11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page123

PHLEBOLYMPHOLOGY

CONTENTS

EDITORIAL

Hugo Partsch (Vienna, Austria) **Page 124**

PHLEBOLOGY

Lessons and Comments from the CACVS Meeting of January 2010 **Page 125**

Georges Jantet (Paris, France)

Current management of visceral venous aneurysms **Page 130**

Athanasios D. Giannoukas, Giorgos S. Sfyroeras (Larissa, Greece)

Efficacy of a 6-month treatment with Daflon 500 mg in patients with venous edema **Page 137**

Zuzana Navrátilová (Brno, Czech Republic)

Tissue fluid pressure and flow in the subcutaneous tissue in lymphedema – hints for manual and pneumatic compression therapy **Page 144**

Waldemar L Olsewski (Warsaw, Poland)

The plantar venous pump: Anatomy and physiological hypotheses **Page 151**

Jean-François Uhl, Claude Gillot (Paris, France)

INSTRUCTIONS FOR AUTHORS **Page 159**

CONGRESS

Congress and conference calendar **Page 160**

11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page124

EDITORIAL

Dear Readers,

This issue of Phlebolymphology contains some very interesting articles offering relevant information of scientific and practical importance.

*The report from **Georges Jantet**, Paris, on the latest "Controversies in Vascular Surgery" meeting, which is held in Paris every January, is an excellent example. This masterly report gives a well-balanced overview of the present state of discussions concerning the management of venous diseases of the lower extremities from the viewpoint of an experienced surgeon. The report is very helpful in clarifying the ongoing arguments between supporters of CHIVA and ASVAL and between believers in venous reflux and those who think that venous obstruction is essential.*

A phlebologist is well aware of aneurysms in the popliteal and saphenous veins, but may be surprised to learn that visceral venous aneurysms occur frequently.

***Giorgos Sfyroeras** and coworkers from **Athanasios Giannoukas's** group, Larissa University, Greece, performed a literature search which identified 93 reports of a total of 193 visceral aneurysms in 193 patients. The article contains 95 references and is a rich source of detailed information on this subject.*

***Zuzana Navratilova** from Brno presents a report on a Czech multicenter trial in which Daflon 500 mg was tested in a total of 196 patients with venous leg edema. After a treatment period of two months, signs and symptoms were significantly reduced.*

*Fascinating new experimental results concerning tissue pressure and fluid movement under the influence of manual massage and intermittent pneumatic compression in patients with lymphedema of the lower extremities are reported by **Waldemar Olzewski**, Warsaw. Interestingly, there was no significant difference between control subjects and patients with lymphedema in subcutaneous tissue pressure, which ranged from -1 to +10 mm Hg. During manual massage the applied force generated surprisingly high pressures of between 100 and 150 mm Hg, leading to local flow of tissue fluid during compression.*

***Jean Francois Uhl** and **Claude Gillot**, University of Paris, summarize their award-winning poster presented at the UIP World Meeting in Monaco 2009 on the anatomy and physiology of the plantar venous pump. It is exciting to see that even in the 21st century new insights into the basic anatomy and physiology of this very important segment of the venous macrocirculation can be obtained by thorough examinations.*

Enjoy your reading!
Hugo Partsch, MD

11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page125

Lessons and Comments from the CACVS Meeting of January 2010

Georges JANTET

Paris, France

The **"CONTROVERSES ET ACTUALITES EN CHIRURGIE VASCULAIRE" (CACVS)** meeting ("CONTROVERSIES AND UPDATES IN VASCULAR SURGERY") is held every January in Paris and lasts two days (Friday and Saturday), with workshops and a parallel all-day meeting on venous diseases on Saturday.

The CACVS meetings started 17 years ago under the very efficient management of J-P. BECQUEMIN, Y. ALIMI, and J-L. GERARD. All the invited speakers are acknowledged experts in vascular or endovascular surgery or promising newcomers to the field. As its title indicates, the meeting focuses on current problems and controversies.

The pattern of the meetings remains unchanged: the speakers present their topic in 8 minutes, thus allowing ample time for questions and discussion. All the presentations, questions, and discussions are simultaneously translated into French or English, and all attendees are presented with a book containing a fuller version of each presentation written in English. The success of the pattern is reflected in the yearly increase in attendance, with 1212 participants in 2010. CACVS has become one of the leading European meetings in this field.

THIS REPORT IS LIMITED TO THE "VENOUS SESSIONS"

The opening session was entitled "**Pelvic congestion syndrome**" (PCS). In a very clear overview of this condition, P. LEMASLE emphasized the problems of diagnosis: the different presentations (from a few labial or vulval varices to severe pelvic pains; urinary symptoms such as hematuria or dysuria; pudendal, gluteal, or vulval varices; recurrent leg varices) may lead to a consultation with a gynecologist, urologist, or vascular specialist, each of whom should be aware of this syndrome. A PCS can be *primary*, when it is caused primarily by an incompetent refluxing utero-ovarian venous system or iliac venous system, or *secondary*, when it is associated with an obstructive pathology, such as May-Thurner syndrome (compression/obstruction of the

Phlebolymphology. 2010;17(3):125-129.

11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page126

left common iliac vein) or the nutcracker syndrome (entrapment of the termination of the left renal vein into which drains the left ovarian vein) or compression/obstruction of an element of the iliac venous system or even the vena cava.

The diagnosis is confirmed by ultrasound (US) examination and, in some cases, by selective pelvic phlebography. Primary pelvic/perineal varices may be associated with incompetent communicators between the pelvis and the lower limbs.

Treatment depends on the pathology and thus may range from simple sclerotherapy (for incompetent communicators) to embolization for primary ovarian venous insufficiency causing reflux or to stenting or even surgery for obstructive lesions.

J. LEAL MONEDERO et al stressed the importance of selective pelvic phlebography with pressure measurements and Valsalva maneuvers, as this is both diagnostic and a pathway for therapy such as embolization or stent placement. They are of the opinion that endovascular treatment is the best option in the presence of compression or reflux.

O. HARTUNG stressed that an obstructive cause of PCS should not be missed as it is eminently suitable for treatment. He presented his experience of 115 patients collected over 13 years, with iliac vein obstruction the cause of PCS in 38 of them. Treatment consisted of stenting of the obstruction and embolization of the varices with postoperative anticoagulation. At 5 years, 54% of patients were asymptomatic and a further 33% were improved with an overall patency rate of 100%.

S. RAJU (in his article, see footnote, p. 129) described in detail two patients with longstanding (10 and 31 years) severe pelvic pain found to be associated with stenoses/occlusions of left iliac veins with profuse venous collaterals. The obstructed veins were balloon dilated and stented, which afforded complete relief of symptoms and proven patency of the stented veins together with disappearance of the venous collaterals at short-term follow-up.

L. TESSARI pointed out that "at least 45% of varices of the great saphenous vein (GSV) do not originate at the saphenofemoral junction (SFJ)". Recent studies have shown that valves are present in the iliac veins in only 10% of women and in the ovarian veins in 50%. Furthermore, free communications are present between the veins across both sides of the pelvis through venous plexuses around the pelvic structures (rectum, uterus, bladder, vagina). Pelvic venous insufficiency can be transmitted to the lower limbs via sites of leakage, one of which, according to C. FRANCESCHI, is situated at the termination of the pudendal canal (Alcock's canal) in the perineum: this canal conveys the internal pudendal vein. TESSARI gave a report on the treatment of pudendal varices by echoguided sclerosing foam (SF) injection of this site of leakage localized by transabdominal and transvaginal ultrasond (US). He found that "in 95 women out of 647 with chronic venous disease of the lower limbs" there was venous reflux at this site which was controlled by the treatment with disappearance of the varices after a mean follow-up of 24 months.

