaneous tissue, and the flow normally runs into the subcutaneous dorsal veins of the penis. The dorsal vein of the penis drains into the subcutaneous plexus of the inferior part of the abdomen. These plexus drains into the saphenous arch. There is a wide communication between veins of both side. The subcutaneous penile venous path drains also into the scrotal veins. Thanks to the veins crossing through the scrotal septum, communication between the paths of the two scrotal veins is possible. A reverse flow can be easily transmitted from one side to the other. The deep venous path of the penis drains into the deep dorsal vein of the penis and through it into the pudendal vein (normally is valved). There is a wide communication between the superficial and deep venous path. A venous collector passing through a subcutaneous fascia hole reaches the dorsal plexus of the penis. A reverse flow can be detected in this collector and transmitted to the lower limb.

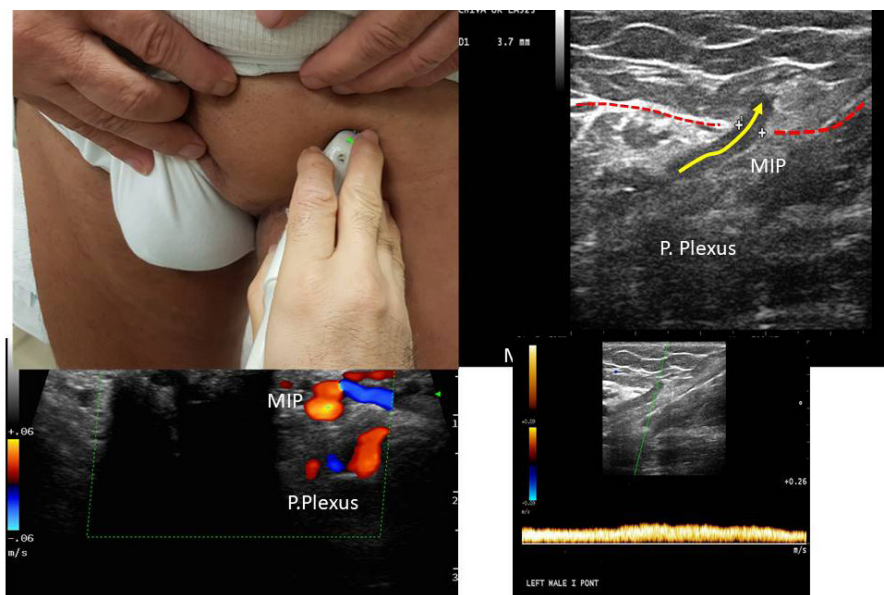


Figure 10 - The Male I Point (MIP). A venous collector rises from the pampiniform plexus and passes through a hole of the subcutaneous fascia (MIP) joining the superficial epigastric vein or directly the GSV arch. Perfectly detectable valsalva reflux in the images lower left of the picture. A valsalva reflux into the pampiniform plexus can spread ipsilateral or contralateral passing through the deep and superficial venous penis plexuses as well as the scrotal veins.

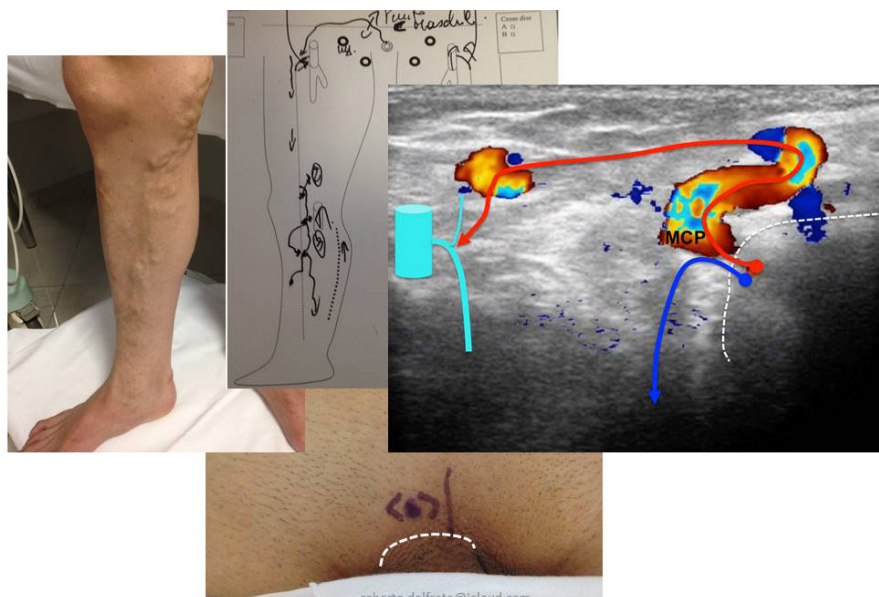


Figure 11 - A clinical case of male C point: medial escape point from the penis venous path. Shunt type 5. In the middle you can see the topographical position of the skin mark, on the right but close to the middle (blue vertical line). The white dotted line highlight the penis

The Male C Point (MCP) is a subcutaneous fascia hole crossed by a venous collector connecting the penis superficial and deep paths to the subcutaneous venous plexus and the GSV arch. The venous penis drainage consists of a deep and a superficial paths extensively interconnected at the corona glans and at the root of the penis. The two main collectors are the superficial and the deep dorsal vein, the former draining into the superficial subcutaneous plexus while the latter joins the internal pudendal vein. The red line represents the reflux transmitted through the MCP into the GSV trunk or arch. The blue line is a further possibility of reflux spreads towards the scrotum with possible contralateral transmission. The white dashed line highlight the root of the penis.

Duplex US assessment

Duplex US scanning is mandatory to perform an accurate venous anatomic-hemodynamic cartography because it is the key point of the strategy and tactics of the CHIVA treatment. The investigation for refluxing pelvic leak points must be performed, when a Valsalva positive reflux is found in any vein, even when an incompetent terminal valve or a direct or indirect perforators are responsible for Valsalva positive reflux (systolic Valsalva reflux). In

fact, an additional inguinal or perineal leak point could be present. The Valsalva maneuver is mandatory to detect a reflux of pelvic origin. A gravitational diastolic reflux (Valvular Muscular Pump activation: VMP) must be confirmed by a Valsalva reflux because the VPM reflux is not specific N1>N3 EP reflux. The exceptional permanent reflux at rest attests to the PLP compensatory role OVS of a pelvic N1 obstruction. We perform the examination with the patient standing and the probe positioned at the saphenofemoral junction. The terminal valve, the OP and the tributaries can be checked. Then the probe is moved cranially to explore the inguinal region (I-Point) and medially to check the anterior perineum (C-Point). The duplex US investigation must be particularly refined in case of Valsalva reflux from the circumflex muscular medial vein (reflux from the obturator vein). This vein can reach the saphenofemoral junction immediately downstream, as well as upstream of the terminal valve. Positioning the Doppler sample on the femoral side of the terminal valve allows understanding its competence or not. The goal is to treat the OP if necessary, maintaining N2-N1 drainage whenever possible. Perineal points (PP, IPP) are best found moving the probe from the proximal thigh cranially, softly to avoid compression of the very superficial veins, following the Valsalva reflux. Investigation of the posterior perineal points is easier if the patients put the foot of the explored leg on an elevated platform (Fig 12). Afterwards, the patients are asked to turn around to investigate the sciatic nerve plexus (fig.13) and moving cranially the probe looking for a Valsalva from the IGP or SGP. A linear probe (7.5-12 MHz) is used first, but a convex or micro convex probe (5-8 MHz) may be necessary in overweight patients. The PRF must be adjusted between 0.75 and 1 kHz, capable of detecting even low speed reflux from 0.05 to

0.10 m/s. The convex probe (5-8 MHz) is necessary to evaluate the abdominal and pelvic vessel, without any need of trans-vaginal or trans-rectal probes.



Figure 12 - PP US investigation . The examination is performed with the Patient in standing position putting the foot of the explored leg on an elevated platform



Figure 13 - US investigation to detect a valsalva refluklux from a IGP or SGP

PLPS skin mark and surgery

A surgical echo-guided mini-invasive treatment under local anesthesia of PLPs responsible for vulvar and/or lower limbs varicose veins is possible, reliable and durable (fig. 14-16). Skin mark is done immediately before surgery thanks to a linear probe at least 12 MHz with the patient first standing and then lying down on the bed. For the PP the skin mark must be checked with the patient already placed in lithotomy position on the operating table but in reverse Trendelenburg position to engorge the labial vein so to make it more visible. The standard lithotomy horizontal position is then restored for surgery. Intraoperative US dissection may be necessary in case of deep groin when treating the obturator point. Surgery consists of a minimally invasive surgical approach under local anesthesia. Local anesthesia is a mixture of lidocaine (2%) and ropivacaine (7.5 mg/dL). Skin incision according to skin mark range from 10 (PP, IPP, CP) to 20 mm (IP, OP). A washing with a rifampicin solution had been done in every surgical procedure in the personal experience, without any systemic antibiotic therapy. Disconnection/ligation of any vein is done with non-absorbable braided coated suture, adding also a polypropylene stitch in case of Perineal and IP treatment. The I point treatment consists of disconnection/ligation of the venous plexus of the round ligament (fig.17-20) at the subcutaneous ring of the inguinal canal. In my experience, the proximal stump is folded up into the inguinal canal. In case of PP or IPP treatment, the disconnection must be done at the vulvar fascia hole (fig.21-27). The fascia hole must be closed with a 6 zero polypropylene stitch, the deep stump of the labial vein lying inside the vulva. The CP disconnection is done only at the subcutaneous fascia, to avoid nervous injuries possible

if the ligation is performed deeper. For this reason, a higher recurrence rate is possible ¹⁸. For gluteal leak points, a minimally invasive surgical approach doesn't exist, and sclerotherapy is the first choice. The OP can be treated during a saphenofemoral disconnection or, in case of competent terminal valve, passing through the pectineus muscle fascia medially to the SFJ. In the latter case a perfect preoperative skin mark is mandatory and intraoperative US may be useful. The MCP and MIP to treat and also be treated with a minimally invasive surgical approach under local anesthesia. Disconnection is done at the subcutaneous fascia hole level.

Delfrate R, Bricchi M, Franceschi C. Minimally-invasive procedure for pelvic leak points in women. Veins and Lymphatics. 2019; 8:7789, 10-16

Open-label trial

273 pelvic leak points free of pelvic congestion syndrome, with at least a 12-month follow-up, were assessed and treated PP (n=177), IP (n =91) and CP (n=5). Follow-up: Period =12 to 92 months (mean =30.51 months). Age from 29 to 77 years (mean=45)

Figure 14 - you can see here the data of our experience of 273 IP, PP AND CP TREATED.

Delfrate R, Bricchi M, Franceschi C. Minimally-invasive procedure for pelvic leak points in women. Veins and Lymphatics. 2019; 8:7789, 10-16

Open-label trial results

273 pelvic leak points free of pelvic congestion syndrom

267 without any reflux redoo (97.8%)

6 PLP with reflux recurrence:2.2%

3 PLP redoo surgery:

2 PP (0.7%), 1 IP(0.3%)

Controls consisted in the examination of the PLP treated with a linear probe , with the patient in standing position, asking the patient to perform a valsalva manoeuvre

Figure 15 - Controls consisted in the examination of the treated PLPs with a Linear Probe , with patient in standing position, asking him to perform a valsalva manoeuvre 267 PLP treated did not show any reflux recurrence at the treated point level Reflux was detected only in 6 of the 273 plp treated Only in 3 cases a redo surgery was done

Delfrate R, Bricchi M, Franceschi C. Minimally-invasive procedure for pelvic leak points in women. Veins and Lymphatics. 2019; 8:7789, 10-16

Conclusions

- This study shows that echo-guided minimally-invasive surgery of pelvic leaks responsible for vulvar and/or lower limbs varicose veins is reliable and durable
- This study also suggests that pelvic varicose embolization prior to PLP reflux ablation is not necessary
- The accurate ultrasound assessment of each specific pelvic leak as well as a special minimally invasive surgical technique is necessary

Figure 16 - Conclusion: the minimally invasive surgical treatment under local anaesthesia of PLPs responsible for vulvar and/or lower limbs varicose veins is possible, reliable and durable

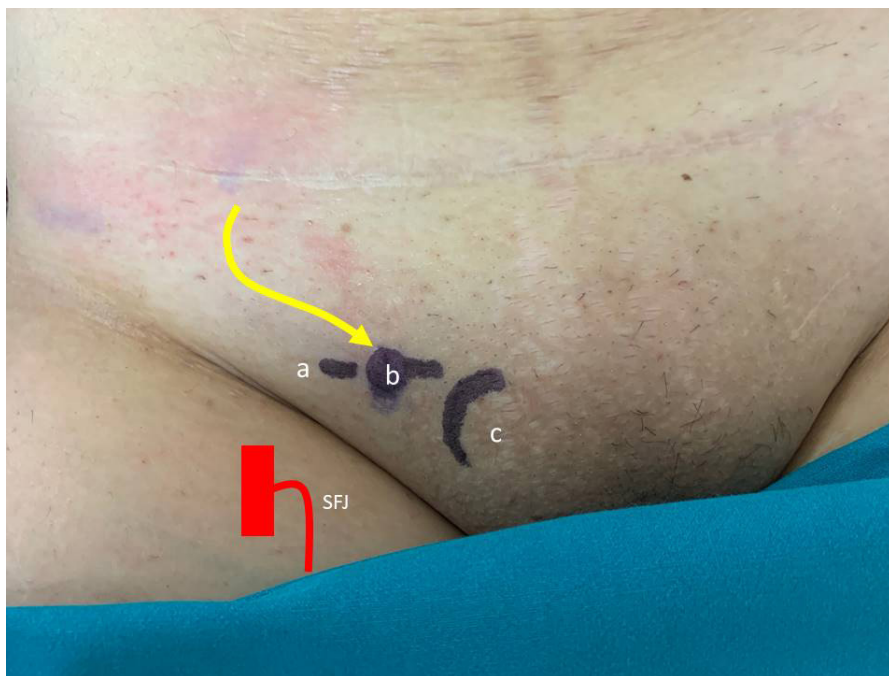


Figure 17 - Topographic anatomy of the IP. The skin incision (a), the IP (b), the pubic tubercle (c), the SFJ, the venous plexus of the round ligament yellow arrow

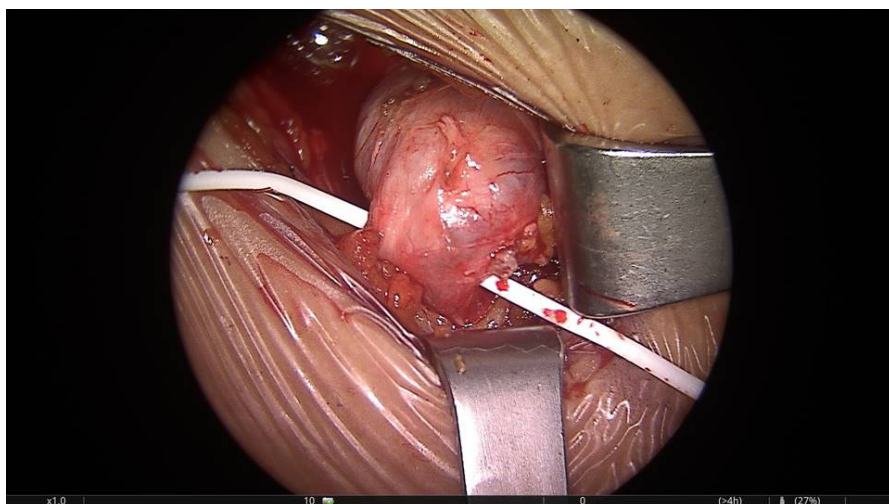


Figure 18 - Venous plexus of the round ligament at of the superficial ring of the inguinal canal on a vessel loop

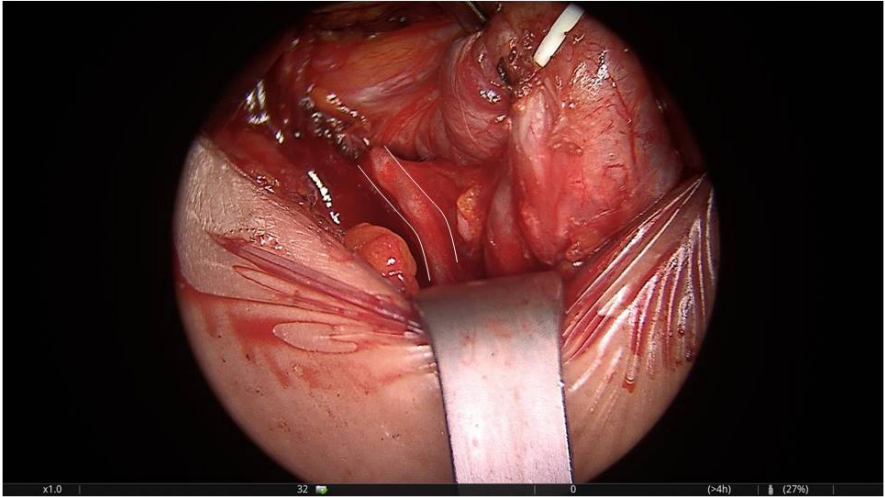


Figure 19 - The genitocrural nerve between the white lines

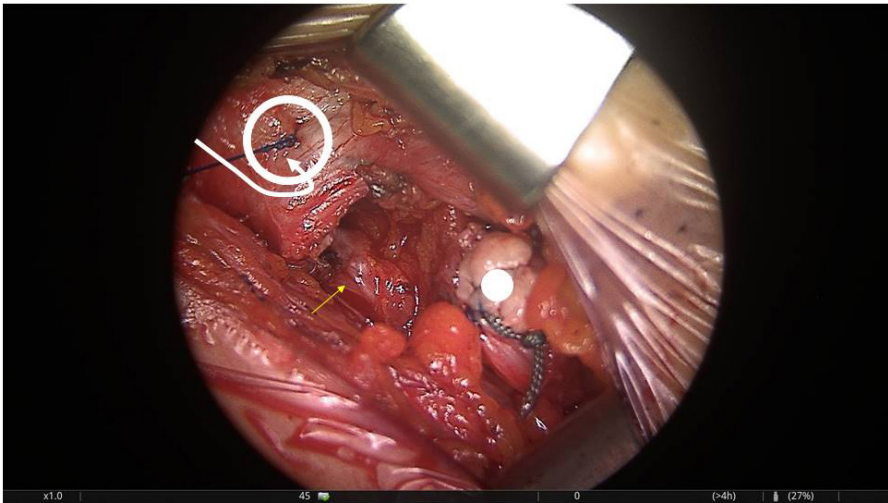


Figure 20 - The venous plexus of the round ligament has been cut. The deep stump is folded up into the inguinal canal (white arrow) with a polypropylene 5 zero stitch (white circle). On the right the superficial stump is detectable (white point)



Figure 21 - Mini-invasive surgical treatment of PP. Lithotomy position in the left upper angle of the picture: the operating table is perfectly horizontal. In the middle the linear probe. In the lower left angle of the picture reversed lithotomy position of the operating table for intraoperative skin marking check. The B-mode image of the labial vein (blue lines) and of the vulvar fascia (red line). The fascia hole representing the PP is clearly detectable. On the right inferior angle the skin mark and the position of the PP is detectable.



Figure 22 - 10 mm skin incision: minimally invasive surgery under local anesthesia. The procedure is possible thanks to a perfect echoduplex haemodynamic diagnosis and US skin mark



Figure 23 - The posterior labial vein passing through the vulvar fascia hole (white dotted line): PP

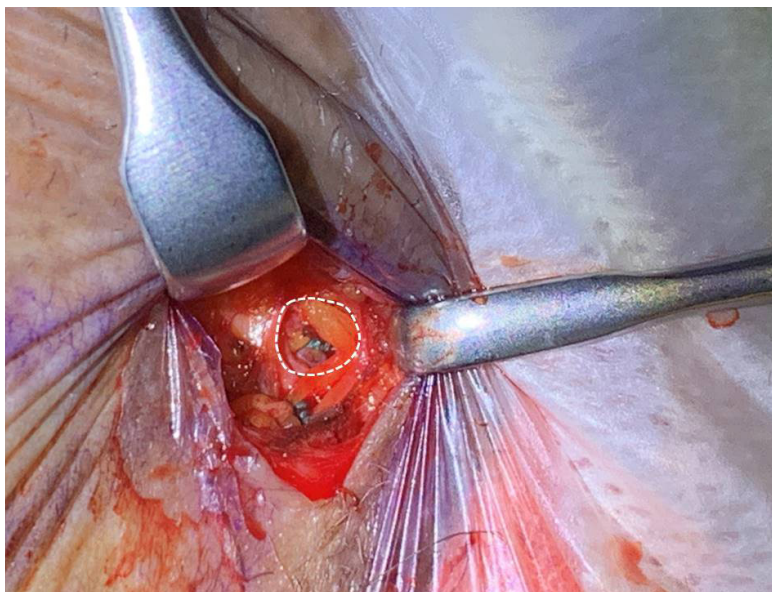


Figure 24 - The labial vein has been cutted and sutured. The vulvar fascia hole is clearly detectable (white dotted line) and also the labial vein stump inside it



Figure 25 - The fascia hole has been closed with a 6 zero polypropylene stitch

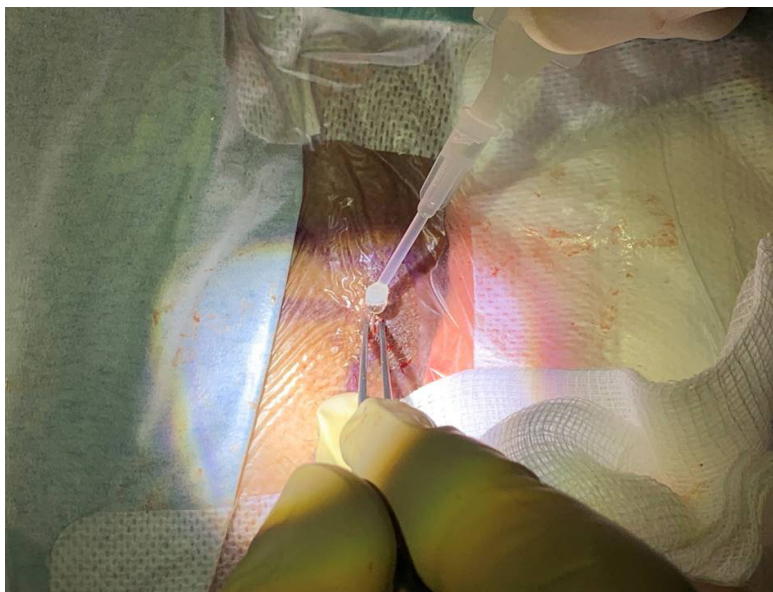


Figure 26 - Glue to close the skin incision

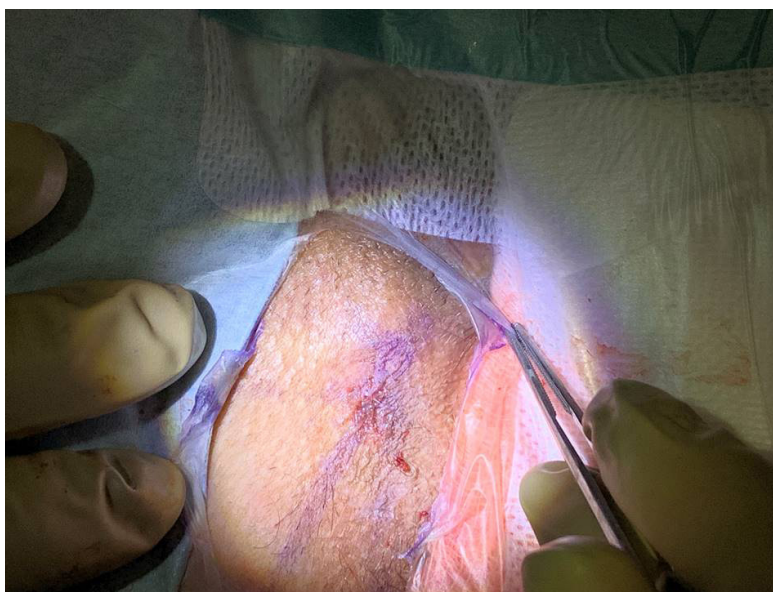


Figure 27 - Final result

Inguinal Pelvic Leak point: I Point: <https://www.youtube.com/watch?v=z3tSXAfMqnc&t=116s>



Perineal Pelvic Leak/ P Point: <https://www.youtube.com/watch?v=ThLN8ApPTOc&t=87s>



References:

1. Jiang P, van Rij AM, Christie RA, Hill GB, Thomson IA. Non-saphenofemoral Venous Reflux in the Groin in Patients with Varicose Veins [Internet]. Vol. 21, European Journal of Vascular and Endovascular Surgery. 2001. p. 550–7. Available from: <http://dx.doi.org/10.1053/ejvs.2001.1375>
2. Barros FS, Perez JMG, Zandonade E, Salles-Cunha SX, Monedero JL, Hilel ABS, et al. Evaluation of pelvic varicose veins using color Doppler ultrasound: comparison of results obtained with ultrasound of the lower limbs, transvaginal ultrasound, and phlebography [Internet]. Vol. 9, Jornal Vascular Brasileiro. 2010. p. 15–23. Available from: <http://dx.doi.org/10.1590/s1677-54492010000200002>

3. García-Gimeno M, Rodríguez-Camarero S, Tagarro-Villalba S, Ramalle-Gomara E, González-González E, Arranz MAG, et al. Duplex mapping of 2036 primary varicose veins [Internet]. Vol. 49, Journal of Vascular Surgery. 2009. p. 681–9. Available from: <http://dx.doi.org/10.1016/j.jvs.2008.09.062>
4. Labropoulos N, Tiongson J, Pryor L, Tassiopoulos AK, Kang SS, Mansour MA, et al. Nonsaphenous superficial vein reflux. J Vasc Surg [Internet]. 2001 Nov;34(5):872–7. Available from: <http://dx.doi.org/10.1067/mva.2001.118813>
5. Perrin MR, Labropoulos N, Leon LR Jr. Presentation of the patient with recurrent varices after surgery (REVAS). J Vasc Surg [Internet]. 2006 Feb;43(2):327–34; discussion 334. Available from: <http://dx.doi.org/10.1016/j.jvs.2005.10.053>
6. Mendoza E, Dörler M, Stücker M, Reich-Schupke S. Frequency of refluxive tributaries of the junction region in the groin in patients with recurrent varicose veins of the thigh [Internet]. Vol. 45, Phlebologie. 2016. p. 149–53. Available from: <http://dx.doi.org/10.12687/phleb2300-2-2016>
7. Franceschi C. Anatomie fonctionnelle et diagnostic des points de fuites bulbo-clitoridiens chez la femme (Point C). J Mal Vasc. 2008;33:S42.
8. Francheschi C, Bahnini A. Treatment of lower extremity venous insufficiency due to pelvic leak points in women. Ann Vasc Surg [Internet]. 2005 Mar;19(2):284–8. Available from: <http://dx.doi.org/10.1007/s10016-004-0180-9>
9. Franceschi C, Bahnini A. Points de fuite pelviens viscéraux et varices des membres inférieurs. Phlébologie [Internet]. 2004; Available from: <https://pascal-francis.inist.fr/vibad/index.php?action=getRecordDetail&idt=15493772>
10. Franceschi C. Theory and practice of the conservative haemodynamic cure of incompetent and varicose veins in ambulatory patients, translated by Evans J. Précy-sous-Thil, France: Editions de l'Armançon. 1988;

11. Samsò JJ. La cura CHIVA en el tratamiento de las varices primarias de las extremidades inferiores. Samsò JJ, editor. Aran Ediciones.; 2019.
12. Criado E, Juan J, Fontcuberta J, Escribano JM. Haemodynamic surgery for varicose veins: rationale, and anatomic and haemodynamic basis. *Phlebology* [Internet]. 2003 Dec 1;18(4):158–66. Available from: <https://doi.org/10.1258/026835503322597974>
13. Hüffer A. Lehrbuch der topographischen anatomie. Springer-Verlag Berlin, Heidelberg, New York 1969. Hüffer A, editor. Springer-Verlag Berlin; 1969.
14. Sala L, Bruni C. Trattato di anatomia umana. Sala L, Bruni C, editors. Vol. 4. Milano: Ed. Vallardi F; 1932.
15. Fusari R, Bruni AC. Trattato di anatomia umana topografica. Fusari R BAC, editor. Torino: UTET; 1936.
16. Pernkopf E. Atlas of Topographical and Applied Human Anatomy. Werner, editor. Vol. II. Platzer; 1964.
17. Chiarugi G, Bucciante L. ISTITUZIONI DI ANATOMIA DELL'UOMO. Ed FV, editor. 1975. (chapter 17; vol. 2).
18. Delfrate R, Bricchi M, Franceschi C. Minimally-invasive procedure for pelvic leak points in women. *Veins and Lymphatics* [Internet]. 2019; Available from: <https://pagepressjournals.org/index.php/vl/article/download/7789/8103>
19. Zamboni P, Mendoza E, Giancesini S. Saphenous vein-sparing strategies in Chronic Venous Diseases. Zamboni P, Mendoza E, Giancesini S, editors. Springer; 2018. (Chapter 8).

7 - Hemodynamic patterns of stripping recurrence.

Stefano Ermini and Felipe Faccini

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Key Points

Recurrence is common after varicose vein surgery

Saphenous-femoral and veins left without drainage by the missing the saphenous vein are common causes of recurrence

Do not forget to evaluate pelvic leaks

Discussion about the effect of the missing saphenous vein and strategies to avoid recurrence.

Introduction

The recurrence after varicose vein operations is a significant problem of modern procedures, and the recurrence at 2 years after most of these procedures is greater than 25%¹. If we consider that we perform most varicose vein procedures in young patients, it is important to study recurrence origin to improve long-term results. Studies showed that the 30-year recurrence after varicose vein operation is around 60%². The study of patterns of recurrence is pivotal to understand the causes and develop techniques with less recurrence.

Patients with recurrences often have a great impact on the quality of life questionnaires, esthetic complaints, and even severe complications of venous insufficiency. This discussion focuses on

a population with previous saphenous stripping but the end result of most ablative methods is similar, as is medium term recurrence³. There are several studies concerning this matter and data from clinical trials showing us that the recurrence after stripping is almost 50% in 10 years and can be over 50% on the longer period¹. Thus, a young patient submitted to saphenous stripping is more likely to recur in life than to be disease free. This chapter presents the results of a study of recurrence after high-ligation and stripping of the saphenous vein currently in press and discusses why recurrences occur and what we can do to avoid it.

We will shortly present the results of a recurrence study to entice and guide discussion. We evaluated symptomatic patients with prior stripping of the saphenous vein. A total of 533 patients (759 limbs) were studied, and 542 limbs included after exclusion of non-venous origin of symptoms. We tested these limbs for reflux, anatomical stump recurrence, and source of recurrence.

The recurrences sources were divided into 5 groups according to the findings (Figure 1). The most common recurrence source was the saphenofemoral junction (SFJ), found in 230 limbs (44.9%). The second most common source of recurrence was reflux at superficial collaterals without an escape point in 143 limbs (27.9%). These collaterals did not have a defined connection with the deep system, for example, abdominal and thigh veins from the subcutaneous tissue. We found pelvic leaks in 70 limbs (13.7%). Thigh perforators caused recurrence in 65 limbs (12.7%). Leg perforators caused reflux in 4 legs (0.78%). According to the junction type of recurrence, we found that a left stump caused recurrence in 137 limbs (59,5%), junction reflux without a left stump in 93 (40,5%) limbs.

Concerning saphenous-femoral junction stump anatomy 260 limbs had an abnormality in the junction as shown in Figure 2. Thirty (30) limbs (11.5%) presented a stump at the junction but we observed no recurrence or reflux. We excluded these cases from the overall recurrence analysis and included them in the anatomic stump analysis. These patients with anatomical recurrence without reflux had veins draining to the junction at a straight angle, craniocaudal position. A hundred thirty-seven limbs (137 or 52% of stumps) presented stump left behind with reflux and 93 limbs (35%) had no stump left behind and with reflux.

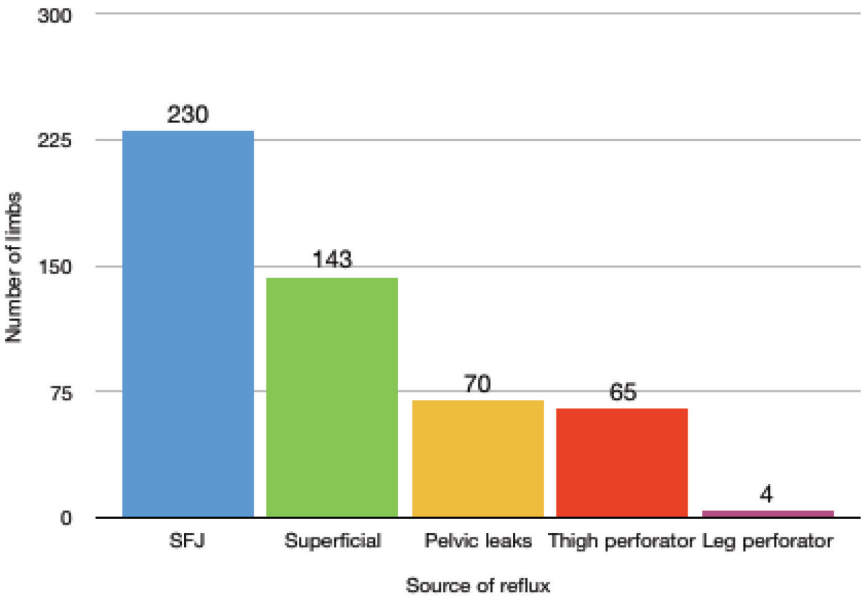


Figure 1: Number of recurrences according to the identified source of reflux.

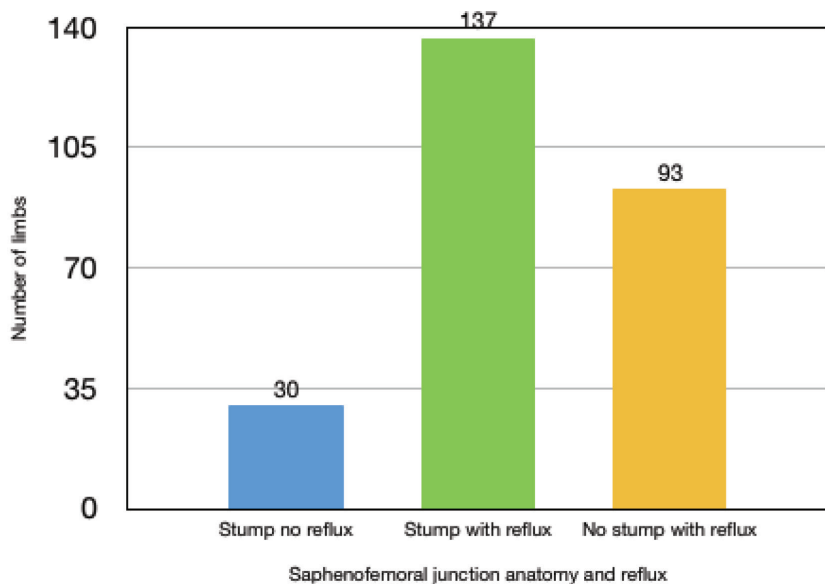


Figure 2: Anatomic finding of the SFJ at the groin of patients with left stump or neoformation of vessels with and without reflux.

Saphenofemoral Junction Recurrence

The saphenofemoral junction was the commonest type of recurrence, accounting for 44,9% of all cases in our series. The analysis of the duplex scan allows us to distinguish between recurrence originating from an adequate flush ligation of the junction (close to the femoral vein) and inadequate distal ligation.

The following two findings are consistent with an inadequate ligation:

- 1) The SFJ terminal valve is visible and
- 2) Saphenous stump connected to a straight collateral, to the great saphenous vein or to the accessory saphenous vein.

The anterior accessory saphenous vein is a frequent cause of reflux and carries potential morbidity similar to the great saphenous vein reflux ⁴. The surgeon may interpret it as the great saphenous vein during the procedure and vice versa.

Several cases have recurrence/degeneration even after adequate anatomical ligation. The duplex scan images that we have considered for a previous flush ligation are:

- 1) The SFJ terminal valve is not visible
- 2) The presence of a cavernous formation that origin directly from the femoral vein
- 3) A short stump with tortuous tributary
- 4) A short stump without connected tributaries.

The difference between a tortuous tributary and a straight one is that a straight tributary is a non-sectioned vein, while a tortuous one is a vein sectioned and grown because of the residual venous pressure. Recurrences from the Saphenous-femoral junction with left stump were 52% (137 cases out of 260), those without a stump left 35% (33 cases out of 260). In 11.5% (30 cases), we found a stump left without recurrence. We will discuss later the hemodynamic analysis of these latter stumps.

Why does a left stump behind grow?

The progression of the saphenous stump after intervention may happen for several reasons. All the hypotheses have several studies showing causality in recurrences, but this area is in constant study and no definitive theory is available.

The physics hypothesis suggests that increasing wall tension and turbulent flow can cause stump growth and recurrence. The Laplace law ($\text{Pressure} = 2 \text{ Tension} / \text{Radius}$) states that the growth of the radius creates an increase in the tension on the venous wall, considering that the venous pressure is the same. A stump left behind has the higher wall tension to induce recurrence. Another physical factor is the turbulence of flow created by dilations (left stump for example) that happens when flow passes in the dilated region creating venous wall stress and triggering venous remodeling⁵.

When does not the left stump grow?

When there is a combination of the following situations:

1. The presence of a continent terminal valve. A stump without recurrence is closed, therefore there can be no pressure gradient in it and therefore achieve a significant flow. We cannot do valve continence diagnostics.
2. The presence of a collateral connected to the junction with an effective emptying gradient. This depends on the length of the collateral segment which has a direct flow towards the saphenous arch.
3. From the angle of incidence of the collateral on the Saphenous arch
4. From the length of the stump.

Recurrence in cases without a left stump:

1. Physics Hypothesis: The lateral pressure on the vein wall during leg muscle systole.
2. Inflammatory/Hemodynamic theories.

The inflammatory hypothesis comprises a granuloma that forms at the junction ligature which would incite the formation of new vessels. These would subsequently create a neo-communication between the deep and superficial system and therefore a recurrence. For example, studies showed that the closure of the cribiform fascia is an efficient anatomical barrier against postoperative neovascularization ⁶.

The hemodynamic hypothesis considers that the interruption of the collaterals generates an obstacle to drainage and an increase in pressure that causes the formation of new vessels that seek a return point to restore proper drainage. The ultrasound finding of small tortuous and multiple vessels on the saphenous ligature represent that. The common finding of several reticular vessels at the groin after crossectomy also shows us this reaction. These new vessels can find their point of return at the ligature site and create the recurrence. This hemodynamic mechanism is further backed by crossectomy versus crossotomy studies. Cappelli et al. have shown that no ligature of collaterals (CHIVA crossotomy) and closure of the fossa ovalis reduces groin recurrences by a sevenfold ⁷. The Crossotomy operation consists in interrupting the saphenous arch between the outlet of the first collateral and the saphenous-femoral junction, thus leaving the collaterals connected with the saphenous vein, and closing the oval fossa.

Another aspect to discuss is the great importance of the duplex evaluation in the venous procedure. Preoperative factors are important to assure high-quality of the procedure. The duplex mapping link to the operation is pivotal, as a good mapping may help surgeons start the procedure knowing what to expect. The problems caused by lack of connection between the operating room and the duplex map can vary from missing a source of reflux to removing the wrong saphenous vein⁸.