In the lively discussion which followed these presentations it was stressed that the existence of PCS could no longer be denied and that it was very probably underdiagnosed. It should be considered in all patients with chronic pelvic pain or with atypical varices (perineal, pudendal, gluteal) or in patients with varices on the medial aspect of the thigh in the presence of a competent SFJ and in recurrent varices of the thigh. It probably also plays an important role in the development of varices during pregnancy. Accurate diagnosis of the cause of PCS and application of the appropriate treatment would probably improve the management of varicose veins of the legs and certainly improve, and even relieve, the disabling symptoms of this syndrome.

In a very instructive session on "**Hemodynamics**", O. PICHOT discussed the use of duplex ultrasound, which is now mandatory in the assessment of a patient with a venous disorder. It allows a better and more detailed analysis of venous hemodynamics than can be obtained by purely clinical means and thus a better planning of the management: accurate and recordable findings are obtained and thus less radical, more selective treatment, adapted to each particular patient, is rendered possible.

In an excellent presentation A. COLIGNON discussed the essential role of the 3 valves involved in SFJ incompetence that have been elucidated by ultrasond (US) examination. The SFJ is the meeting point of the abdominal (pelvic) venous system and the lower limb venous system and is "controlled" by the 3 valves of the ostial valvular system at the SFJ—the lowest *iliac valve*

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(when present), the *ostial (terminal) valve* of the GSV, and the *pre-terminal valve* of the GSV. This system separates the abdominal from the lower limb venous systems and explains the importance of the SFJ in venous hemodynamics. Careful hemodynamic study of these valves has clarified the role of each one and has led to the more conservative management of this important part of the venous system: this was not possible before the advent of US imaging.

The traditional view of the etiology of superficial venous insufficiency (SVI) —the "*valvular hypothesis*"—was based on the concept of the development of points of reflux, mostly at the SFJ, from the deep to the superficial venous systems, leading to venous hypertension in the superficial system and progressive valvular decompensation retrogradely down the leg, with gradual dilatation of the tributaries of the saphenous veins leading to the development of varices and CVI, with its accompanying trophic changes. Treatment was based on this concept and explains why the radical "destruction" of the SFJ was almost systematically recommended.

The present trend favors the "*parietal hypothesis*", which is based on careful study of the results of the traditional treatment and hemodynamic studies. This suggests that the disease starts in the wall of the peripheral veins, which dilate in an antegrade direction towards the groin. This explains, for example, why varices can develop in the absence of any SFJ or SPJ (saphenopopliteal junction) incompetence and why this incompetence, when present, can disappear when the only treatment has been the removal of peripheral varices by phlebectomy.

P. PITTALUGA et al favor the "*parietal hypothesis*". They consider that the enlarging incompetent network of superficial varices creates a "*varicose reservoir*" the drainage of which causes an overload on the draining saphenous veins, which become functionally incompetent. Thus treatment aims at removing the "*reservoir*" exclusively. The ASVAL ("Ablation Sélective des Varices sous Anesthésie Locale") method is based on this concept. Treatment is thus much simplified, is carried out under local anesthesia, and is more conservative as only the varices are removed and the saphenous veins are preserved.

A fruitful discussion took place after these presentations. Ideally, all physicians involved in the vascular field should be trained in the use of ultrasond (US). As regards the ASVAL method, long-term follow-up (5 years minimum and preferably 10 years) will show whether it is valid and, in particular, whether it applies to all varices whatever their severity. There was a short discussion involving the (rare) supporters of the CHIVA ("Cure Conservatrice et Hémodynamique de l'Insuffisance Veineuse en Ambulatoire") method who contend that the ASVAL method is essentially the same as the CHIVA method. This is denied by the ASVAL supporters who point out that the two methods are different in concept, clarity, and execution. At this stage, neither has any satisfactory long-term evidence!

The session on "**Thermal ablation and sclerotherapy**" opened with a cautionary presentation by N. LABROPOULOS who reviewed the literature and concluded that, as regards ablation of the saphenous veins, thermal ablation by either laser or radiofrequency produced good cosmetic results in the short and medium term. Foam sclerotherapy is more effective than liquid sclerotherapy, but requires repeated treatments to obtain saphenous vein closure rates comparable to those of thermal ablation, and the closure rates of the tributaries were better than those of the saphenous trunks when the tributaries were less than 6 mm in diameter. He also expressed a possible concern regarding the effect of repeated treatment with foam on the "cognitive function of the patients". He stressed the need for well-designed and powered randomized controlled trials with long-term follow-up to assess these newer methods.

C. WITTENS pointed out in his presentation that it was totally unreasonable to compare the results of new minimally invasive techniques with those of "old-fashioned surgery" — this being the case in all published articles except one! The comparison should be with modern venous surgery techniques, which he described and which incorporate the use of US investigation pre-operatively, careful SFJ ligature, limited and invaginating stripping, early ambulation, etc.

T. PROEBSTLE reported on the interesting results of a prospective European multicenter trial to elucidate whether accessory saphenous veins should be treated concomitantly with the GSV during thermal ablation. In a series of 93 limbs treated by thermal ablation of the GSV, an accessory anterior saphenous vein was present in 43 (48%), but only 2 showed reflux. However, at 2-year follow-up this had increased to 16 (30%).

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Unfortunately, no predictive parameter was found to determine which of these accessory veins would become incompetent. Posterior accessory saphenous veins were initially present in 6 limbs (7%), but none developed reflux over the 2-year follow-up. The debate therefore remains open.

In a series of 91 consecutive patients (106 limbs), M. GOUGH *et* al reported the use of endovenous laser ablation (EVLA) in the management of recurrent varices after surgery when the recurrence was associated with the presence of a refluxing residual GSV, accessory saphenous vein or SSV (if neovascularization connected the residual truncal vein to the deep vein, this was additionally injected with sclerosing foam). He discussed the technical difficulties and reported that this method, adopted as the method of choice in his unit, is safe and effective, but has not been compared with other methods of treatment.

L. KABNICK et al studied the thrombosis produced in the GSV after radiofrequency ablation (RFA) or EVLA and, particularly, the outcome when the thrombosis involved the SFJ (with the danger of spread). Apparently, this type of thrombus behaves differently from a "spontaneous" thrombus and definite recommendations as to management require further studies.

G. SPREAFICO et al studied the relationship between the size of the GSV (measured at various levels in the standing position) and the outcome of EVLA of the GSV in a series of 145 selected patients. They concluded that a saphenous trunk with a mean diameter of 10 mm "can always be permanently occluded if a sufficient amount of energy and adequate tumescent anesthesia are administered".

T. BAYENS et al, concerned by the transient neurological and cardiac embolic complications of foam sclerotherapy, advocate performing a "crossectomy" of the GSV or SSV "through a 1-cm incision, under US control" before injecting the foam through a catheter introduced at the ankle. In a series of 111 patients (188 limbs), a complete (100%) occlusion rate was obtained with complete disappearance of the saphenous vein on US at 1-year follow-up. No neurological or cardiac abnormalities were reported. As a comment on this presentation, it should be pointed out that the "operation" described is not a "crossectomy" — it is, at best, a ligature of the saphenous trunk below the junction with the deep veins, leaving a stump draining several tributaries...the commonest cause of recurrent varices after surgery!

As M. LUGLI et al discussed in their presentation during the session on "**Anesthesia for varicose veins",** SFJ ligature and stripping can be performed satisfactorily under local or tumescent anesthesia. So, why is it, ask J. VANHANDENHOVE et al, that "general anesthesia for varicose veins remains so popular in Europe"? They are unable to suggest an answer! In a similar "vein"(!), M. PERRIN analyzes "why traditional surgery remains so popular in France": he suggests it is due to a lack of teaching and training in the use of US and other methods of treatment together with Health Service regulations concerning fees. While this may well be partly the case as regards surgery, a fair comment could well be added. Surgeons have shown repeatedly that they are perfectly prepared to change their treatment methods when it is shown that it is in the long-term interest of the patient (even if it is not in their financial interest). They are also less likely to be impressed by "newer, fashionable" methods, often with a strong commercial background, as such "discoveries" have been acclaimed in the past, only to disappear as they have not stood the test of time. C. Wittens (see above) points out that most comparisons with surgery are flawed. A further possible flaw is in the severity of the varices treated by surgery compared with those treated by conservative methods: are the varices treated surgically more severe or advanced than those treated non-surgically? There is circumstantial evidence that this may be the case. At present, all varices are classed C2 in the CEAP classification irrespective of their size or extent; should this be refined to take into consideration their total physical size/volume? Should the volume of the "*varicose reservoir*" be quantified?

A separate session was allocated to the difficult and specialized subject of "**Vascular malformations**", which are not to be confused with vascular tumors.

C. LAURIAN et al and P. BURROWS et al discussed high-flow arteriovenous malformations (AVMs) which are congenital vascular anomalies made up of 3 components: feeding arteries, fistulae or "nidus" (the body) of small vessels, and draining veins. Congenital arteriovenous fistulas (AVFs) are a rare form of malformation, but the acquired form is typically the result of penetrating injuries. AVMs can involve deep as well as superficial

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tissues including bone; they evolve over time and may lead to irreversible damage to the surrounding tissues, leading to major functional impairment of limbs. AVFs, which can lead to high output cardiac failure, are easier to control than AVMs, treatment of which is usually not undertaken until significant symptoms or marked progression occurs. US and CT-scanning have led to a better understanding of these lesions and allowed a more aggressive therapeutic approach. Active treatment includes percutaneous sclerotherapy, and embolization often combined with some reconstructive surgery; occasionally amputation is necessary. Sclerotherapy is delivered percutaneously into the nidus of the malformation: ethanol is very effective, but can cause severe complications. Embolization involves the intra-arterial injection of particulate agents into the feeding arteries producing an occluding thrombosis, but recanalization can occur. Liquid embolic agents, such as adhesive acrylic polymers, are also used as they reach the nidus itself where they polymerize instantly producing a strong exothermic reaction, which results in local necrosis. Adjuvant pharmacological agents have also been used. When the AVM is drained by a single vein, as in direct AVFs, this can be occluded by coils and a sclerosant. Over the past decade the need for amputation has been reduced.

B. CRIQUI presented another type of vascular malformation - a Maffuci syndrome which is a very rare "congenital non-hereditary mesodermal dysplasia associating soft tissue venous malformations and multiple enchondromas most commonly in the phalanges of the hands and feet". The vascular lesions are slow-flow capillary and cavernous venous malformations presenting as bluish nodules on the limb extremities and, very rarely, in other sites. The enchondromas carry a 30% risk of malignant transformation to chondrosarcomas; there is also a higher risk of developing other malignant tumors. Treatment is recommended only if the patient is symptomatic or malignant change has occurred, but regular surveillance is mandatory.

Another, more common, form of vascular malformation is Klippel-Trenaunay syndrome (KTS), which was discussed by A. ALOMARI and by P. GLOVICSKI. KTS is clinically characterized by the combination of slow-flow vascular malformations (lymphatic, capillary, and venous) in a hypertrophied limb. Clinically, the capillary malformation presents as a nevus (port wine stain) situated on the lateral aspect of the limb; the venous malformation presents characteristically as a large varicose dilatation of a persistent embryonic "lateral marginal vein" (the vein of Servelle), which is tortuous and incompetent (involvement of the deep venous system is controversial, but many patients also have a persistent embryonic sciatic vein); the lymphatic malformation is manifest by the frequent presence of skin vesicles, lymphatic cysts in the deep tissues, and by lymphedema of the limb. These malformations can extend to the pelvis and the external genitalia. The limb hypertrophy is due to extrafascial fatty overgrowth and hypertrophy of the bone (occasionally, however, the affected limb is atrophic). KTS is a sporadic mesodermal abnormality due to genetic mutation characterized by an arrest in the development of veins, capillaries, and lymphatics, producing a low-flow vascular malformation. It should be distinguished from Parkes-Weber syndrome, which is a high-flow, high-shunt AVM of different management and prognosis. Treatment of KTS is essentially conservative: at the Mayo Clinic, during the period 1987-2007, 684 patients with KTS were seen, but only 49 (7%) were operated on. The incompetent superficial veins are treated on their merits either surgically or by conservative endovenous methods; some centers perform debulking operations. A multidisciplinary approach is often necessary and orthopedic procedures may be necessary to control limb overgrowth.

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*Footnote: S. Raju was absent from the meeting but his contribution, published in the CACVS book of articles related to the presentations, is included in this report as it illustrates the relief of severe symptoms which can be obtained once the correct diagnosis is made.

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Current management of visceral venous aneurysms

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ABSTRACT

Visceral venous aneurysms are considered rare clinical entities with not variable pathogenesis, clinical presentation, natural history, and management. In an electronic search of the pertinent English and French literature, ninety-three reports were identified, including 176 patients with 198 visceral venous aneurysms. Patients' ages ranged from 0 to 87 years, and there was no apparent male/female preponderance. The commonest location was the portal venous system (87 of 93 reports, 170 of 176 patients, 191 of 198 aneurysms). Portal system venous aneurysms were present with abdominal pain (44.7%), gastrointestinal bleeding (7.3%), or were asymptomatic (38.2%). Portal hypertension was present in 30.8% and liver cirrhosis in 28.3%. Thrombosis and rupture occurred in 13.6% and in 2.2%, respectively. Adjacent organ (common bile duct, duodenum, inferior vena cava) compression was reported in 2.2% The management ranged from watchful waiting to intervention. Indication for operation was symptoms and complications. In 94% of the cases, aneurysm diameter remained stable with no complications during follow-up. Aneurysms of the renal veins and inferior mesenteric vein were also reported. Of six cases of renal vein aneurysm, three were treated surgically and the remaining three were asymptomatic.

Venous aneurysms are reported in the popliteal, jugular, and saphenous veins, but rarely occur in other veins. Visceral venous aneurysms have been increasingly described in recent years probably because of the increasing availability of advanced radiologic imaging in clinical practice. Their prevalence, clinical presentation, and complications have not been adequately reviewed. Most visceral aneurysms are reported in the form of case reports, and there are few published case series that specifically address indications for surgery and optimal surgical techniques.

In a systematic Medline search undertaken to identify all reported cases of visceral venous aneurysms using the keywords "visceral vein", "splachnic vein" "portal vein", "intrahepatic portal vein", "extrahepatic portal vein", "splenic vein", "superior mesenteric vein", "umbilical vein", inferior mesenteric vein", "renal vein", and "aneurysm" ninety-three reports were

Keywords:
vein aneurysm, portal vein, renal vein, inferior mesenteric vein, visceral

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11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page131

identified, including 198 visceral venous aneurysms in 176 patients.

Patients' ages ranged from 0-87 years and there was no apparent male/female preponderance. The most frequent location of visceral venous aneurysms was the portal venous system (87/93 reports, 170/176 patients 191/198 aneurysms).[1-87] Aneurysms of the renal vein (6 reports, 6 patients, 6 aneurysms)[88-93] and inferior mesenteric vein (1 aneurysm)[66] were also described. *Figure 1* summarizes the incidence of the visceral venous aneurysms.