Tributary recurrence

Tributaries creating recurrence was the second most common cause in our patients. In these cases, the tributaries have no feeding escape point, but the reflux originates from several small veins that develop for superficial tissue drainage. The stripping causes a severe change in superficial tissue drainage. It leaves many veins without proper drainage, causing areas of focal venous hypertension in the leg. In the long term, venous hypertension translates into shear stress to the vein wall and causes venous remodeling, creating focal recurrence ⁵. Animal models and clinical studies showed this remodeling effect. Thus, data supports the fact that excessive vein removal might create further varicose veins in the long term. Pfisterer et al. showed that the lack of drainage causes alterations in pressure and flow causing an increase in MMP-9 (Metalloproteases) causing recurrence ⁵.

Pelvic Leaks

Another important source of recurrence were pelvic leaks (new or undetected). Intra-abdominal chronic venous

disease is common in women and men with varicocele. Duplex scan misdiagnoses these leaks and blame the saphenous vein or junction for the reflux, especially if they drain reflux direct to the junction. Our data suggest that 13.7% of the legs have pelvic leaks as the source of recurrence. We may prevent some of these recurrences if the duplex scan includes a thorough analysis of the groin area.

Pelvic leaks are treated by ligation at the point of exit (from the pelvis to the leg) or endovascular obstruction of abdominal veins from above. Franceschi et al. published the results of the open treatment at the “exit” of the abdomen with excellent results⁹. More recently, the endovascular treatment has been used to treat reflux from abdominal veins to the leg with success. The results of both techniques are debatable, and we need clinical trials to validate its use^{10,11}.

Perforators

We found a reflux source at perforators in 13.5% of all examined legs. We found most perforators with reflux in the thigh (94.2%) as compared to the leg (5.8%). Thigh perforators behave hemodynamically as an escape point, like the saphenofemoral junction, for example. They present centrifugal flow during muscle relaxing and centripetal flow during muscle contraction. Leg perforators causing recurrence may have outward flow only during muscle relaxation or outward flow both in muscle contraction and relaxation. The hemodynamic differences between Thigh and Leg perforators may explain why most recurrences found were in thigh perforators. The presence of venous valves at the deep system is much more common in the leg than in more proximal veins¹².

Thus, the height of the blood column above a perforator is greater in the thigh than in the leg.

Conclusions

There are several ways to minimize recurrence depending on its source. The quality of the duplex scan and mapping is important to help the surgeon avoid pitfalls of venous anatomy. We consider that the greater the connection between duplex scan and operating room, the better. The duplex scan should include saphenous-femoral junction anatomy and hemodynamic assessment. We should test pelvic leak points to avoid leaving a pelvic recurrence. Perforators are another Achilles heel of venous operations and the duplex scan should test the perforators involved in the reflux.

Incompetent tributaries without an escape point are a frequent source of recurrence. They relate to the excessive destruction of veins, and we consider conservative strategies may avoid remodeling and recurrence. When we eliminate the saphenous vein, the collaterals of the thigh and abdomen may become a problem even without an additional reflux source. The veins left without proper drainage may create superficial reflux and recurrence.

The consequences of a new escape point are different depending on the absence or presence of the saphenous vein. If the patient does not have the saphenous vein, the new escape point will create a vast varicose network to drain its blood. In fact, the collateral network will grow until it drains to a deeper system (saphenous to deep, perforator to deep). If the saphenous vein is

still there, the new escape point will probably find drainage before it forms a great superficial network. The authors' experience with saphenous sparing procedures showed us that recurrence with the saphenous vein in place does not create the vast network of collaterals thigh and leg. If there is a good drainage to the saphenous vein, capable of draining the increased flow rate from the new reflux, the patient will not have any recurrences. If the saphenous vein cannot drain all the flow adequately, a new varicose vein develops. The saphenous vein is therefore useful for limiting the development of varicose veins in the situation described. Since most recurrences from the new escape point are in the thigh, we consider that this segment is the most important saphenous segment to preserve. If we try to foresee an evolution of the varicose disease, the saphenous tract of the thigh and not that of the leg is more important to preserve. In contrast, most surgical procedures remove the thigh segment and leave the leg segment.

Concerning the saphenofemoral junction, the surgeon should try to consider sources of recurrence when doing a procedure. Femoral vein and terminal valve incompetence should receive the saphenous ligature close to the femoral vein. The stump works as an increase in the Common Femoral Vein radius that leads to increased pressure and shear force creating a tendency to recur. We should prefer approaches validated by clinical trials in the intervention. Preserving saphenous groin collaterals (and the great saphenous vein trunk as a result) and closing the cribiform fascia may help to avoid recurrence. Studies show that unique approaches at the operation have different recurrence incidence and the surgical team should try to follow the techniques that have less recurrence.

References

1. Fischer R, Chandler JG, De Maeseneer MG, Frings N, Lefebvre-Vilarbedo M, Earnshaw JJ, et al. The unresolved problem of recurrent saphenofemoral reflux. *J Am Coll Surg* [Internet]. 2002 Jul;195(1):80–94. Available from: <https://www.ncbi.nlm.nih.gov/pubmed/12113548>
2. Fischer R, Linde N, Duff C, Jeanneret C, Chandler JG, Seeber P. Late recurrent saphenofemoral junction reflux after ligation and stripping of the greater saphenous vein. *J Vasc Surg* [Internet]. 2001 Aug;34(2):236–40. Available from: <http://dx.doi.org/10.1067/mva.2001.115802>
3. Nesbitt C, Bedenis R, Bhattacharya V, Stansby G. Endovenous ablation (radiofrequency and laser) and foam sclerotherapy versus open surgery for great saphenous vein varices. *Cochrane Database Syst Rev* [Internet]. 2014 Jul 30;(7):CD005624. Available from: <http://dx.doi.org/10.1002/14651858.CD005624.pub3>
4. Schul MW, Vayuvegula S, Keaton TJ. The clinical relevance of anterior accessory great saphenous vein reflux [Internet]. *Journal of Vascular Surgery: Venous and Lymphatic Disorders*. 2020. Available from: <http://dx.doi.org/10.1016/j.jvsv.2020.02.010>
5. Pfisterer L, König G, Hecker M, Korff T. Pathogenesis of varicose veins—lessons from biomechanics. *Vasa* [Internet]. 2014;43(2):88–99. Available from: <https://econtent.hogrefe.com/doi/pdf/10.1024/0301-1526/a000335>
6. De Maeseneer MG, Philipsen TE, Vandenbroeck CP, Lauwers PR, Hendriks JM, De Hert SG, et al. Closure of the cribriform fascia: an efficient anatomical barrier against postoperative neovascularisation at the saphenofemoral junction? A prospective study. *Eur J Vasc Endovasc Surg* [Internet]. 2007 Sep;34(3):361–6. Available from: <http://dx.doi.org/10.1016/j.ejvs.2007.03.020>
7. Cappelli M, Molino-Lova R, Giangrandi I, Ermini S, Giancesini S. Ligation of the saphenofemoral junction tributaries as risk factor for groin recurrence. *Journal of Vascular Surgery: Venous and Lymphatic Disorders* [Internet]. 2018 Mar 1;6(2):224–9. Available from: <http://www.sciencedirect.com/science/article/pii/S2213333X17304365>

8. Faccini FP, Arendt AL, Pereira RQ, Oliveira AR de. CHIVA to spare the small and great saphenous veins after wrong-site surgery on a normal saphenous vein: a case report. *J vasc bras* [Internet]. 2019 [cited 2019 Mar 15];18. Available from: http://www.scielo.br/scielo.php?pid=S1677-54492019000100601&script=sci_arttext
9. Francheschi C, Bahnini A. Treatment of lower extremity venous insufficiency due to pelvic leak points in women. *Ann Vasc Surg* [Internet]. 2005 Mar;19(2):284–8. Available from: <http://dx.doi.org/10.1007/s10016-004-0180-9>
10. Rabe E, Pannier F. Embolization is not essential in the treatment of leg varices due to pelvic venous insufficiency [Internet]. Vol. 30, *Phlebology: The Journal of Venous Disease*. 2015. p. 86–8. Available from: <http://dx.doi.org/10.1177/0268355515569412>
11. Whiteley M. Letter regarding embolization is not essential in the treatment of leg varices due to pelvic venous insufficiency [Internet]. Vol. 31, *Phlebology: The Journal of Venous Disease*. 2016. p. 588–588. Available from: <http://dx.doi.org/10.1177/0268355516647319>
12. Caggiati A. The venous valves of the lower limbs. *Phlebolympology* [Internet]. 2013 Apr 9 [cited 2019 Jul 20];20(2):87–95. Available from: <https://www.phlebolympology.org/the-venous-valves-of-the-lower-limbs/>

8 - CHIVA for Beginners

Felipe Faccini and Claude Franceschi

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Learning Approach

Why should we preserve the veins, even if varicose? Two main reasons: 1-Superficial veins elimination impairs the skin drainage that is responsible for recurrence and cosmetic secondary events (matting, bruising, telangiectasia, spider veins). 2- Great saphenous veins are eligible for vital arterial by-pass even if incompetent. As a matter of fact, varicose veins are not the cause of venous hemodynamics impairment that overloads it, they are more like a sign. Consequently, the treatment should consist of ablating the overload while preserving the low pressure physiologic draining flow (whatever its downwards or upwards direction). Thus, we may obtain proper skin drainage into the deep veins, through any superficial-deep vein connection.

The usual reactive thinking about saphenous reflux is to eliminate the “sick” portions of the venous system. Most books and papers about saphenous preservation bring us a lot of information. The reader then gets a book that starts discussing fluid mechanics and physics. The chapter about cases shows pictures of enormous collateral veins and tells that those veins are like fireman roses. They collapse after the shunt is closed (like a fire hydrant valve). The first reaction is throwing the book away.

The reader may think it is nonsense and too much trouble to learn. We disagree completely. We think, even if the reader keeps doing ablations, there are many cases in which the surgeon can avoid destroying the saphenous vein and collaterals. There is no need for a complete and fast migration to preserving procedures, one can only perform the simple cases first and then move up to the difficult cases.

The primary author of this chapter kept doing stripping and ablations for a period before performing complex CHIVA cases alone. I have performed several ablations plus flush ligation of the shunt before noticing that the saphenous vein removal/burning was unnecessary. It was difficult to shift from the paradigm of vein destruction to vein preservation, being born and raised, learning and perfecting ways to destroy a vein. The approach of dividing saphenous preserving procedures according to the complexity and potential complications came from the learning period faced. If a surgeon begins with tough cases, he or she will probably see several cases of phlebitis and will give up. Saphenous veins or collaterals left without drainage will likely thrombose. The phlebitis results from most ablation methods, so even when it happens it is not a disgrace. Although, if you aim to preserve the vein, you will be disappointed if that vein is destroyed.

Introduction

Venous hemodynamics shows us that most of these venous resections/burnings are unnecessary. They may be the source of several problems, such as recurrences, matting, telangiectasia, post-operative pain, nerve damage, skin marks and so on. The difficulty learning curve of CHIVA makes many surgeons avoid

the technique in their practice. However, most CHIVA procedures are not so difficult. Several patients present with simpler cases. For example, a patient with a few centimeters of the saphenous vein with reflux that drains to one collateral in the thigh or leg. We see such patients being offered stripping, foam or endolaser of the saphenous vein and collateral treatment. They come for a second or third opinion. We offer a procedure under local anesthesia in which we will ligate a vein connection and send them back to work. A simple flush ligation of the exit of the collateral from the saphenous vein can treat these cases under local anesthesia with immediate recovery. Most times, the saphenous vein can recover upward flow. The size of the collaterals does not matter much, and even big veins can wilt. The diameter and length of the saphenous vein with reflux are important, since long reflux portions are more difficult to treat. The Perthes maneuver with tourniquets placed at the escape points represent an easy and reliable clinical way to predict the effect of its disconnection. The definitive collapse of the varicose vein needs the time of its progressive remodeling, from some days to some weeks.

Some argue that leaving the saphenous vein with reflux may grow to recurrence (even though many of these regain upward flow). As we all know and will discuss in the recurrence chapter, the same (or worse) occurs with procedures eliminating the saphenous vein in these cases. All procedures have the recurrences that happen because of disease progression. Destructive venous eliminating procedures cause recurrences because veins create pathways to overcome the flow obstacles imputed by the procedure.

Simpler CHIVA Procedures

Procedures without saphenous-femoral or saphenous-popliteal junction involvement are not as hemodynamically demanding as those with junction reflux. The cases with only one collateral out of the saphenous vein are easier than cases with several collaterals in-and-out of the saphenous vein. Patients with short segments of a small diameter saphenous vein with reflux are much simpler to treat than those with long and large segments of vein with reflux.

The importance of the duplex ultrasound is pivotal, and we consider that the surgeon should do the examination, or at least be present to check findings. This is valid not only for saphenous preserving procedures. We have reported complications directly linked to the quality of the duplex scan and its relation to the surgical team ¹. The operator investigates reflux at the junction and collaterals that might transfer reflux to the saphenous vein. It is important to do the guideline examination with Valsalva and calf compression. We also use active maneuvers to contract calf muscles because they mimic walking better than calf compression (Parana maneuver) ².

Patients with reflux that enter the saphenous vein in its upper part (from the femoral vein or collaterals near the groin) are usually more difficult to treat. For educational purposes, we will consider them advanced cases. There are cases with reflux with multiple enters and exits to and from the saphenous vein. In our experience, these cases usually need deeper knowledge of hemodynamics and fractionating the column of pressure. The cases of reflux in the Giacomini vein are very demanding, and we

consider advanced cases. Reflux of the small saphenous vein has a great variety of anatomic details, and we will leave this vein for the advanced practitioner chapter. The cases we consider shoo-ins to a surgeon who wants to practice CHIVA are: 1) Single tributary (with or without saphenous reflux) and 2) Perforators above the knee.

The procedure

The initial evaluation comprises a duplex scan performed by the surgeon or some member of the team with active participation of the surgeon. The examination comprises reflux testing of the deep and superficial venous systems with usual Valsalva and calf compression plus a muscle contraction test. We base all the treatments reported in this chapter in active contraction of the calf muscles (if you are not familiar with dynamic reflux testing, refer to the reflux chapter). If the duplex characteristics confirm that we can perform the procedure, we mark the skin (depicted case-by-case). We use a metal probe to make a pressure mark on the skin during the duplex scan. We mark the exact point of disconnection. After drying the gel of the skin, we mark this point with a permanent marker, including some signal to show us at the operation what veins should be ligated. This is pivotal, since ligating the wrong side of a bifurcation (trifurcation) is a disaster to the technique. If we ligate the wrong vein, we might end up the operation with no improvement or a superficial thrombophlebitis. We should incise the skin with the full map in mind.

Lidocaine is the common anesthetic used in most CHIVA centers at a solution of 1% concentration without vasoconstrictor. The maximum dose is 4mg/Kg of the patient. The half-life of Lidocaine is 1.5-2h. In this 1% solution, every ml has 10 mg of the

drug. For example, a 50 kg person may use up to 200 mg of the drug, or 20 ml. For the simple CHIVA cases, this is usually more than enough. More complex cases, bilateral groin dissection for example, may need unique approaches. Using Lidocaine with vasoconstrictor increases the maximum dosis to 7 mg/Kg allowing us to increase the volume safely. The anesthesiologists avoid sedation as much as possible, and we advise patients that they may feel the touching of the skin. The team should take care with the conversation and remember that the patients are awake.

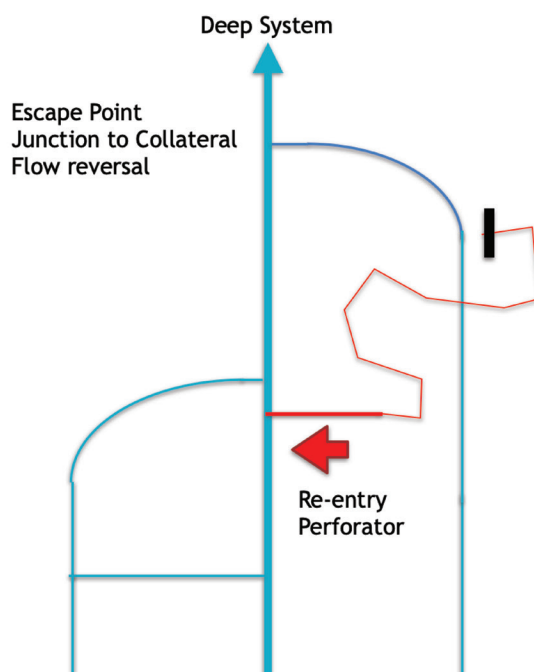
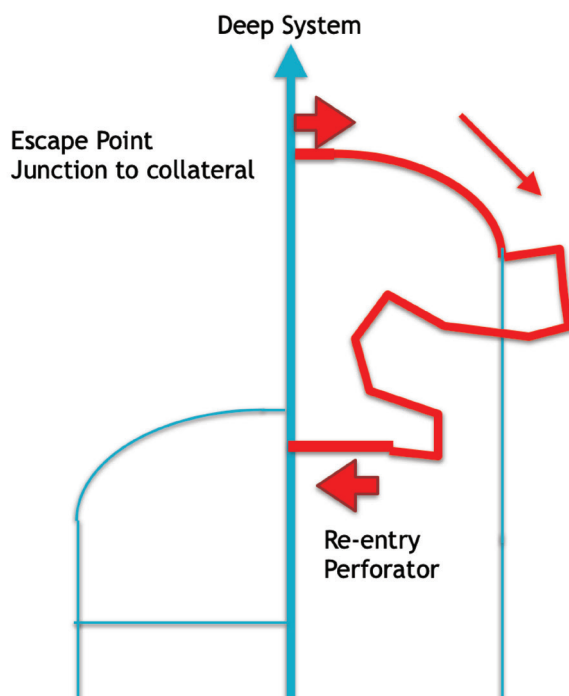
We perform the incision depending on the depth and adipose tissue in the region. In skinny patients and regions, a 3 mm incision may suffice. In the thigh of more obese patients, we may need to perform bigger incisions. We perform the ligation close to the saphenous vein; the idea is avoiding a stump that may grow with the passing years. The saphenous vein is individualized and identified with a rubber/silicone band. After careful attention to the anatomy and correlation to the preoperative map, we ligate with unabsorbable thread and cut the collateral. The revision of hemostasis follows, and nylon skin sutures.

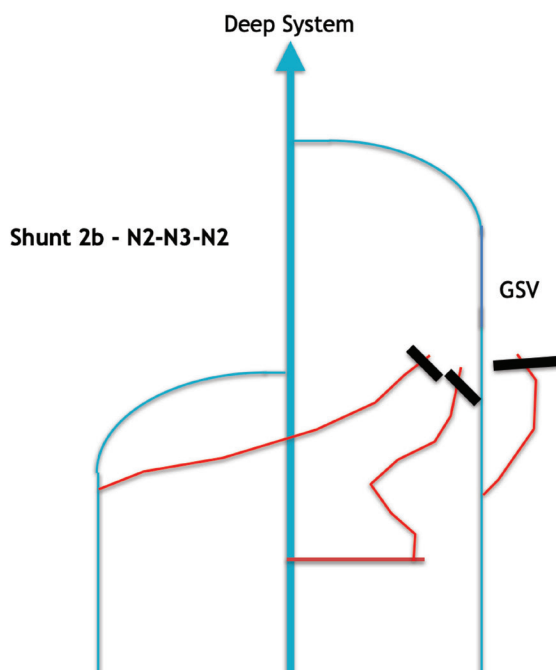
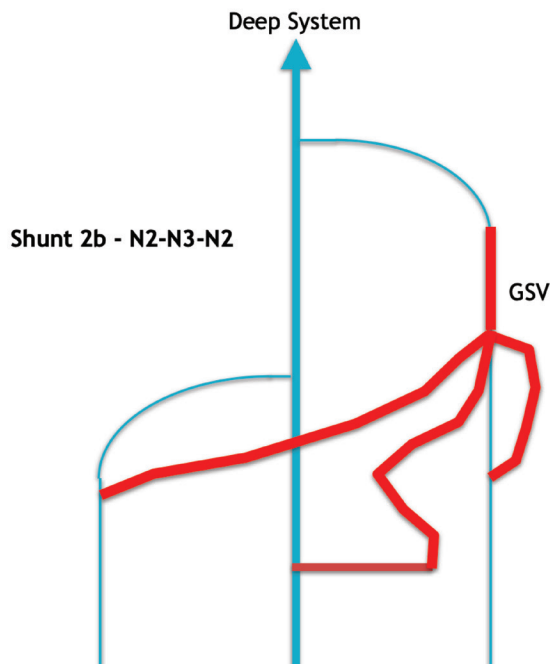
A small gauze pad or common dressing covers the sutures, and 20-30 mmHg elastic stockings are used for 7-14 days. The patient is discharged immediately after the procedure, instructed to walk 2 hours a day and have a normal life. We usually see the patient 6 days after the procedure to remove skin sutures and perform a control duplex ultrasound. Patients that come from other states or countries stay a week nearby, or we make arrangements with a doctor from the patient's region. Using deep vein thrombosis prophylaxis is debatable after varicose vein

surgery. We use 10 days of prophylaxis as a routine in our clinic (see Perioperative chapter).

Single tributary, with or without saphenous reflux.

A simple procedure can treat the cases in which a single tributary of the saphenous vein causes. We can do this in collaterals causing or not aspiration reflux to a small length of the saphenous vein with or without junction reflux. The evaluation should test reflux at the saphenous vein and collateral, with and without collateral compression. In these cases, the procedure comprises the ligation flush to the saphenous vein using unabsorbable material, excising a few centimeters of the collateral. Before proceeding to the treatment, we should test what happens with the reflux when the collateral is closed. Basically, we may have 3 results from this test. (1) Saphenous and collateral reflux disappear while closing the collateral. This is the sign that the result of the ligature will be good (remember that we are dealing with small vein and short reflux). (2) Collateral reflux resolved and no saphenous flow whatsoever. This suggests that you may be closing the saphenous vein and should repeat the test more carefully - do not close the saphenous vein with your finger, only the collateral. (3) Saphenous reflux persists while we compress the collateral. These cases usually have another source/outflow of reflux and should be treated by seasoned hemodynamic surgeons.





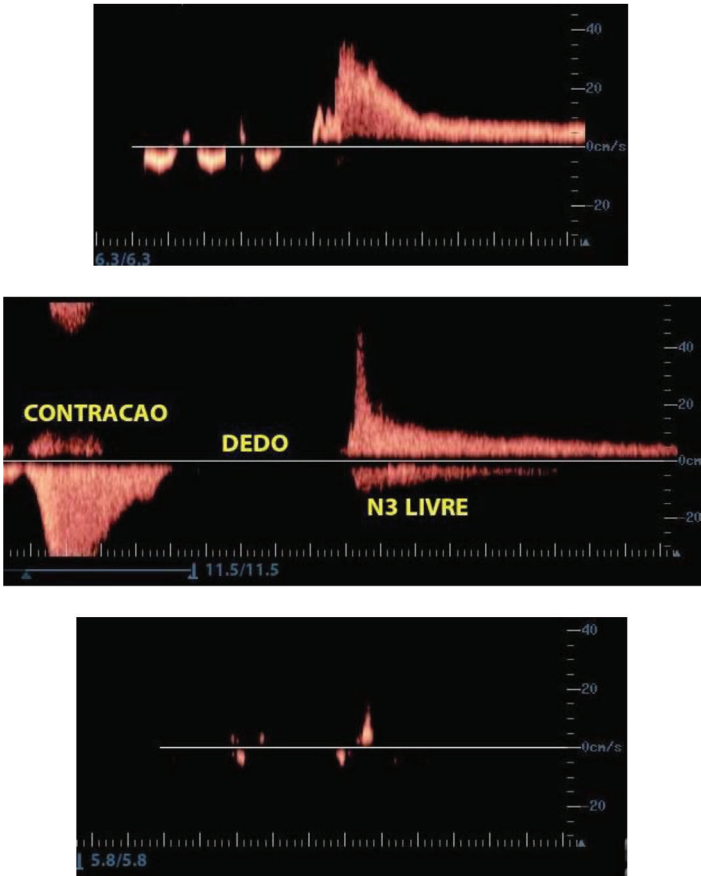
Disappearing Reflux Test

The cases with reflux of the saphenous vein from the saphenofemoral junction or saphenous axis that disappear after compression of the collateral. At this point, it is important to make in-depth analysis of the test. If you are about to ligate the saphenous junction and the reflux disappears during the close of the collateral, it is an indication of possible thrombophlebitis. On the other hand, in cases where the junction and proximal saphenous vein is untouched, the reflux disappearing is a sign that the ligation of the collateral may reverse the flow.

The test comprises a dynamic reflux test or calf compression with the probe at the proximal portion of the saphenous vein (or at the reflux site). The reflux occurs in the diastole phase (relaxation of muscles) and may disappear when we finger press the collateral. Two pivotal details should be in mind. If there is reflux at the deep system, the case becomes advanced and should not be performed by unseasoned surgeons. The test should press the collateral away from the saphenous vein, we are not testing the saphenous compression but the collaterals'. If you press the saphenous vein during the test, it warrants a false result. We should consider the size and length of the saphenous vein when we perform this procedure. If the saphenous vein is too long, it diminishes the probability of flow reversal. This happens because the chance of a saphenous perforator increases, and also because the energy of the distal blood may not be enough to revert the flow. It does not mean that the patient will not improve clinically because even without flow reversal, most patients improve after transmural pressure lowering. Although, as mentioned before, cases with persistent

reflux need more advanced treatment and will be approached in another chapter.

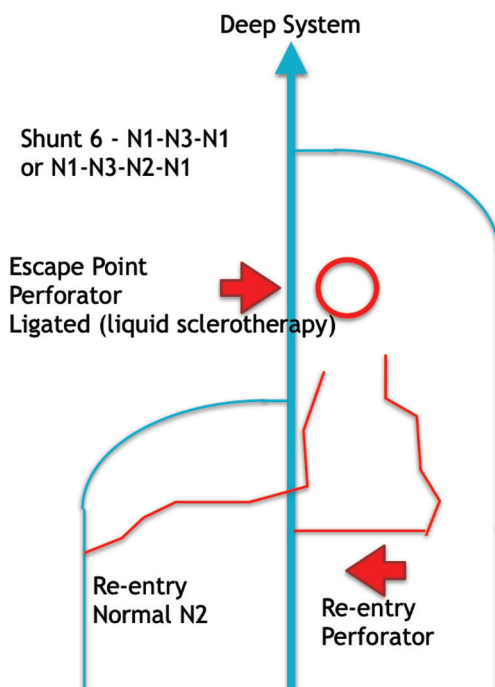
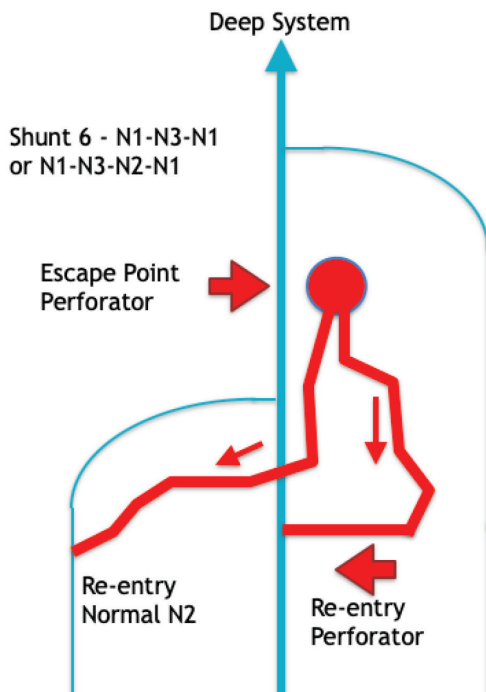
We present 3 figures that represent one case. The first wave shows important reflux at the saphenofemoral junction of a patient with C4 class and enormous veins. The second waveform tests while we press and release the compression of the collateral. It has 3 phases, the systole centripetal flow, no reflux (during collateral compression) and the last diastolic reflux when we release the collateral. The third waveform shows the saphenous vein of the same patient soon after CHIVA ligation of the collateral.



Thigh perforator (not applicable to leg perforators).

The deep veins in the thigh have long valveless portions, and sometimes a perforator causes reflux from the deep system to the superficial system. The duplex ultrasound of these cases should test the perforators during systole, and diastole of leg muscles. We should follow the superficial pathway of reflux and test the re-entry of blood. We should always check the deep system for signs of previous disease. Reflux with systole and diastole with outward flow is characteristic of deep problems, and needs further analysis. If the perforator has no or inward flow during systole and outward flow during diastole, we may proceed with the treatment. Please refer to the chapter about perforators for further perforator analysis.

We perform the ligation of the perforator at its closest point to the fascia using unabsorbable material. The hole in the fascia is closed with non-absorbable suture. The collateral usually wilt, but we usually excise a few centimeters of the main vein, as long as it does not create additional surgical trauma. Some surgeons use sclerotherapy at the proximal portion of the perforator if the vein has a long intramuscular pathway. There is a recent trend for ablating veins with a puncture, there is a possibility to treat this perforator with small diameter laser fibers using the endolaser technique.



How can we predict the esthetic result of CHIVA?

The Perthes test was first developed to test the function of the deep venous system. Later, Mahorner and Ochsner described the use of the Perthes test as a way to test if the patient would benefit from ligation of the long saphenous vein^{3,4}. Hemodynamic surgery uses the Perthes test as a routine. The result of a Perthes test is very predictive of the result of conservative surgery. The modern test performed in most clinics differs a little from the first tests. Implementing Duplex Ultrasound and advancing knowledge on hemodynamics made us think we do not need 5 minutes of walking to test the leg as first suggested. Today we perform a quick walk in the clinic with a rubber band in the upper thigh and re-check the veins. Sometimes, if we want to test distinct escape points, we may put the rubber in other positions. Usually, the results of the conservative procedure are close to the results of a Perthes test. The doctor should take care and remember that the rubber band closes all the veins in the circumference. For example, if the reflux comes from the accessory saphenous vein, and we see a magnificent wilt of all veins during the test, predicting a significant result after ligation. If we ligate the great saphenous vein instead of the accessory vein, the postoperative results will be terrible. We should remember that the rubber band closes all veins in the circumference, and complete duplex ultrasound will tell you what veins to ligate.

Some patients have esthetic results in Perthes tests less than ideal. These cases need additional intraoperative resection (fractionation) or sclerotherapy. Some cases have an enormous collateral that wilts less than you would like during the test. We may include another incision to fractionate this collateral or resect 1-2 cm of the vein distal to the N3 ligature. We should take care not to

leave non-drained collaterals. Another option is explaining to the patient and getting Informed Consent, mentioning that if a vein remains you might need to do a sclerotherapy a few months after the procedure. The surgeon may choose the approach depending on the experience in sclerotherapy and patient expectations.



See the video showing the telangiectasia and collaterals disappearing after CHIVA in the following QR code.



References

1. Faccini FP, Arendt AL, Pereira RQ, Oliveira AR de. CHIVA to spare the small and great saphenous veins after wrong-site surgery on a normal saphenous vein: a case report. J vasc bras [Internet]. 2019 [cited 2019 Mar 15];18. Available from: http://www.scielo.br/scielo.php?pid=S1677-54492019000100601&script=sci_arttext
2. Ermini S, Passariello F, Vasculab F. The Paraná Manoeuvre [Internet]. 2017. Available from: <http://dx.doi.org/10.24019/2017.parana>
3. Barone M. MULTIPLE PERTHES' TEST FOR SEGMENTAL OCCLUSION OF THE DEEP VEINS [Internet]. Vol. 131, Journal of the American Medical Association. 1946. p. 1406. Available from: <http://dx.doi.org/10.1001/jama.1946.02870340012004>
4. Mahorner HR, Ochsner A. A NEW TEST FOR EVALUATING CIRCULATION IN THE VENOUS SYSTEM OF THE LOWER EXTREMITY AFFECTED BY VARICOSITIES. Arch Surg [Internet]. 1936 Sep 1 [cited 2020 May 4];33(3):479-92. Available from: <https://jamanetwork.com/journals/jamasurgery/article-abstract/542869>

9 - CHIVA for Specialists

Felipe Faccini, Stefano Ermini and Claude Franceschi

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This chapter describes the cases of CHIVA in which there is a great involvement of the saphenous vein, junction and multiple saphenous collaterals. There is a considerable difficulty in the management, and we do not think surgeons should perform these procedures without prior practical training. Actually, we do not think anyone should perform any surgery without training. The major purpose of the chapter is to explain the procedures and, mainly, explain how the blood will flow after the CHIVA interruptions. We divided that treatment according to the flow in a venous shunt. The escape point includes saphenous junctions and perforators. The reflux pathway involves the saphenous veins and collaterals. The reentry comprises the perforators or normal saphenous veins that drive the blood back to the deep system. We also discuss the re-entry in the chapter about perforators.

Treating the Escape points:

Escape points are the source of reflux according to the CHIVA theory. The main escape points are the saphenous vein's junctions, pelvic/abdominal leaks, and perforators. We map the characteristics of the reflux with a carefully performed duplex scan. Saphenous junction reflux is treated with a crossotomy (not crossectomy) in the greater saphenous vein or proximal ligation in

the small saphenous vein. Pelvic leaks with well-defined leaking points are treated accordingly (see pelvic leaks chapter). We should treat abdominal, leg or pelvic veins that join in a big venous pool and drain reflux to the saphenous vein by ligation of the end of the collateral at the saphenous vein and a few centimeters of phlebectomy.

The crossotomy

In the cases that present saphenous junction reflux coming from the femoral vein, we usually perform a crossotomy. The purpose is to stop the escape of blood from the deep system and maintain the saphenous vein and the normal collaterals to keep blood flow. We should be sure about the source of reflux. The junction should be tested exactly at the exit from the femoral vein with Valsalva and muscle contraction, the reflux should be present in both maneuvers. We should be careful not to consider junctional flow in a patient with reflux distal to the junction. If we do a crossotomy in a non-junctional reflux, we will sacrifice the junction and will not solve the reflux. We commonly see reflux coming from pelvic leaks, abdominal veins and lymph nodes that drain at the groin tributaries. The surgeon should be sure, the reflux source mapped and the map in mind during the groin operation. If the reflux comes from the femoral vein to the saphenous vein directly, we perform the crossotomy. If the reflux comes from a pelvic leak, abdominal vein or lymph node, the source should be treated accordingly.

Groin management is important to the success of CHIVA, and we will describe the crossotomy. We suggest the surgeon starting on CHIVA not to change these technical approaches

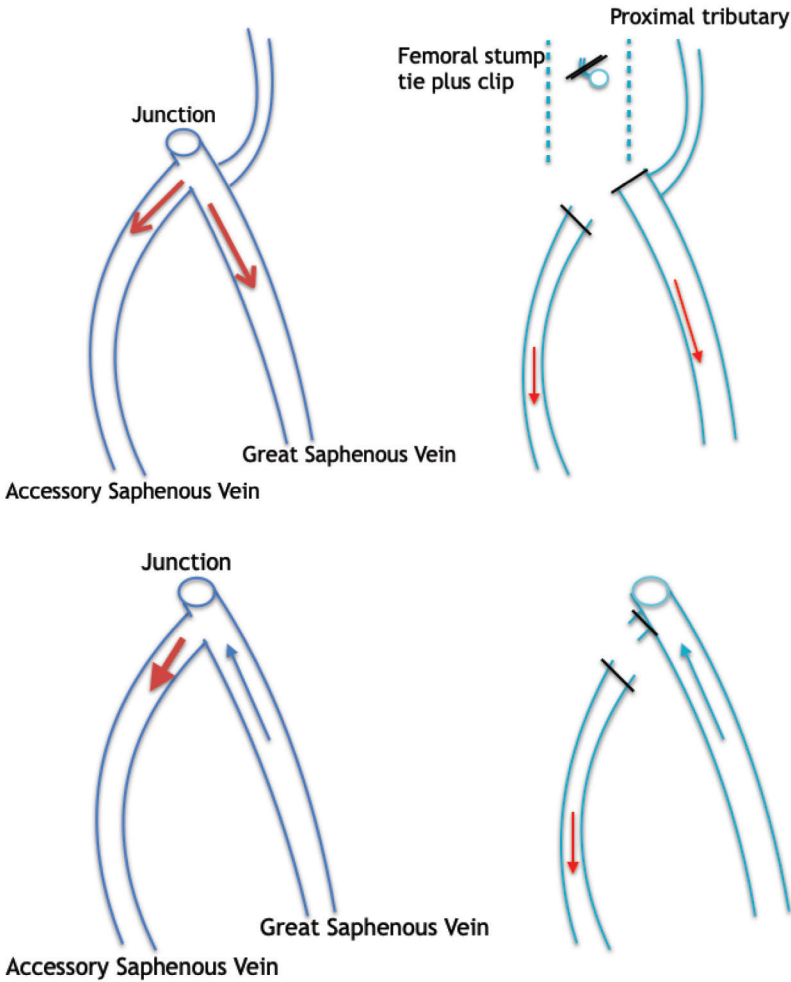
without great thinking and reading. There are distinct types of crossotomies, but every minor detail can cause recurrences ¹. After local anesthesia with lidocaine 1%, we perform an incision and dissection similar to that of crossectomy. We find the saphenofemoral junction and its tributaries and individualize the saphenous arch. At this point, we use silicone bands to pull the saphenous vein and observe the junction itself. We should take care with accessory saphenous veins that might exist and show in the preoperative duplex. At this point, we revise the anatomy and perform a triple non-absorbable ligation between the first tributary and the femoral vein and cut the saphenous vein between the ties (two proximal and one distal). We place a titanium clip close to the femoral vein to avoid leaving a stump. We suture the cribriform fascia with non-absorbable material, and the incision is closed. The idea is to keep all tributaries flowing to the remaining distal saphenous arch. Some cases have the first tributary too close to allow three sutures. In these cases, we may do the 2 proximal ones and leave the distal to receive a needle suture after removing the clamp. As a last resource, we may have to ligate the first tributary.

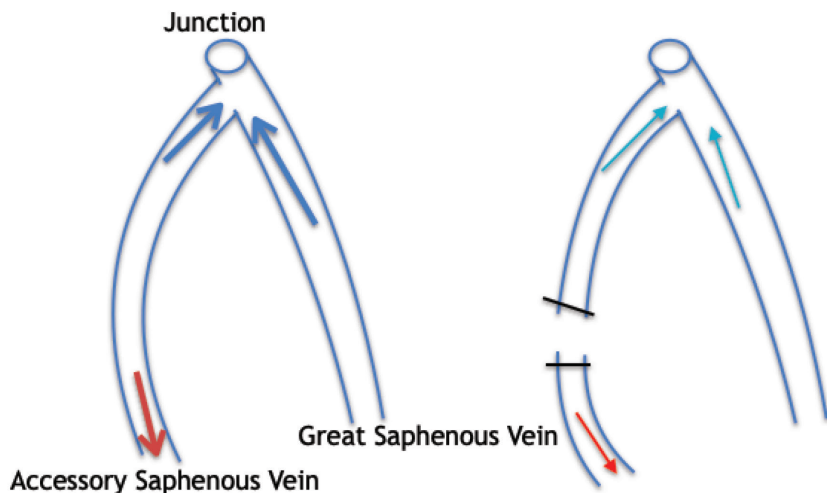
The Accessory Saphenous Veins

There are 3 situations of reflux at the accessory saphenous veins. The reflux may start on the proximal accessory vein or distal one. The saphenous vein may present reflux concomitant reflux or not. If the saphenous vein has concomitant reflux, we should treat it, performing a crossotomy as described plus a ligation of the accessory vein. If we identify no saphenous reflux, the accessory vein should be ligated proximally or distally, depending on the origin of reflux. We should avoid redo operations at the groin as much as possible.