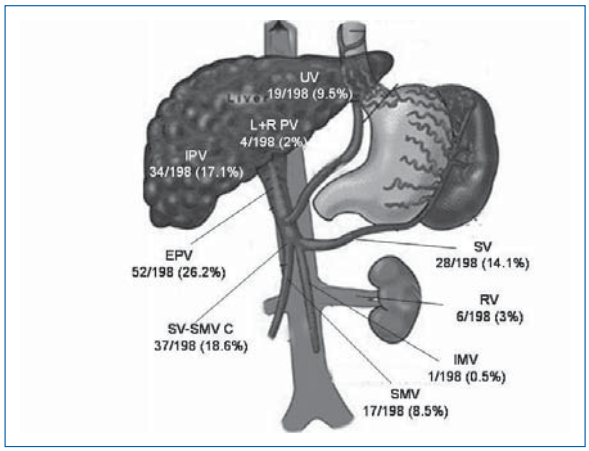

Figure 1. *Incidence of the visceral venous aneurysms. PV: portal vein EPV: extrahepatic portal vein , IPV: intrahepatic portal vein, SMV: superior mesenteric vein, SV: splenic vein, SV-SMV C: splenic vein- superior mesenteric vein confluence, IMV: inferior mesenteric vein RV: renal vein*

Portal venous system

The most frequent location of visceral venous aneurysms is the portal venous system and represents 3% of all venous aneurysms.[46] Koc reported a 0.43% prevalence of portal venous aneurysm among 4186 patients.[81] As there are variations in the diameters of both normal and cirrhotic portal veins, an aneurysm of the portal venous system is considered to be present if the vessel diameter is larger than 20 mm, especially if the morphology is saccular or fusiform.[44,48,81,94] Aneurysms are usually located at the main portal vein, the junction of the superior mesenteric vein and the splenic vein, or at the hepatic hilus.[42,46] Intra-hepatic venous aneurysms are rare.[81]

In the portal venous system the aneurysm was located in the main extrahepatic portal vein in 52 cases, splenic vein in 28 cases, superior mesenteric vein in 17 cases, splenic–superior mesenteric vein confluence in 37 cases, right portal vein in 3 cases, left portal vein in 1 case, intrahepatic portal vein in 34 cases, and umbilical portion of the left portal vein in 19 cases. Extrahepatic portal venous aneurysms ranged from 2.0 to 8.0 cm in diameter and intrahepatic from 1.0 to 7.0 cm.

There are two main theories regarding the etiology of portal vein aneurysms: congenital and acquired. During embryonic development, three anastomoses form between right and left vitelline veins around the future duodenum. A complex process of involution and interconnection of these vitelline veins results in the portal vein. Abnormal development of the portal venous system during this critical period may give rise to an extrahepatic portal vein aneurysm.[95] Incomplete regression of the distal right primitive vitelline vein,[46,95,96] or a variant branching pattern of the portal vein[54] may later form a portal vein aneurysm. Incomplete regression of the distal right vitelline vein leads to a diverticulum that would develop into an aneurysm in the proximal superior mesenteric vein.[95] Portal vein anomalies including the right anterior segmental portal vein or the right anterior and posterior segmental portal veins originating from the umbilical portion of the portal vein, and a rightward deviation of the umbilical portion of the portal vein, are associated with aneurysms of the umbilical portion of the left portal vein.[54] An inherent weakness of the vessel wall is another potential explanation of a congenital origin. The congenital theory implies a developmental defect of the vein wall as the main cause of aneurysm development. Congenitally or developmentally defective segments may give rise to an aneurysm.[47] The congenital theory is based on the presence of aneurysms in children and young adults without portal hypertension.[4,5,10,17,33,35] In utero diagnosis of a portal vein aneurysm is evidence in support of the congenital theory.[34] The acquired lesions are secondary to chronic liver disease, mainly cirrhosis, portal hypertension, trauma, and pancreatitis.[14,42,44,46,81,94] Data regarding these possible etiological factors are available for 162 patients. Portal hypertension was reported in 30.8% (50/162) and liver cirrhosis in 28.3% (46/162) of the patients. Thrombophilia was recently suggested to be an etiologic factor of portal aneurysms. Recurrent thrombosis can cause portal vein occlusion, which results in acute or chronic symptoms of portal hypertension and aneurysm formation.[81]

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The clinical importance of a portal vein aneurysm is related to its size. A small aneurysm usually does not produce symptoms, while large ones are described as the cause of duodenal compression,[43,80] inferior vena cava compression,[43] biliary tract obstruction,[33] and portal vein thrombosis.[1,5,19,24,31,46,55,57,61,62,66,74,75,77,81] Data regarding clinical presentation are available for 123 patients. Abdominal pain was reported in 44.7% (55/123) and gastrointestinal bleeding in 7.3% (9/123) of the patients. The aneurysm was asymptomatic and discovered incidentally during abdominal scanning, usually abdominal CT scan and abdominal ultrasound, in 38.2% of the patients (47/123). Other symptoms such as fever, abdominal distension, nausea, loss of appetite, weight loss, vomit, malaise, and jaundice were infrequently reported.

Congenital portal venous aneurysms are generally considered stable lesions and regular follow-up is usually sufficient. Acquired portal venous aneurysms, mainly when they are combined with liver cirrhosis and portal hypertension, can have a more unpredictable clinical course and require closer follow-up, and intervention when complications occur.[9] Portal venous system aneurysms require no treatment in most cases. Serial follow-up of patients with abdominal ultrasound is usually sufficient.[46,81] In 88% of the patients who were followed up, aneurysm diameter remained stable and no complications occurred. Portal vein thrombosis may necessitate anticoagulation therapy or percutaneous intervention with thrombectomy or thrombolysis.[81]

Reported complications of untreated visceral venous aneurysms are thrombosis, rupture, and compression of adjacent structures. Complete thrombosis occurred in 24 patients (13.6%) and nonocclusive thrombus in six patients. Rupture was described in four patients (2.2%), one of them during the postpartum period. Two of these four ruptures were splenic vein aneurysms, one intrahepatic and one aneurysm of the right portal vein. Ruptured aneurysm diameter was 2 cm in three of the four cases. The aneurysm compressed the common bile duct in two cases, the duodenum in two cases, and the inferior vena cava in one case.

Management ranged from watchful waiting to intervention.[5] There are data for 87 patients, 53 of whom were followed up for between 1 to 72 months (mean 21.15). Follow-up was most commonly performed using abdominal ultrasound. In 50 (94%) of the 53 patients, aneurysm diameter remained stable and no complications occurred. In two patients the aneurysm diameter increased and one underwent cavernous transformation. Thirty-four patients in total underwent surgery. In most cases, the indication for surgery was the occurrence of a complication (thrombosis and rupture) or the presence of symptoms. Operations performed included splenectomy (7 patients), aneurysmorrhaphy (8), aneurysmectomy (3), aneurysmectomy and splenectomy (1), aneurysmectomy with splenectomy and shunt (1), aneurysmorrhaphy and splenectomy (1), distal pancreatectomy and splenectomy (2), aneurysmorrhaphy and portocaval shunt (1), splenectomy, distal pancreatectomy and lienorenal shunt (1), splenectomy and splenorenal shunt (1), portocaval shunt (2), splenorenal shunt (1), liver transplantation (2), and transhepatic thrombectomy and thrombolysis (3).