Whenever there is doubt about treating saphenous and accessory veins, it is best to treat both at the same time. The redo operations at the groin demand high expertise and have more complications².

Some cases have reflux proximal to the accessory vein, but no reflux at the saphenous vein itself. We perform a ligation of the proximal connection of the accessory vein with the great saphenous vein or femoral vein. The cases of distal reflux at the accessory vein is treated by ligation of the accessory vein where it gets more superficial at the thigh.





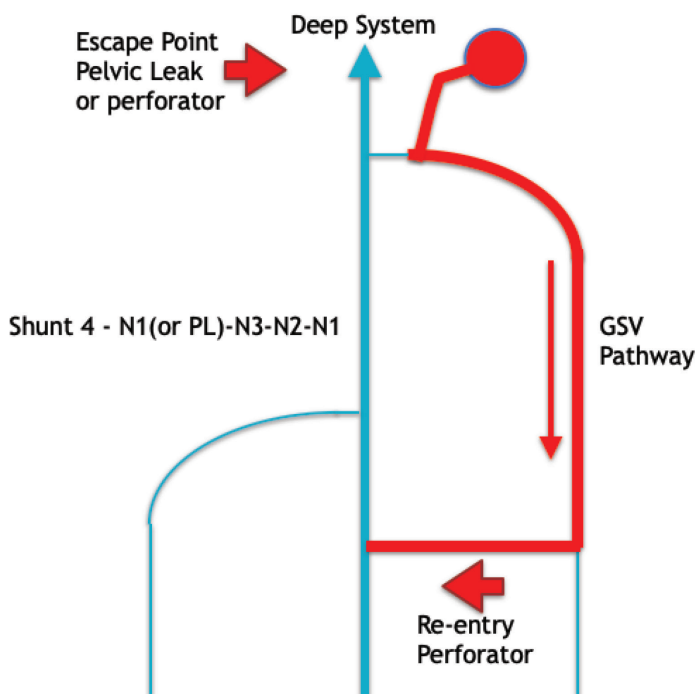
Pelvic Leaks and Abdominal Tributaries

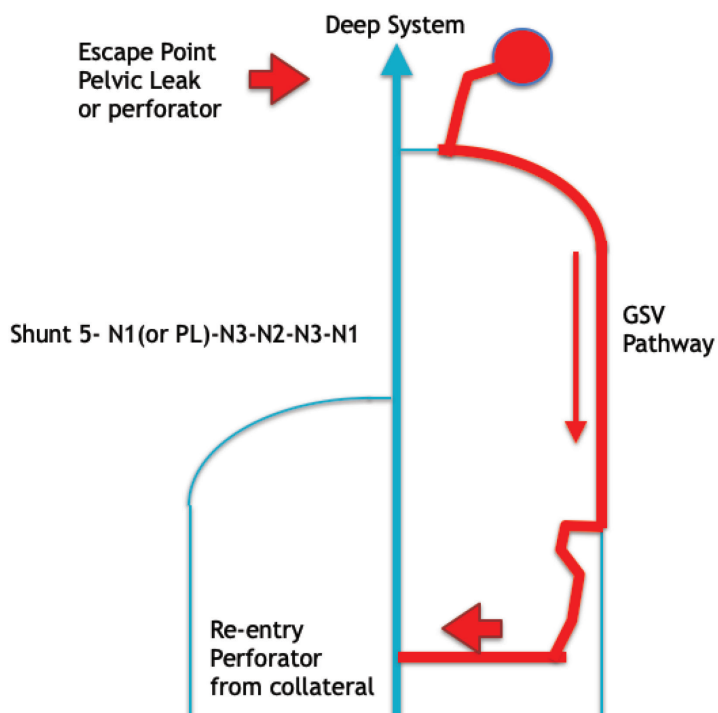
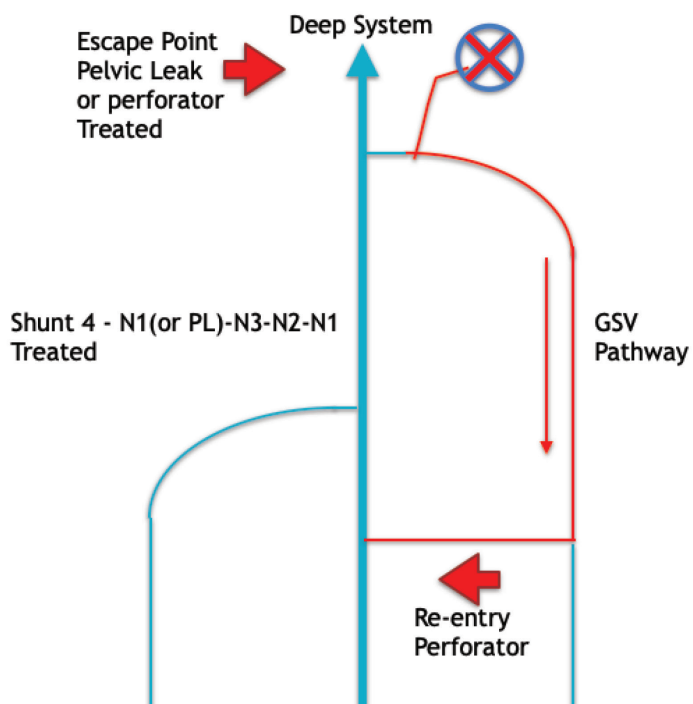
There is a full chapter about pelvic leaks but the relation of these leaks with saphenous reflux is worth mentioning. Non-ostial saphenous reflux sometimes comes from a pelvic leak or proximal tributary. The great or accessory saphenous vein has no reflux at its connection to the deep system at the saphenous-femoral junction, but distal to this connection it receives a tributary that drains reflux and creates saphenous reflux. This reflux may be Valsalva positive or not depending if the tributary comes from a real pelvic leak or a junction of superficial collaterals.

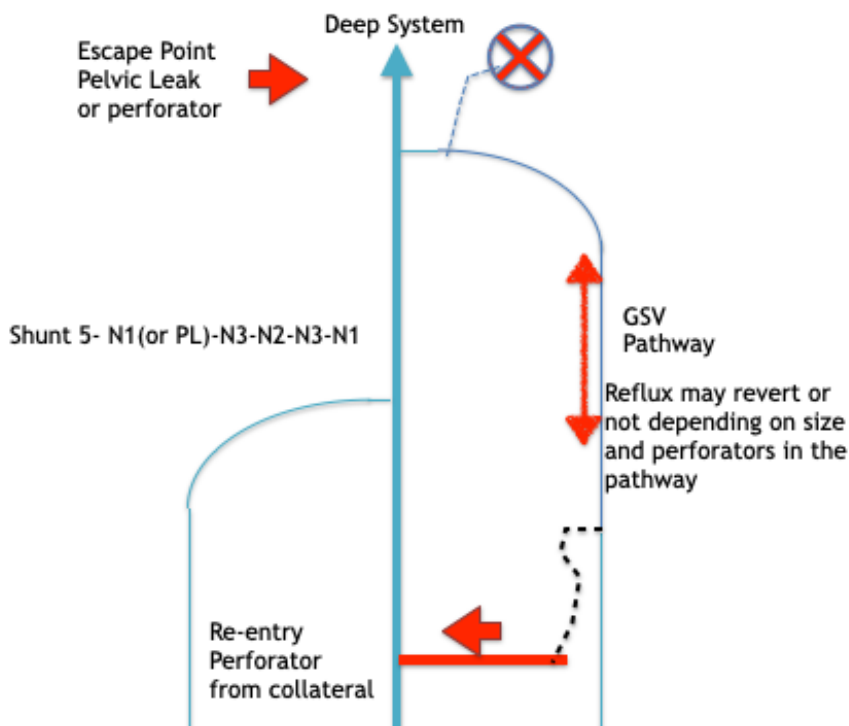
In these cases, with a competent terminal valve of the saphenous vein but reflux at the preterminal valve, we do not warrant a crossotomy. We may treat the proximal pelvic/abdominal vein and/or the distal collateral through what the reflux leaves the saphenous vein. Cases with abdominal/pelvic leak should have the leak treated to control the disease.

This approach may or may not resolve the saphenous reflux, depending on saphenous size and presence of a perforator at the saphenous pathway of the reflux.

In these cases, there are 2 important rules. If the terminal saphenous valve is competent, there is no sense in performing a crossotomy. The surgical procedure for these cases is pelvic leak/abdominal tributary resolution and ligation of the distal collateral of the saphenous vein. Many of these patients have milder cases, and might be treated with sclerotherapy of the proximal collateral and/or distal one (see hemodynamic sclerotherapy chapters).







The small saphenous vein poses difficulties because of the relation of its junction with important nerves and great anatomical junction variants. The CHIVA procedure is under local anesthesia, lowering nerve damage risk. However, the damage is a possibility and some surgeons prefer to avoid approaching the area. The anatomy usually does not pose difficulty as we prepare the operation with a careful duplex scan. We should evaluate the Giacomini vein and common connection with muscle veins. The Giacomini vein can have physiologic flow towards the foot; thus we should check its size and reflux characteristics. We should notice additional connections between the small saphenous vein and the deep system, both at its junction and at posterior perforators.

The surgical procedure is ligation of the saphenous vein at its connection to the deep system and excision of a few centimeters of it. If there is an additional connection to the deep veins, it is ligated as well. If the Giacomini vein drains at the small saphenous vein close to its junction, it should be spared, draining to the popliteal vein/junction. The deep muscle veins using the saphenous-popliteal junction to enter the popliteal vein should also be preserved. The ligature should be distal to the Giacomini vein and to the muscle veins entering the popliteal vein to preserve their physiologic drainage. Some centers avoid dissecting the junction of the small saphenous vein for fear of nerve damage. They do a distal ligation and complete the proximal vein treatment with sclerotherapy ³, we do not use this approach because most times we touch a nerve during local anesthesia the patient warns us.

The Pathway

Once the proximal part of the reflux is treated, we should focus on the pathway of reflux, the veins from the source to the destiny of reflux. We should take care not to leave collaterals or saphenous veins without drainage. If we leave a portion without drainage to the deep system, we will probably have a superficial thrombophlebitis at that portion. Thus, we should map where the blood is going to in case we stop a reflux connection.

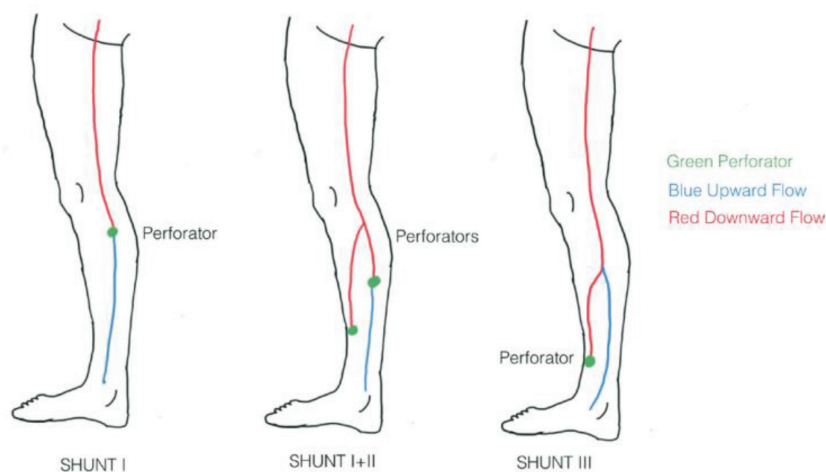
A collateral should be ligated where it **exits** the deep system (a pelvic leak, for example) or where it **exits** the saphenous vein. The “**entrances**” of the collateral to the deep system (perforator) or the saphenous vein should be left as drainage. Sometimes the collateral is long, even though the ligation of its exit may suffice

hemodynamically, esthetic results are less than optimal. Here we perform additional fractionating of the blood column at this collateral, always keeping its drainage.

The saphenous vein should maintain drainage to a perforator if we are to ligate its junction. Every collateral ligated should also keep drainage. The easiest way to think about drainage (or re-entry) is that the perforator becomes the “new saphenous junction”, once the real one is not working well. Luckily, the new re-entry is down at the leg and has gravity at its favor. If the drainage is optimal and the saphenous vein keeps its flow after mimicking collateral treatment during the duplex mapping, we proceed the all-in-one CHIVA procedure. If the reflux ceases totally during the maneuver, we should decide the best approach to deal with the case.

CHIVA 1 step versus 2 steps

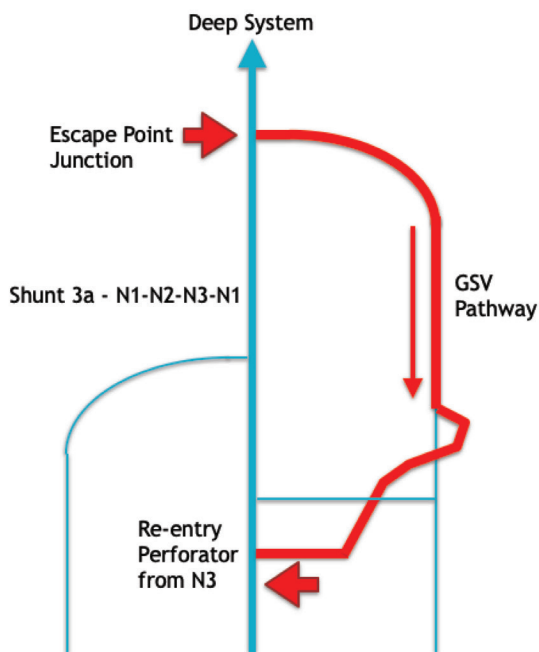
There are cases in which the patient has a saphenous vein with reflux from the junction to a collateral, and this collateral drains its reflux to a perforator. We perform the collateral finger compression test and the reflux disappears totally at the saphenous vein. This is called shunt type III. The simple ligation of the N3 collateral will probably result in saphenous thrombosis (much like an ablation without the heat), and this destroys the saphenous vein and causes development of collaterals and telangiectasias. To sum up, thrombosis creates all the undesired effects we want to avoid.

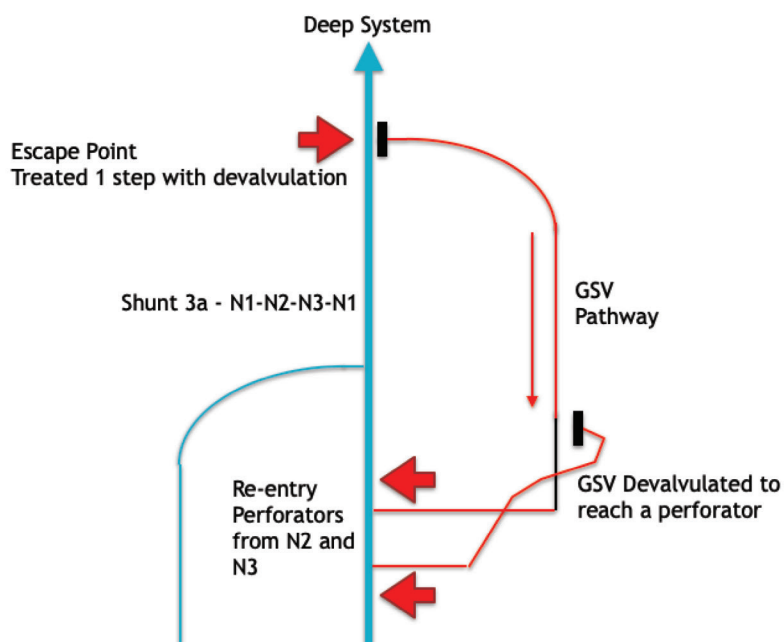
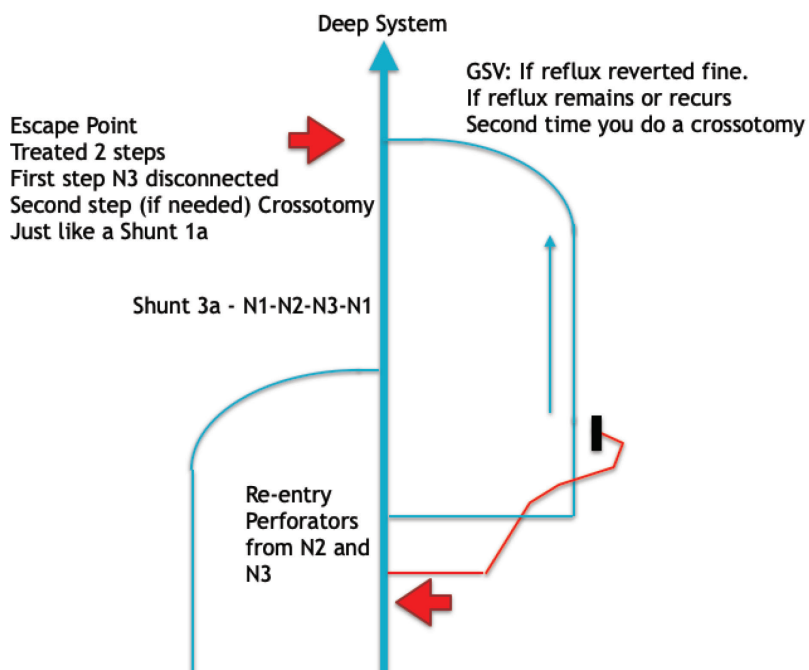


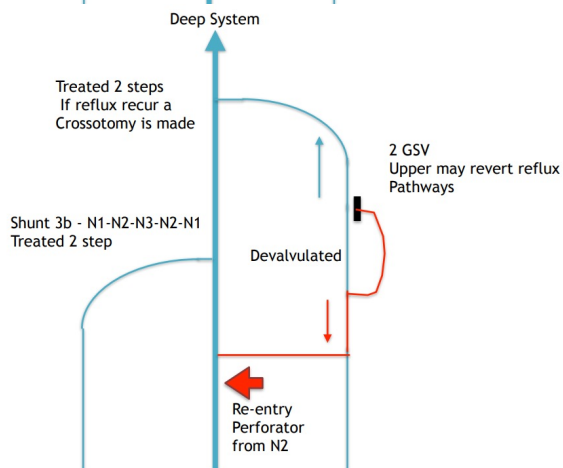
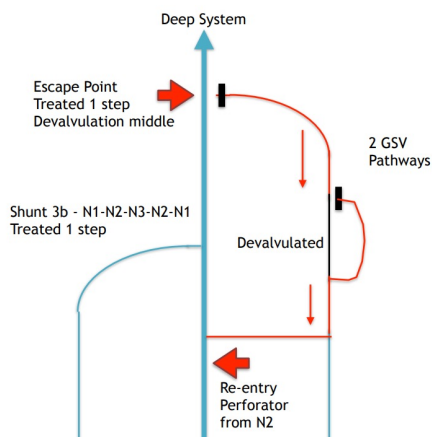
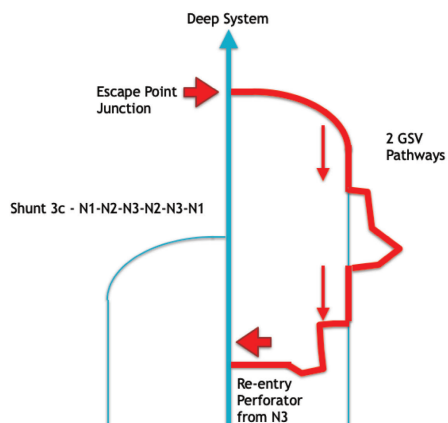
There are 2 options to deal with these cases and preserve the saphenous vein. We may divide the procedure in 2 steps. First, we perform the ligation of the collateral and keep the saphenous-femoral junction to operate in another procedure, if needed. Many cases will have flow reversion and the saphenous vein regains upward flow. Other cases will not have flow reversion, and we will have to do the junction procedure a few months after. The second alternative is to perform a devalvulation of the saphenous vein distal to the collateral to help reflux get to a saphenous perforator in the leg. In this procedure, we perform the crossotomy, the N3 collateral ligation and devalvulation of the distal saphenous vein. The surgeon does it in the first procedure. The two-step procedure is the mainstay, as studies have shown that saphenous phlebitis causes skin varicosities.

The choice depends on several aspects. The patient may perceive the second operation like a recurrence and not a planned second step. We have seen even vascular specialists arguing that even if we plan it, they would consider it a recurrence.

The insurance companies may not want to pay for the second procedure. We usually try to perform the first alternative and perform a 1-day approach when a reason exists to do so (insurance, patient desire). Some case peculiarities may help foresee the result. We avoid junction procedure when patients have a short segment of saphenous vein, <6.5 mm saphenous vein and no femoral reflux. These cases have a better chance of flow reversion with long-term results. The overall chance of flow reversion in all cases is greater than 40% in the first year and close to 30% at three years. A study showed that the results of 2 stage CHIVA operation for SHUNT III is good, as 89,7 % of patients referred as cured and 10.3% felt improvement, no failures at three years according to patient assessment ⁴.







Flow Reversal versus Shunt Zero

Shunt zero refers to the desired result of CHIVA when the reflux, column of blood or perforator position prevents reversion of flow. We see a long-lasting low speed reflux during muscle diastole. It is the result of eliminating the reflux source and drains to perforators. The transmural pressure is usually diminished and the clinical result of these cases is good and long-lasting. We should identify these cases and explain it to the patient, as they may be submitted to duplex scans by other teams and have saphenous stripping or laser indicated due to a reflux. The reflux of Shunt Zero is benign and should not be considered for intervention.

When we treat a collateral that is responsible for the reflux correctly, two cases may happen. First, the distal blood drive versus proximal column of blood and perforator position makes it easier for the blood to get to the deep system at the saphenous junction. In these cases, we may keep the junction and the saphenous vein loses reflux after operation. The second case happens when the position of perforators and higher column of blood prevents upward flow. In these cases, we should adequately ligate the junction and create a shunt zero draining to a perforator.

References

1. Delfrate R, Bricchi M, Franceschi C. Multiple ligation of the proximal greater saphenous vein in the CHIVA treatment of primary varicose veins. *Veins and [Internet]*. 2014; Available from: <http://www.pagepressjournals.org/index.php/vl/article/view/1919>
2. Matkovski PD, Oliveira da Rocha Filho J, de Souza Rocha A, Laurindo Cabral A, Knihs CA, Gonçalves da Rocha Loures JM, et al. Tratamento da recidiva da crossa da veia safena magna por acesso proximal. *Jornal Vascular Brasileiro [Internet]*. 2017;16(4):335–8. Available from: <http://www.redalyc.org/articulo.oa?id=245054655007>
3. Li X, Fan L, Ren S, Li X. Outcomes of Foam Sclerotherapy plus Ligation versus Foam Sclerotherapy Alone for Venous Ulcers in Lower Extremities. *Ann Vasc Surg [Internet]*. 2017 Nov;45:160–5. Available from: <http://dx.doi.org/10.1016/j.avsg.2017.06.055>
4. Escribano JM, Juan J, Bofill R, Maeso J, Rodríguez-Mori A, Matas M. Durability of reflux-elimination by a minimal invasive CHIVA procedure on patients with varicose veins. A 3-year prospective case study. *Eur J Vasc Endovasc Surg [Internet]*. 2003 Feb;25(2):159–63. Available from: <https://www.ncbi.nlm.nih.gov/pubmed/12552478>

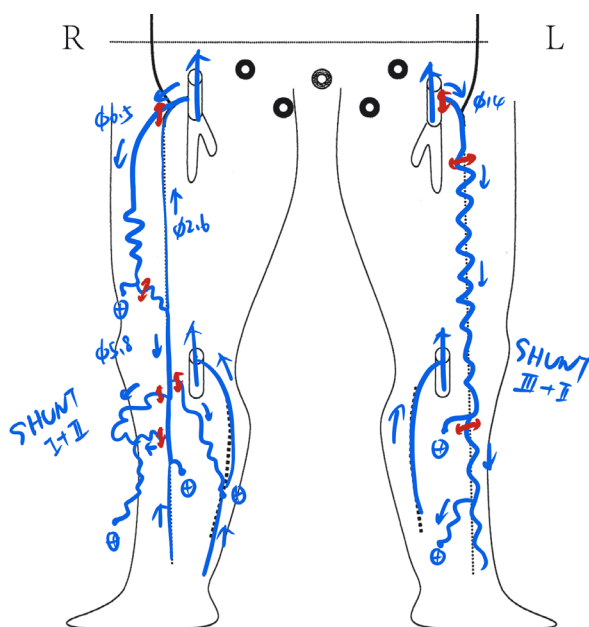
10 - CHIVA CASES

Sophie Zhu

<https://doi.org/10.5281/zenodo.6491381>

CASE 1

A 70-year-old female presented with varicose veins in both legs for over 10 years. She had chronic eczema and skin pigmentation of the left calf. No DVT history. Perthes test showed varicose veins totally collapsed. Hemodynamic ultrasound showed SHUNT 3 in left and SHUNT I+II in right. CHIVA was performed at both legs in one surgery. 10 months follow-up showed varicose veins collapsed and skin improved.

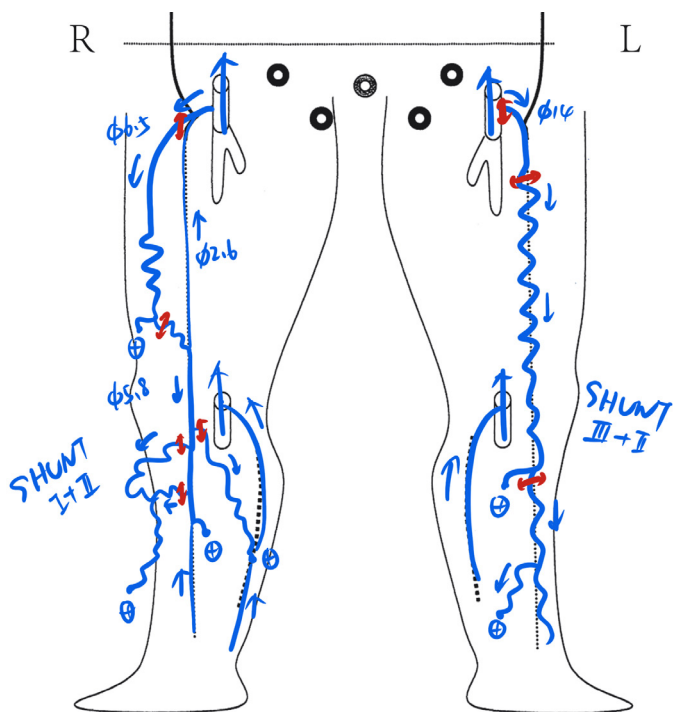






CASE 2:

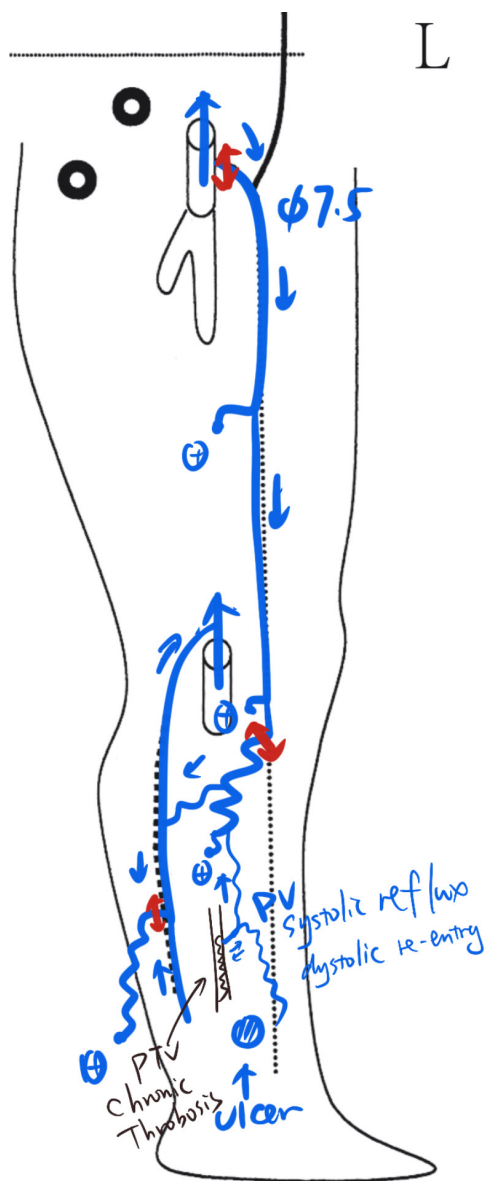
A 48-year-old female presented with varicose veins and leg edema in left leg for over 5 years. Hemodynamic ultrasound showed SHUNT III in left leg. SFJ, anterior accessory saphenous vein (AASV) and its tributaries were incompetent. CHIVA2-step1 was performed. The patient was checked by duplex ultrasound in 2 months after operation and the SFJ and AASV presented competent. After 2 years follow up, it showed no need to perform step 2.





CASE 3:

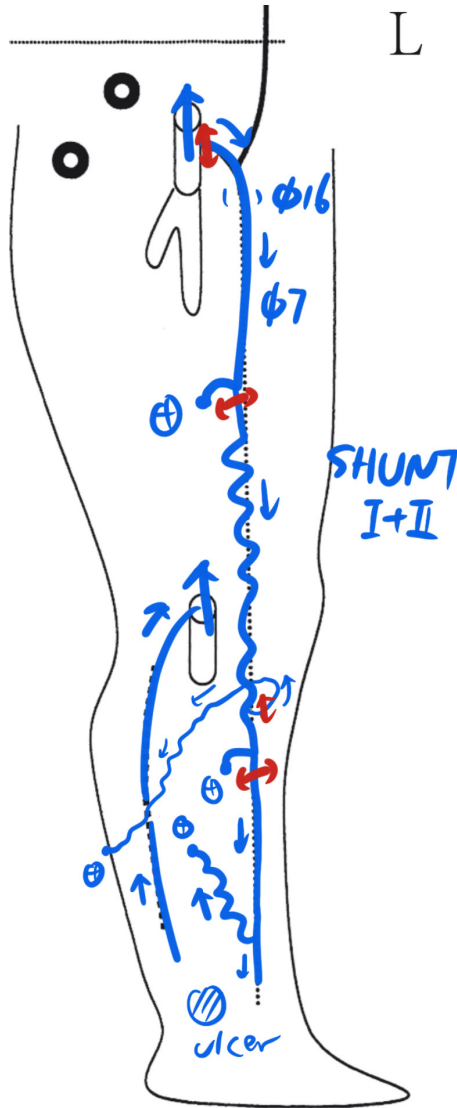
A 62-year-old female presented with varicose veins for 16 years and recurrent venous ulcer for 1 year. Hemodynamic ultrasound showed SHUNT I+II in left leg. SFJ, GSV and its tributaries were incompetent. Obstacle was found in post tibial vein and systolic reflux tested in a perforator nearby. CHIVA was performed without disturbing GSV and the reflux perforator. The ulcer was healed in 2 weeks post operation.





CASE 4:

A 70-year-old male presented with unhealed venous ulcer for 2 years. Hemodynamic ultrasound showed SHUNT I+II in left leg. CHIVA was performed with pressure column fragmentated. The ulcer was healed in 10 days after CHIVA procedure.





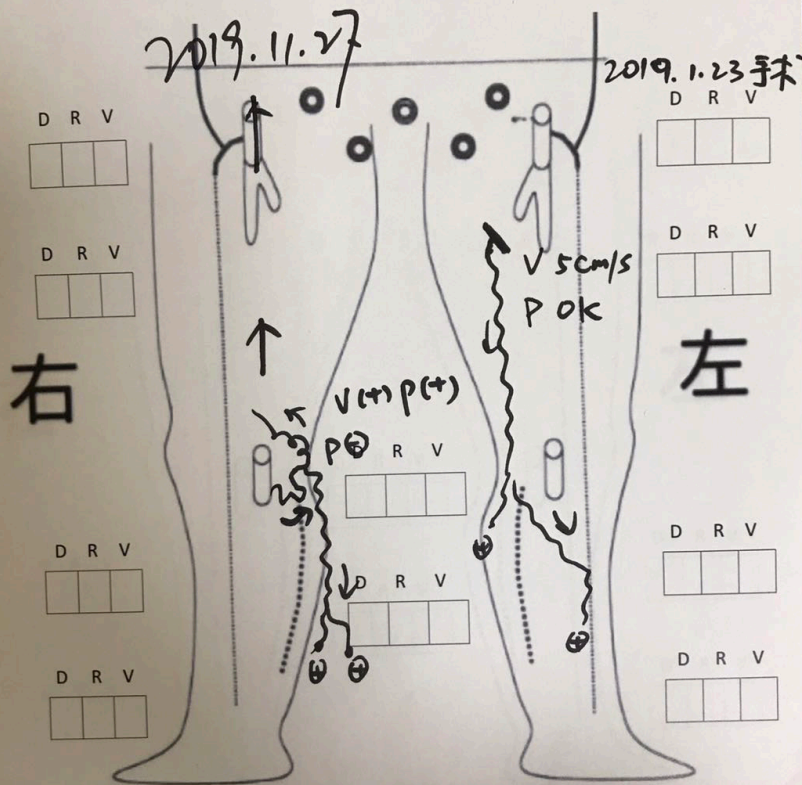
CASE 5:

A 69-year-old male presented with severe varicose veins in the lateral side of left leg. Hemodynamic ultrasound showed a diastolic reflux perforator dilated on lateral thigh and presented SHUNT VI. CHIVA was performed with closure of escape point and fragmentation of pressure column. Bulged varicose veins were collapse in 6 months.



超声血流动力图

姓名: [REDACTED] 诊断: _____ 病案号: _____



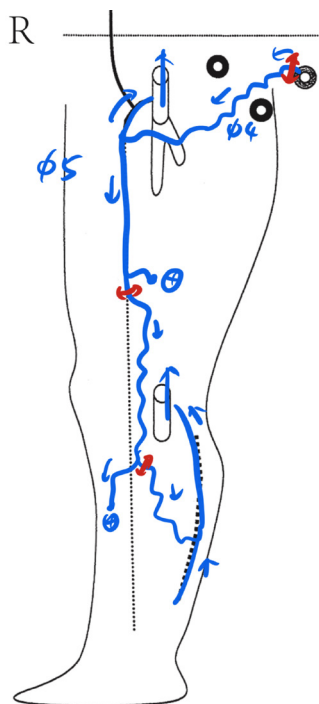
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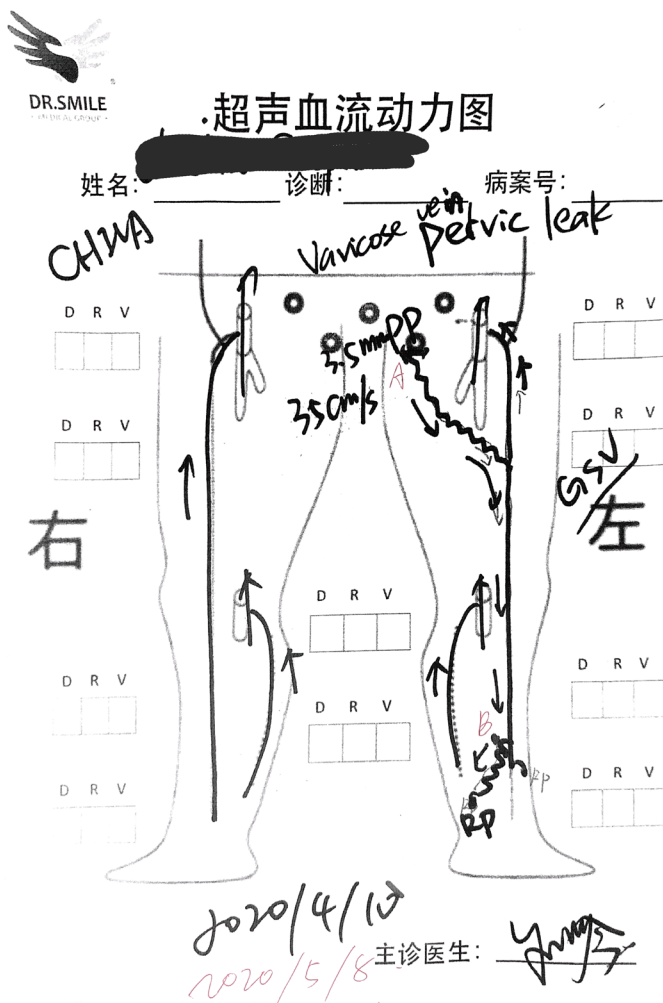
CASE 6:

A 37-year-old female presented with varicose veins for 7 years after delivery. She felt swelling and pain of varicose veins during the period. Hemodynamic ultrasound showed pelvic leak in CP and presented as SHUNT VI. CHIVA was performed with closure of escape points. Symptoms improved after procedure.

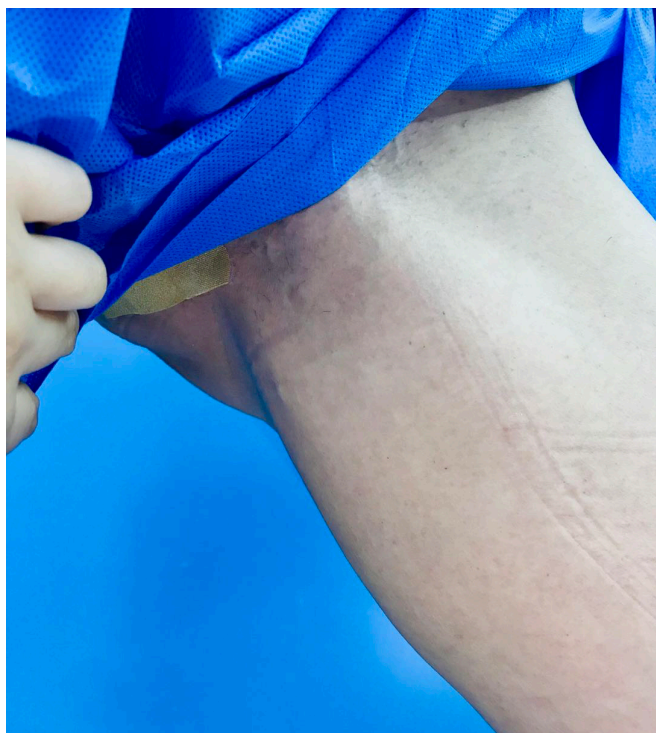


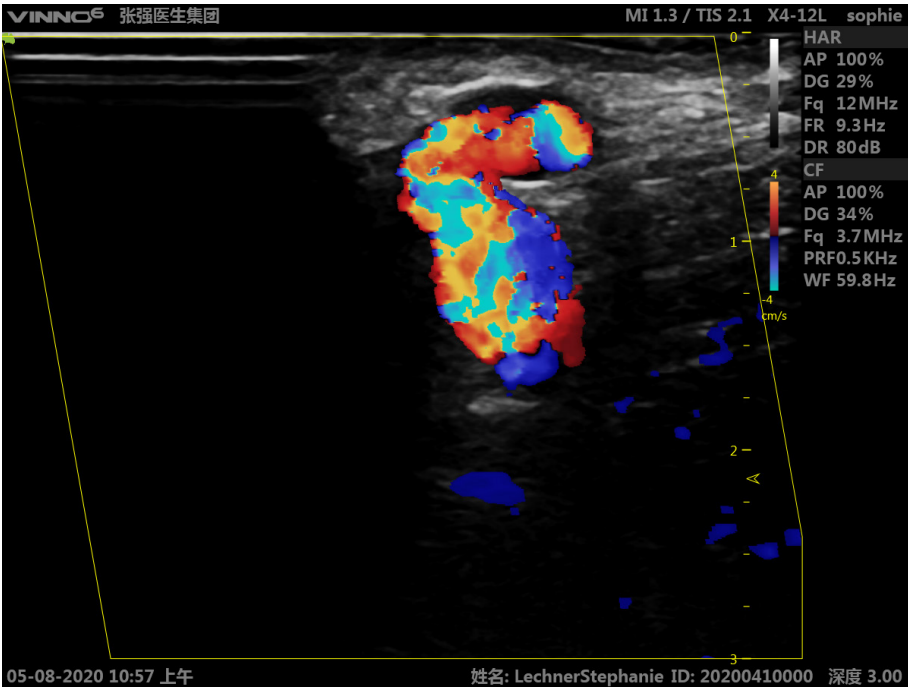
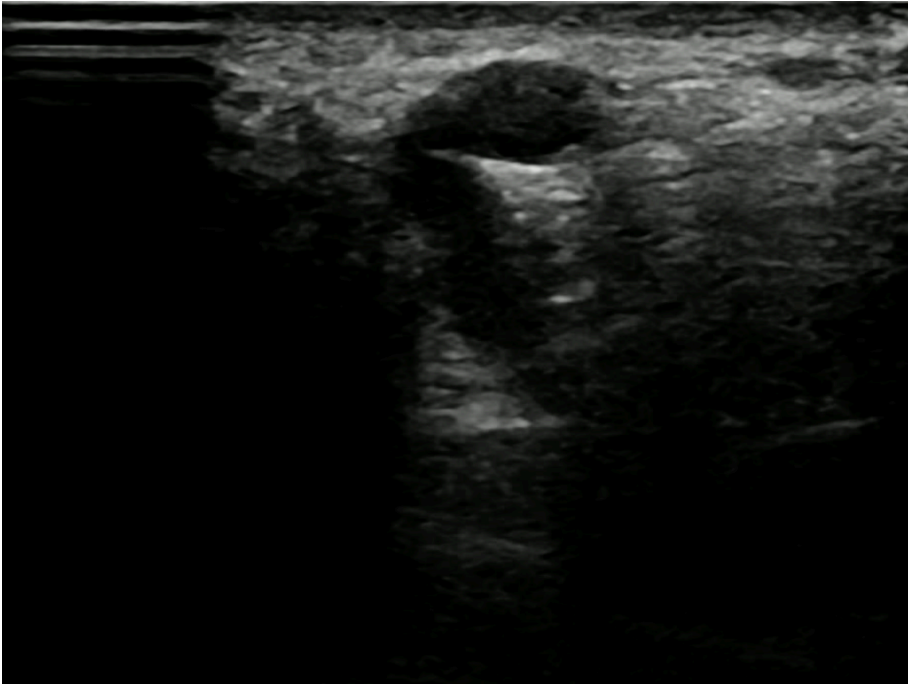
CASE 7:

A 45-year-old female presented with perineal and calf varicose veins for 1 years with pain of varicosities in standing position. Hemodynamic ultrasound showed pelvic leak in P point and presented as SHUNT VI. CHIVA was performed with closure of escape points. Pain disappeared after the procedure.



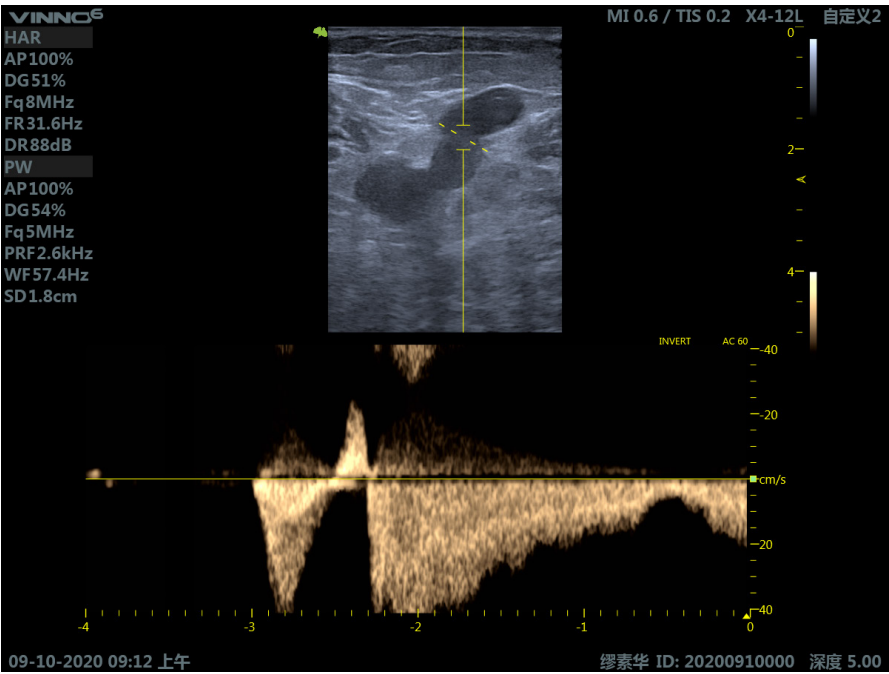


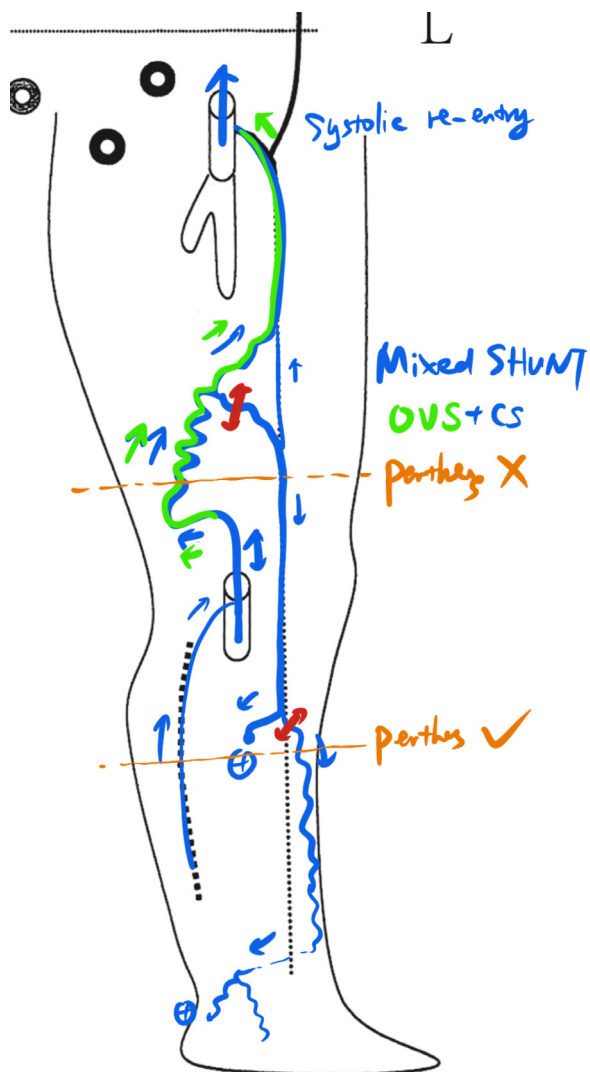




CASE 8:

A 64-year-old female presented with varicose veins in left calf for over 30 years. She felt heaviness in calf after long time standing. She had a history of leg swelling and pain which wasn't diagnosed and treated after a procedure for ectopic pregnancy 15 years ago. Several years later varicose veins were found at posterior thigh. Hemodynamic ultrasound showed a combination of open vicarious shunt and closed shunt. Femoral vein was patent and mild incompetent. CHIVA was performed with open vicarious shunt preserved and closed shunt disconnected.



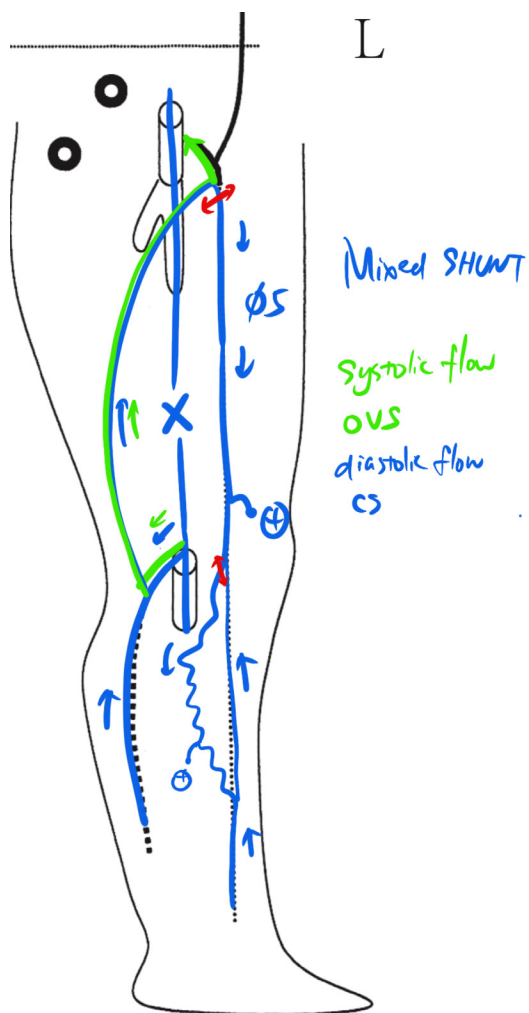


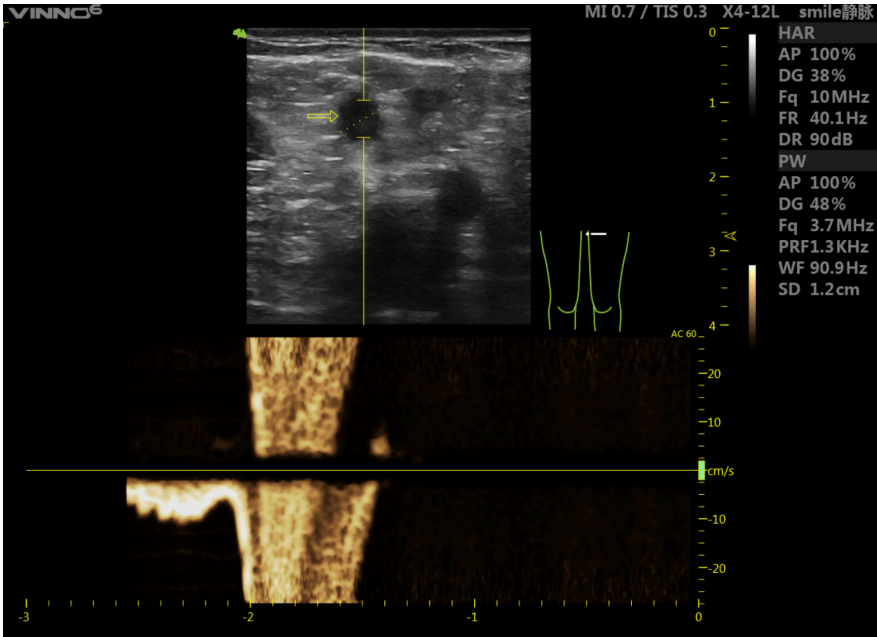
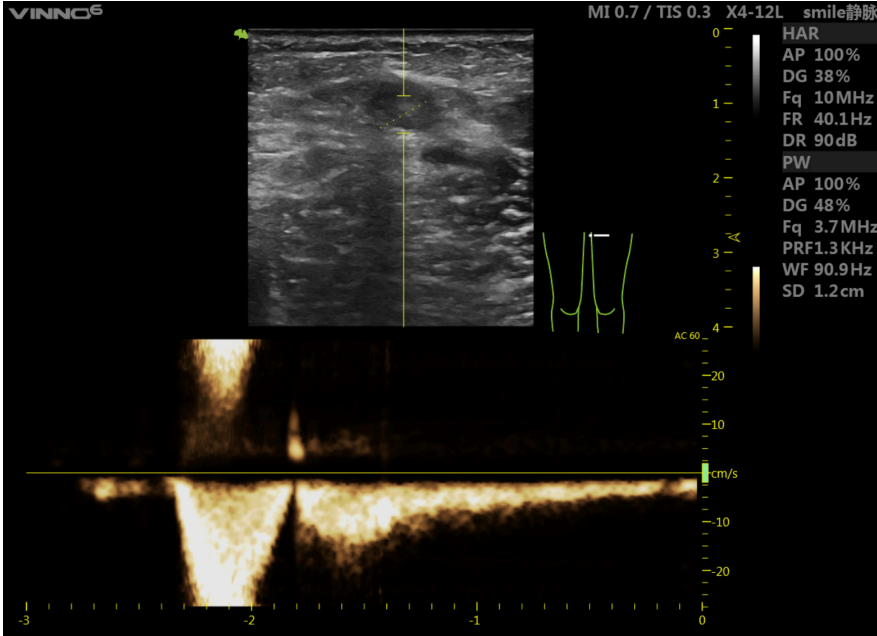


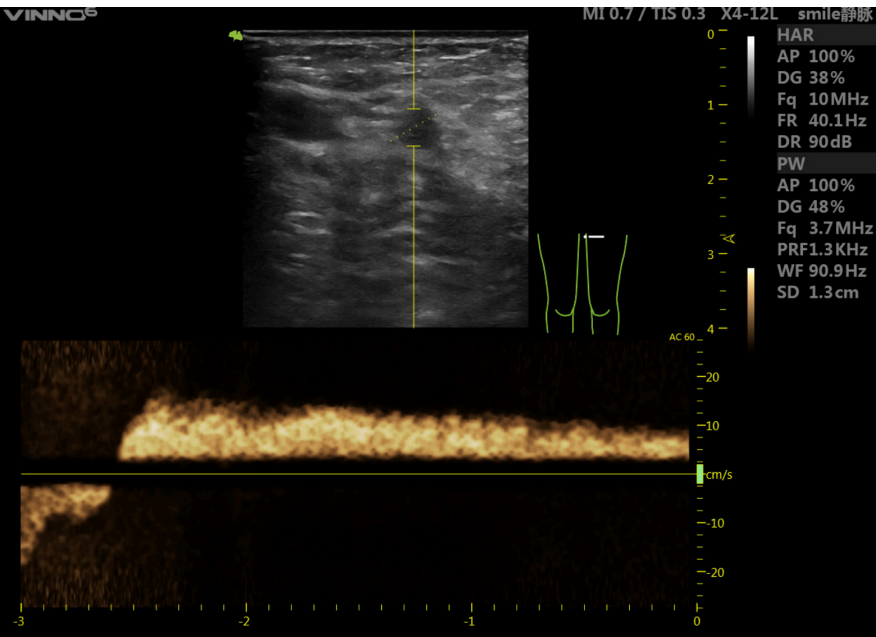


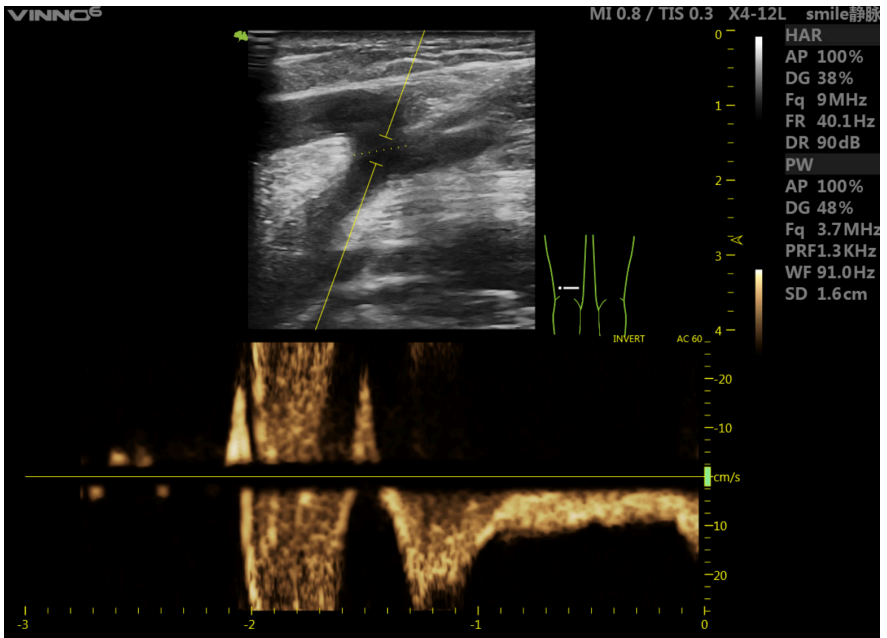
CASE 9:

A 35-year-old male presented with varicose veins. He had a history of stab wound 13 years ago. Hemodynamic ultrasound showed MIXED SHUNT and femoral vein obstacle. CHIVA was performed with open vicarious shunt preserved and closed shunt disconnected.









11 - CHIVP - Hemodynamic Deep Reflux Treatment

Claude Franceschi and Felipe Faccini

<https://doi.org/10.5281/zenodo.6491408>

The term CHIVP (the P stands for Deep - Profundo) is used to refer to the use of the principles of hemodynamic treatment for varicose veins in the cases of Deep Venous Insufficiency. After an event that dramatically changes the deep venous system (trauma, malformations or thrombosis) occurs a sequence of reactions follows. These reactions usually create alternative ways to get blood drainage and later recanalization of veins. Some patients achieve good recovery and remain asymptomatic.

Unfortunately, some patients have overcompensation or recanalization with severe venous sequelae creating an undesirable shunt. The term overcompensation refers to patients that develop a vicarious shunt to drain the blood stopped at the trauma or thrombosis. The compensation may be perfect or it creates sometimes a new undesirable pathway. For example, a patient with iliac thrombosis with a Palma shunt or a patient with femoral thrombosis compensated by a Giacomini vein going to the saphenous vein and back to the femoral in the groin. In theory, it drains the flow in the right direction, but sometimes it develops a vein that diverts the blood flow from its way back to the heart. Recanalization with severe sequelae also may cause

symptoms later after a deep venous thrombosis. For example, a tibial vein has all valves destroyed but keeps flow may perpetuate reflux and symptoms. The hemodynamic technique aims to get: Gravitational Hydrostatic Pressure Fractionation, Closed Shunts disconnection and Drainage respect.

We reserve the hemodynamic correction CHIVP for patients with important symptoms such as resistant venous ulcer and great compromise in the quality of life not responding to simpler measures. The Duplex examination is important, and inexperienced surgeons should not perform these procedures. We consider the level of difficulty in terms of hemodynamics to be the highest and complications of unsuccessful procedure may be important. The Duplex examination should search for closed shunts that allow dynamic fractionation of the hydrostatic pressure column. We discuss elsewhere these shunts in this book. The strategy must take in account not only the venous incompetence but also the hemodynamic relevance of the frequent associated obstructions. These cases are not common, and there are no clinical trials about this technique. Anecdotal cases performed by several groups proficient on venous hemodynamics have had significant results and we present this chapter as an additional paradigm discussion.

Deep venous obstruction assessment:

We always take the clinical signs and symptoms, echo color Doppler and posterior tibial vein pressure into consideration. The operator measures the pressure at the posterior tibial vein (PTV) when the flow reappears with a calf cuff, deflated slowly. Much like Ankle-brachial Index.. Pressures greater than 20 mmHg in a patient

in supine position are consistent with severe disease. These are the parameters to test the obstruction in the venous insufficiency and consider the expected results after the gravitational pressure fractionation by CHIVP. We examine the venous system, including a complete assessment of deep veins. The treatment includes dilation of all treatable important obstructions when the posterior tibial vein pressure is higher than 20 mmHg, before considering CHIVP. In other cases, these obstructions of a main vein can be clinically less significant, most of the time thanks to a good collateral compensation (see Figure 1).

In addition, some obstructions can be artifacts with no pathological value, as the frequent pseudo May Turner Syndrome horizontal supine position during Venography or Duplex Us show a total compression of the Left Iliac Vein by the Right Iliac Artery. Some cases have the disappearance of the obstruction when examined in a semi-seated position (see QR code 1).

QRCode 1:



Ilio-Caval obstruction:

The permanent thigh swelling and venous claudication are signs of Ilio-Caval hemodynamic block to the flow. The iliac obstruction has a pitfall to consider, the iliac size diminishes when the person is in a supine position or dehydrated. Dehydration because of examinations with fasting may also help to diagnose a false stenosis. A study has shown that there is significant overdiagnosis of obstructions in recumbent patients¹. We should discuss that many iliac compressions are not real and elevating the back of the patient to fill the vein makes some obstructions disappear^{2,3}.

There are two main Duplex US findings associated with iliac-cava obstructions. The absence of breathing modulation of venous flow at the femoral vein appears in these cases. The presence of collateral veins (open vicarious shunt - see shunt chapter) through hypogastric and femoral collateral, including superficial veins and saphenous junction collaterals. Cardiac rhythm alterations and right heart insufficiency may also alter the breathing modulation. This happens because of reflex opening of micro-shunts, we should always search actively for the iliac and cava veins to distinguish it.

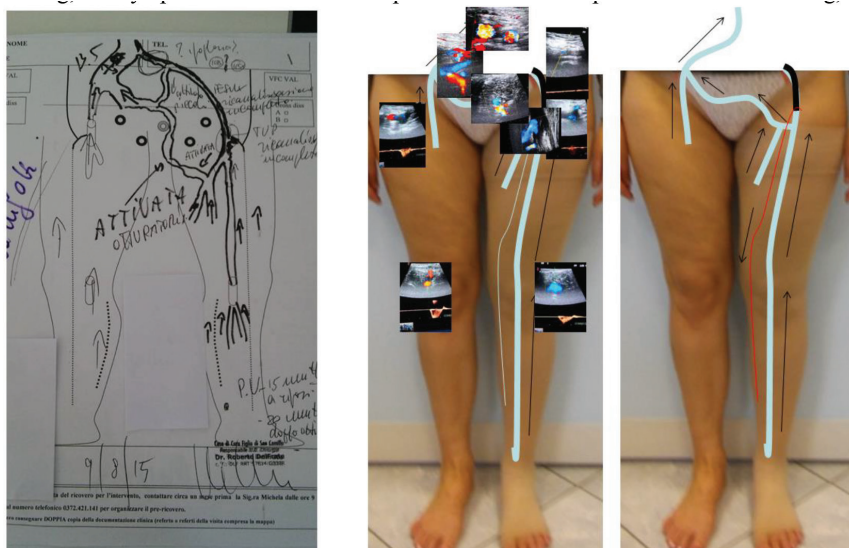


Figure 1: Adequate left iliac vein thrombosis compensation with PTV pressure of 20 mmHg. We observed that cases well compensated without symptoms, usually have pressure below 20 mmHg, and symptomatic cases with complications have PTV pressure above 20 mmHg,

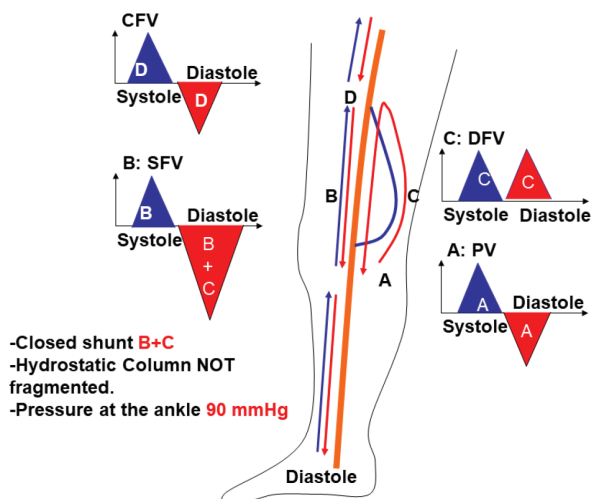
Lower extremity obstruction and reflux:

Venous claudication is a reliable symptom of femoropopliteal obstruction, as is permanent calf swelling. The duplex ultrasound is fundamental to test deep obstruction of leg veins. The examination of deep veins is demanding, and few considerations are important. The greater the volume ejected from the distal venous system, the better. We use the Parana Maneuver to verify reflux in most of these cases, besides calf squeezing. The Deep femoral shunts are better examined with calf squeezing than Parana Maneuver. The three most common types of deep shunts are (1) Superficial Femoral Vein, (2) Deep Femoral Vein and (3) Tibial vein.

Superficial Femoral closed shunts occur with duplication of the femoral vein, in which one side allows reflux of blood in its

upper connection. Figure 2 helps us understand the anatomy and hemodynamics of this shunt before and after the procedure. Deep femoral shunts to the popliteal vein or superficial femoral. We show the hemodynamics of this shunt in Figure 3. The tibial shunt has a tibial vein with reflux that connects with the superficial system through a perforator. Figure 4 shows an interesting case of tibial shunt. A male patient with a history of motorbike accident had 3 duplex scans with normal results, but symptoms were disturbing and incapacitating. We examined carefully the deep system and found a tibial shunt with flow out through a perforator. The flow was intense during systole of calf muscles and very weak during diastole (the superficial veins failed to show reflux because of this absence of flow reversal). Figure 5 shows the most common shunts and the places of disconnection.

Example : Superficial Femoral V Closed Shunt B+C



Superficial Femoral V Closed Shunt Disconnection

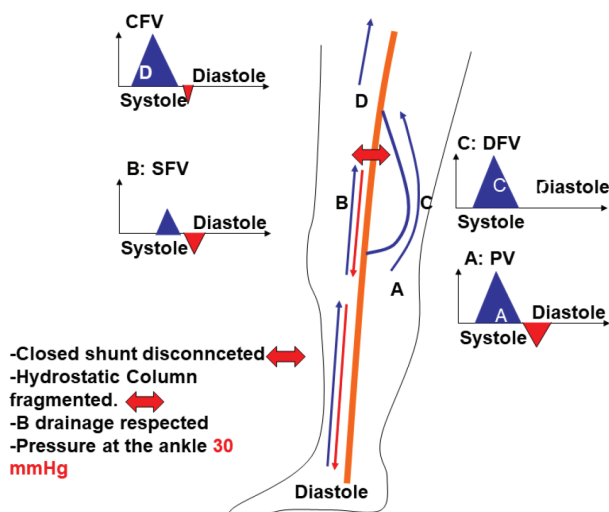


Figure 2: Duplex ultrasound of Femoral closed shunt preoperative and postoperative.

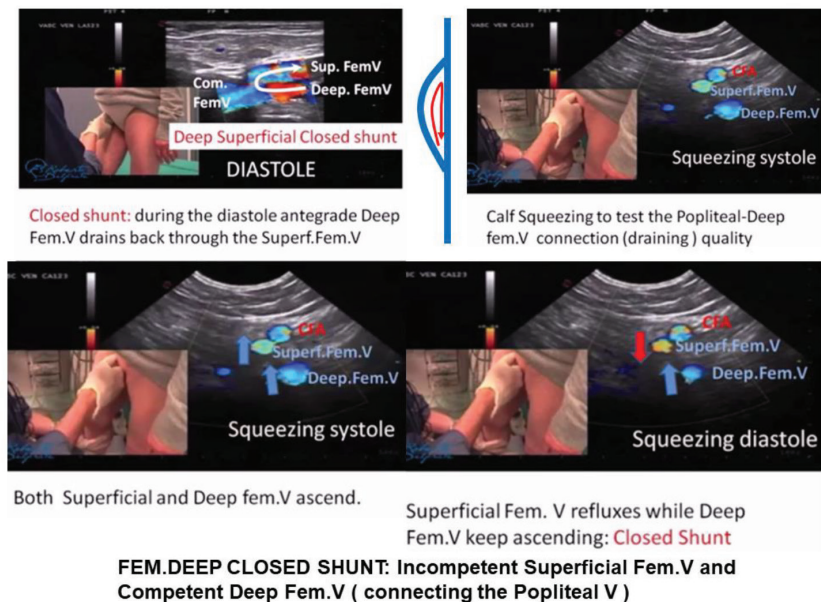


Figure 3: Deep Femoral Closed shunt assessment with Duplex ultrasound.



Figure 4: Tibial shunt with flow out of the tibial vein to the superficial system through a perforator and tibial vein (same incision). Simple ligation of the perforator and tibial vein solved symptoms with no recurrence at 2-year follow-up.

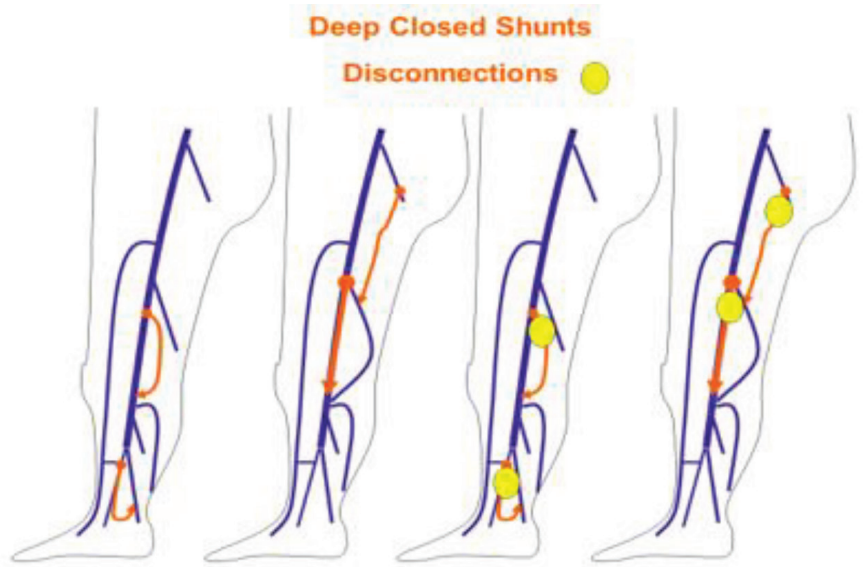
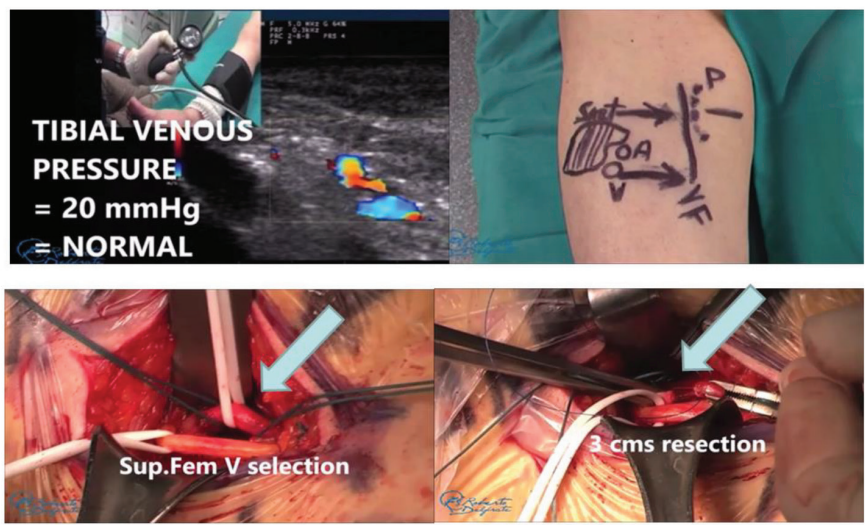


Figure 5: Possible Deep Venous Closed Shunts and disconnections. The first leg shows superficial femoral shunt and tibial shunt. The second leg shows deep femoral shunt. The third leg shows the disconnection to treat leg 1 and the fourth shows disconnection to treat leg 2.

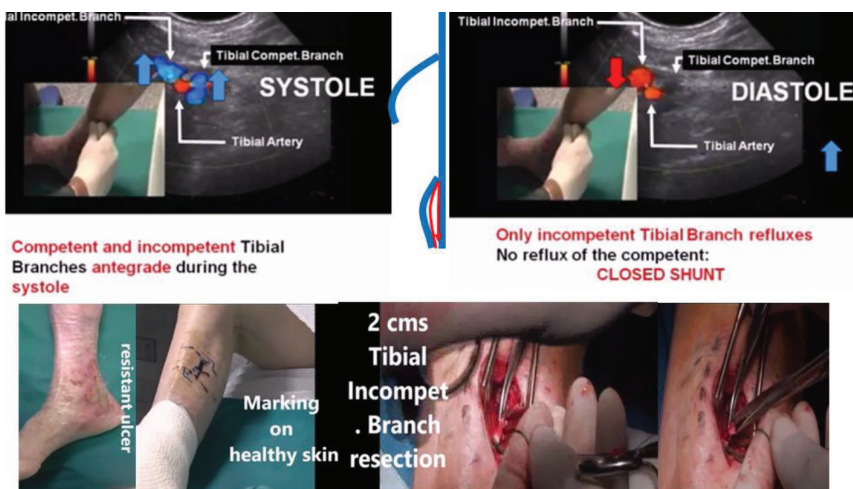
CHIVP Procedure

We use local anesthesia if possible, but regional or general anesthesia is used according to the case. The preoperative duplex mapping is pivotal to the result, as is the intraoperative duplex sometimes. The surgeons should do or take part actively in this examination. The ligation of the wrong femoral vein in a duplication case cannot happen. We have reported that lack of surgeons link to duplex ultrasound may lead to wrong site surgery ⁴. The procedure consists of flush ligation of the vein with reflux near the escape point (Figures 6, 7 and QR code 2). Some patients have superficial shunts combined with the deep ones (i.e. femoral and small saphenous vein concomitantly). We always treat the deep system first and wait weeks before deciding about intervention at the other system. Some cases improve even without the correction of the superficial disease.



**FEMORAL DEEP CLOSED SHUNT: Venous Pressure
Checking Skin Marking. Superf.Fem.V Dissection and 23
cm resection**

Figure 6. Example of femoral disconnection and Posterior Tibial vein Measurement.



TIBIAL DEEP CLOSED SHUNT: Duplicated PTV. 1 collat. Is incompet. The other one is competent. 2 cm resection in healthy tissues.

Figure 7. Example of Posterior Tibial Vein disconnection.

QRCode 2 . CHIVP. Two cases in video.



References

1. van Vuuren TMAJ, Kurstjens RLM, Wittens CHA, van Laanen JHH, de Graaf R. Illusory Angiographic Signs of Significant Iliac Vein Compression in Healthy Volunteers. *Eur J Vasc Endovasc Surg* [Internet]. 2018 Dec;56(6):874–9. Available from: <http://dx.doi.org/10.1016/j.ejvs.2018.07.022>
2. Zamboni P, Franceschi C. How to Assess Illusory May-Thurner Syndrome by Ultrasound. *Eur J Vasc Endovasc Surg* [Internet]. 2019 Aug;58(2):305. Available from: <http://dx.doi.org/10.1016/j.ejvs.2019.01.034>
3. Zamboni P, Franceschi C, Del Frate R. The overtreatment of illusory May Thurner syndrome. 1 [Internet]. 2019 Jan 18 [cited 2020 Apr 28];8(1). Available from: <https://pagepressjournals.org/index.php/vl/article/view/8020>
4. Faccini FP, Arendt AL, Pereira RQ, Oliveira AR de. CHIVA to spare the small and great saphenous veins after wrong-site surgery on a normal saphenous vein: a case report. *J vasc bras* [Internet]. 2019 [cited 2019 Mar 15];18. Available from: http://www.scielo.br/scielo.php?pid=S1677-54492019000100601&script=sci_arttext

12 - CHIVA Results and Scientific Evidences

Jose Maria Escribano and Sergi Bellmunt

<https://doi.org/10.5281/zenodo.6491416>

Key Points

There are meta-analyses of trials and randomised clinical trials that have shown lower recurrence after CHIVA than after saphenous stripping.

This chapter presents a summary of the results of the major publications and discusses its characteristics.

Meta Analysis - Bellmunt-Montoya, Escribano et al. ¹

Types of interventions

RCTs that assess the CHIVA method compared with other procedures to treat varicose veins.

Primary outcomes

Recurrence of varicose veins was defined as the detection of new varicose veins by clinical or ultrasound evaluation after a minimum follow-up of one year.

Authors' conclusions

The CHIVA method reduces recurrence of varicose veins and produces fewer side effects than vein stripping. However, we based these conclusions on a few trials with a high risk of bias as

the effects of surgery could not be concealed. We need new RCTs to confirm these results and to compare CHIVA with approaches other than open surgery.

Included studies

1.- Randomized Clinical Trial - Carandina et al. ²

Conclusions: Recurrent varices occurred more frequently following saphenous stripping than after CHIVA treatment. The deliberate preservation of the saphenous trunk as a route of venous drainage in the CHIVA group may have been a factor reducing the recurrence rate.

2.- Randomized Clinical Trial - Iborra-Ortega et al. ³

Conclusions: In our series, both surgical techniques offered similar clinical and aesthetic outcomes after five years' follow-up.

3.- Randomized Clinical Trial - Pares et al. ⁴

Conclusions: The present results show that, thanks to specific venous hemodynamic evaluation, the CHIVA method is more effective than stripping with clinical marking or stripping with duplex marking to treat varicose veins. When carrying out a stripping intervention, Duplex marking does not improve the clinical results of this ablative technique.

4.- Randomized Clinical Trial - Zamboni P et al. ⁵

Conclusions: This study supports the effectiveness of surgical therapy for leg ulceration secondary to superficial venous reflux.

Comments

Carandina et al.², Iborra et al.³ and Parés et al.⁴ studies: These three studies include 721 patients. The combined result of the three is significantly favorable to the CHIVA strategy (RR: 0.63; 95% CI: 0.51-0.78; I² = 0%; NNTB: 6, 95% CI: 4-10) concerning recurrence.

The study by Iborra-Ortega (2006) included only C2 patients, while the Zamboni (2003) study included only C6 patients. The follow-up of the patients varies according to the studies, with a minimum of 3 years (Zamboni, 2003) and a maximum of 10 years (Carandina, 2008).

Three studies compared the CHIVA strategy with saphenous stripping (Carandina, 2008; Iborra-Ortega, 2006, and Pares, 2010), while the Zamboni (2003) study compared the CHIVA strategy with medical treatment (compression stockings).

The different studies included other variations among them, such as the inclusion only of patients with type 1 + 2 venovenous shunts and therefore with CHIVA 1 strategy (Carandina), the practice of undrained CHIVA (CHIVA 1 + 2) and crossectomy in the study by Iborra or CHIVA 2 (Zamboni and Pares).

The quality of GSV drainage is a predictor of better outcome of the procedure at 3 years, as shown by Cappelli et al⁶. Also, crossotomy has better outcomes than crossectomy, as shown in another study by Cappelli et al⁷. The overall results might have been even better if all studies had practiced drained CHIVA and crossotomy.

The way of evaluating the result in the different publications has not been exactly superimposable. This, together with a limited number of cases, makes the evidence obtained limited ... although certainly favorable to CHIVA.

Despite all of that, the European Clinical Practice Guidelines⁸, in which no member of the “CHIVA group” participated, has unfairly treated the degree of evidence and treatment recommendation. Besides, lowering its degree without justification, the guidelines add that it should only be practiced by groups with great experience??.... That comes from what kind of evidence? Other treatments can be performed by undocumented people? This guideline includes 18 Cochrane reviews but, unfortunately the panellists did not aware about the Cochrane Review about CHIVA published in 2013 which included more randomized controlled CHIVA trials (RCT) than the guideline, because of a more sensitive search, and a complete evaluation of the evidence was performed based on pre-specified criteria. We do not agree with the statements of the guideline about the evidence. Data derived from multiple randomized clinical trials represents a level of evidence “A”, however, the recommendation about CHIVA has a level of evidence “B” in this guideline. We don’t discuss the class of recommendation (IIb for CHIVA) but, for example, the recommendation about the ASVAL technique, another conservative technique, based on a large retrospective cohort and a small prospective cohort, has a better class of recommendation (IIa) and the same level of evidence.