The type of the procedure is based on the location and size of the aneurysm, the presence of complications, and the comorbidities (portal hypertension and liver cirrhosis). Aneurysmorraphy is the easiest procedure for excision of the aneurysm, mainly when it is saccular, and restores normal luminal diameter of the portal vein. In cases of fusiform aneurysms, if an aneurysmectomy is performed, the conduit used to replace the portal vein can be an allograft from a cadaveric donor, or a synthetic graft.[80] The location of the aneurysm is significant for the choice of the procedure. The location was determined in 30 of the 34 operated patients: in 29 it was the extrahepatic portal system. In 4 of them the aneurysm was located in the splenic vein. All patients underwent splenectomy, combined with distal pancreatectomy in three cases.[49,59,79,86] Two of the four patients with superior mesenteric vein aneurysm underwent aneurysmorraphy, one aneurysmectomy, and one arterial thrombolysis and transhepatic thrombus aspiration.[19,20,41,66] Patients operated for an aneurysm of the extrahepatic main portal vein or superior mesenteric-splenic vein confluence underwent various procedures, most frequently aneurysmorrhaphy.[1,31,43,55,58,69,77,80] A single patient with intrahepatic portal aneurysm was operated: he had documented portal hypertension and underwent splenectomy.[57] Several patients with documented portal hypertension underwent surgical shunt procedures, alone[4,5] or combined with various other procedures.[3,24,76,77] These shunt procedures are performed to decompress portal hypertension and do not specifically treat the venous aneurysm. Patients with

11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page133

liver cirrhosis present increased perioperative risk and two out of the five who underwent surgery died during follow-up. Because of the low reported rate of rupture and the risk of surgery in the presence of portal hypertension and liver cirrhosis, there is no strong evidence that prophylactic resection of the portal vein aneurysm is beneficial in these patients.[80]

Nine patients with portal venous aneurysm died during follow-up, resulting in 10.3% mortality. Three of them presented with complications; rupture or thrombosis. Five of these nine patients were operated, two underwent liver transplantation because of liver cirrhosis, and two had a coexisting malignancy.

Renal vein

Renal vein aneurysms are very rare, with only six cases reported in the English-language literature.[88-93] Patient ages ranged from 33-73 years. Five patients were male and three presented with abdominal pain. The remaining three aneurysms were discovered incidentally or during laparotomy.[93] Aneurysm diameter ranged from 4 to 5.5 cm. The aneurysm was located in the left renal vein in four cases. The left renal vein is considered to be affected more often by aneurysm formation because of its more complicated embryologic development.[88] Renal vein aneurysms must be differentiated from a distended left renal vein, which is recognized as a normal variant. The nutcracker phenomenon is attributed to compression of the left renal vein as it courses between the superior mesenteric artery anteriorly and the aorta posteriorly.[97] Renal vein aneurysms should also be differentiated from idiopathic renal vein varices, especially solitary ones. Renal vein varices are usually smaller than aneurysms and typically are accompanied by a dilated venous network adjacent to the renal pelvis and upper ureter.[98] Because of the small number of renal vein aneurysms reported, there are insufficient data regarding optimal treatment. Three of the six patients were treated surgically, two underwent renal vein reconstruction, and one nephrectomy.[89,92,93]

Inferior mesenteric vein

The only case of inferior mesenteric vein aneurysm is described in a 31-year-old woman who also had a superior mesenteric vein aneurysm and presented with thrombosis.[66] She presented aneurysmal dilatation of the inferior vena cava, the hemiazygos vein, the right ovarian vein, and the right iliac internal vein. She underwent arterial thrombolysis and transhepatic thrombus aspiration that resulted in recanalization of the superior mesenteric vein aneurysm. The inferior mesenteric vein aneurysm remained occluded.

A summary of types of treatments of patients with visceral venous aneurysms is displayed in *Figure 2*.

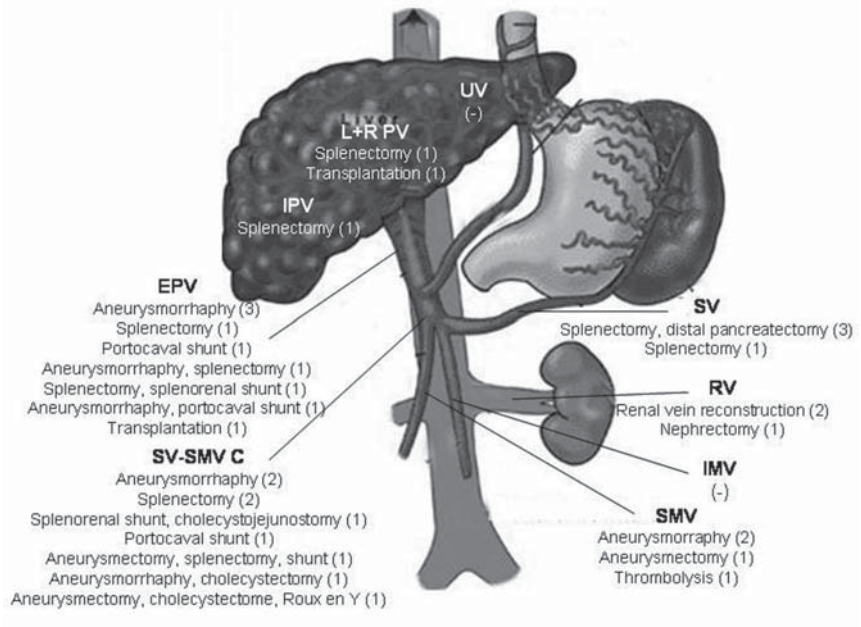

Figure 2.
Types of treatments of patients with visceral venous aneurysms. PV: portal vein EPV: extrahepatic portal vein , IPV: intrahepatic portal vein, SMV: superior mesenteric vein, SV: splenic vein, SV-SMV C: splenic vein- superior mesenteric vein confluence, IMV: inferior mesenteric vein RV: renal vein

11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page134

CONCLUSION

Visceral venous aneurysms may not be as uncommon as previously thought and their most frequent location is the portal system. They are often associated with cirrhosis and portal hypertension and their presentation includes abdominal pain and other nonspecific symptoms, or they are discovered incidentally. Watchful waiting is an appropriate treatment, except when complications occur. Most common complications include thrombosis and rupture.

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Efficacy of a 6-month treatment with Daflon 500 mg* in patients with venous edema (Efficacy of Daflon 500 mg* in Edema Treatment. EDET)

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SUMMARY

Edema is often an early sign of significant fluid retention, which could eventually result in venous complications. It is commonly associated with venous symptoms. This study assesses the contribution of Daflon 500 mg to improving symptoms and reducing venous edema in patients with chronic venous disease.

METHODS

Patients, aged ≥18 years, with venous edema without skin changes, assessed as at least 4 cm on a 10-cm visual analogue scale, complaining of at least 3 symptoms (among pain, heaviness, sensation of swelling, sensation of tension, and restless legs), were included.

They received Daflon 500 mg 2 tabs/day for 6 months. Primary end points were the reduction of leg perimeter and leg volume assessed respectively by tape and the disk model method of calculation. Improvements in clinical symptoms using different scales were the secondary criteria.

RESULTS

From month 2, edema was significantly reduced by Daflon 500 mg (P<0.001), in terms of both leg perimeter measurement and volume calculation. Symptoms (sensation of swelling, of tension, pain, heavy leg sensation, and restless legs) were significantly improved by Daflon 500 mg from month 2 (P<0.001). No treatment-related side effects were reported and the acceptability was considered excellent by most patients.

*Daflon 500 mg is also registered under various trade names including: Alvenor, Ardium, Arvenum 500, Capiven, Detralex, Elatec, Flebotropin, Variton, Viatec.