In recent days, we have notice about the publication, available online, of a new RCT that compares radiofrequency with

Stripping and with CHIVA by Gozález Cañas et al ⁹ in which they randomized 225 limbs to RFA, stripping or CHIVA.

Conclusions: RFA is non-inferior in terms of clinical recurrence to HL/S and CHIVA in the treatment of VV 6 because of the insufficiency of GSV.

In this RCT, type 3 veno-venous shunt was treated following CHIVA 1+2 strategy like it was in the Iborra RCT. However, it is the first study where the hemodynamic strategy presents worse results than stripping.

A new update of Cochrane Review is starting up for this reason, although a change in the conclusions is not foreseeable given the weight of the article regarding the rest of the RCTs.

A letter to the Journal of Vascular Surgery Venous and Lymphatic Disorders has been published together with the article, commenting on methodological limitations¹⁰.

Finally, it is worth commenting on the publication of a network meta-analysis. As a summary, network meta-analyses represent an interesting methodological proposal for application in clinical epidemiology and public health. A more comprehensive approach than the traditionally used, facilitating access to information that may be relevant in situations where the evidence from direct comparisons is scarce or non-existent. The effect of treatments can be evaluated regarding the multiple alternatives available. However, we should recognize that the method is in its initial stages, and the application of the evidence provided by indirect comparisons to guide clinical decision-making is controversial.

Meta Analysis -Liquin Guo et al.¹¹

Conclusion: CHIVA seemed to have superior clinical benefits on long-term efficacy for treating varicose veins. However, the conclusion still needs additional trials for supporting evidence.

The study was performed in accordance with PRISMA guidelines. The Cochrane Risk of Bias assessment tool was used to assess the quality of included trials.

Inclusion criteria were: randomized controlled trials (RCTs) that compared different procedures; sufficient raw data of long-term outcomes; follow-up period ≥ 1 year; English-language.

Only 2 RCT CHIVA were included ... So the authors understandably admit that the conclusion still needs additional trials for supporting evidence.

References

1. Bellmunt-Montoya S, Escribano JM, Dilme J, Martinez-Zapata MJ. CHIVA method for the treatment of chronic venous insufficiency. *Cochrane Database Syst Rev* [Internet]. 2015;(6). Available from: <https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD009648.pub3/abstract>
2. Carandina S, Mari C, De Palma M, Marcellino MG, Cisno C, Legnaro A, et al. Varicose vein stripping vs haemodynamic correction (CHIVA): a long term randomised trial. *Eur J Vasc Endovasc Surg* [Internet]. 2008 Feb;35(2):230–7. Available from: <http://dx.doi.org/10.1016/j.ejvs.2007.09.011>
3. Iborra-Ortega E, Barjau-Urrea E, Vila-Coll R, Ballón-Carazas H, Cairols-Castellote MA. Estudio comparativo de dos técnicas quirúrgicas en el tratamiento de las varices de las extremidades inferiores: resultados tras cinco años de seguimiento. *Angiología* [Internet]. 2006 Jan 1;58(6):459–68. Available from: <http://www.sciencedirect.com/science/article/pii/S000331700675009X>

4. Parés JO, Juan J, Tellez R, Mata A, Moreno C, Quer FX, et al. Varicose vein surgery: stripping versus the CHIVA method: a randomized controlled trial. *Ann Surg* [Internet]. 2010 Apr;251(4):624–31. Available from: <http://dx.doi.org/10.1097/SLA.0b013e3181d0d0a3>
5. Zamboni P, Cisno C, Marchetti F, Mazza P, Fogato L, Carandina S, et al. Minimally invasive surgical management of primary venous ulcers vs. compression treatment: a randomized clinical trial. *Eur J Vasc Endovasc Surg* [Internet]. 2003 Apr;25(4):313–8. Available from: <http://dx.doi.org/10.1053/ejvs.2002.1871>
6. Cappelli M, Lova RM, Ermini S, Turchi A, Bono G, Bahnini A, et al. Ambulatory conservative hemodynamic management of varicose veins: critical analysis of results at 3 years. *Ann Vasc Surg* [Internet]. 2000 Jul;14(4):376–84. Available from: <http://dx.doi.org/10.1007/s100169910064>
7. Cappelli M, Molino-Lova R, Giangrandi I, Ermini S, Giancesini S. Ligation of the saphenofemoral junction tributaries as risk factor for groin recurrence. *Journal of Vascular Surgery: Venous and Lymphatic Disorders* [Internet]. 2018 Mar 1;6(2):224–9. Available from: <http://www.sciencedirect.com/science/article/pii/S2213333X17304365>
8. Wittens C, Davies AH, Bækgaard N, Broholm R, Cavezzi A, Chastanet S, et al. Editor's Choice - Management of Chronic Venous Disease: Clinical Practice Guidelines of the European Society for Vascular Surgery (ESVS). *Eur J Vasc Endovasc Surg* [Internet]. 2015 Jun;49(6):678–737. Available from: <http://dx.doi.org/10.1016/j.ejvs.2015.02.007>
9. González Cañas E, Florit López S, Vilagut RV, Guevara-Noriega KA, Santos Espí M, Rios J, et al. A randomized controlled noninferiority trial comparing radiofrequency with stripping and conservative hemodynamic cure for venous insufficiency technique for insufficiency of the great saphenous vein. *J Vasc Surg Venous Lymphat Disord* [Internet]. 2021 Jan;9(1):101–12. Available from: <http://dx.doi.org/10.1016/j.jvsv.2020.04.019>
10. Escribano JM, Bellmunt S. Applying the correct CHIVA strategy in a randomized, controlled trial. *J Vasc Surg Venous Lymphat*

Disord [Internet]. 2021 Jan;9(1):286. Available from: <http://dx.doi.org/10.1016/j.jvsv.2020.07.013>

11. Guo L, Huang R, Zhao D, Xu G, Liu H, Yang J, et al. Long-term efficacy of different procedures for treatment of varicose veins: A network meta-analysis. *Medicine* [Internet]. 2019 Feb;98(7):e14495. Available from: <http://dx.doi.org/10.1097/MD.00000000000014495>

13 - CHIVA Perioperative and Long-term Care

Felipe Faccini, Ani Arendt, Ivía Binotto and Alexandre Roth de Oliveira

<https://doi.org/10.5281/zenodo.6491420>

Advantages of CHIVA

There is a full chapter to discuss clinical trial results of CHIVA in this book with the authors of a Cochrane review about the subject ¹. We will make a brief comment on how we see the characteristics and advantages of CHIVA, priming how we explain to the patients before the operation. We will present the results separately according to the characteristic.

Nerve Damage: The clinical trials showed that CHIVA poses less nerve damage than stripping technique. Most results of clinical trials about other surgical techniques show similar nerve damage as compared to stripping, as we recently published in a review about nerve damages and malpractice ². We perform CHIVA under local anesthesia, while other techniques use general, spinal or tumescent anesthesia. We have observed that during a CHIVA operation, the patient warns the surgeon if he/she gets too close to a nerve. A few times I have heard “ouch” or “stop” during a procedure, and this warning avoided nerve damage.

Recovery/Pain: The local anesthesia brings an easy recovery after the procedure. The CHIVA patients begin a normal lifestyle immediately. Surgeons achieve the same results

with tumescent anesthesia and newer procedures. Although procedures with general or spinal anesthesia have a slower return to normal activities. The pain after CHIVA does not bother most of the patients. We make most incisions in regions covered by the elastic stockings. We saw that 55% of patients do not take any painkillers after the operation. Patients with groin incisions also have quick recovery, but take painkillers more often. The choice to treat postoperative pain is based in acetaminophen, and we never use opioids,

Bruises: The saphenous preserving procedures avoid all the surgical trauma of vein burning or removal. The clinical trials about CHIVA versus stripping showed that it has fewer hematomas. Fewer incisions and less surgical trauma decrease the burden of these hematomas. Obviously, if a superficial thrombophlebitis happens, we lose this advantage. Fortunately, we see only a few cases of phlebitis in well performed CHIVA.

Superficial phlebitis: The clinical trials are ambiguous concerning this matter. One small clinical trial suggests a higher risk of superficial phlebitis³. This is not confirmed by other trials and by the meta-analysis. The trial in question had 100 patients in both groups, and we consider that small sample bias may cause its results. We have less than 2% of superficial phlebitis in our experience in Brazil, even performing duplex after surgery in all patients. The trial with more phlebitis presented 4 out of 51 patients in CHIVA and zero out of 49 in stripping patients. We need to be careful in performing and reading trials, to make sure they compare the same thing. If we use several routine Duplex mappings to diagnose a complication in one technique, we should use it in the other.

Recurrence: The randomized trials have also compared the recurrence after CHIVA to stripping in randomized trials. Parés et al. found less recurrence at 5 years with CHIVA as assessed by independent observers ⁴. The study was not blind, as the observers of the endpoints performed duplex mapping and could see that the saphenous vein was still in place. Other randomized clinical trials with smaller samples did not find recurrence advantage. The meta-analysis joining all randomized trials found a risk ratio for recurrence at 5 years of 0.63 favoring CHIVA. Carandina et al. found that the recurrence after CHIVA is lower than stripping recurrence after 10 years ⁵.

Preoperative Care

We examine the patient, preferably at the same day of the operation, to mark the skin with a duplex scan. The same surgeon who does the operation performs the duplex mapping. The patient then does all the paperwork, consent, and administrative protocol and goes to the operating room. Our map entails what veins to ligate and keep. A misplaced ligation may have disastrous consequences, and the surgeon should be sure about the anatomy before ligating a vein. We give all the instructions about the postoperative period to the patients beforehand, to help patient understanding and following the recovery steps.

Our informed consent has an explanation that the veins will remain and are expected to wilt, but may not. We include in the consent several data we discuss in this book with lay words, and we have had no legal problem so far. We have heard of a patient in another center that created legal problems for the team. He thought they would keep his saphenous vein, and they eliminated

it in the operation. We should inform the patient fully and keep a written consent. We have migrated from destructive methods to only preserving methods. Furthermore, we observed that patients get as passionate about their saphenous vein as their surgeon is. After you explain the vicarious (bypass - by proxy) shunt created when the saphenous vein is absent, most patients fight for their saphenous vein. If you intend to preserve and tell that to the patient, it is better not to change your mind in the process or present a full explanation if you do so.

Special Cases

Anticoagulated patients: Most procedures have an important limitation in anticoagulated patients. As we perform CHIVA procedures under local anesthesia and minimal dissection and hematoma occur after the procedure, we do not stop anticoagulation medications before CHIVA. It is advantageous as compared to other venous procedures because stop and retake anticoagulants is related to complications.

Venous Ulcers: The CHIVA incisions are usually far from the ulcer as we aim for the beginning of the reflux and the ulcer is normally at the end of it. We perform the procedure normally. Sometimes we postpone “cosmetic” collateral incisions for a second procedure after the ulcer is healed. This approach has been tested in a clinical trial that showed CHIVA was superior to compression alone both in speed of ulcer healing and in recurrence ⁶.

Arterial and Venous disease: We should obviously evaluate deeply the arterial obstruction before performing a CHIVA operation. If the arterial obstruction is important, we

should avoid as much as possible to treat the venous system. Although some cases with severe venous disease perpetuating the arterial symptoms or severe arterial disease perpetuating venous ulcers. We usually approach the arterial system first in these cases, if a procedure is warranted. We perform the CHIVA procedure normally if the venous disease is severe. The saphenous vein will be spared if a bypass is needed. The saphenous vein of varicose patients is used without difficulty in bypass (as we will discuss in the correlated chapters).

Perioperative Care

We perform simpler cases under local anesthesia without sedation, but the anesthesiologist is present to deal with mishaps. This is satisfactory for most patients, with exception to obese and two groins at the same day. In our region, there is a mentality of operating both legs, we cannot do one side and after the other. Thus, we use a protocol of diluted local anesthetics and allow the anesthetist to do a light sedation in these cases. We use the same protocol in obese patients successfully. When the procedure ends, the patient puts 20-30mmHg elastic stockings in the operative room and goes to the recovery room. The patient is instructed to be active and walk. We use gauze dressings in all incisions under the elastic stockings. This avoids blood stains in the elastic stockings and patient's apprehension after discharge.

We follow the changed Aldrete Kroulik score ⁷ to discharge the patient from the day-hospital. Usually, it takes an hour after the procedure until the patient eats a light meal and urinates. Some CHIVA centers have operation rooms in the clinic and follow similar protocols, but the patients leave the clinic faster. We usually

check the hemodynamic results of the procedure immediately or in the day after with duplex scan and repeat the duplex scan at the sixth-day visit to remove skin sutures.

We ask the patient to use the elastic stockings daily for 14 days (cases with small collaterals only 7 days) and walk as much as possible (goal 2h a day) in the postoperative period. Not only that, but we prescribe the new anticoagulants for 10 days after the procedure using prophylaxis dosage. Thrombosis prophylaxis is very debatable after varicose surgery, the incidence of deep thrombosis is around 1% clinical and 5-10 times greater with routine duplex ⁸. We use prophylaxis in all patients, unless a contraindication exists.

The pain management in the postoperative period is simple and we prescribe common analgesia. We use Acetaminophen or Dipyron on demand. The analgesic need is scant, 55% of our patients do not take a single pill of painkiller drugs at home. The first hours are the most painful, we include in our solution of local anesthesia Ropivacaine in low concentration to have an enduring effect until the patient settles at home.

Recurrences

The recurrences after CHIVA differ partly from the recurrences seen in other methods. The saphenous vein is collecting blood from collaterals (either to flow to the deep system directly or through a perforator). Thus, we do not see the “bypass” collaterals that develop a superficial network until they can drain to a perforator. These recurrences account for close to 28% of recurrences (see recurrence chapter).

The recurrences from neovascularization at the junction are like the recurrences after most methods, although as we keep all the groin tributaries ⁹ and take extra care with technical details ¹⁰, these recurrences are less frequent. In the cases of a junctional reflux happens, we proceed sclerotherapy or redo at the groin as most techniques.

Further recurrence may happen from an extra escape point of a pelvic leak, thigh perforator or because of drainage of skin blood from the thigh and abdomen. When we preserve the saphenous vein, these recurrences will automatically drain to the saphenous vein. In this setting, two situations may happen. First, the saphenous vein preserved with CHIVA drains to a good perforator. If we create an adequate Shunt Zero flow, we may not have a clinical recurrence despite new escape point reflux. The extra blood from the new veins with reflux will drain to the saphenous vein without an overload of the good perforator (no clinical recurrence occurs). Second, it overloads the saphenous vein as it drains to a small perforator (new collaterals will develop). In these cases, a high pressure happens in the saphenous vein, and it will probably drain to a new collateral in the leg or near the knee, creating a clinical recurrence. If this happens, we usually do sclerotherapy of this new collateral/reflux source or ligate it.

If a recurrence occurs, we re-categorize the patients according to the shunt classification and choose the adequate treatment. Most cases are managed by hemodynamic sclerotherapy or hemodynamic laser+sclerotherapy with no major intervention (see respective chapters for further details). A few cases may have an important reflux source and may require another CHIVA under local anesthesia. We never had to

solve a CHIVA recurrence with a destructive procedure, but non-specialized centers may use this approach.

Air Plethysmography

Some centers use plethysmography to follow patients after venous procedures, and we consider its use pivotal to know the results of a surgical technique, along with quality-of-life questionnaires. The problem with plethysmography is that it lacks perfect correlation with the clinical presentation. CHIVA leaves the veins in place and uses perforators to return blood to the deep system. These perforators are usually at the leg. The main parameters of air plethysmography are Venous Volume, Venous Filling, Residual Volume and Ejection Fraction. A clinical trial comparing CHIVA and compression has shown that CHIVA improved the Volume, Filling and Residual volume at six months⁶. At three years, the Volume and Filling were better than before the operation, but with a smaller difference. Residual volume was even smaller at 3 years. These patients did not have clinical symptoms or recurrence. There is a great debate among scholars to explain the partial increase in filling and volume without recurrence or symptoms. We should remember that CHIVA keeps the veins of the leg flowing, and they flow to a leg perforator, not to the saphenous junction.

References

1. Bellmunt-Montoya S, Escribano JM, Dilme J, Martinez-Zapata MJ. CHIVA method for the treatment of chronic venous insufficiency. *Cochrane Database Syst Rev* [Internet]. 2015;(6). Available from: <https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD009648.pub3/abstract>
2. Arendt AL, Faccini FP. Nerve Injury in venous procedures: Malpractice, characteristics, and strategies to avoid it [Internet]. Vol. 3, *Journal of Theoretical and Applied Vascular Research*. 2018. Available from: <http://dx.doi.org/10.24019/jtavvr.73>
3. Iborra-Ortega E, Barjau-Urrea E, Vila-Coll R, Ballón-Carazas H, Cairols-Castellote MA. Estudio comparativo de dos técnicas quirúrgicas en el tratamiento de las varices de las extremidades inferiores: resultados tras cinco años de seguimiento. *Angiología* [Internet]. 2006 Jan 1;58(6):459–68. Available from: <http://www.sciencedirect.com/science/article/pii/S000331700675009X>
4. Parés JO, Juan J, Tellez R, Mata A, Moreno C, Quer FX, et al. Varicose vein surgery: stripping versus the CHIVA method: a randomized controlled trial. *Ann Surg* [Internet]. 2010 Apr;251(4):624–31. Available from: <http://dx.doi.org/10.1097/SLA.0b013e3181d0d0a3>
5. Carandina S, Mari C, De Palma M, Marcellino MG, Cisno C, Legnaro A, et al. Varicose vein stripping vs haemodynamic correction (CHIVA): a long term randomised trial. *Eur J Vasc Endovasc Surg* [Internet]. 2008 Feb;35(2):230–7. Available from: <http://dx.doi.org/10.1016/j.ejvs.2007.09.011>
6. Zamboni P, Cisno C, Marchetti F, Mazza P, Fogato L, Carandina S, et al. Minimally invasive surgical management of primary venous ulcers vs. compression treatment: a randomized clinical trial. *Eur J Vasc Endovasc Surg* [Internet]. 2003 Apr;25(4):313–8. Available from: <http://dx.doi.org/10.1053/ejvs.2002.1871>
7. Trevisani L, Cifalà V, Gilli G, Matarese V, Zelante A, Sartori S. Post-Anaesthetic Discharge Scoring System to assess patient recovery and discharge after colonoscopy. *World J Gastrointest Endosc* [Internet]. 2013 Oct 16;5(10):502–7. Available from: <http://dx.doi.org/10.4253/wjge.v5.i10.502>

8. Testroote MJG, Wittens CHA. Prevention of venous thromboembolism in patients undergoing surgical treatment of varicose veins. *Phlebology* [Internet]. 2013 Mar;28 Suppl 1:86–90. Available from: <http://dx.doi.org/10.1177/0268355512475121>
9. Cappelli M, Lova RM, Giangrandi I, Ermini S, Giancesini S. Ligation of the Saphenofemoral Junction Tributaries as Risk Factor for Groin Recurrence. *Journal of Vascular Surgery: Venous and Lymphatic Disorders* [Internet]. 2018;6(2):290. Available from: <http://dx.doi.org/10.1016/j.jvsv.2017.12.030>
10. De Maeseneer MG, Philipsen TE, Vandenbroeck CP, Lauwers PR, Hendriks JM, De Hert SG, et al. Closure of the cribriform fascia: an efficient anatomical barrier against postoperative neovascularisation at the saphenofemoral junction? A prospective study. *Eur J Vasc Endovasc Surg* [Internet]. 2007 Sep;34(3):361–6. Available from: <http://dx.doi.org/10.1016/j.ejvs.2007.03.020>

14 - Sclerotherapy and CHIVA

Erika Mendoza and Massimo Cappelli

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1 – Sclerotherapy in the CHIVA context – a contradiction?

The goal of sclerotherapy is to obliterate a vessel thanks to an endothelium lesion provoked by chemical substances and inducing an inflammatory process with thrombus formation, well fixed to the wall. Thus, sclerotherapy is an obliterating treatment, and seems in contradiction to CHIVA, a venous preserving treatment, specially preserving the saphenous veins. In some situations, nevertheless, sclerotherapy can be applied in the context of CHIVA strategy, but it must be applied correctly. In this chapter, we present the correct preparation of a safe foam to help with a precise application as needed in the CHIVA context, and then we explain the different situations in which the sclerotherapy can be applied in saphenous vein sparing therapy.

2. General aspects of Sclerosing agents and application

2.1. Agents and preparation

Different sclerosing agent are available, specially detergents and dehydrating substances. Among the dehydrating substances, the following are applied.

- Hypertonic as the saline solution (Sodium Chloride to 20%).

- Not hypertonic as salicylate and glycerol that interact with the wall by opening the water channels with cellular dehydration of the endothelium.

The problem with these substances consists in the fact, that they are liquid, and they mix with blood, behaving as fluids. They can't be controlled in their advancing through the vein, and thus they are not the choice in the CHIVA context.

- Among the detergents we find:
- Anionic as sodium tetradecyl sulfate (e.g. Trombovar®, Sotradecol®, Tromboject®)
- Not anionic as polidocanol (Aethoxysclerol®, Sclerovein®, Asclera®)

Most often detergents are used in the context of sclerotherapy, specially Polidocanol. They attack the cell wall proteins, disrupting the membrane of the endothelium.

The detergents have the property that they are quickly deactivated when in contact with blood: plasma proteins bind the detergent within seconds. Detergents can be used in two different forms: liquid and foam.

- **Liquid application:** The substance mixes quickly with blood, so the inactivation is achieved within seconds. This makes it less aggressive as compared to foam and gives it a delimited indication, specially to treat small vessels.
- **Foam application:** Foam has a high cohesion itself, with the tendency of filling the room where it is introduced, displacing the blood. This filling possibility has its limits in large vessels. The contact-time with the vein wall is higher for foam than for liquid. The

inactivation will only work on the surface of the foam, leaving a higher active time to the sclerosing agent within the foam. This makes the foam more aggressive, even though the sclerosing agent is diluted with air, compared to the liquids that mix with the blood and allows a sclerotherapy of larger vessels than spider or reticular veins.

There are different ways to prepare foam, using different components. The most often used way is the wet foam by Tessari (Tessari 2000). In the author's experience, sometimes a foam with higher consistency is necessary, like the so-called dry foam according to Monfreux (Monfreux 2013). The way to manufacture both is explained in Fig. 1 and in Table 1.

To apply the foam to the patient, use a smaller syringe, never larger than 3 ml. This is easier to handle and avoids application of too large amounts of foam. And with every refilling procedure, the foam is renovated.

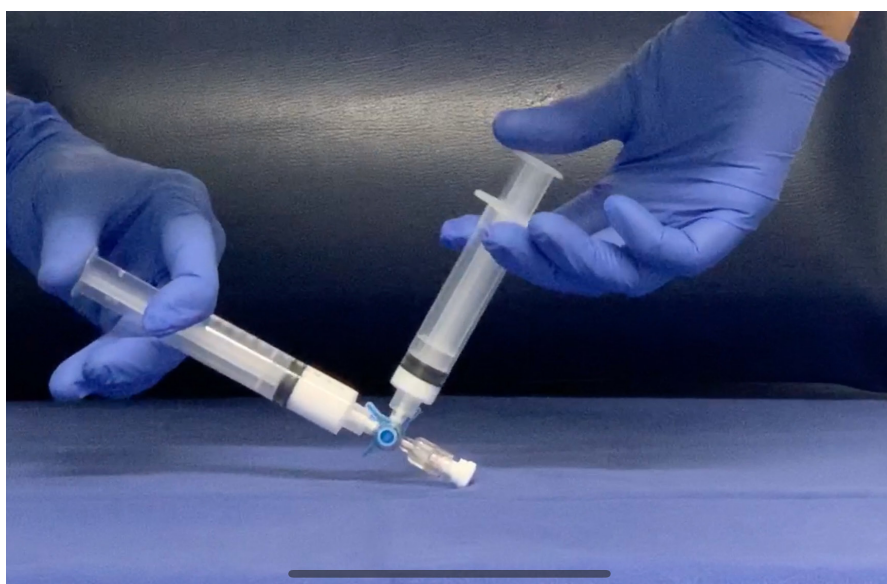
Table 1: Legend: Properties of sclerotherapy-foam (adapted from Giancesini S, Delfrate R, Cappelli M, Mendoza E, CHIVA Surgical Tips and Tricks; in: Zamboni P, Mendoza E, Giancesini S (Eds), Saphenous Vein-Sparing Strategies in Chronic Venous Disease, Springer, 2018: 181-202)

	Wet foam according to Tessari	Dry Foam according to Monfreux
Preparation	4 parts of air and 1 part of liquid, according to Tessari's method (see Fig. 1).	8 parts of air and 1 part of liquid (this makes 9 ml filling in a 10 ml syringe)
Concentration	All concentrations of sclerosing agent can be used, the less the concentration the foam would behave more like a liquid.	Only feasible with high concentrations of sclerosing agent (2-3%)
Foam stability	Low foam stability, hence action time is reduced with disaggregation of the foam within some seconds	High stability, hence increased action time, even inside the vessel
Diffusion inside the vessel	High diffusion in the vessels, as it has a low viscosity with bubbles of different sizes	Low diffusion of the foam because of its high viscosity with small homogeneous bubbles, so the progression is controllable by stopping the application
Application	Extended sclerosing action over a long distance, e.g. long tributaries, saphenous veins (not in CHIVA context)	• When powerful action is needed punctually with control of the extension inside the vessel • Recidives of the sapheno-femoral junction after stripping, • closure of a perforator • closure of the origin of the anterior accessory saphenous vein.

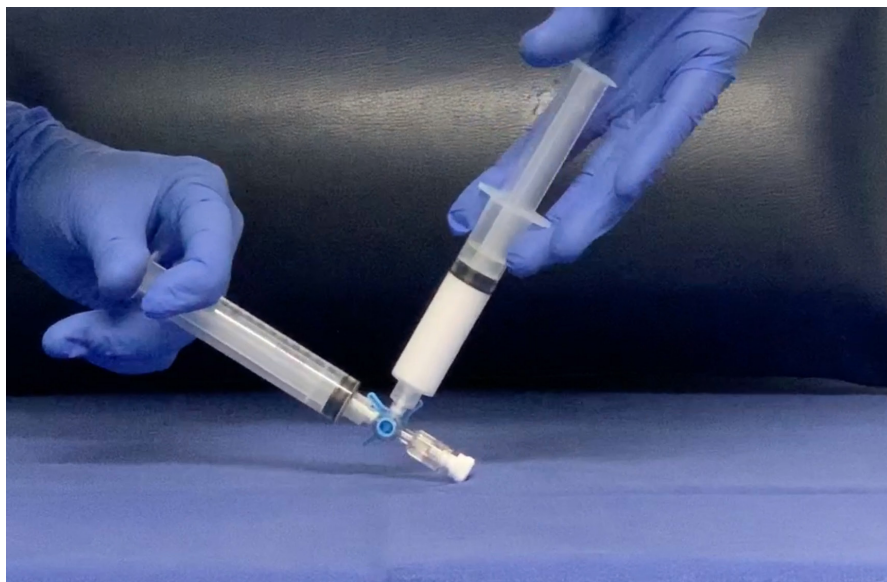
Figure1 - Foam preparation



a: Left: To prepare Tessari foam, 2 ml of sclerosing agent is introduced in a 10-ml syringe, added by 8 ml of air. Middle: To prepare Monfreux foam, 1 ml of sclerosing agent is introduced in a 10-ml syringe, added by 8 ml of air. Right: To prepare Monfreux foam, be careful to extract really only 1 ml, best use a smaller syringe

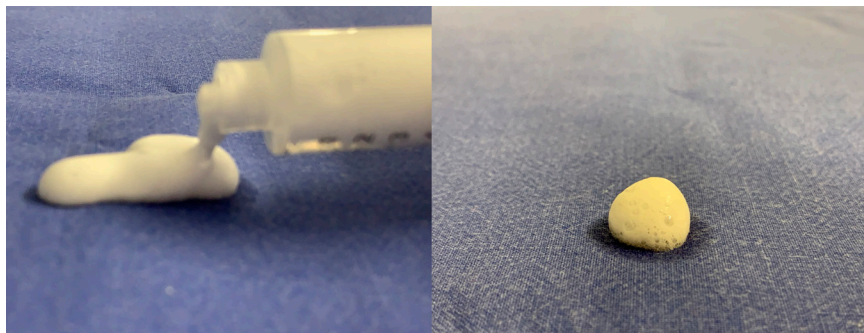


b The 10 ml syringe is connected to another, empty 10 ml syringe by a three-way stopcock. The content of the syringe is pushed back and forth manually, until a homogeneous foam is achieved.



c The three-way stopcock can be positioned at 90° (Left) or slightly turned (right). In this case, the lumen for the foam to pass is less, and the foam will have bubbles of lesser diameter (Images © Erika Mendoza, PhleboPic)

Fig. 2 Foam consistency



Left: Tessari Foam is more liquid, right: Monfreux foam has higher thick and stable. (Images © Erika Mendoza, PhleboPic)

2.2. Effect of sclerotherapy on the vein

As explained above, the sclerosing agent aims to produce an endothelial lesion. In consequence, a vein wall inflammatory process starts with subsequent thrombus formation inside the vessel, well adhered to the vein wall. The end-point of this process is the vein obliteration after thrombus organization by granulation tissue.

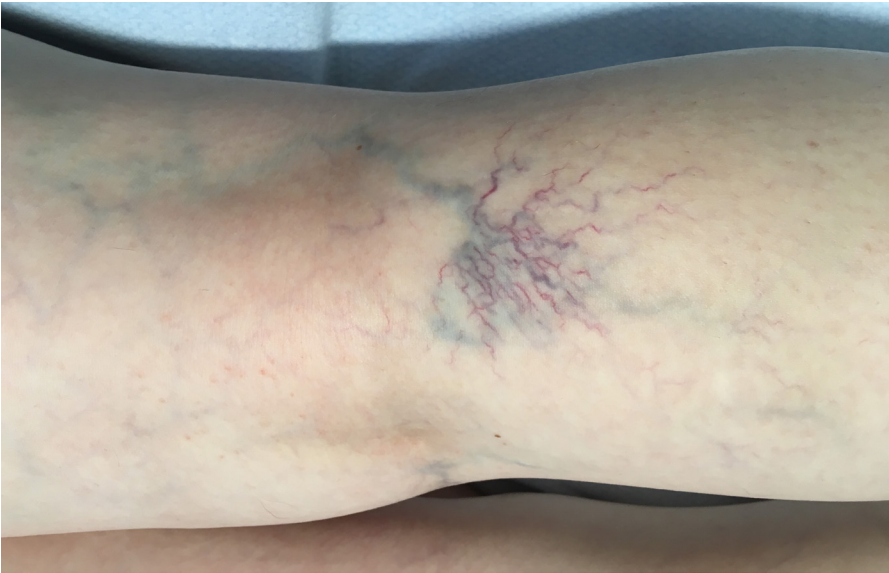
In case of an extensive lesion of the vein wall, involving not only the endothelium, but also the external part of the media and the adventitia layer, no granulation tissue will be involved: the vasa venorum from the adventitia layer will spread into the thrombus and provoke thrombus lysis and early recanalization before the formation of fibrous organization. Thus, the critical moment in the therapy is to decide the correct concentration and application of sclerotherapy to damage only the endothelium and not the whole vein wall, as the latter will induce more recanalization.

Still, sometimes after the recanalization of a vein after sclerotherapy we find a caliber reduction and sometimes not due to scarification of the vein wall.

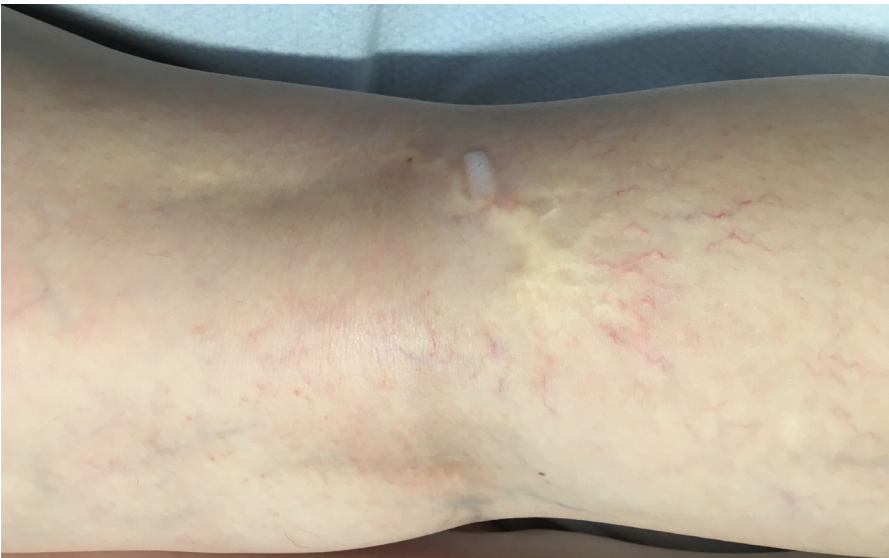
Sclerothrombus formation in the vessel induces pigmentation and induration below the skin, which is an undesirable side effect. Patients have to be informed about this and followed up carefully after 2 – 4 weeks. In case of formation of these hyperpigmented hard vessel alterations, a puncture with a needle Size 1 (yellow, 20 Gauge, 0,9 mm diameter) will allow squeezing out the gelatinous material (see Fig 3).

Eccentric compression after the sclerotherapy reduces the caliber in very superficial vessels and hence possibly the thrombus dimensions.

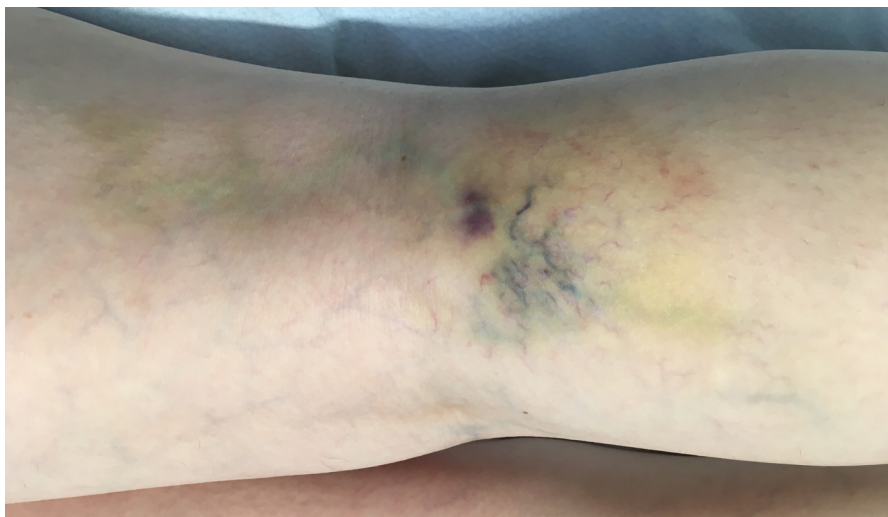
Figure 3



a Reticular and spider veins before sclerotherapy



b Same patient immediately after introduction of Tessari Foam (1%)



c Same patient 3 weeks later with formation of sclerothrombus and pigmentation



d Another patient immediately after puncture with 1G Needle



e Soft expression of gelatinous material to reduce hyperpigmentation

(Images © Erika Mendoza, PhleboPic)

3. Sclerotherapy as a tactic in the CHIVA strategy

Application possibilities for Sclerotherapy as a tactic in CHIVA strategy

- 1 For treating selectively the escape points N1-N2/N3 which are difficult to manage with surgery, unless an extensive surgical procedure with risk of functional damage and not good aesthetic result
 - A) Some perforators
 - B) saphenopopliteal junction in some cases
- 2 Pelvic shunts with low flow
- 3 Treatment of peculiar Shunt II

4 For remodeling the saphenous hemodynamics (1° Step CHIVA 2)

a) Small tributaries

b) Tortuous tributaries

Please note: These applications are routinely applied by the authors with Polidocanol, not the other sclerosing agents.

3.1. Sclerotherapy in the context of perforator-treatment

Perforating veins used to be draining pathways and thus are usually not touched in the CHIVA context. Only if there is a diastolic reflux through a perforating vein so that we can be sure, that the perforating vein is the (proximal) escape point, it will be treated. In this seldom cases when a perforating vein is disconnected according to CHIVA strategy, one of the main targets is not to leave any stump at the level of the deep vein after treating an escape point because it would be a source of recurrences. A combination of surgery and sclerotherapy is the answer to this problem in difficult anatomical situations.

3.2. Perforators show different characteristics that have to be analyzed before we decide how to treat them.

Which veins are connected? We distinguish:

- Perforators connecting the saphenous vein (N2) with the deep vein (N1).
 - These can be short and without tortuosity – which allows a surgery with little trauma to surrounding structures – thus only surgery will do.

- These can also be long and tortuous, as it is often the case with perforating veins at the medial aspect of the thigh – in these cases sclerotherapy might help to improve surgical outcome.
- Perforators connecting tributaries (N3) with the deep veins (N1).

Is the perforator mono- or multitruncular?

- Monotruncular perforator: We can find only one vein connecting the deep and the superficial vein, without branching at the subfascial level – if this vein is not too tortuous a surgical flush ligation at the level of the deep vein is possible.
- Multitruncular perforator: The perforator branches between the deep and the superficial vein, connecting the same or different superficial or deep veins (see Fig 4). In this case, caution in the context of the treatment decision to avoid recurrences is mandatory.

Figure 4 gives a schematic overview of multitruncular perforating veins with their treatment options, according to origin and pathway of perforating veins. They are divided in

- Type I – one refluxive perforator connected to the deep vein
- Type II – two (refluxive) perforating veins are connected to the deep vein

In case of Type I (one connection to the deep vein) the branching of the perforator can occur extrafascial (Type Ia, Fig 4) or subfascial (Type Ib, Fig 5). In both cases, the correct way would be to interrupt both parts of the tributary – which would be achieved, if the perforator had been prepared until the connection to the deep vein or if the branching had been made clear by ultrasound before the intervention.

Fig. 4 Types of multitruncular perforators and classical treatment errors

Type IA

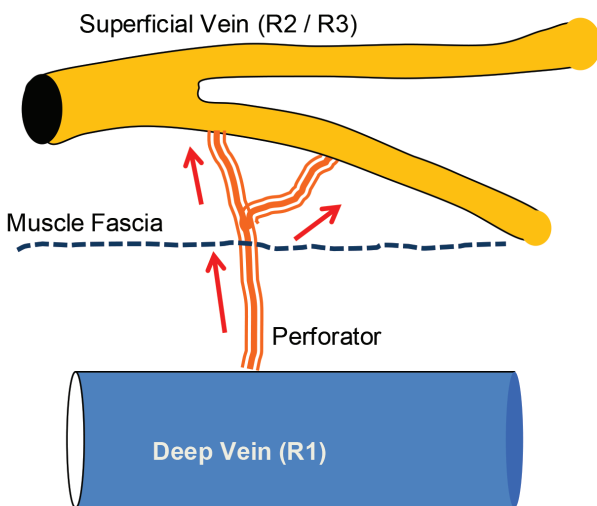


Figure 4a Type IA – One refluxive perforator connected with the deep vein and branching to feed the same superficial vessel with two arms. In this case, the perforator branches above the fascia, this can also happen below, in the muscular compartment (see Fig 5).