Keywords:
chronic venous disease, edema, pharmacological treatment, Daflon 500 mg, micronized purified flavonoid fraction (MPFF)

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11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page138

INTRODUCTION

Edema of the lower limbs is not a disease per se, but a sign of underlying disorders which may accompany numerous diseases. The causes of edema are important to identify because they will have major consequences for treatment. Generally, the causes of lower-limb edema are suggested by the clinical examination of the patient. The clinical interview should aim to identify any history of the condition, establish whether edema is acute or chronic, and look for possible precipitating factors. To confirm the diagnosis of venous edema, the clinical examination should exclude edema related to other diseases and verify whether the edema is isolated or diffuse, painful or not painful, its consistency, the existence of urticaria-like lesions suggesting angioedema, the existence of a serous effusion (peritoneum, pleura), signs of thromboembolic disease, or clinical evidence of internal organ disease (heart, kidney, liver).[1]

Edema related to chronic venous disease (CVD) is sporadic, unilateral or bilateral, has no component of inflammation (leg skin is white, not red), is limited to the legs, but may also involve the foot and the ankle (not toes) and is increased by heating, hormonal load, prolonged standing or sitting, but decreases at rest or when walking. On examination, venous edema is initially manifested around the ankle and is variable in intensity, usually worsening during the day and then disappearing after prolonged elevation of the legs.

When edema becomes chronic, thickening of the skin and lymphedema may develop. It is not uncommon that venous and lymphatic edema are combined in the severe stages of CVD. The combination of edema and varicose veins, ankle telangiectasia, hyperpigmented dermatitis, white atrophy, cutaneous sclerosis, and eczema or venous ulcers on the lower limb is a good indication of the venous origin of edema.[2]

On the other hand, venous edema is often accompanied by symptoms like pain, heaviness, sensation of swelling or tension, and restless legs, the cause of which is believed to be linked to the pressure edema exerts on skin nerve endings.[3]

Micronized purified flavonoid fraction (MPFF) [Daflon 500 mg] is a well-established oral flavonoid with venoprotective properties.[4] It consists of 90% micronized diosmin and 10% flavonoids expressed as hesperidin, diosmetin, linarin, and isorhoifolin.[5] The micronization of diosmin to particles with a diameter <2 µm has improved the oral absorption of Daflon 500 mg.[6]

Daflon 500 mg significantly decreases capillary hyperpermeability,[7-9] resulting in a decrease in edema in two trials,[7,8] and weight loss (1.5 kg) and a decreased sensation of swelling in one study,[7] and by an improvement of the symptoms of capillary fragility (spontaneous ecchymosis, epistaxis, purpura, petechiae, gingivorrhagia, metrorrhagia and conjunctival hemorrhage) in another trial.[9] These interesting product features made us choose Daflon 500 mg for the present trial. In three further studies that have used different methods to quantify leg edema, beneficial effects of Daflon 500 mg have also been demonstrated.[10-12]

CVD-related edema may be assessed by either ankle circumference or leg volume. Ankle circumference must be taken at the same height to avoid artefacts, which is made possible by the use of Leg-o-Meter.[13] Water displacement is considered the most valuable method for assessing the volume of an edema, but it is time-consuming and may pose implementation challenges in the clinical and clinical trial environments.[14] Leg volume may be calculated indirectly using the disk model.[15] A series of ankle and leg circumferences are used to calculate the volume of each cross-section in millimeters. The sum of the disk volumes provides an estimate of total leg volume.[14]

The intensity of symptoms and their impact on quality of life should be considered in edematous patients. The 10-cm visual analogue scale (VAS) has been extensively used to assess symptoms in all types of diseases, including CVD.[16] A complement to the VAS and to the clinical, etiological, anatomical, pathophysiological (CEAP) classification of CVD is the Venous Clinical Severity Score (VCSS), which includes 10 hallmarks of venous disease that are likely to show the greatest response to therapy, each scored on a severity scale from 0 to 3. These include pain, edema, and inflammation. Scores obtained for each item are added up to comprise the overall VCSS, which ranges from 0 to 30.[17] To fully assess an outcome, the effects on the physician, patient, and community should be reported. This notion is at the heart of quality of care that considers quality of life. A widely used and well-validated instrument is the CIVIQ-20, which has over time been developed and validated in 13 languages, with questions on physical health, psychological and social well-being, and pain.[18]

11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page139

The aim of the present study was to assess the contribution of Daflon 500 mg to the reduction of CVD-related edema and symptoms.

METHODS

Design

The study was conducted in 27 centers (dermatology and angiology departments) located in the Czech Republic, according to an open design.

Patients

Ambulatory male and female patients, aged ≥18 years, assigned C3 (edema without skin changes) in the CEAP classification, presenting with venous edema, assessed as at least 4 cm on a 10-cm VAS, complaining of at least 3 symptoms (from among pain, heaviness, sensation of swelling, sensation of tension, and restless legs), were included after having given their written informed consent and having met the following inclusion criteria: no history of concomitant disease, no abnormal laboratory values, and having stopped taking phlebotropic drugs for 2 weeks. The main patient exclusion criteria were congenital angiodysplasia, deep vein thrombosis, superficial phlebitis, arteriopathy, uncontrolled diabetes, renal failure, lymphedema or ankle ankylosis, vasculitis or blood disorders, allergy to a drug, unauthorized concomitant pharmacological therapy (mainly venotropics, nonsteroidal anti-inflammatory drugs, other local therapy, systemic steroids, diuretics, ergotamine, beta-blockers, calcium inhibitors) or nonpharmacological therapy (sclerotherapy, surgical treatment, normovolemic hemodilution, laser therapy, local UV and ultrasound therapy, oxygen therapy), alcohol or drug abuse, pregnancy or breastfeeding. Patients were also excluded if the cause of their edema was renal, hepatic, cardiac, iatrogenic, or other than venous.

Therapy

Following a 2-week run-in period during which patients had to stop any unauthorized treatment, patients received Daflon 500 mg (2 tablets/day in the morning). The treatment duration was 6 months.

Assessments

The two primary end points of the study were reduction in calf circumference, measured with the Leg-o-Meter,[13] and decrease in leg volume, as assessed using the disk model[15] after 2 and 6 months of therapy. For the calculation of leg volume, leg perimeter was taken at several points at 3-cm intervals, starting 3 cm below the saphenofemoral junction and ending just above the malleolus. Main secondary criteria were the evaluation of venous symptoms with both the VAS[16] and the VCSS,[17] and the self-evaluation of the patients' quality of life with the CIVIQ-20[18] during the course of the study.

After the selection visit (day –14), patients were seen at baseline (day 0), then at months 2 and 6.

At each visit, (day 0, month 2, month 6) assessments were carried out as follows:

- clinical evaluation of the appearance of the edema
- assessment by the investigator of the therapeutic effect on calf circumference using the Leg-O-Meter
- assessment by the investigator of the therapeutic effect on leg volume using the disk model method
- evaluation of the intensity of pain, leg heaviness, sensation of swelling, of tension, restless legs using the 10-cm VAS
- self-assessment of the quality of life with CIVIQ-20
- screening for adverse effects and acceptability

Treatment compliance was assessed by tablet count.

Statistical analysis

Statistical analysis was performed using BMDP software. In all statistical tests, the level of significance was set at 5%.

The intention-to-treat (ITT) population, considered for acceptability analysis, was defined as all selected patients with at least one visit and corresponding assessments available. The per protocol (PP) population was defined as those selected patients who completed the study in accordance with the protocol.

The change in parameters during the course of the study was analyzed using one-way analysis of variance.

RESULTS

Twenty-seven centers participated in the study. Out of the 215 patients selected for participation, 213 were included, and 196 completed the study in accordance with the protocol. Main demographic and baseline clinical characteristics of the study population are

11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page140

displayed in *Table I*, while *Table II* presents the clinical findings on admission in relation to the venous status of included patients.