Type IA Treatment

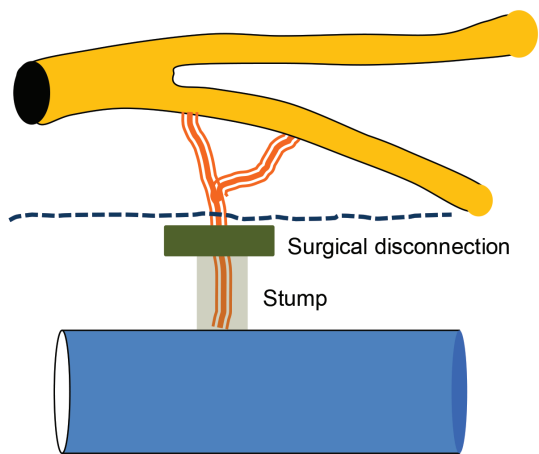
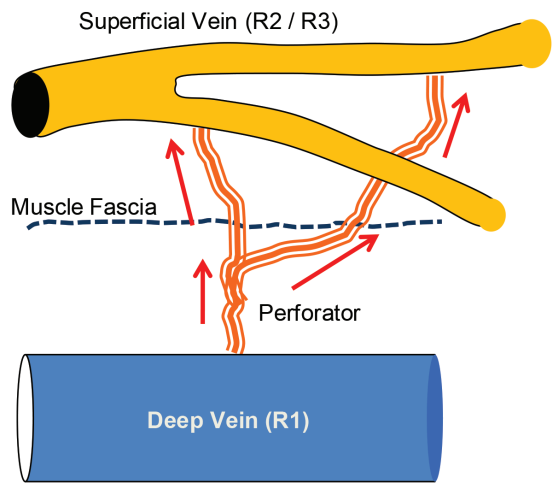


Figure 4b Surgical treatment with stump: Surgical disconnection of the perforator on subfascial level. This leaves a stump between the disconnection point and the deep vein (light green area).

Fig 5

Type IB



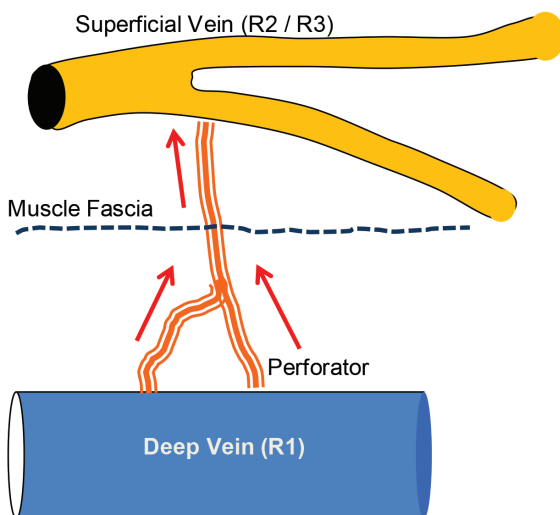
a Type IB: One refluxive perforator connected to the deep vein, division of the refluxing perforator at subfascial level and feeding two different superficial vessels with reflux.

b interruption of only one of both branches of the perforator. The reflux in Vein 2 is interrupted, Reflux in Vein 1 will persist.

Type II A describes the situation, where two branches of the refluxing perforator part from one deep vein to feed one superficial vein. The subfascial disconnection of the perforator (unitroncular at this level) will lead to a stump with two connections to the deep vein (Fig 6).

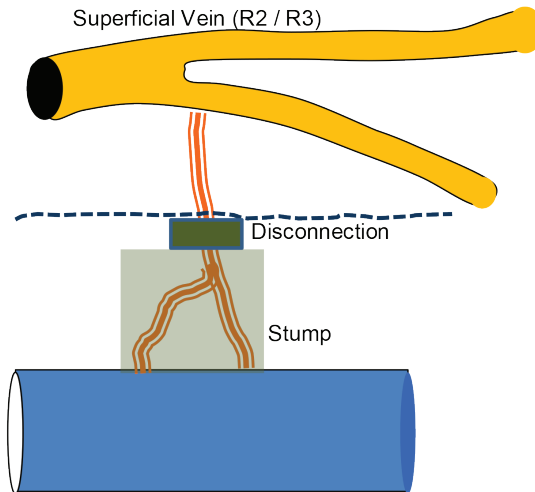
Figure 6

Type II A



a two branches of the perforator are connected to the deep vein, feeding one superficial vein.

Type IIA Treatment

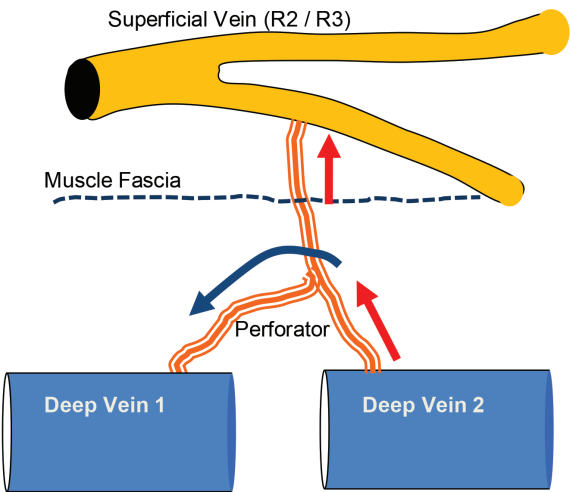


b Disconnection of only the portion at fascial level will leave two connected stumps in the muscle compartment

Type IIB: At the inner aspect of the calf, we can find the situation, that a refluxive perforator from one deep vein joins in another – non refluxive – perforator from another deep vein and both connect to a superficial vein. The deep multitruncularity can involve pump collectors (e.g.: vessels connecting soleus veins with Posterior tibial veins or Peroneal veins). In this case, the subfascial disconnection of the refluxing perforator results in abolition of the insufficiency point for the superficial vein and in a stable, draining condition for the perforator, which is drained in the same deep compartment into another deep vein.

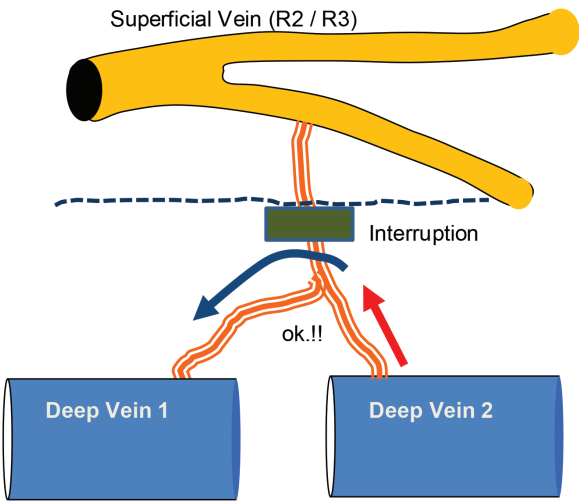
Fig 7 Type IIB

Type IIB



a refluxing and not refluxing perforators connected to different deep veins joining under the fascia and connecting to one superficial vein

Type IIB Treatment



b fascial interruption of the perforating vein leaves a stable situation

Images 4-7 prepared by Massimo Cappelli

When a perforator is disconnected with a surgical procedure, even if subfascial, often a stump is left (see Fig. 4-7). Therefore, the optimal indications for surgery of perforators without leaving any stump are the following:

- Short perforators without branching (e.g.: Cockett perforators in thin people)
- A peculiar refluxing multitruncular perforator represented by a perforator of an internal pump collector (vein connecting the posterior tibial vein with a soleus muscular vein) (see Fig. 7)

All the other perforators could be treated with sclerotherapy in addition to surgery or sclerotherapy alone to avoid leaving a stump or other refluxing branches in case of multitruncularity – without provoking the large lesion necessary to do a radical surgery.

Hence the indications of perforator sclerotherapy in CHIVA treatment depend on the length of the subfascial tract and the types of multitruncularity and the superficial vein to which the perforator is connected.

3.3. Treatment of perforating veins connecting N1 – N2

- The first step is the surgical disconnection of the perforator from the saphenous trunk to avoid the extension of the sclerosing action to the saphenous trunk.
- Afterwards, introduction of a small catheter in the subfascial perforator and injection of liquid, low concentrated sclerosing agent. Foam should not be

used to avoid longer persistence in the deep vein, with subsequent risk of deep vein thrombosis.

- Activation of the calf pump to wash the deep vein and promote the inactivation of the sclerosing agent at this site. In the experience of the author, this method allows a satisfactory closure of the perforator without stump and avoiding large surgery.

3.4. Perforators connected to a superficial tributary (N1 – N3):

- No saphenous vein involved: Usually these perforators and tributaries are not too large and could be treated with foam sclerotherapy in one session without the need of surgery. In case the perforator is large, the surgery combined with sclerotherapy technique could also be applied here (see 1).
- Refluxing perforator fills a tributary, which shortly after joins a saphenous vein. This saphenous vein is incompetent as a result of this perforating vein. Surgical disconnection of the tributary en niveau of the saphenous vein and sclerotherapy of the tributary with the same

4. Treatment of the saphenopopliteal junction with sclerotherapy

In case of the saphenopopliteal junction, we often find the same difficulties to perform a flush ligation at the level of the deep

vein as seen with the perforating veins. Some surgeons consider it is not worth it to risk neurological lesions, deep venous thrombosis and bad aesthetic results because of a large incision, just for treating varicose veins. The consequence is that many stumps are left after surgical treatment with high rate of recurrence, especially if we had a systolic reflux.

The same can happen, when disconnecting the short saphenous vein distally to the first tributary of the junction, which might be the thigh extension of the short saphenous vein or the Giacomini vein). If the tributary is large and well drained, the stump will be washed. In case of a

- Competent Giacomini vein (The flow is towards the Great saphenous vein)
- Thigh extension of the small saphenous vein with a small caliber compared to the caliber of the saphenous arch

the stump will be poorly washed and could be the source of recurrence.

The sclerotherapy will allow obliterating the escape point flush with the popliteal vein. The procedure is the same as explained for the saphenous perforator treatment, performing the surgical disconnection first and then applying liquid low dose sclerotherapy, and performing calf movements afterwards for a better washout of the deep vein. This technique impedes the stump formation in the experience of the author.

5. Pelvic shunts with low flow and sclerotherapy

Pelvic reflux represents a broad investigation, diagnostic and treatment field, exposed in other chapters.

In case of low flow through the pelvic leak points, a sclerotherapy has shown to be helpful to avoid a surgical intervention. To protect the saphenous trunk, either the connection between the refluxive tributary with the saphenous vein should be interrupted first or the saphenous vein must be thoroughly compressed to avoid sclerosing agent dripping inside.

Best indications for sclerotherapy in case of pelvic leak points are the dorsal leak points (gluteal) and the perineal or inguinal points with a long subcutaneous run before drain into the saphenous vein.

6. Treatment of tributaries connected to the saphenous veins

Treatment of tributaries with sclerotherapy at their confluence to the saphenous vein is possible instead of surgery in case of small very superficial vessels or tributaries of the saphenous trunk with a very deep connection to the saphenous vein due to a thick subcutaneous fat layer to avoid large scars:

- Shunt Type 1+2 in addition to the treatment of the junction
- Shunt Type 2 where the tributary is the only refluxing segment

- Shunt Type 4+2
- Shunt Type 3 and V for remodelling the saphenous haemodynamics (1° Step CHIVA 2, see Chapter 6.4.1)
- Residual visible tributaries after CHIVA
- Tributary recurrence after CHIVA

This treatment could be performed with sclerotherapy in case the tributary is small or very tortuous. Peripheral vessels should be treated with sclerotherapy without involving the saphenous trunk, applying a digital compression at the junction (reflux outlet) or re-entry level in the saphenous axe. Nevertheless, in the author's experience, the saphenous trunk is involved by the sclerosing action in 11% of the cases after one week, but with complete recanalization after 3 months, generally with calibre reduction.

On the other hand, a stump of the tributary at the level of the junction with the saphenous trunk should be avoided.

According to different types of vessel connection, straight or tortuous, various compressions and kinds of therapy will be used. Straight junction means, that the part of the vessel next to its connection to the saphenous vein is rectilinear, sometimes it runs next to it within the fascial compartment for some cm. It is independent of the fact, that the more superficial part of the tributary is tortuous. We find a tortuous junction in case of no straight segment between the tortuous tributary and the saphenous vein (see Fig 8).



Fig. 8: a) Foam-Sclerotherapy of the tributary, stopping at the lumen of the GSV. The foam is visible as a white image with ultrasound shadow below it (Arrows pointing to the foam are located in the shadow region). (Image owned by Massimo Cappelli)



b) Result after Sclerotherapy of a tributary with straight outlet. Note that the tributary is closed (filled with echogenic material) until the connection to the GSV, which is washed out by higher blood flow. (Image owned by Massimo Cappelli)



c) Result after sclerotherapy of a tributary with tortuous outlet. The GSV is without intraluminal echos (black), the tributaries are closed with echogenic contents. (Image owned by Massimo Cappelli)

6.1. Sclerotherapy of a tributary with a straight junction

Refluxive tributaries with a straight junction (see fig. 8a) can be treated under ultrasound control and with compression technique of the saphenous vein at the point of the tributary connection.:

Compression of the outlet point during injection of liquid agents: The outlet is identified with ultrasound and marked on the skin. Then a compression with a finger is performed at that level during the injection.

Specific compression techniques for foam such as bending the probe compressing the outlet level when the foam shows up are currently being investigated using wet foam at low concentration and with air/liquid ratio 4:1 (see Table 1)

6.2. Sclerotherapy of a tributary with a tortuous junction

In this case, the compression applied at the junction level will involve a large part of the tributary, too, impeding the sclerosing action flush with the saphenous trunk. So, often a stump will be left. This problem can be avoided using dry foam (see Table 1). The needle is inserted in the tortuous vein and 0.5 to 1 cc of the dry foam manufactured with 2% polidocanol is applied slowly under ultrasound observation of the point where tributary and saphenous vein meet. The high viscosity of the foam allows us to follow its slow progression. As soon as the foam reaches the connection with the saphenous vein, a compression with the US probe at junction level is performed. The injection must be soft and discontinuous, verifying the foam movement towards the junction. Glass syringes are perfect for this purpose.

To increase viscosity, we can add glycerine to the sclerosing agent.

Another way to regulate the progression of the dry foam in the tributary towards the saphenous vein is applying a blood-pressure cuff proximally to the injection point. This cuff is filled with 80-90 mm Hg before the injection. This stops the flow in the saphenous vein – and in the tributary. After applying foam to the tributary we deflate the cuff slowly, supervising the foam progression until the junction point from the tributary into the saphenous vein – at this moment we leave the pressure for 2 minutes to allow an inactivation of the foam by blood proteins, before opening the cuff.

7 Sclerotherapy post CHIVA

Overview

Sclerotherapy post CHIVA

1. Disconnected vessels from the saphenous trunk when still visible after a while and spider veins correlated.

2. Recurrences

- Escape points N1-N2/N3 which are difficult to manage with surgery
- Some Perforators
- The stump following the small saphenous vein disconnection in the popliteal area.
- Pelvic leak point with low flow
- New refluxing vessels connected with the saphenous trunk

3. Matting post-CHIVA

According to the author's experience, the use of sclerotherapy in post-CHIVA follow up is applied in around 15% of the cases, but this value is going to grow up in relation to follow up duration. The recurrence rate is less in case of drained saphenous trunk after therapy.

A total of 2794 previously not treated patients underwent CHIVA intervention on GSV between 1991 and 2013. Of these, 22% were male and 78% female with ages comprised between 16 and 88 years (mean 55 sd 14,1), 51% right legs 49% left legs. They

were evaluated at each follow-up in the office. During the follow-up (minimum 1 year and maximum 22 years, mean 7 years) 415 patients (15% of all the patients) underwent sclerotherapy for the following reasons:

- 134 patients had residual visible tributaries (sclerotherapy of the tributary)
- 25 patients for spider veins (sclerotherapy of the spider vein)
- 20 patients for perforating veins (sclerotherapy of the perforator)
- 9 patients for pelvic reflux (sclerotherapy of the groin tributary)
- 227 patients presented new refluxing saphenous tributaries (sclerotherapy of the tributary)

All patients were controlled 2 weeks after sclerotherapy. In 46 cases (11%) a thrombus extension into the GSV was found, which remitted in all cases after 3 months, leaving a patent GSV (Mendoza and Cappelli 2017).

In case of sclerotherapy post CHIVA in non-disconnected tributaries, same techniques as explained in section 6 will be applied.

7.1. Sclerotherapy of disconnected vessels

In case of vessels remaining visible after having been disconnected from the saphenous vein, liquid sclerosing agents with low concentration should be used because the pressure inside

the tributary is low and the liquid can re-enter into the saphenous trunk more distally. In case of a large re-entry connection, a disconnection should be considered or the saphenous vein should be compressed during the injection (see section 6). Ex-centric compression should be applied after sclerotherapy.

7.2. Matting post-CHIVA

Matting is characterized by an area of red spider veins as an expression of a dilation of the most superficial venous subpapillar network. It can appear after any surgical or sclerotherapeutic procedure. According to clinical experience, we can differentiate two types of matting on the time of appearance.

Early matting appears due to a transmural pressure excess in the dermic subpapillar venous plexus. This happens, if the veins in the leg after the CHIVA procedure have an increased residual pressure. This is the case, if after the therapy the drainage path for the vessel is not appropriate to its diameter, generating poorly or not drained systems, especially in zones affected by cellulite (cold areas). Another reason is the vasodilation due to an excessive inflammatory reaction after too aggressive sclerotherapy.

Late matting appears after months and is a sign of a progressive valve incompetence of the peripheral vessels without re-entry (higher than 3rd order of division) as a consequence of transmural pressure excess related to hydrostatic pressure increase. Diagnostic with ultrasound should search for tributaries with descending flow into the matting area and treat them with wet foam under ultrasound control with small quantities of wet foam.

15 - Hemodynamic Laser + Sclerotherapy Protocol

Felipe Faccini and Claudia Sathler-Melo

<https://doi.org/10.5281/zenodo.6491502>

Key points:

Hemodynamic Laser + Sclerotherapy protocol

We can revert the saphenous reflux with sclerotherapy and maybe prevent future deterioration of the venous system.

Numerous cases that have their saphenous vein ablated in recent years for esthetic problems would be better off with simpler procedures.

The hemodynamic sclerotherapy is an important alternative to more aggressive procedures. We have been able to improve patients' symptoms and eliminate reflux (including saphenous) with these procedures for years as mentioned in the previous chapter. The only thing in common to both ascending and descending theories of reflux is that long-term reflux deteriorated the venous system with time. We have been able to eliminate veins that create reflux in the saphenous vein and end this reflux. We consider that there is a possibility to control the evolution of the disease if we treat it early and adequately. We will not re-discuss the hemodynamics of the cases that are discussed in the previous chapter. We will present in this chapter a technique we adapted with success. We united a widely used laser + sclerotherapy protocol for venous esthetic

procedures¹ hemodynamics^{2,3} and started doing Hemodynamic laser + sclerotherapy.

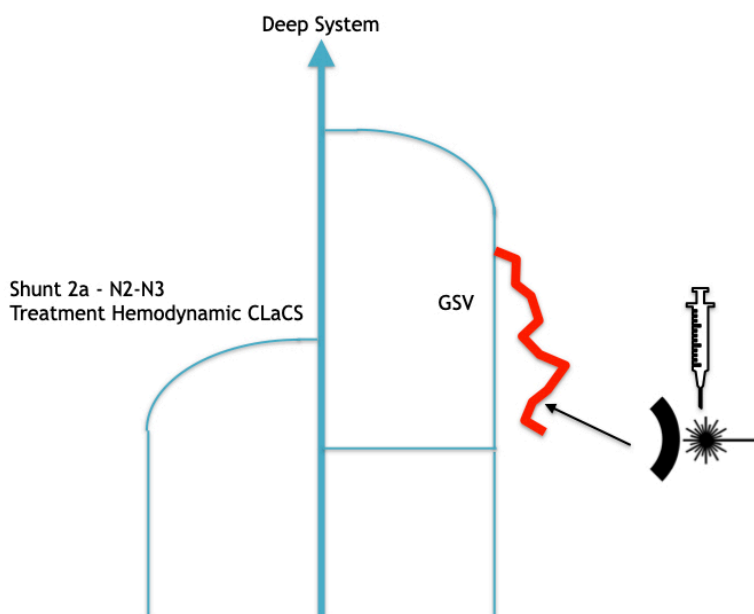
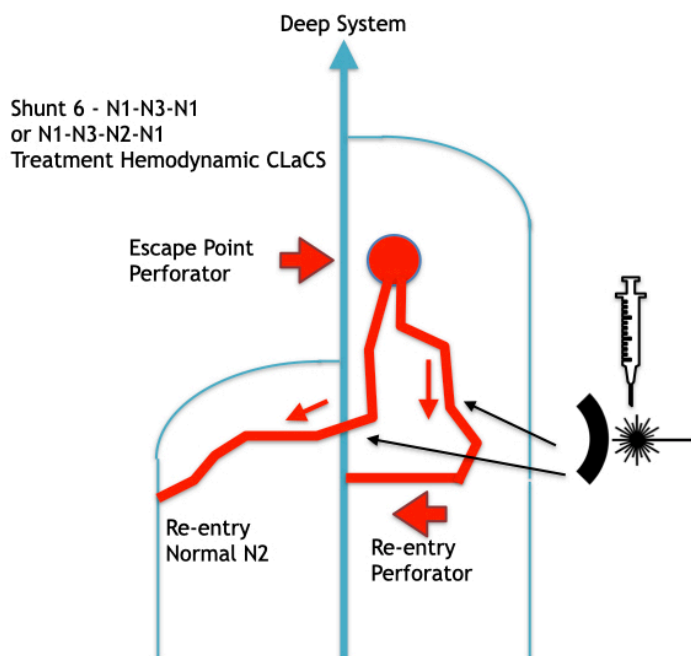
We used a common laser + sclerotherapy protocol with hemodynamics and duplex mapping to define the vein to treat. The hemodynamic laser + sclerotherapy protocol treats small veins and its feeder to get great esthetic results and is adjunct to another treatment to deal with bigger veins. We start the treatment with laser and dextrose sclerotherapy from the bigger veins to the smaller ones (sometimes the telangiectasia disappears after we treat proximal collaterals) and we use ultrasound to define what vein needs treatment. The advantages of this technique are using only Dextrose and in low volume to treat these veins. Dextrose is a thick viscous liquid at 75% and will hardly fill veins distant from the ones we treat, avoiding an ulcer and brown spot complications. Dextrose creates no allergic reactions. The major disadvantage of Dextrose is the mild effect on veins, which is compensated with the synergistic laser effect.

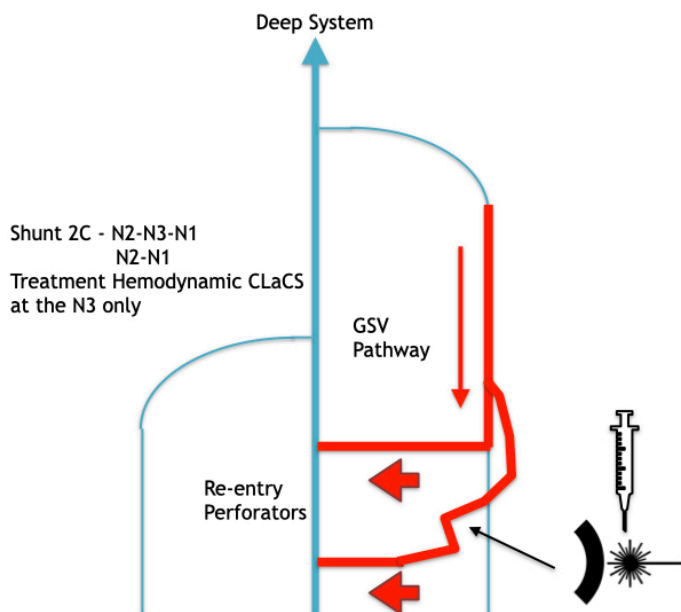
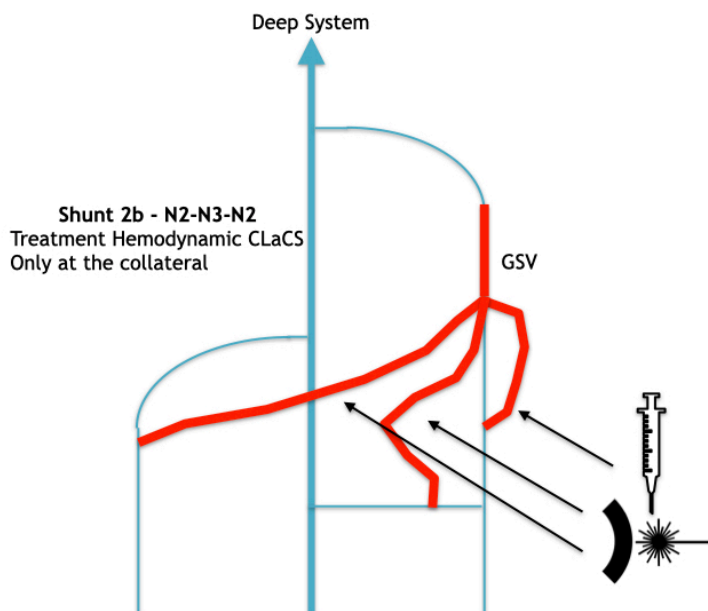
Hemodynamic Laser + Sclerotherapy Protocol

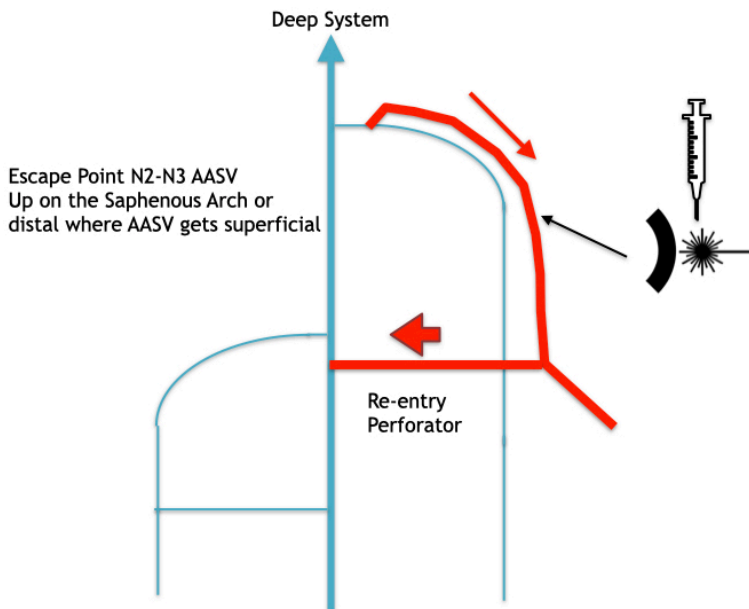
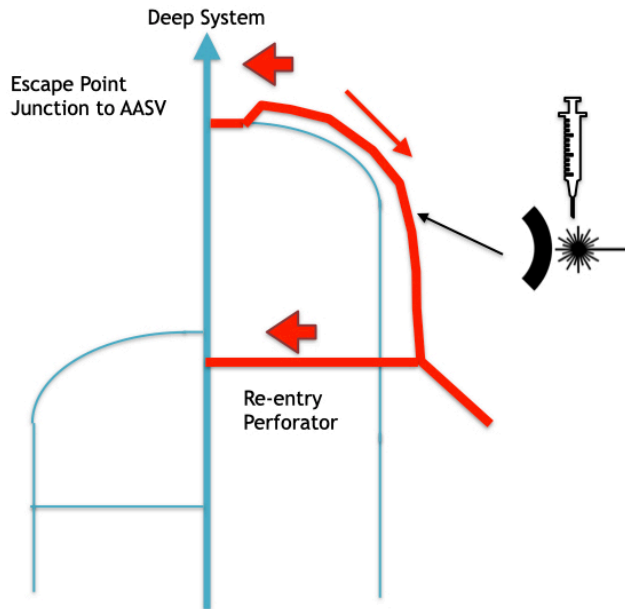
We treat CEAP class C1-C3 patients by sclerotherapy of collaterals according to sparing saphenous veins principles CHIVA principles as previously described 2,4,5. We have adapted a technique widely used in Brazil to treat smaller veins¹. The procedure comprises using Nd-YAG laser 1064 shots at the collateral prior to the injection of sclerosing agent Dextrose 75% to create a synergistic effect. The laser causes contraction of the vein and minimizes the volume of Dextrose. We use a spot size of 3-9 mm depending on the vein size. The < 0.10 mm use 3mm spot, the <2.5mm use the 6mm spot and the >2.5 mm collaterals use 9mm

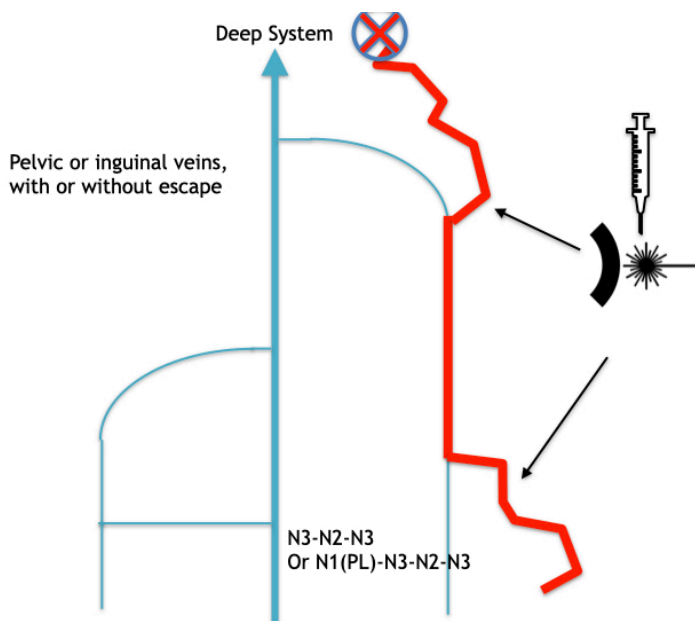
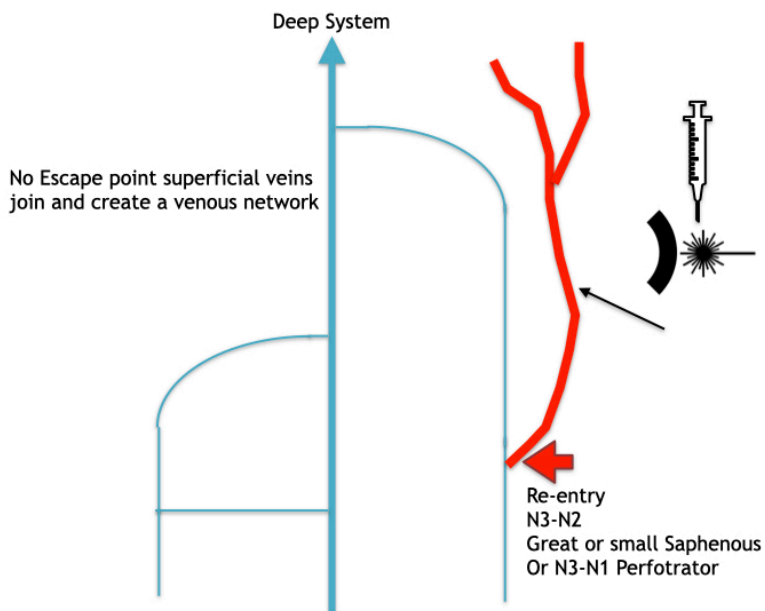
spot. The fluency varies from 40 to 90 J/cm and pulse range 15-50 Msec. The local application of cool air is used to minimize pain and to protect skin damage, as well. After treatment of a few centimeters with the laser, we inject cold 75% dextrose in the portions of the vein still open. Deep superficial thigh veins receive eco-guided Dextrose injection and laser/dextrose in the superficial part. Both the injections and laser follow the roadmap of augmented reality equipment and previous ultrasound map ⁶. If the collaterals are large we use roll cotton to keep focal compression and elastic stocking class 2 to help diminish local thrombi and skin marks.

The clinical use of hemodynamic sclerotherapy is primarily for Shunt type 2 patients, shunt type 6 and accessory saphenous vein. A normal size saphenous vein with reflux or no saphenous vein involvement are suitable for this procedure. The size of the collaterals is not so relevant, but we make focal and general compression after the procedure for large veins larger than 2.5 mm. It is important to mention that we have been using this procedure mostly for C1 and C2 patients that present to the office with esthetic complaints and that the long-term results are not available. Although, we consider that numerous cases that have their saphenous vein ablated for esthetic problems would be better off with hemodynamic sclerotherapy. The cases with symptoms and greater saphenous involvement are a different case and warrant operations.









Discussion

The prevalence of telangiectasias in the general population is high and symptoms may be present in these patients^{7,8}. Thus, treatment and ultrasound examination may help CEAP Class C0-C3 patients, if simpler non-intervention treatments fail. Many patients with esthetic-only complaints and CEAP class C1-C3 present reflux detected in a duplex scan. Engelhorn et al. found that women with telangiectasias (CEAP Class C1) had saphenous vein reflux detected in 46% of their extremities, 78% of them complaining of venous symptoms⁹. Patients with only esthetic complaints may also benefit from simpler treatments not eliminating the saphenous vein. The hemodynamic laser + sclerotherapy shows us that the reflux per se is not a sine qua non justification to saphenous ablation. Hemodynamic sclerotherapy may achieve good esthetic/clinical results and does eliminate symptoms as controls reflux at the microvenous valves. In the low CEAP cases, the elimination of saphenous collaterals aspirating blood or causing focal venous hypertension may prevent the venous system from deteriorating or even reverting reflux of the saphenous vein sometimes.

The success of flow reversal in the saphenous vein depends on a few factors. The competence of the terminal femoral valve is important because it breaks the height of the column of blood. The patients with important femoral reflux may not reverse the flow after treatment of the collaterals. Physical characteristics of the vein also play a role, as we observed that the longer and larger the incompetent saphenous vein the more difficult to correct the reflux, and the longer and larger the competent vein distal the easier to revert flow.

Direct saphenous perforators are also decisive to maintain reflux. The successful reversion of flow in the great saphenous vein is impressive, but patients experience an improvement of symptoms with sclerotherapy even if reflux remains ⁵.

References

1. Miyake RK. Cryo-laser and cryo-sclerotherapy guided by Augmented Reality: Report of 140 Cases. *Phlebologie* [Internet]. 2014 May 4;43(05):257–61. Available from: <http://www.thieme-connect.de/DOI/DOI?10.12687/phleb2218-5-2014>
2. Franceschi C, Cappelli M, Ermini S, Giancesini S, Mendoza E, Passariello F, et al. CHIVA: hemodynamic concept, strategy and results. *Int Angiol* [Internet]. 2016 Feb;35(1):8–30. Available from: <https://www.ncbi.nlm.nih.gov/pubmed/26044838>
3. Labropoulos N, Giannoukas AD, Delis K, Mansour MA, Kang SS, Nicolaides AN, et al. Where does venous reflux start? *J Vasc Surg* [Internet]. 1997 Nov;26(5):736–42. Available from: [http://dx.doi.org/10.1016/s0741-5214\(97\)70084-3](http://dx.doi.org/10.1016/s0741-5214(97)70084-3)
4. Faccini FP, Ermini S, Franceschi C. CHIVA to treat saphenous vein insufficiency in chronic venous disease: characteristics and results. *J vasc bras* [Internet]. 2019 [cited 2019 Mar 15];18. Available from: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1677-54492019000100401&lng=en&tlng=en
5. Mendoza E, Cappelli M. Sclerotherapy technique in CHIVA strategy. *Phlebologie* [Internet]. 2018 Jan 4 [cited 2019 Aug 26];46(02):66–74. Available from: <https://www.thieme-connect.com/products/ejournals/abstract/10.12687/phleb2355-2-2017>
6. Ganesh S. Depth and Size Limits for the Visibility of Veins Using the VeinViewer Imaging System [Internet]. University of Tennessee Health Science Center; 2007 [cited 2020 May 6]. Available from: <https://dc.uthsc.edu/dissertations/94/>

7. Fowkes FG, Evans CJ, Lee AJ. Prevalence and risk factors of chronic venous insufficiency. *Angiology* [Internet]. 2001 Aug;52 Suppl 1:S5–15. Available from: <http://dx.doi.org/10.1177/0003319701052001S02>
8. Zimmet SE. Sclerotherapy treatment of telangiectasias and varicose veins. *Tech Vasc Interv Radiol* [Internet]. 2003 Sep;6(3):116–20. Available from: [http://dx.doi.org/10.1053/s1089-2516\(03\)00044-1](http://dx.doi.org/10.1053/s1089-2516(03)00044-1)
9. Engelhorn CA, Engelhorn ALV, Cassou MF, Salles-Cunha S. Patterns of saphenous venous reflux in women presenting with lower extremity telangiectasias. *Dermatol Surg* [Internet]. 2007 Mar;33(3):282–8. Available from: <http://dx.doi.org/10.1111/j.1524-4725.2007.33063.x>

16 - ASVAL

Claudia Carvalho Sathler-Melo

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Introduction

The XXI century medical science outlines an exponential expansion of knowledge and paradigm disruptions. However, we might have forgotten to consider the principles of patient care, such as core problems of varicose vein treatments: “The recurrence of varicose veins is high as time goes by”. The morbidity of Chronic Venous Disease (CVD) is relevant, including leg ulcers, and it can lead to severe social and economic impacts. Therefore, we can do another statement: “Medical intervention in patients with advanced CVD (c4-c6) is justifiable”.

After these statements, we can ask: “Are medical interventions justified in patients with mild-to-moderate CVD (c1-c3)? What would be the mid-term/long-term results if we just let patients with no treatment? After 10 years, how much problems would we have?

Published data show that the number of patients submitted to thermal ablations has grown exponentially since 2012. The number of procedures is inversely proportional to the number of specialists trained in vein diseases. Patients with few symptoms are being massively treated by cardiologists and general surgeons¹. Analyzing data carefully, even when results in the short term are

better than traditional options like high ligation/stripping, in the long term, those ablations do not interrupt the natural evolution of disease. The long-term results cannot show an obvious recurrence benefit. If patients have few symptoms and procedures are offered to mitigate the future expression of varicose veins, we have a dilemma.

Fortunately, consciousness about this issue is getting stronger and debates to better understand the role of Saphenous Veins (SV) in the CVD have received more and more attention. First, concerning CVD, it is crucial to separate 2 groups: patients with mild-to-moderate disease (c1-c3) from patients with severe disease (c4-c6). Second, if we can admit that there is no perfect method to interrupt the natural evolution of varicose veins, we must not use aggressive or “radical” interventions to treat patients with mild-to-moderate disease (c1-c3). Sparing the saphenous vein is a worthy form to escape from naive interventionism and, probably, to reduce eventual iatrogenic effects like worsen recurrence ². Last, but not least, better than having thousands of occluded veins over the years, we should pursue global benefits to our patients meaning less invasiveness, clinical, cosmetic and ultrasonographic improvement, fewer costs and less recurrence in the long term.

Sparing Saphenous Veins Strategies

There are two published options to spare Saphenous Veins, CHIVA (Cure Conservatrice et Hemodynamique de l'Insuffisance Veineuse en Ambulatoire) and ASVAL (Ablation Sélective des Varices sous Anesthésie Locale). The long-term results of these techniques have been studied and tested against other methods. CHIVA's concepts, and strategies are the object of other chapters.

Thus, only some commentaries regarding the major differences between CHIVA and ASVAL are pertinent in this chapter.

Described by Franceschi in the late 1980s³, CHIVA was the first method to propose the preservation of the saphenous vein systematically. Franceschi et al. advocate to spare the saphenous vein with a more physiologic approach, aiming to minimize surgical trauma, risks and complications in venous surgery. The expertise in vascular ultrasound and venous hemodynamic is mandatory to elaborate the strategy before the procedure. The most important fundamentals of CHIVA are to detect and disconnect the pathological venous-venous shunts and to reduce the length of reflux venous segments without extracting the veins. CHIVA treats all classes of disease (C1 to C6) using the theory of reflux created by shunts.