Variable	Average
[illegible]	8
Age (years)	48 ± 12
Weight (kg)	77 ± 14
Height (cm)	169 ± 7
SBP/ DBP (mm Hg)	125 ± 12 / 78 ± 8
Heart rate (bpm)	71 ± 7
BMI (kg/m²)	27 ± 5
Standing or sitting more than 8 h (%)	25
Smoking (% yes)	13
Hormonal treatment (% yes)	23
Duration of hormonal treatment (years)	6
Number of pregnancies	2

Table I: Demographics and clinical characteristics of the study population at baseline

SBP/DBP: systolic/diastolic blood pressure; BMI: body mass index (=weight/height²); bpm: beats per minute

Variable	Average
Family history of chronic venous disease (%), with • one parent involved • both parents involved	85 78 20
History of deep vein thrombosis (%)	8
Duration of CVD (years)	13 ± 10
Previous nonpharmacological treatment for CVD (% yes), of which • stripping • sclerotherapy	27 57 31

Table II: Characteristics of the venous status at baseline

SBP/DBP: systolic/diastolic blood pressure; CVD: chronic venous disease

Patients were mostly women (92%) and a family history of CVD was found in almost 75%. A personal history of deep vein thrombosis was present in 8% of the patients and the duration of CVD was over 13 years in most of the cases.

Primary end points

Right from month 2, both the ankle and calf circumferences were significantly reduced as compared with those at baseline (24.4 cm vs. 25 cm; $P<0.001$ for ankle perimeter, and 39.9 cm vs. 40.6 cm; $P<0.001$ for calf perimeter). The reduction in perimeters continued until month 6, as shown in *Figures 1 and 2*.

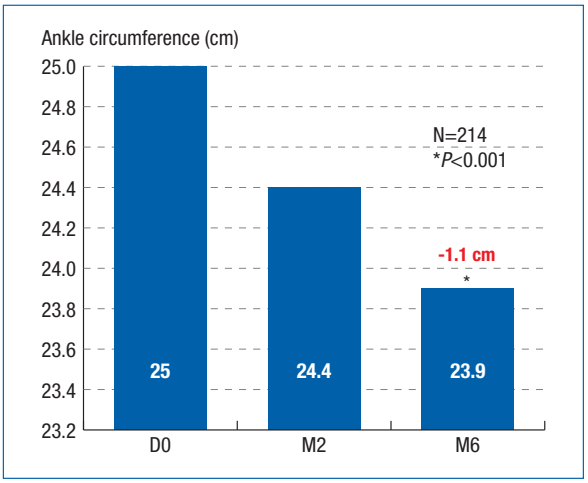

Figure 1. *Ankle circumference at baseline (D0) and after 2- and 6-month treatment with Daflon 500 mg (respectively at M2 and M6)*

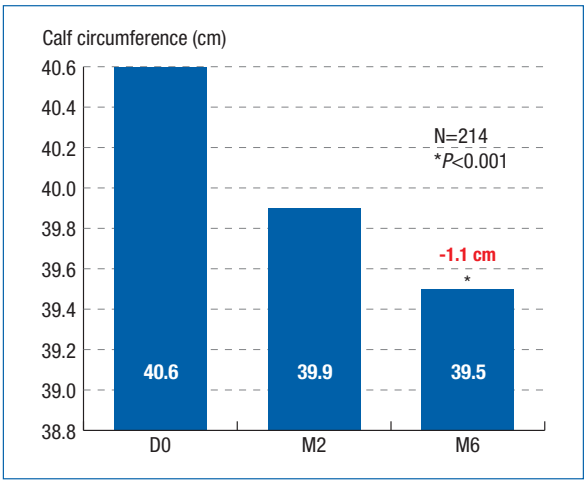

Figure 2. *Calf circumference at baseline (D0) and after 2- and 6-month treatment with Daflon 500 mg (respectively at M2 and M6)*

Leg volume had decreased by an average 78 cm³ after 2 months of Daflon 500 mg treatment, and 121 cm³ after 6 months (*Figure 3*). This was statistically significant at both times ($P< 0.001$).

11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page141

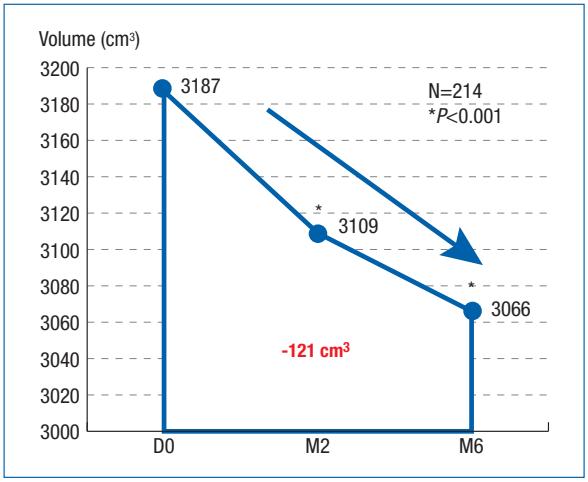

Figure 3. Assessment of leg volume by the disk model at baseline (D0) and after 2- and 6-month treatment with Daflon 500 mg (respectively at M2 and M6)

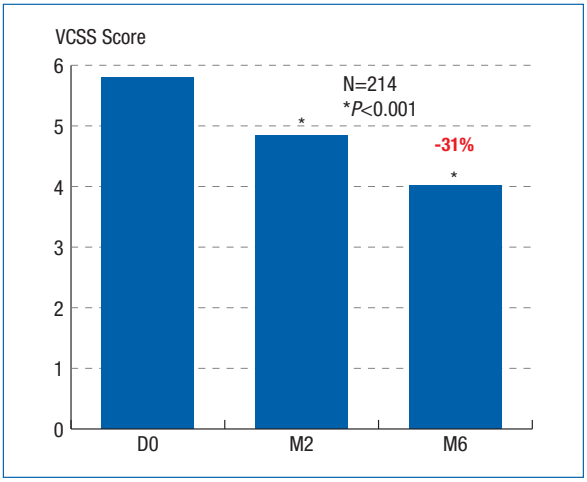

Figure 5. Assessment of Venous Clinical Severity Score (VCSS) at baseline (D0) and after 2- and 6-month treatment with Daflon 500 mg (respectively at M2 and M6)

Secondary criteria

The reduction in symptom intensity, as measured with VAS, was shown to be significant at both month 2 and month 6 of treatment (*Figure 4*). This was true for all symptoms. The VCSS assessment showed significant difference between baseline (score, 5.8), month 2 (score, 4.8), and month 6 (score, 4) scores (*Figure 5*). The CIVIQ score decreased substantially for all 20 questions, meaning that quality of life was improved with therapy (*Figure 6*).