ASVAL postulates that reflux can originate from epifascial veins and, many times, ascends to reach SV until junctions, in an advanced stage of disease. Another difference is selectiveness, as patients must have the “varicose reservoir” which is removed. Besides, we should not apply ASVAL to patients with reflux in a total extension of the saphenous vein. CHIVA and ASVAL use local anesthesia and ambulatory settings.

Literature mentions that CHIVA offers many tricky points: necessity of advanced ultrasound training, various presentations implying unique approaches with a long learning curve and, consequently, some confusion about its results. ASVAL is simpler but not simplistic, as we are going to discover further...

ASVAL

The ASVAL technique (**A**blation **S**élective des **V**arices sous **A**nesthésie **L**ocale) proposes that isolated microphlebectomies may treat the patient without saphenous vein ablation. Pittaluga and Chastanet proposed it in 2005, questioning the descending theory concepts of reflux and most current treatments that eliminate or destroy the saphenous vein. Many studies are challenging that explanation for reflux origin, starting from junctions and going down to the ankle level at the saphenous trunks^{4,5,6}. Many reasons give support to the belief some cases of reflux start at epifascial veins. The veins are weaker than saphenous veins and dilate more easily. Then, the dilation and reflux progresses ascending to the saphenous vein in advanced stages of disease. Another relevant aspect is that venous wall changes would justify flow abnormalities before valves dysfunction^{7,8}.

Taking this into consideration, we can treat varicose epifascial veins to stop reflux in saphenous veins or, at least, to minimize it. One can adopt this strategy in most patients belonging to initial CEAP clinical classes (C2 and C3), considering they show a segmental pattern of reflux without terminal valve reflux in most cases⁹. Worthy of note, as highlighted before, is the importance of ASVAL *as the only published tactic that does not touch the saphenous vein*, meanwhile it can abolish reflux or reduce its impact on them.

Sparing saphenous veins may be crucial to attenuate recurrence of varicose veins and degeneration of the saphenous vein after the procedure. A study has shown that tributary resection may prevent saphenous vein degeneration¹⁰. Saphenous sparing

techniques may have fewer recurrence of varicose veins in the long term ¹¹. Secondly, we still preserve a graft for coronary bypasses. ASVAL is performed for over 10 years and has good clinical and cosmetic results in prospective observational studies ^{12,13,14}.

The aim of this chapter is to offer a detailed description of this approach and help the reader select and treat these patients.

The Concept of ASVAL

Pathophysiology of Varicose Veins

The ancient question, a chicken and egg dilemma, might have been solved before any treatment for varicose veins: Where does venous reflux start? Does the function of valves fail or there is an impairment of venous wall, firstly? Unfortunately, we do not have the ultimate answer to this issue, but only presumptions ¹⁵.

However, there are excellent reasons to believe varicosities could stem in minor veins, outside the saphenous compartment. In a standing position, the pressure is higher at the lower part of the limb, reaching 90 mm Hg at the ankle when the valves are open. These veins may remain epifascial, creating a dilated, refluxive, or stagnant venous network. When this refluxive network becomes large enough, it could create a filling effect in the intra-fascial saphenous vein. Afterwards, alleged differences of pressure would create a gradient, favoring decompensation of the saphenous wall. The more advanced is the disease, the more the extension up the saphenous vein, reaching the saphenofemoral or popliteal junction, eventually. The saphenous vein is the superficial vein with the thickest and most muscular wall. Because of its

double fascia protection, it would be the last vein to experience decompensation as varicose disease progresses. The theory of descending progression dates back to the seventh century and was explained scientifically in 1963 by Ludbrook and Beale ⁵. Many publications query this theory. Color-Doppler ultrasound made it possible to understand venous hemodynamic in real-time and to suppose the possibility of local or multifocal early distal evolution, sometimes ascending or antegrade ¹⁶. Several authors have reported that the ostial valve is frequently competent (>50%) when there is trunk reflux.

Another additional aspirating reflux source would come from the vast territory of micro-veins dotted by micro-valves. The Skin changes of chronic venous disease relate to these micro-valves dysfunction. That vast forest of invisible tiny vessels could transfer abnormal pressure throughout six levels of branches, reaching the saphenous vein at the last level ¹⁷.

Summarizing, If there is no saphenous reflux, early treatment of varicose veins might be useful to prevent it spreading to the saphenous vein. If reflux starts at the periphery and advances to impair the saphenous vein, why should we destroy it? On the opposite, we should treat the “varicose reservoir” to ease undue overcharge at the saphenous system. Results expected are reduction of vein diameters and in reflux velocity or even abolishment of it ¹³.

Saphenous sparing would not be possible using ASVAL principles when saphenous reflux extends in the entire trunk. This approach involves venous reservoir and offers better results in patients with CEAP (C2 and C3). Authors have properly named it the ‘à la carte’ treatment, fitting every singular patient.

The main argument in favor of this saphenous sparing approach is the harmful effect that resection of the saphenous vein has on the long-term progression of venous insufficiency¹⁰. The saphenous vein plays a physiological role in superficial drainage, besides its availability as revascularization conduit if needed.

Selection of Patients Eligible for ASVAL

As mentioned before, ASVAL is not for some patients with advanced stage of venous insufficiency. CHIVA was designed to all patients in all clinical classes. To someone, other options would include saphenous thermal or chemical ablation. The criteria below will guide the selection process to determine the patients that would benefit from ASVAL.

Extent of the Varicosities

Studies have underlined the relevance of the extent of the varicose reservoir as a determinant factor for the hemodynamic and clinical efficiency of ASVAL ¹². Authors have divided the extent of the varicose reservoir according to the number of zones to be treated by phlebectomy, with each limb divided into up to 32 zones in the preoperative clinical mapping. Each limb is divided into four surface areas (anterior, posterior, lateral, and medial), and then each surface area divided into eight zones: the thigh into three zones (the upper third, middle third, and lower third), the calf into three zones (the upper third, middle third, and lower third), plus one zone for the knee, and one zone for the foot. This arrangement reflects their clinical examination technique, in which they examine each lower limb in a standing position, from the front, from the back, and from each of its profiles (medial and lateral). There is a significant linear trend between the outcomes after ASVAL and the number of zones

to treat: if this number is above seven, the abolition of the saphenous reflux was 6.81 times and a symptom relief was 2.91 times more likely.

Ultrasound Duplex Preoperative Assessment

The duplex ultrasound with the patient standing up has a paramount role in the care of varicose vein patients. The examination with the patient lying down has lowered, and it can impair valve closure¹⁸. Another important maneuver is the reflux reversibility test, that should evaluate patients with saphenous vein reflux draining to a principal tributary at the thigh. The test comprises positioning the ultrasound probe at the insertion point of the tributary in the saphenous vein and moving it 5 cm up in the saphenous vein. Then, we should test reflux at this point with and without compression of the tributary (occlude it without saphenous occlusion). If the reflux disappears with tributary compression, we consider the reversibility test as positive. A study reported the value of this test on 293 lower limbs: the positive predictive value of the reversibility test for the abolition of reflux of the great saphenous vein was 95.7% and 94.7% at 1 and 2 years of follow-up¹⁹. The negative predictive value was weak at 36% and 14% at 1 and 2 years of follow-up, and the preoperative positivity of the reversibility test did not have any correlation with the symptom relief or the cosmetic improvement. It means that if the positivity of the test is a major criterion to preserve the saphenous vein in ASVAL technique. This does not mean that a negative test is a reason to eliminate it. We observed that even when the reversibility test is negative, abolition of the saphenous reflux, cosmetic improvement, and/or symptom relief can occur. This is probably because the test is not technically workable in the presence of multiple varicose tributaries.

Phlebectomy Reflux Elimination Success Test (PREST) Prediction Model

Biemans et al.¹⁴ have reported a PREST prediction model including CEAP classification, number of reflux segments, saphenous diameter (above the tributary), and reflux elimination test result. This model helps to predict the probability of restoring saphenous competence to a given preoperative score. For example, for patients with 14 points, saphenous reflux in one segment (3 points), CEAP C2 (3 points), positive reflux elimination test result (2 points), and saphenous vein diameter of 5 mm (6 points), the model can predict that phlebectomy will be effective in 90% of patients.

Other Criteria

A study has reported that a patient showing reflux in the entire saphenous vein (thigh to distal leg) is not eligible for ASVAL¹². We should also consider the gestational history of the patients. A study reported the benefit of ASVAL for nulliparous patients for the reduction of complexity, signs, and symptoms if a varicose vein recurs after pregnancy²⁰. The young age, initial clinical classes (c2-c3) and the absence of symptoms with a cosmetic concern are also criteria that plead in favor of the preservation of the saphenous vein.

Technique

Skin Marking

The skin marking before the surgery is mandatory to perform a thorough removal of the venous reservoir. We have highlighted that the removal of a large venous reservoir is the key to get a good clinical

and hemodynamic outcome after ASVAL¹². It also diminishes the risk of lymphatic complication after varicose vein surgery.

Anesthesia

The administration of tumescent local anesthesia is essential for ASVAL. It is a very effective anesthesia, and it reduces dramatically the bleeding because of the subcutaneous high pressure caused by the infiltration. In addition, the volume of the mixture leads to a hydro dissection of the perivenous tissue facilitating the extraction of the vein. It gives the surgeon excellent comfort for removing all sizes of varicose veins. Some report that using isotonic bicarbonate instead of saline solution would improve further the efficiency of the lidocaine and allow reducing the total amount of lidocaine used. This allows us to inject larger volumes of tumescence and therefore to treat larger surfaces of the lower limb²¹. Since 2008, we have used a mixture of 500 cc isotonic bicarbonate combined with 14 cc of 1% lidocaine and 1% epinephrine. As we are far below from the toxic doses, we don't have any restriction regarding the amount of mixture to infiltrate. We use an infiltrating pump to get a homogenous infiltration, but we could also use a set of syringes. The infiltration is done around the vein and parallel to the skin with a 21-Gauge needle at a 45° angle, making a back-and-forth movement to decrease the pain during the injection by decreasing the local pressure. We start the injection at one side, and it progresses side by side, each new stick being done in a previously infiltrated area to avoid any pain. One can use a topical anesthetic besides tumescent local anesthesia to decrease the pain of the first stick, but it is not essential.

Microsurgery

Using loops is mandatory to remove the varicose veins by microphlebectomy. We use a 2X350 magnification to be precise enough without losing the peripheral vision. The incisions are done with a 18-gauge needle. Depending on the characteristics of the skin and the vein size, we may use a 21- or 25-gauge needle. The bevel of the needle makes a flap on the skin that facilitates the penetration of the hook through the skin and gives an excellent cosmetic result. The purpose of the flap is also to make the skin adaptable to the vein size. If the vein size is large, the skin will enlarge easily because of the flap. As it is a tangential and irregular flap, the skin healing will be less visible, contrary to a perpendicular incision performed with a blade which makes the scars more visible.

The smaller the hook is, the better the cosmetic result will be. In our experience, the best tool is the Muller hook n°0. The phlebectomy should be atraumatic and with a precise skin marking that enables a micro-incision in front of the vein, avoiding scratching the subcutaneous tissues to get the veins. It is recommended to avoid leaving a piece of VVs to be as efficient as possible and to get the best cosmetic result since it limits the risk of staining. One important trick is to cut the fibrotic tissue around the vein. We easily cut this fibrotic tissue on the hook with a blade N°11, using the loops. The division of the fibrotic tissue facilitates the extraction of the vein and decreases the risk of it breaking during the pullout, which would prolong the procedure. Vein breaking also poses a risk of bleeding and pigmentation if we leave a remaining piece of vein under the skin. The ligation of

connected veins is essential to decrease the bruising and to get the best cosmetic results. Finishing meticulously all the steps improves the quality of the healing and improves the return to daily activities.

Results

The follow-up (12, 24, 36, and 48 months) after an ASVAL procedure shows freedom of saphenous vein reflux in 69.2%, 68.7%, 68.0%, and 66.3%, respectively, improvement of symptoms in 84.2%, 83.4%, 81.4%, and 78.0%, respectively, improvement of esthetics in 93.2%, 92.7%, 91.6% and 89.9%.

Postoperative Management

Using stitches is unnecessary since we perform the incisions with the 18-gauge needle. We recommend use of SteriStrips to avoid blisters. The walking is immediately at the end of the procedure, and the patient could leave the hospital/office 1 h after. We encourage the patients to walk at least 2 h daily until postoperative day 8. They also can resume exercise activities the day of the surgery and swim the day after if one applies a protective film spray on the SteriStrip. In our experience, wearing a stocking is unnecessary after the first postoperative day following microphlebectomy²².

Conclusion

The ASVAL technique calls into question the usual approach to treat the saphenous vein by high ligation and stripping or by endothermal or chemical ablation in the presence of varicose veins with saphenous reflux. It leads to the opposite

concept of an individualized ‘à la carte’ treatment. Every patient has a different clinical and hemodynamic situation of the disease at the time of treatment. One cannot match all patients with diverse presentations to a ‘one size fits all’ treatment as in ablative strategy. We have now at our disposal simple tools to test the patients, select the excellent indications, and perform properly the ASVAL technique.

The microphlebectomy technique used for performing ASVAL is a mini-invasive revisited technique of phlebectomies described many years ago, with an addition of new tools, new tips and tricks enabling to reach the highest clinical and cosmetic patient expectation. Moreover, we systematically improve venous hemodynamic parameters and can keep results in the short/mid/long term in most patients²³.

References

1. Crawford JM, Gasparis A, Almeida J, Elias S, Wakefield T, Lal BK, et al. A review of United States endovenous ablation practice trends from the Medicare Data Utilization and Payment Database. *J Vasc Surg Venous Lymphat Disord* [Internet]. 2019 Jul;7(4):471–9. Available from: <http://dx.doi.org/10.1016/j.jvsv.2019.01.066>
2. Bellmunt-Montoya S, Escribano JM, Dilme J, Martinez-Zapata MJ. CHIVA method for the treatment of chronic venous insufficiency. *Cochrane Database Syst Rev* [Internet]. 2015;(6). Available from: <https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD009648.pub3/abstract>
3. Franceschi C. Theory and Practice of the: Conservative Haemodynamic Cure of Incompetent and Varicose Veins in Ambulatory Patients [Internet]. Éditions de l’Armançon; 1993. 126 p. Available from: https://play.google.com/store/books/details?id=j_u_NwAACAAJ

4. Labropoulos N, Leon L, Kwon S, Tassiopoulos A, Gonzalez-Fajardo JA, Kang SS, et al. Study of the venous reflux progression. *J Vasc Surg* [Internet]. 2005 Feb;41(2):291–5. Available from: <http://dx.doi.org/10.1016/j.jvs.2004.11.014>
5. Caggiati A, Rosi C, Heyn R, Franceschini M, Acconcia MC. Age-related variations of varicose veins anatomy. *J Vasc Surg* [Internet]. 2006 Dec;44(6):1291–5. Available from: <http://dx.doi.org/10.1016/j.jvs.2006.07.040>
6. Bernardini E, De Rango P, Piccioli R, Bisacci C, Pagliuca V, Genovese G, et al. Development of primary superficial venous insufficiency: the ascending theory. Observational and hemodynamic data from a 9-year experience. *Ann Vasc Surg* [Internet]. 2010 Aug;24(6):709–20. Available from: <http://dx.doi.org/10.1016/j.avsg.2010.01.011>
7. Porto LC, da Silveira PR, de Carvalho JJ, Panico MD. Connective tissue accumulation in the muscle layer in normal and varicose saphenous veins. *Angiology* [Internet]. 1995 Mar;46(3):243–9. Available from: <http://dx.doi.org/10.1177/000331979504600308>
8. Raffetto JD, Khalil RA. Mechanisms of varicose vein formation: valve dysfunction and wall dilation. *Phlebology* [Internet]. 2008;23(2):85–98. Available from: <http://dx.doi.org/10.1258/phleb.2007.007027>
9. Engelhorn CA, Engelhorn ALV, Cassou MF, Salles-Cunha SX. Patterns of saphenous reflux in women with primary varicose veins. *J Vasc Surg* [Internet]. 2005 Apr;41(4):645–51. Available from: <http://dx.doi.org/10.1016/j.jvs.2004.12.051>
10. Creton D. Diameter reduction of the proximal long saphenous vein after ablation of a distal incompetent tributary. *Dermatol Surg* [Internet]. 1999 May;25(5):394–7. Available from: <http://dx.doi.org/10.1046/j.1524-4725.1999.08269.x>
11. Parés JO, Juan J, Tellez R, Mata A, Moreno C, Quer FX, et al. Varicose vein surgery: stripping versus the CHIVA method: a randomized controlled trial. *Ann Surg* [Internet]. 2010 Apr;251(4):624–31. Available from: <http://dx.doi.org/10.1097/SLA.0b013e3181d0d0a3>

12. Pittaluga P, Chastanet S, Rea B, Barbe R. Midterm results of the surgical treatment of varices by phlebectomy with conservation of a refluxing saphenous vein. *J Vasc Surg* [Internet]. 2009 Jul;50(1):107–18. Available from: <http://dx.doi.org/10.1016/j.jvs.2008.12.067>
13. Pittaluga P, Chastanet S, Locret T, Barbe R. The effect of isolated phlebectomy on reflux and diameter of the great saphenous vein: a prospective study. *Eur J Vasc Endovasc Surg* [Internet]. 2010 Jul;40(1):122–8. Available from: <http://dx.doi.org/10.1016/j.ejvs.2010.03.031>
14. Biemans AAM, van den Bos RR, Hollestein LM, Maessen-Visch MB, Vergouwe Y, Neumann HAM, et al. The effect of single phlebectomies of a large varicose tributary on great saphenous vein reflux. *J Vasc Surg Venous Lymphat Disord* [Internet]. 2014 Apr;2(2):179–87. Available from: <http://dx.doi.org/10.1016/j.jvsv.2013.11.003>
15. Labropoulos N, Giannoukas AD, Delis K, Mansour MA, Kang SS, Nicolaides AN, et al. Where does venous reflux start? *J Vasc Surg* [Internet]. 1997 Nov;26(5):736–42. Available from: [http://dx.doi.org/10.1016/s0741-5214\(97\)70084-3](http://dx.doi.org/10.1016/s0741-5214(97)70084-3)
16. Labropoulos N, Kokkosis AA, Spentzouris G, Gasparis AP, Tassiopoulos AK. The distribution and significance of varicosities in the saphenous trunks. *J Vasc Surg* [Internet]. 2010 Jan;51(1):96–103. Available from: <http://dx.doi.org/10.1016/j.jvs.2009.08.069>
17. Vincent JR, Jones GT, Hill GB, van Rij AM. Failure of microvenous valves in small superficial veins is a key to the skin changes of venous insufficiency. *J Vasc Surg* [Internet]. 2011 Dec;54(6 Suppl):62S – 9S.e1–3. Available from: <http://dx.doi.org/10.1016/j.jvs.2011.06.085>
18. Masuda EM, Kistner RL, Eklof B. Prospective study of duplex scanning for venous reflux: comparison of Valsalva and pneumatic cuff techniques in the reverse Trendelenburg and standing positions. *J Vasc Surg* [Internet]. 1994 Nov;20(5):711–20. Available from: [http://dx.doi.org/10.1016/s0741-5214\(94\)70158-x](http://dx.doi.org/10.1016/s0741-5214(94)70158-x)
19. Chastanet S, Pittaluga P. Influence of the competence of the saphenofemoral junction on the mode of treatment of varicose

veins by surgery. *Phlebology* [Internet]. 2014 May;29(1 suppl):61–5. Available from: <http://dx.doi.org/10.1177/0268355514529207>

20. Pittaluga P, Chastagnet S. Varicose Vein Recurrence After Pregnancy: Influence of The Preservation of The Saphenous Vein in Nullipara Patients. *Blucher Medical Proceedings* [Internet]. 2014;1(1):81–2. Available from: <http://www.proceedings.blucher.com.br/article-details/varicose-vein-recurrence-after-pregnancy-influence-of-the-preservation-of-the-saphenous-vein-in-nullipara-patients-9419>
21. Creton D, Réa B, Pittaluga P, Chastagnet S, Allaert FA. Evaluation of the pain in varicose vein surgery under tumescent local anaesthesia using sodium bicarbonate as excipient without any intravenous sedation. *Phlebology* [Internet]. 2012 Oct;27(7):368–73. Available from: <http://dx.doi.org/10.1258/phleb.2011.011026>
22. Pittaluga P, Chastagnet S. Value of postoperative compression after mini-invasive surgical treatment of varicose veins. *J Vasc Surg Venous Lymphat Disord* [Internet]. 2013 Oct;1(4):385–91. Available from: <http://dx.doi.org/10.1016/j.jvsv.2013.01.003>
23. Pittaluga P, Chastagnet S. Treatment of varicose veins by ASVAL: results at 10 years. *Ann Vasc Surg* [Internet]. 2017;38:e10. Available from: https://www.researchgate.net/profile/Paul_Pittaluga/publication/323492247_Ten-Year_Outcomes_of_Treatment_of_Varicose_Veins_by_Ambulatory_Selective_Ablation_of_Varices_Under_Local_Anesthesia_ASVAL/links/5b250664aca272277fb4ece2/Ten-Year-Outcomes-of-Treatment-of-Varicose-Veins-by-Ambulatory-Selective-Ablation-of-Varices-Under-Local-Anesthesia-ASVAL.pdf

17 - CHIVA - The GSV for arterial bypass.

Roberto Delfrate

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There is a great debate about the treatment of the venous insufficiency of the lower limb, especially focused on the greater saphenous vein treatment. But not all the surgeons or angiologists know perfectly the histoarchitecture of the greater saphenous vein. So that many consider the incompetent great saphenous vein not suitable for a bypass if needed because of the degeneration of its venous wall. The saphenous CHIVA conservation aim is dual: to restore its drainage function whatever its flow direction provided an improvement of its pressure and flow content and preservation of the greater saphenous vein trunk considered suitable for potential future bypass¹⁻⁹. We know that 2-3% of patients treated for varicose veins will need an arterial by-pass¹⁰. Some studies confirm the saphenous vein with reflux is suitable for arterial by-pass¹¹⁻¹². 70% of varicose patients had venous segments eligible for coronary by-pass¹². Greater saphenous vein homograft prevails over the post stripping cryopreserved saphenous allografts 13-17. Therefore, if the greater saphenous veins preservation is a condition for a recurrence rate reduction, it is also of great interest as a potential venous graft.

Venous anatomy and histoarchitecture:

Renaut first described propulsive and receptive veins. Later Dubreuil and Payard proposed a more refined vein classification

considering histoarchitecture¹⁹: fibrous veins, fibrous-elastic veins, propulsive veins. The fibrous veins are not expandable, mainly composed of thick fibrous tissue without muscular fibers or elastic tissue, like the veins in the brain. The fibrous elastic veins contain elastic fibers in the media layer and also a few muscular fibers. The veins of the neck and the superior vena cava drain in the gravitational direction are typical examples. The veins below the diaphragm muscle and legs are propulsive veins and have a muscular fiber layer.

The great saphenous vein is a typical propulsive vein and is also the longest vein of the human body. Its hypoplasia occurs in 25% of varicose veins (fig1) and in 12% of healthy veins²⁰. Hypoplasia is the incomplete development of a vein or a part of it. It is less severe in degree than aplasia, and the hypoplastic vein has a reduced caliber with a normal structure. Aplasia is the lack of development of a vein or of a segment. “Venous aneurysms” are focal dilations of a vein with a caliber increase of at least 50% (fig.2)²¹. The great saphenous vein wall has three different layers: intima, media, and adventitia. It is located inside the two layers of the subcutaneous fascia and is recognizable in the ultrasound transversal section for the image of the Egyptian eye. This “saphenous eye” was first described by Bailly²². It has vessels in the adventitial layer, and also in the media layer between the smooth muscle fibers.

Figure 1

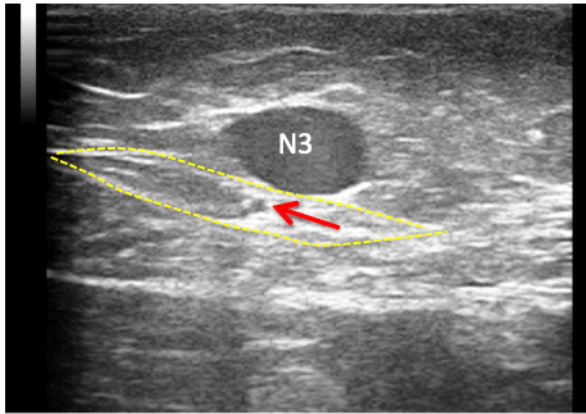


Figure 2



The smooth muscular fiber layer of propulsive veins increases with time. Chiarugi and Bucciante ¹⁹ showed the increase of the muscular fibers in the inferior cava vein and in the great saphenous veins during the lifetime (muscular hyperplasia and hypertrophy). In their opinion, this phenomenon was the consequence of the pressure work the vein did for a long time. Their study shows histological specimens in young and old people showing the difference of the muscular component in the media layer in both groups.

When the greater saphenous vein is incompetent, it becomes part of a shunt. A shunt is a group of veins overloaded by one or more escape points with an increase in the transmural pressure. An increase in the muscular fibers of the incompetent great saphenous vein is a consequence of the overload and is coherent with the Chiarugi-Bucciante hypothesis. Other studies confirm the aptitude of the smooth muscle cells to proliferate in response to an increase of the pressure work²³. The arterialization of the vein wall after arterial bypass in mice also confirms the phenomenon²⁴⁻²⁵.

Post CHIVA Saphenous Histoarchitecture:

To verify the histoarchitecture of the great saphenous vein preserved with the CHIVA strategy, histological specimens from a removed short segment of it were examined²⁶. We checked the histological specimens in a group of 22 patients at least 12 months after CHIVA. The patients needed a second procedure to fractionate the saphenous vein to further hydrostatic pressure column control (fig.3). We removed a short segment of great saphenous vein just below a perfectly draining direct non-terminal perforator, preserving the saphenous flow above. In these patients, the B-mode evaluation of the GSV performed before the surgery showed a normal vein wall, no segmental varicose dilations or signs of previous phlebitis (fig.4-5). I performed the first CHIVA procedure, ultrasound evaluation and second fragmentation procedure of all patients.

Figure 3

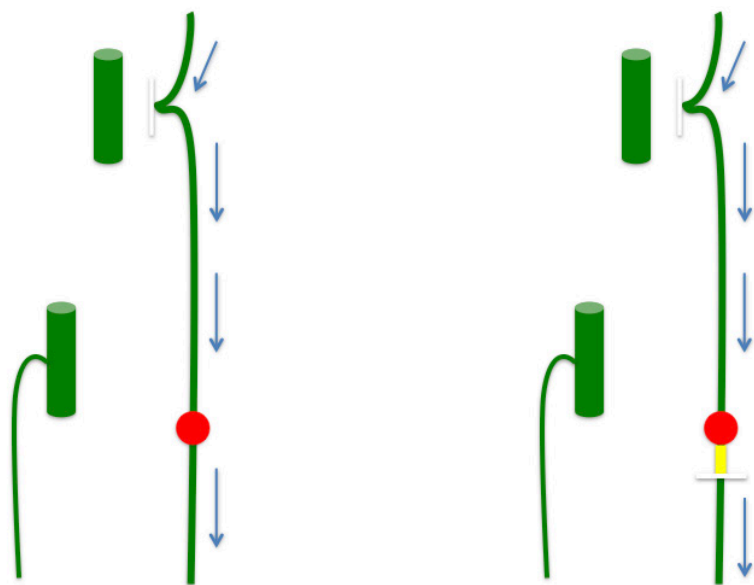


Figure 4

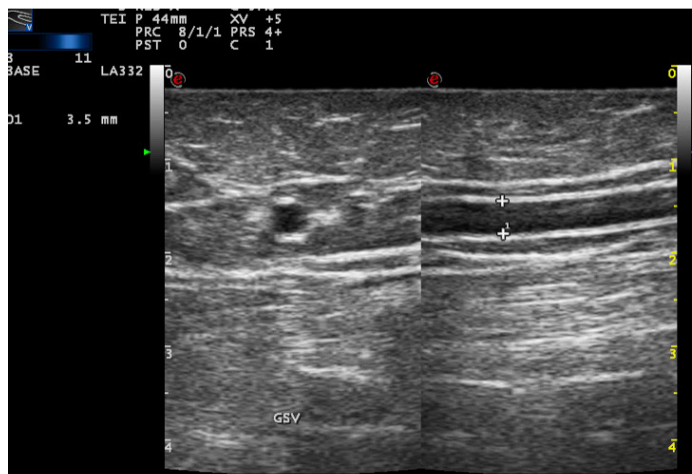
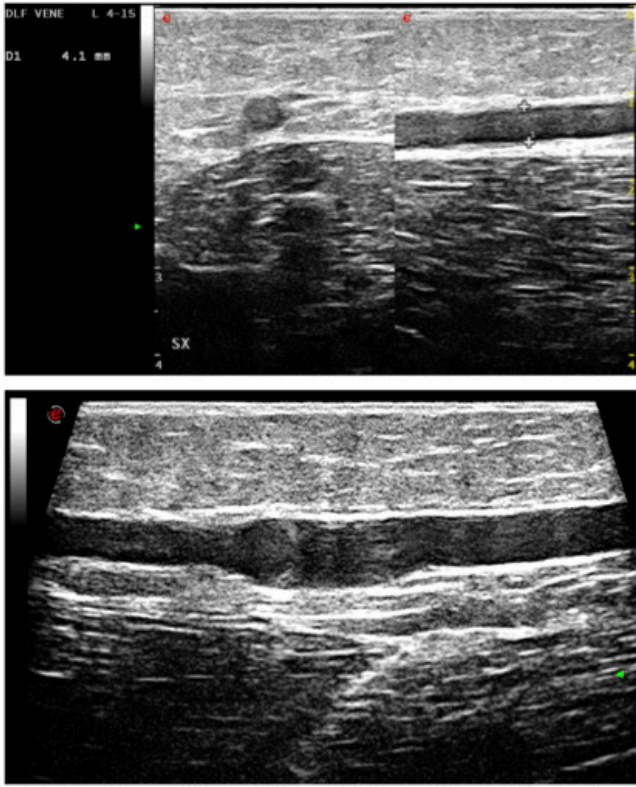


Figure 5

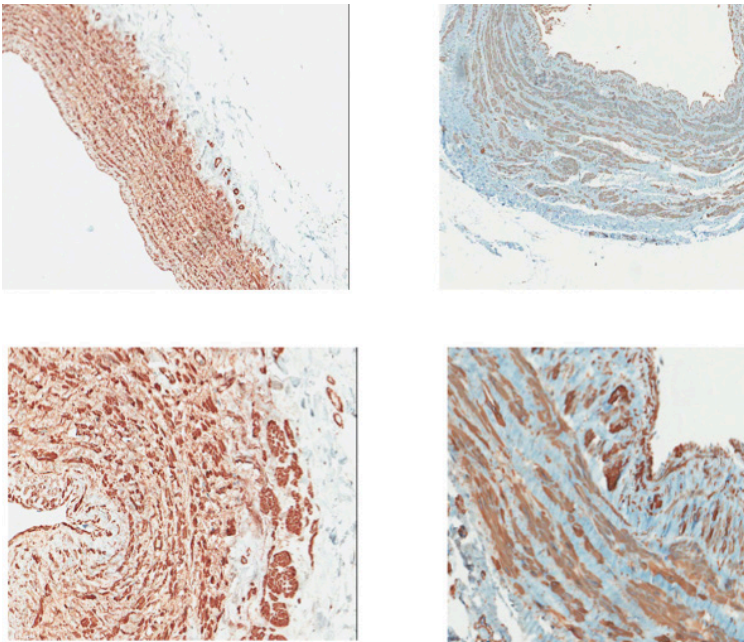


All 21 cases had perfectly maintained vein histoarchitecture (fig.6). The histological specimen showed a structure deterioration, compatible with the segmental venous enlarged aspect shown by the ultrasound in 1 case. The control group was 8 patients who had coronary bypass and a spare segment of saphenous vein analyzed. We observed an increase in the smooth muscle layer in the post-CHIVA saphenous vein as compared to the control group (fig.7). Hypertrophy and hyperplasia may be secondary to the increased pressure work to the saphenous vein. This observation is in line with those made by Chiarugi-Buccianti regarding the propulsive veins.

Figure 6

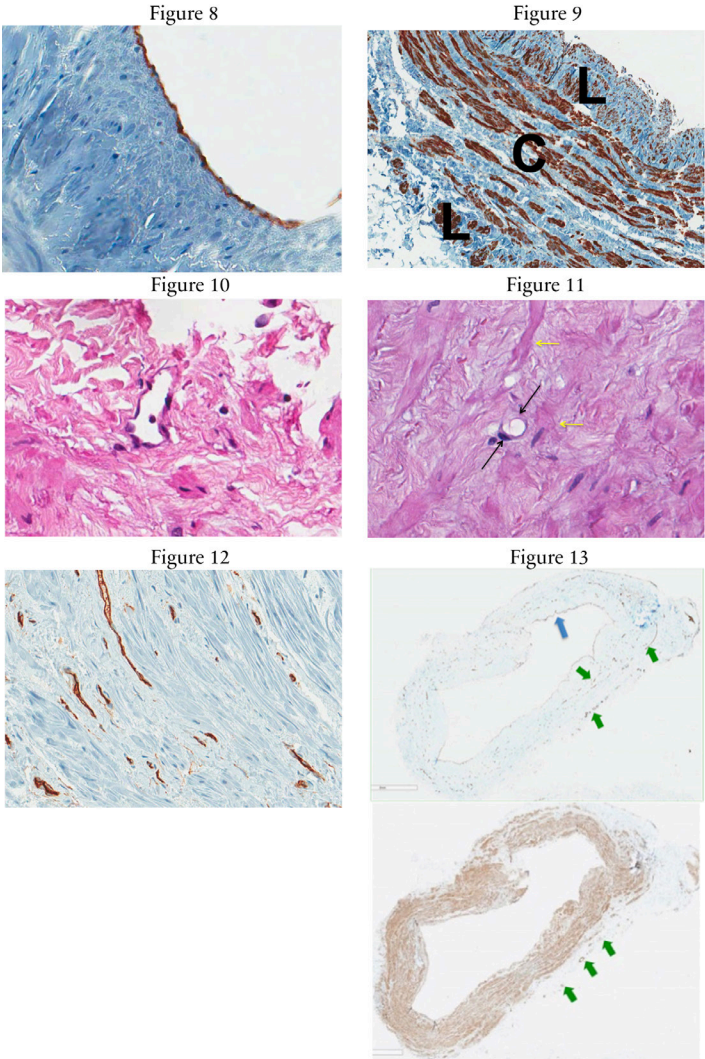


Figure 7



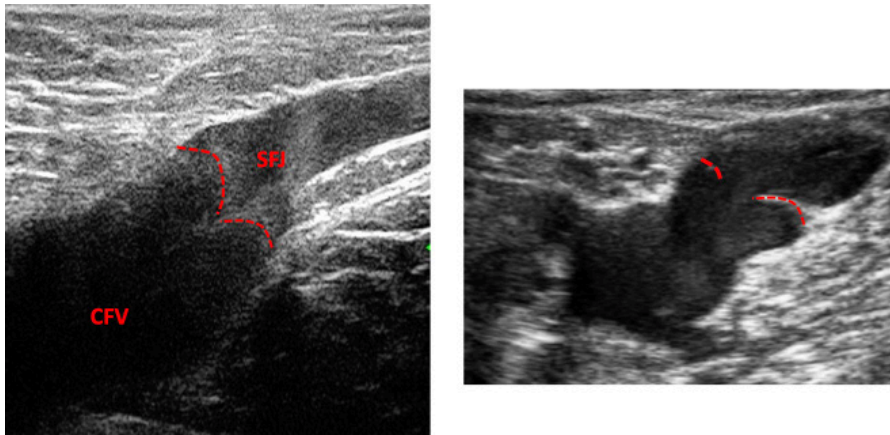
The post-CHIVA greater saphenous vein was morphologically and immunohistochemically examined by hematoxylin-eosin stain (H&E) and CD31, CD34, CD68, SMA, and Desmine antibodies. A normal endothelium internally covered all these vessels, lined in connective tissue from intima (fig.8). Zamboni et al. ²³ described the endothelium as a monolayer of endothelial cells with the long axis oriented according to the flow direction. They hypothesized a

change of orientation of the long axis in the presence of turbulent flow because of overload and inflammation. There are three different smooth muscle fibers to compose the muscle layer: the internal longitudinal, the medium circular, and the external longitudinal (fig.9). We observed hyperplasia and hypertrophy, but no inflammatory cells within the vessel layers in the samples one year after reducing transmural pressure.



We detected feeding capillaries in the media and adventitia layers (fig.10-11-12). These vasa venarum are particularly developed in the SFJ wall close to the terminal valve, maybe because they originate on the femoral side of the terminal valve (fig.13). This could explain neo-angiogenesis causing residual junction stump, especially with an ostial terminal valve (fig.14). We detected nerve fibers with H&E stain in the adventitia layer (fig.15). Sympathetic nerve fibers are present in the connective tissue surrounding the vein wall, in the adventitia, and also in the media and intima in the greater saphenous vein wall ²⁷. These authors hypothesized the sympathetic control of the smooth muscle fibers activity and of the vasa venarum tone. They highlight the unknown role of denervation on vein grafts implanted in the coronary arterial system.

Figure 14



We also analyzed the wall structure of the anterior accessory saphenous vein. This vein runs superficial to the muscle fascia in the upper third of the thigh, between the two layers of the subcutaneous fascia. The ultrasound appearance is like the classic egyptian eye, but its position is anterior to the greater saphenous vein and aligned with the underlying femoral vessels. The anterior accessory saphenous vein has all three wall layers

detectable, but the media has only internal longitudinal and external circular muscle layers (fig.16). It's a weaker vein respect the great saphenous vein.

Figure 15

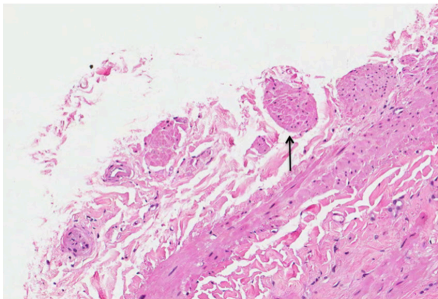
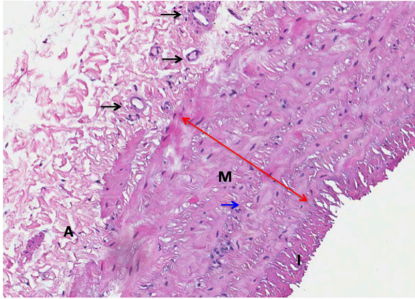


Figure 16



In conclusion, according to our results and corroborated by other studies ¹¹⁻¹², we can use the saphenous vein with reflux post-CHIVA for lower limb or coronary bypasses, if the B-mode appearance is regular (fig.17-20).

Figure 17

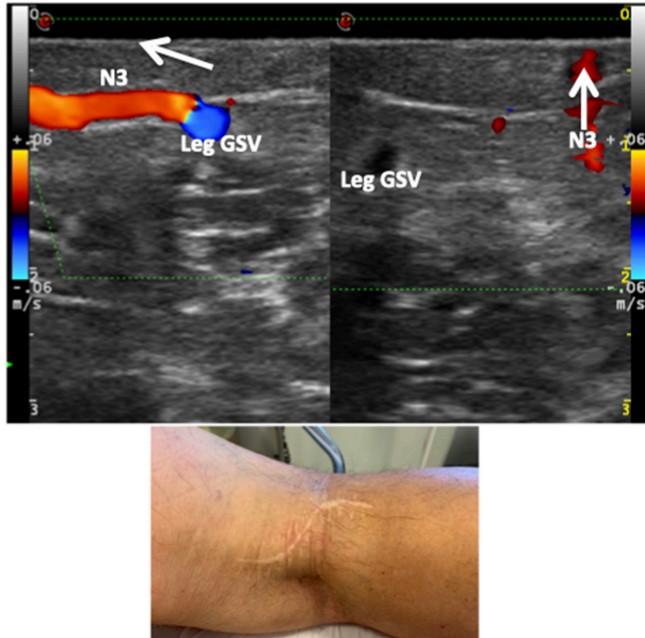


Figure 18

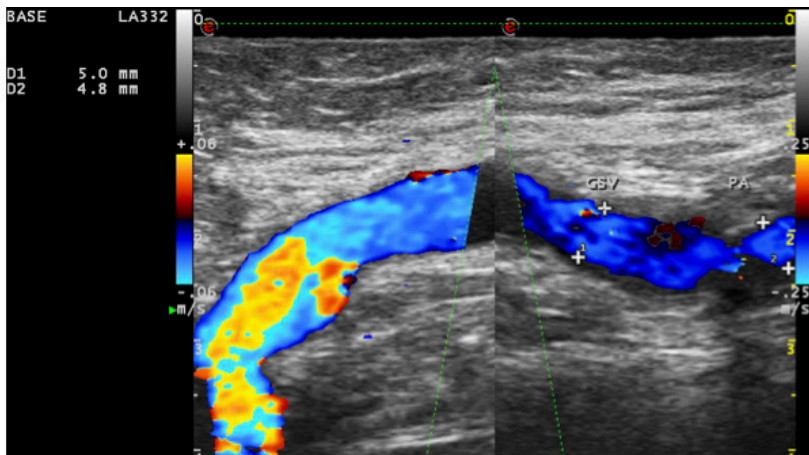
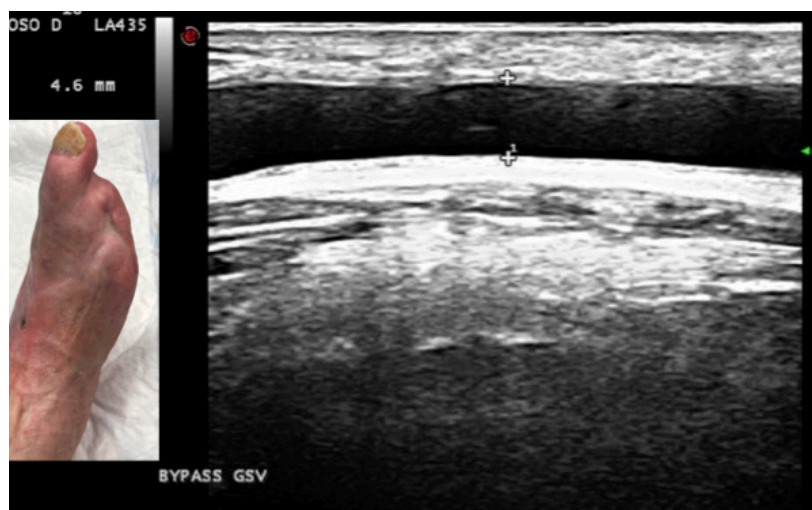


Figure 19



Figure 20



Vein wall, inflammation and venous insufficiency pathophysiology:

As it is well-known terminal nervous fibers from the sympathetic nervous system innervate the muscular layer. Venous insufficiency evolution relates to innervation changes and inflammatory phenomena. Regarding pathophysiology for the development of chronic venous insufficiency, the joint effect of the immune system and the sympathetic nervous system is a novel and complementary hypothesis. During the activation of the immune system a significant retraction of noradrenergic sympathetic nerves could occur²⁸⁻²⁹. This leads to an impairment in the sympathetic-mediated functions within the involved tissues. The local or immune cells (present because of cytokines and inflammation) releases semaphorins and neurotrophins. These molecules may cause the retraction neural effect. The α -adrenergic receptors expressed in smooth muscle cells control wall tone through sympathetic innervation³⁰.

Many studies support the existence of inflammatory phenomena associated with chronic venous insufficiency³¹⁻³³. The presence of cellular infiltrates may define inflammatory response, but also the existence of measurable proinflammatory cytokines. Our study of histological evaluation of the saphenous vein in chronic venous insufficiency showed that all layers of the vein are optically normal. Abnormalities in venous valves, reduced number of valves, and / or congenital weakness of the venous wall could cause hemodynamic changes in venous circulation. These changes cause local congestion and chronic venous dilation, hallmarks of chronic venous insufficiency. Evidence suggests that chronic venous insufficiency and local inflammatory phenomena relate to

retraction of noradrenergic sympathetic nerves. This contributes to a decrease in venous tone, congestion, and dilation. These hypotheses require and deserve further research.

References

- 1 Chastanet S, Pittaluga P. Ten-Year Outcomes of Treatment of Varicose Veins by Ambulatory Selective Ablation of Varices Under Local Anesthesia (ASVAL). *J Vasc Surg Venous and Lymphatic Disorders* March 2018. 6(2),289
- 2 Papakonstantinou NA, Baikoussis NG, Goudevenos J, Papadopoulos G, Apostolakis E. No touch technique of saphenous vein harvesting: Is great graft patency rate provided? *E. J Thorac Cardiovasc Surg*. 2015 Oct;150(4):880-8
- 3 Papakonstantinou NA, Baikoussis NG, Goudevenos J, Papadopoulos G, Apostolakis E. Novel no touch technique of saphenous vein harvesting: Is great graft patency rate provided? *Ann Card Anaesth*. 2016 Jul-Sep;19(3):481-8
- 4 Samano N, Geijer H, Liden M, Fremes S, Bodin L, Souza D. The no-touch saphenous vein for coronary artery bypass grafting maintains a patency, after 16 years, comparable to the left internal thoracic artery: a randomized trial.REGISTRATION:ClinicalTrials.gov NCT01686100. The American Association for Thoracic Surgery. Published by Elsevier Inc 2015
- 5 Twine CP, McLain AD. Choice of bypass graft material for lower limb arterial bypasses. *Cochrane Database of Systematic Reviews* 2010, Issue 5. Art. No.: CD001487. DOI: 10.1002/14651858. CD001487.pub2
- 6 Priya Sastry, Rasmus Rivinius, Rebecca Harvey, Richard A Parker, Ann-Kathrin Rahm, Dierk Thomas, Sukumaran Nair, Stephen R Large, The influence of endoscopic vein harvesting on outcomes after coronary bypass grafting: a meta-analysis of 267,525 patients. *Eur J Cardiothorac Surg*. 2013 Dec;44(6):980-9. doi: 10.1093/ejcts/ezt121
- 7 Etem Caliskan, Domingos Ramos de Souza³, Andreas Böning, Oliver J Liakopoulos, Yeong-Hoon Choi, John Pepper⁶, C

Michael Gibson, Louis P Perrault, Randall K Wolf, Ki-Bong Kim, Maximilian Y Emmert. Saphenous Vein Grafts in Contemporary Coronary Artery Bypass Graft Surgery. *Nat Rev Cardiol*. 2020 Mar;17(3):155-169

- 8 Albers M, Romiti M, Francisco Cardoso Brochado-Neto, Nelson De Luccia, Carlos Alberto Bragança Pereira Santos. Meta-analysis of popliteal-to-distal vein bypass grafts for critical ischemia. *J Vasc Surg* 2006;43:498-503
- 9 Twine CP, McLain AD. Graft type for femoropopliteal bypass surgery. *Cochrane Database of Systematic Reviews* 2010, Issue 5. Art. No.: CD001487. DOI:10.1002/14651858.CD001487.pub2
- 10 Moritz A¹, Grabenwöger F, Raderer F, Ptakovsky H, Magometschnigg H, Ullrich R, Staudacher M. Use of varicose veins as arterial bypass grafts. *Cardiovasc Surg*. 1993 Oct;1(5):508-12
- 11 Lofgren EP. In Bergan JJ, Yao JST AND (eds) AND Surgery of the veins 1985 285-299
- 12 Cohn JD¹, Korver KF. Selection of saphenous vein conduit in varicose vein disease. *Ann Thorac Surg*. 2006 Apr;81(4):1269-74.
- 13 Ganichot F, Jurus C. Allogreffes veineuses conservées à 4°C dans les pontages sousinguinaux: résultats à long terme dans 170 cas. *Ann Chir Vasc* 2000 ;14 : 553-560
- 14 Streichenberger R, Barjoud H, Adeleine P, Larese A, Nemoz C, Chatelard P, Nedey C, Sabben. Allogreffes veineuses conservées à 4°C dans les pontages sousinguinaux: résultats à long terme dans 170 cas. *Ann Chir Vasc* 2000 ;14 : 553-560
- 15 Masmejan S, Deslarzes-Dubuis C, Petitprez S, Longchamp A, Haller C2, Saucy F, Corpataux JM, Déglise S. Ten Year Experience of Using Cryopreserved Arterial Allografts for Distal Bypass in Critical Limb Ischaemia. *Eur J Vasc Endovasc Surg*. 2019 Jun;57(6):823-831
- 16 Ziza V, Canaud L, Gandet T, Molinari N, Alonso W, Chastan R, Branchereau P, Picard E. Outcomes of cold-stored venous allograft for below-knee bypasses in patients with critical limb ischemia. *J Vasc Surg*. 2015 Oct;62(4):974-83.
- 17 Hartranft CA, Noland S, Kulwicki A, Holden CR, Hartranft T. Cryopreserved saphenous vein graft in infrainguinal bypass. *J Vasc Surg*. 2014 ; 60(5) :1291-1296

- 19 Chiarugi G, Bucciante L. ISTITUZIONI DI ANATOMIA DELL'UOMO. Francesco Vallardi ed. XI edition. 1975, vol 2, chapter 13
- 20 Caggiati A, Mendoza E. Segmental Hypoplasia of the Great Saphenous Vein and Varicose Disease . Eur J Vasc Endovasc Surg . 2004; 28, 257-261. doi: 10.1016/j.ejvs.2004.06.002
- 21 Caggiati A, MD, Bergan JJ, Gloviczk P, Eklof B, Allegra C, MD, Partsch H . Nomenclature of the veins of the lower limb: Extensions, refinements, and clinical application. J Vasc Surg April 2005; 719-24
- 22 Bailly M. Cartographie CHIVA. In Enciclopèdie Medico-Chirurgicale. Paris. Thecniques 1993. P 43-161-B, 1-4
- 23 Zamboni P, Mendoza E, Giancesini S. Saphenous vein-sparing strategies in Chronic Venous Diseases. Springer. Chapter 2. 2018. ISBN 978-3-319-70638-2
- 24 Stephanie K, Stravakis G, Takahas M, Taylor G, Folkman MJ, Gimbrone MA, Garcia-Cardena G. et al. Early Adaptive Responses of the Vascular Wall during Venous Arterialization in Mice. Am J Pathol. 2004 Jan; 164(1): 81-89.
- 25 Westerband A¹, Crouse D, Richter LC, Aguirre ML, Wixon CC, James DC, Mills JL, Hunter GC, Heimark RL. Vein adaptation to arterialization in an experimental model. J Vasc Surg. 2001 Mar;33(3):561-9.
- 26 Delfrate R. Thanks to the CHIVA strategy, may the histoarchitecture of great saphenous vein- sparing, make it suitable as graft for bypasses? Veins and Lymphatics. 2019, 8(1). <https://doi.org/10.4081/vl.2019.8227>
- 27 Loesch A, Dashwood MR. On the Sympathetic Innervation of the Human Greater Saphenous Vein: Relevance to Clinical Practice. *Current Vascular Pharmacology*, 2009, 7, 58-67
- 28 Bottasso E. Toward the existence of a sympathetic neuroplasticity adaptive mechanism influencing the immune response. A hypothetical view-part I. Front Endocrinol. (2019) 10:632. doi: 10.3389/fendo.2019.00632
- 29 Bottasso E. Toward the existence of a sympathetic neuroplasticity adaptive mechanism influencing the immune response. A hypothetical view-part II. Front Endocrinol. (2019) 10:632. doi: 10.3389/fendo.2019.00632

- 30 Jänig W, editor. Functional anatomy of the peripheral sympathetic and parasympathetic system. In: *The Integrative Action of the Autonomic Nervous System: Neurobiology of Homeostasis*. Cambridge, UK: Cambridge University Press (2006). p. 13–34. doi: 10.1017/CBO9780511541667.004
- 31 Tisato V, Zauli G, Voltan R, Giancesini S, di Iasio MG, Volpi I, Fiorentini G, Zamboni P, Secchiero P. Endothelial cells obtained from patients affected by chronic venous disease exhibit a pro-inflammatory phenotype. *PLoS One*. (2012) 7:e39543. doi: 10.1371/journal.pone.0039543
- 32 Tisato V, Zauli G, Giancesini S, Menegatti E, Brunelli L, Manfredini R, Zamboni P, Secchiero P. Modulation of circulating cytokine-chemokine profile in patients affected by chronic venous insufficiency undergoing surgical hemodynamic correction. *J Immunol Res*. (2014) 2014:473765. doi: 10.1155/2014/473765
- 33 Solá Ldel R, Aceves M, Dueñas AI, González-Fajardo JA, Vaquero C, Crespo MS, García-Rodríguez C. Varicose veins show enhanced chemokine expression. *Eur J Vasc Endovasc Surg*. (2009) 38:635–41. doi: 10.1016/j.ejvs.2009.07.021

18 - Techniques for arterial bypass using a dilated saphenous vein

Alberto Muñoz and Andres Jimenez

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Key Points:

We can use the saphenous vein with dilation as a bypass graft. Most patients with varicose veins have ectatic or focal dilations of the saphenous vein. It rarely involves the whole vein but parts of it.

There are techniques proven safe to use dilated veins with excellent results.

The first femoropopliteal bypass with reversed vein graft was performed by Kunlin in 1948. It had varicose dilatation, and remained patent until the patient died 28 years later (1,2). The gold standard material in bypass surgery of blood vessels is one of the patient's own arteries or veins. We use an autologous arterial bypass only for coronary artery bypass grafting (Internal thoracic, radial, and gastroepiploic arteries). Using arterial grafts for peripheral bypass is anecdotal. The greater saphenous vein is the conduit of choice for peripheral reconstructions. Still, it may be unavailable if the vein is absent or phlebitic. This occurs after bypass, phlebitis or if we ablated the vein to treat varicose veins.

Chronic venous insufficiency (CVI) affects approximately 50–55% of adult women and 40–50% of adult men (3). As population

age increases, the number of patients who suffer CVI requiring arterial reconstruction will increase. The invasive treatment of varicose veins during the past century consisted mainly of ablation by surgery or sclerotherapy. Its basis was the removal of all visible varicose veins. Victor Salleras, a surgeon from Barcelona, in a presentation in Bogota in 1972, during the XI Latin-American Congress of the International Society for Cardiovascular Surgery, emphasized that for the cure of varicose veins, the treatment should be the high ligation and removal of both saphenous veins, of all varicosities and the ligation of all the incompetent perforating veins (4). They named the operation “radical surgery”, just as if the disease was a malignant tumor. These principles of surgical treatment had a significant influence in the operation performed to our days. In our country, stripping from groin to ankle is the most common procedure in many centers. Introducing duplex scanning for the investigation of venous disease changed completely the vision of varicose veins. Duplex mapping brought several new anatomical and physiological concepts (5,6). Claude Franceschi in 1988, based in hemodynamic investigations with duplex scanning, developed and published CHIVA treatment as a technique to treat venous hypertension preserving the saphenous veins and the venous capital (7).

The aim of this chapter is to show the importance of preserving the saphenous vein since the patients presenting with varicose veins are usually young. Two facts are important, (1) it is not possible to predict who will have symptomatic atherosclerosis and (2) the population longevity is increasing. Thus, we warrant avoiding saphenous vein ablation to preserve a conduit for arterial bypass. As written by Denton Cooley in one of his books,

the public has accepted the value of bypass surgery to prolong life. We can preserve the saphenous vein in the treatment of varicose veins, for possible arterial conduit. An intelligent patient will understand the reason for preserving his veins and won't insist in the removal for aesthetic reasons (8). Russel Samson has proposed a new society named S.O.S. (Save Our Saphenous), worried by the substantial amount of saphenous veins ablated without need (9).

The Greater Saphenous Vein as arterial substitute

Autologous arterial and venous grafts are the best conduits for bypass for cardiovascular disease reconstruction. We also use it for venous and arterial repairs in other diseases, such as trauma or oncologic resections. In small vessels (< 6 mm) bypass, synthetic grafts have unacceptably low patency rates, less than 25% at 3 years in peripheral and coronary bypass surgeries compared to over 70% for autologous arterial or vein grafts (10,11). This failure results from surface thrombogenicity, because of lack of endothelial cells, and also from anastomotic intimal hyperplasia. The greater saphenous vein is the conduit of choice for infra-inguinal arterial bypass grafting bypass (12,13) and the most common for Coronary artery bypass grafting, specially for the right coronary artery and the circumflex (14,15). The increasing incidence of varicose veins, stripping and ablation in the population makes the venous graft unavailable for bypass. It is reported that the vein is absent or inadequate in about 20% to 40% of patients (12).

Pannetta et al. (16) studied the relation between preexisting saphenous vein disease and its relation to graft failure. The study found unsuspected preexisting saphenous vein disease in approximately 12% of cases and suggests its detection

is possible with duplex ultrasonography and intraoperative examination.

Mcfarland et al. (17) studied 35 legs previously intervened for varicose veins and found that the below knee great saphenous vein did not undergo varicose dilatation. In 7 of the 9 veins examined postoperatively, this segment remained patent after the above knee stripping. Varicose veins resulting from saphenofemoral incompetence treated by greater saphenous vein stripping to the knee, still leave in the leg, a non-varicose good quality segment for bypass. Rutherford et al. showed that previous saphenous vein surgery should not categorically exclude patients as having no usable ipsilateral vein for bypass. High ligation in patients with saphenofemoral incompetence achieves excellent preservation of residual greater saphenous vein length and caliber (18).

Preoperative Vein Mapping before Bypass

Contrary to a frequent statement, the greater saphenous veins of patients with varicose veins are suitable for arterial bypass. Duplex scanning allows mapping precisely the venous system studying the greater saphenous vein anatomy, its accessories, tributaries, perforating veins. It also helps to mark the location of the incisions, to identify areas of fibrosis, thrombophlebitis and the extent of saphenous vein to harvest. In some patients we presume the vein to be absent or inadequate, and it is present and of good quality.

Cohn (19) in a morphology study of saphenous veins with ultrasound before coronary bypass, assessed greater saphenous vein of patients with venous telangiectasia and varicose veins. The study showed that in most of the legs the greater saphenous vein is

normal and can be used to a bypass. The varicosities are extra-fascial and are not directly in the saphenous trunk with reflux. Even the dilated saphenous vein can be an appropriate graft, because it has certain areas dilated and others normal. Labropoulos (20,21) studied the distribution and significance of varicosities in the saphenous trunks and established a definition for varicosities in the saphenous trunks as 1) normal, 2) focal dilation (1.5-3 times the diameter), 3) varicosities, and 4) aneurysms (3 times the diameter). Using this definition, he found focal dilation to be much more common than varicosities in the saphenous trunks. Cohn et al. also found that most varicose veins are in the saphenous veins, tributaries or accessory veins. Similarly, Zamboni et al. (22) detected that the varicose veins were in the saphenous tributaries in 98% of the limbs and the saphenous trunk was without varicosities.

The best portion of vein for coronary bypass is the below knee and for infra-inguinal bypass depends on the length required, usually from groin down to the leg. The size of the great saphenous vein is an important determinant of its usefulness as an arterial conduit for infra-inguinal bypass. Thus, we can measure it at different levels and look for vein wall or lumen alterations. Ultrasound mapping of the greater saphenous vein is the most convenient way of assessing vein patency and length preoperatively, reducing unnecessary surgical dissection. Evidence supports the use of preoperative ultrasound assessment of the saphenous vein (23,24,25,26). Benefits include a smaller scar, reduced harvest time and minimizing unnecessary incisions and flaps that predispose to wound complications (27).

We must perform duplex mapping with the patient in the reverse Trendelenburg position, sitting or standing in a warm

environment. Compression with the use of a tourniquet can enlarge the vein diameter to test vein elasticity and its distension. We check compressibility, diameter and wall for mural thickening at different levels.

Techniques to maximize the use of a dilated saphenous vein for bypass

The BASIL trial showed the important benefits of lower limb revascularization with greater saphenous vein over prosthetic graft and angioplasty (28). Techniques to maximize autologous veins for infra-inguinal bypass include a shorter bypass with a more distal graft origin and more proximal landing target artery, when we have reduced length of the ipsilateral saphenous vein. We should not use the greater saphenous vein if it is sclerotic, do not distend at the time of vein preparation, or its diameter is less than 3 mm in diameter after distension.

We usually discard saphenous veins with ectasia or varicosities during arterial bypass, despite their physiological endothelial flow surface. Its different caliber, irregular and thin wall can predispose to rupture, aneurysm, intimal hyperplasia, and thrombosis (29,30). However, in some patients, this could be the only autologous conduit available. There are several techniques to use a saphenous vein with focal dilatation.

The figure-of-eight or purse-string suture technique is used to eliminate the small varicose dilation and is used to improve an otherwise normal saphenous vein with partial eccentric venous aneurysms or focal dilation. However, these sutures may cause a kink or stenosis in the graft. In case of a bigger fusiform aneurysm

it is better to resect it and perform a veno-venous anastomosis, if the length of the saphenous vein is enough for the bypass.

In case the saphenous length is insufficient, several authors have used a technique that uses a mesh tube to provide external support. The external mesh is used to stabilize the vein and minimize stress in the high pressure arterial system to diminish the rate of stenosis and improve patency. Preclinical animal studies with external support of autologous vein bypasses with focal dilatation, varicosities or aneurysms, have shown a less-pronounced neointima formation, improving long-term patency rates if compared to unsupported grafts (31,32,33,34). Several small clinical series have shown that we can use both polytetrafluoroethylene (PTFE) and polyester prosthetic reinforcement of vein grafts with focal dilation or aneurysms with acceptable results - Table 1 (2,35,36,37,38,39,40,41,42,43,44,45).

Moritz et al. published (36) a reduction in the diameter by an external wrapping of the vein with a constrictive dacron mesh tube surrounding it as an external support to adjust the ectasis or varicose vein. They used it for bypass graft in 13 infra-inguinal arterial reconstructions and had good intermediate-term patency. Veins contract from 15 to 6 mm diameter without folds on the inner flow surface. His early reports were on the carotid of sheep, showing less diameter and intimal hyperplasia after six months. The first clinical experience he reported was on 13 infra-inguinal arterial reconstructions, 10 grafts showed patency after 17 months of follow-up, and two were patent despite severe outflow obstructions (37). A study used this technique for coronary bypass in 6 patients, showing patency in postoperative angiography (38). They showed no folds in the flow surface after a reduction of over 50% of diameter (39).

Table 1. Experiences of external reinforcement for dilatations on saphenous vein as arterial conduit.

Year Author	Number of patients (n)	Bypass tech- nique	External reinforce- ment	Primary patency	Assisted primary patency	Secondary patency	Limb Salvage	Mean follow- up (mon- ths)
1992 Moritz (36)	19	IABG	Total: 10 / Partial: 9 PTFE	18 (94.7%)	(-)	(-)	18 (94.7%)	13
1993 Moritz (37)	6	CABG	Total Polyester mesh	6	(-)	(-)		(-) (Angio- graphy befo- re discharge)
2007 Melliere (2)	12	IABG	Partial PTFE / Dacron	10 (83.3%)	(-)	(-)	83.3%	68
2009 Arvela (43)	50	IABG	Total Polyester mesh	82.3%*	88.6%*	92.1%*	90.0%	7 (0-36)
2011 Carella (44)	21	IABG	Total: 15, Partial: 6 Polyester mesh	57.1%**	81%**	(-)	85.7%*** - AFS	32
2017 Neufang (42)	57	IABG	Segmental (1-4 seg- ments per vein graft) / 1 total PTFE	54%***	73%***	73%***	83%	79

*At six months

** At 24 months

*** At 60 months

CABG: coronary artery bypass graft, IABG: Infra-inguinal Arterial Bypass Graft

AFS: amputation-free survival, (-): none described.

Arvela et al. in a study with a similar wrapping in 50 patients reported adequate patencies, primary 82.3%, assisted primary 88.6% and secondary 92.1% at 6 months (40).

Neufang et al. tested the reinforcement of ectatic veins with external polytetrafluoroethylene (PTFE) for infra-inguinal bypass grafts to avoid prosthetic bypass in 3.8% of 932 infra-inguinal bypasses (41). The prosthesis covered the ectasia and extra 5-10 mm of the healthy segment. They used full coverage with a long prosthesis for veins with multiple and more extended dilated segments. The latest publication of these data comprises a retrospective cohort of 54 patients during a ten-year period. The results showed a primary, primarily assisted, and secondary 5-year patency rates of 54%, 73%, and 73%, respectively, and limb salvage of 83% (42).

Melliere et al. (2,43) reviewed their experience with 12 patients, who underwent infra-inguinal bypass with prosthetic reinforcements of dacron and PTFE. Ten bypasses remained patent throughout follow-up from 1 to 11 years (median 4). Doppler ultrasound revealed no stenosis in the reinforced zones and no dilatation in the unreinforced zones.

Carrela et al. (44) reported their experience with 249 infra-popliteal bypasses with autologous conduits and in 21 of them used a varicose vein or focally dilated covered with dacron mesh in 21 to treat limb-threatening ischemia. The mean follow-up time was 32 months. They found no dilatation or infection. Primary patency at 24 months was 57.1% (SE $\pm$ 3.9), assisted 81% (SE $\pm$ 3.2), and amputation-free survival rate of 85.7% (SE $\pm$ 2.8). In the bypasses without mesh, primary patency was 63.8%, secondary

80.5%, and amputation-free survival rate 89.3% at 24 months. They concluded that Polyester external mesh is a valid method to perform bypass in ectatic or varicose veins and that it prevents vein dilatation during arterialization process.

Another technique to wrap an ectatic conduit is the self-covered technique described by Iida et al. (45). If there is a varix in the great saphenous vein, they harvested a more extended segment (3 to 4 cm) and cut the proximal end of the saphenous vein by 3 cm. They pass the graft with segmental varix through the short section of the saphenous vein. Thus, they cover the dilation with a short cylinder of the vein. They performed this procedure in two coronary bypasses, and control angiography at 1 year confirmed adequate patency.

There have been few case reports of use of an ectatic saphenous vein, without reinforcement. Mun et al. (46) used a varicose vein in the bypass of a 77-year-old man with limb ischemia and varicose veins, a reversed femoropopliteal bypass with patency and no structural changes documented by CTA at 15 months.

Guntani et al. (47) reports a case with chronic limb ischemia with gangrene and sepsis. They performed a reversed left femoral-dorsal artery bypass using ipsilateral great saphenous vein. The authors describe the partial resection of the saccular venous aneurysm, and they used the varicose veins at its full length without splicing with good results. They achieved limb salvage and the follow-up for two years was uneventful, without aneurysmal degeneration or intimal hyperplasia of the graft.

In conclusion, approximately 80% of the great saphenous veins trunks in patients with varicosities are normal, slightly

dilated or have one or more minor areas of focal dilatation. If the vein is otherwise acceptable, it should not be a contraindication for its use as a conduit, especially in patients with no other available vein. We may use the conduit by wrapping with autogenous or prosthetic reinforcement on the dilated zones. These techniques can have better patency and limb salvage than those achieved with prosthetic material. We should encourage the practice of saphenous vein preservation to treat varicose veins and incorporate it into the treatment armamentarium.

References

1. Kunlin J, Bitry-Boely C, Pajot A. Evolution sur 28 ans d'un long pontage veineux femoropoplite pour arteriopathied Actualites Chirurgicales. In 79eme Congres Francais de Chirurgie. Paris, Masson, 1978.
2. Melliére D, Desgrange P, Allaire E, Becquemin J- P. Long term results of venous bypass for lower extremity arteries with selective short segment prosthetic reinforcement of varicose dilatations. *Ann Vasc Surg* 2007;21:45-49.
3. M.P. Goldman, R.A. Weiss, J.J. Bergan. Diagnosis and treatment of varicose veins: a review. *J Am Acad Dermatol*, 31 (1994), pp. 394-413
4. Saleras V. Tratamiento Quirúrgico de las varices y del síndrome postrombótico. Actualizaciones Cardiovasculares, Memorias del XI Congreso del Capítulo Latinoamericano de la International Cardiovascular Society. Editorial Estela. Bogota: 777-781.
5. Franceschi C. Investigation vasculaire par ultrasonographie Doppler. Collection médecine ultrasonore Paris: Masson editeur, 1977.
6. Caggiati A, Bergan JJ, Gloviczki P, Jantet G, Wendell-Smith CP, Partsch H, et al. Nomenclature of the veins of the lower limbs: an international interdisciplinary consensus statement. *J Vasc Surg* 2002; 36:416-22.

7. Franceschi C. theory and Practice of the Conservative Haemodynamic Cure of Incompetent and Varicose Veins in ambulatory Patients. evans J, translator: Precy-sous-thil, 1988.
8. Cooley DA, Wukasch DC: Techniques in Vascular Surgery, WB Saunders, Philadelphia, 1979, pp 201-202.
9. Samson R.H. Calling SOS—Save our saphenous!. Vascular Specialist Online. 2013; (Available at:). <https://vascularspecialistonline.com/calling-sos- save-our-saphenous/> (Accessed August 2, 2020).
10. M. Albers, M. Romiti, C. A. Pereira, M. Antonini, M. Wulkan, Meta-analysis of allograft bypass grafting to infrapopliteal arteries. Eur. J. Vasc. Endovasc. Surg. 28, 462–472 (2004).
11. R. B. Chard, D. C. Johnson, G. R. Nunn, T. B. Cartmill, Aorta-coronary bypass grafting with polytetrafluoroethylene conduits. Early and late outcome in eight patients. J. Thorac.Cardiovasc. Surg. 94, 132–134 (1987)
12. Autogenous reversed vein bypass for lower extremity ischemia in patients with absent or inadequate greater saphenous vein Am J Surg, 153 (1987), pp. 505-51.
13. P. Klinkert, A. Schepers, D.H. Burger, J.H. van Bockel, P.J. Breslau. Vein versus polytetrafluoroethylene in above-knee femoropopliteal bypass grafting: five-year results of a randomized controlled trial. J Vasc Surg, 37 (2003), pp. 149-155
14. Hillis LD, Smith PK, Anderson JL, Bittl JA, Bridges CR, Byrne JG, Cigarroa JE, Disesa VJ, Hiratzka LF, Hutter AM Jr, Jessen ME, Keeley EC, Lahey SJ, Lange RA, London MJ, Mack MJ, Patel MR, Puskas JD, Sabik JE, Selnes O, Shahian DM, Trost JC, Winniford MD. 2011 ACCF/ AHA Guideline for Coronary Artery Bypass Graft Surgery: executive summary--a report of the American College of Cardiology Foundation/ American Heart Association Task Force on Practice Guidelines. Circulation. 2011;124:2610–2642.
15. P. Collins, C. M. Webb, C. F. Chong, N. E. Moat; Radial Artery Versus Saphenous Vein Patency (RSVP) Trial Investigators, Radial artery versus saphenous vein patency randomized trial: Five-year angiographic follow-up. Circulation 117, 2859–2864 (2008).

16. Panetta TE, Marin ML, Veith FJ, Goldsmith J, Gordon RE, Jones AM, et al. Unsuspected preexisting saphenous vein disease: an unrecognized cause of vein bypass failure. *J Vasc Surg*. 1992;15(1):102-12.
17. MacFarlane R, Godwin RJ, Barabas AP. Are varicose veins and coronary artery bypass surgery compatible? *Lancet* 1985;2:859.
18. Rutherford RB, Sawyer JD, Jones DN. The fate of residual saphenous veins after partial removal or ligation. *J Vasc Surg* 1990;12:422-428.
19. Cohn J.D., K.F. Korver. Selection of Saphenous Vein Conduit in Varicose Vein disease. *Ann Thorac Surg*, 81 (2006), pp. 1269-1274.
20. Labropoulos N, L. Leon, C.A. Engelhorn, S.I. Amaral, H. Rodriguez, S.S. Kang, et al. Saphenofemoral junction reflux in patients with a normal saphenous trunk *Eur J Vasc Endovasc Surg*, 28 (6) (2004), pp. 595-599.
21. Labropoulos N, Kokkosis AA, Spentzouris G, et al. The distribution and significance of varicosities in the saphenous trunks. *J Vasc Surg* 2010; 51: 96-103.
22. Zamboni P, Cappelli M, Marcellino MG, Murgia AP, Pisano L, Fabi P. Does a saphenous varicose vein exist? *Phlebology* 1997;12:74-7
23. Kupinski AM, Evans SM, Khan AM, et al. Ultrasonic characterization of the saphenous vein. *Cardiovasc Surg* 1993;1:513-7.
24. Head HD, Brown MF. Preoperative vein mapping for coronary artery bypass operations, *Ann Thorac Surg*, 1994, vol. 59 (pg. 144-8)
25. Barros FS, Pontes SM, Lima ML, Henrique JS, Roldi ML, Reis F, et al. Echocolor Doppler saphenous vein mapping prior to myocardial revascularization, *Rev Bras Cir CardioVasc*, 1999, vol. 14 (pg. 303-7).
26. Giannoukas AD, Labropoulos N, Stravridis G, Bailey D, Glenville B, Nicolaides AN. Pre-bypass quality assessment of the long saphenous vein wall with ultrasound and histology, *Eur J Vasc EndoVasc Surg*, 1997, vol. 14 (pg. 37-40).

27. Luckraz H, Lowe J, Pugh N, Azzu AA. Preoperative long saphenous vein mapping predicts vein anatomy and quality leading to improved postoperative leg morbidity, *Interact CardioVasc Thorac Surg*, 2008, vol. 7 (pg. 188-91).
28. Bradbury AW, Adam DJ, Bell J, Forbes JF, Fowkes FG, Gillespie I, et al. Bypass versus ^[SEP]Angioplasty in Severe Ischaemia of the Leg (BASIL) trial: An intention-to-treat analysis of amputation-free and overall survival in patients randomized to a bypass surgery-first or a balloon angioplasty-first revascularization strategy. *J Vasc Surg*. 2010;51(5 Suppl):5S- 17S. ^[SEP]35.
29. Kazui T, Harada H, Komatsu S. Saphenous vein aneurysm following coronary artery bypass grafting. *Cardiovasc Surg* 1988; 29: 364-367.
30. De la Rocha ac, Peixoto ra, Baird RJ. Atherosclerosis and aneurysm formation in a saphenous graft. *Br J Surg* 1973; 60: 72-73.
31. Jeremy JY, Bulbulia R, Johnson JL, Gadsdon P, Vijayan V, Skukla N, et al. A bioabsorbable (polyglactin), non-restrictive, external sheath inhibits porcine saphenous vein graft thickening. *J Thorac Cardiovasc Surg* 2004;127(6):1766e72.
32. Bambang LS, Moczar M, Lecerf L, Loisanse D. External biodegradable supporting conduit protects endothelium in vein graft in arterial interposition. *Int J Artif Organs* 1997;7: 397e406.
33. Dashwood MR, Angelini GD, Wan S, Yim A, Mehta D, Izzat MB, et al. Does external stenting reduce porcine vein graft occlusion via an action on vascular nerves. *J Card Surg* 2002;17(6):556e60.
34. Vijayan V, Smith FC, Angelini GD, Bulbulia RA, Jeremy JY. External support and the prevention of neointima formation in vein grafts. *Eur J Vasc Endovasc Surg* 2002;24:13e22.
35. Parsonnet VLA, Shah IH. New stent for support of veins in arterial grafts. *Arch Surg* 1963;X:696e702.
36. Moritz A, Magometschnigg H, Staudacher M, Ptakovsky H, Raderer F, Ullrich R, et al. [Stented dilated or varicose veins as arterial bypass transplants: experimental and initial clinical results]. *Vasa*. 1991;20(3):222-9.

37. Moritz A, Grabenwöger F, Raderer F, Ptakovsky H, Magometschnigg H, Ullrich R, et al. Use of varicose veins as arterial bypass grafts. *Cardiovasc Surg*. 1993 Oct;1(5):508–12.
38. Moritz A, Grabenwöger F, Wolner E. Mesh tube-calibrated varicose veins for coronary artery bypass grafting. *Ann Thorac Surg*. 1994;57(1):240–2.
39. Moritz A, Grabenwöger F, Raderer F, Ptakovsky H, Staudacher M, Magometschnigg H, et al. Mesh Tube—Constricted Varicose Veins Used as Bypass Grafts for Infrainguinal Arterial Reconstruction. *Arch Surg*. 1992;127(4):416–20.
40. Arvela E, Kauhanen P, Albäck A, Lepäntalo M, Neufang A, Adili F, et al. Initial Experience with a New Method of External Polyester Scaffolding for Infrainguinal Vein Grafts. *Eur J Vasc Endovasc Surg*. 2009;38(4):456–62.
41. Neufang A, Dorweiler B, Espinola-Klein C, Reinsteller J, Kirch D, Schmiedt H, et al. External reinforcement of varicose vein with PTFE prosthesis in infrainguinal bypass surgery e clinical results. *Thorac Cardiovasc Surg* 2003;51(2):62e6.
42. Neufang A, Espinola-Klein C, Savvidis S, Schmiedt W, Poplawski A, Vahl CF, et al. External polytetrafluoroethylene reinforcement of varicose autologous vein grafts in peripheral bypass surgery produces durable bypass function. *J Vasc Surg*. 2018;67(6):1778–87.
43. Mellièrè D, Le Chevillier B, Kovarsky S. Wrapped autologous greater saphenous vein bypass for severe limb ischemia in patients with varicose veins. Preliminary report. *J Cardiovasc Surg (Torino)* 1995;36:117e20.
44. Carella GS, Stilo F, Benedetto F, David A, Risitano DC, Buemi M, et al. Femorodistal bypass with varicose veins covered by prosthetic mesh. *J Surg Res*. 2011;168(2):189–94. Bednarkiwicz M, Vala D, Faidutti B. Use of an internal saphenous varicose vein covered by a polyfluoroethylene prosthesis in a femoropopliteal bypass graft (letter). *J Vasc Surg* 1998;27: 588e9.
45. Souyry P, Peillon C, Watelet J, Planet M, Plissonnier D, Del Gallo G, et al. Prosthetic reinforcement of varicose saphenous vein grafts for infrainguinal bypass. *Ann Vasc Surg* 1999;13:290e3.

46. Iida H, Sunazawa T. Self-covered technique for a varix on a saphenous vein graft. *Ann Thorac Surg* [Internet]. 2011;91(5):1632–3.
47. Mun YS, Cho BS, Jang JH, Lee MS, Kwon OS. Femoropopliteal Bypass with Varicose Greater Saphenous Vein. *Int J Angiol*. 2016;25(5):e108–10.
48. Guntani A, Yoshiga R, Mii S. Distal bypass with a varicose vein graft for critical limb ischemia: report of a case. *Surg Case Reports*. 2019;5(1):4–7.