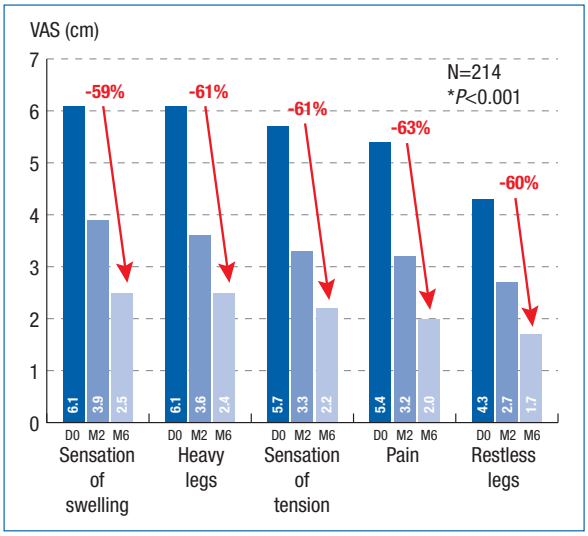

Figure 4. Assessment of symptom intensity using a visual analogue scale (VAS) at baseline (D0) and after 2- and 6-month treatment with Daflon 500 mg (respectively at M2 and M6)

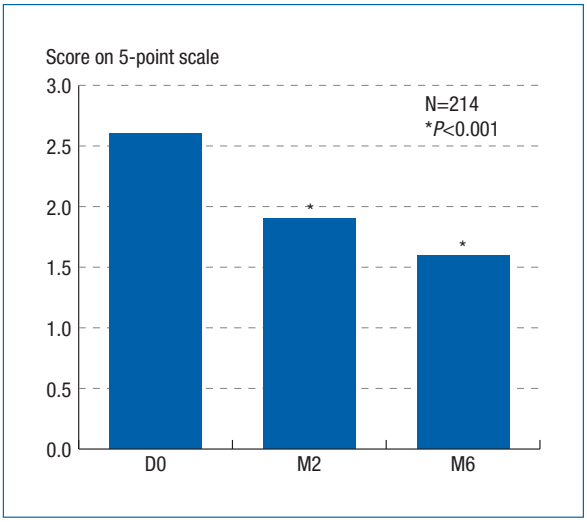

Figure 6. Assessment with a five-point Lickert scale of well-being at baseline (D0) and after 2- and 6-month treatment with Daflon 500 mg (respectively at M2 and M6). Average score to the following question: 'During the past 4 weeks, to what extent did you feel bothered/limited in your work or your other daily activities because of your leg problems?'

The overall efficacy of the treatment was assessed by both the investigators and patients. For 93.5% of physicians, Daflon 500 mg was considered to be good to excellent, while 91% of patients were satisfied or very satisfied, and for 82% of them it was decided to continue Daflon 500 mg.

11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page142

Acceptability

No change in body weight, heart rate, or blood pressure was reported during the study, and no side effects in relation to treatment were observed. The acceptability of the Daflon 500 mg treatment was excellent, and no patient reported poor acceptability or deterioration.

Compliance

Assessment of treatment compliance during the course of the study showed 99 to 100% compliance.

COMMENTS

The present study confirms previously reported results on the beneficial effects of Daflon 500 mg in the treatment of edema associated or not with venous symptoms.[19] Our data show that pharmacological therapy with Daflon 500 mg significantly reduces the perimeter and volume of lower limbs, while improving clinical symptoms and quality of life.

Edema is often an early sign of significant fluid retention, which could eventually result in complications. However, accuracy and consistency in assessing edema is a challenge. A variety of methods to measure edema quantitatively have been proposed (volumetry and ankle circumference). Among these, ankle and calf perimeter have shown excellent reliability.[14] Previous research has shown that the disk model method of calculating leg volume is highly correlated with water displacement volumetry.[20] The disk model method was previously chosen to assess the efficacy of venoactive therapy in reducing edema.[21] In this last study of 253 consecutive outpatients in CEAP classes C3 to C4 who were treated for 4 weeks, the difference in leg volume was statistically significant ($P = 0.0109$) in favor of active treatment. This points to the usefulness of the disk model method in assessing edema in clinical research.

The efficacy of Daflon 500 mg in reducing venous symptoms was also demonstrated from the second month of therapy. Subjective assessment with a VAS was complemented by the physician-related VCSS and the patient-reported quality of life questionnaire CIVIQ-20.

It is noticeable from this study that severity scores were not distributed over the whole 0 to 30 VCSS scale and that the mean score obtained at each study time was not very high (less than 6 at baseline). This was observed in a previous survey performed by French angiologists,[22] in which a markedly lower clinical severity score was found in the [C1-C2-C3] group of patients compared with the [C4-C5-C6] group. This might be because the VCSS was designed by the authors to evaluate the most severe forms of CVD, above C4.

The CIVIQ-20 proved sensitive to clinical changes and well adapted to the assessment of efficacy of therapies even at early stages.[23] The present study lends further weight to this observation

CONCLUSION

The results of the present study are conclusive evidence that Daflon 500 mg is effective in the treatment of edema and the reduction of venous symptoms. Six-month treatment with Daflon 500 mg significantly reduced leg edema, while improving some clinical symptoms of CVD.

The efficacy and the acceptability of this treatment were evaluated as good to excellent by a large majority of the investigators and patients as well, suggesting that better compliance may be expected from patients with Daflon 500 mg, thus optimizing therapeutic efficacy.

This article is adapted from the previous publication 'Z Navratilova. Efficacy of Detralex in edema treatment. Interni Med. 2009;11(2):87-90 [in Czech]' with Dr Navratilova's permission.

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11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page143

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11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page144

Tissue fluid pressure and flow in the subcutaneous tissue in lymphedema – hints for manual and pneumatic compression therapy

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Keywords:
lymphedema, tissue fluid, subcutaneous tissue, manual massage, pneumatic compression

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ABSTRACT

Physiotherapy of lymphedema requires knowledge of: a) how high external pressures should be applied manually or set in compression devices in order generate tissue pressures high enough to move the fluid to the non-swollen regions and b) how to measure the tissue fluid flow.

We measured tissue fluid pressure and flow under the skin in the subcutaneous tissue of lymphedematous limbs stage II to IV at rest and during manual and pneumatic compression under various pressures and sleeve inflation timing.

In obstructive lymphedema of lower limbs tissue fluid pressures in the subcutaneous tissue was 2.5±3.0 mmHg (range-1 to +10 mmHg) and did not differ from those measured in normal subjects. During manual massage the applied force generated pressures ranging from 60 to 120 mmHg. Pneumatic compression generated tissue fluid pressures depending on sleeve inflation pressures, however, they were on the average 20% lower than in the inflated chambers. The high pressure gradient across skin and subcutis could be explained by skin rigidity (fibrosis), low hydraulic conductivity of subcutis and dissipation of the applied force in subcutis to the proximal non-compressed regions. Strain gauge put around the limb provided data on girth changes during compression and allowed to calculate the approximate volume of the proximally displaced fluid. It showed that tissue fluid flow occurred during manual compression only during pressing of tissues to stop immediately after its cessation. In contrast, pneumatic sequential compression produced unidirectional flow toward groin without backflow. The total proximally displaced volume from ankle to groin was up to 100ml/cycle.

The obtained data should be useful for physiotherapy allowing to set the manual or pneumatic compression parameters at levels corresponding to the physiological conditions.

11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page145

INTRODUCTION

Treatment of lymphedema of limbs is a combined modality comprising administration of medicines,[1,2] compression procedures based on manual and pneumatic massage,[3] wearing elastic stockings or bandages preventing accumulation of fluid and growth of expanded skin and subcutis, also enhancing the efficiency of muscular pump,[4] and in selected cases lymphovenous shunts,[5] liposuction[6] and debulking of abundant tissues.[7]

The mechanism of action of administered anti-lymphedema medicines as diosmins and related drugs as well as indications for surgical procedures have been well defined and the results of treatment can be quantified. In contrast, compression procedures bring about diverse effects because of differences in manual massage protocols, pneumatic devices and poor knowledge what pressures and compression timing should be used. There is no information in the literature on mobile tissue fluid pressure and flow in human skin and subcutaneous tissue under normal conditions and in various types of lymphedema. We previously measured lymph pressures and flow in human calf collectors, however, the obtained data did not give insight into the hydraulic conditions in the interstitium[8] In lymphedema most lymphatic collectors do not contract as they have a fibrotic wall and are partially obliterated. The bulk of the capillary filtrate accumulates in tissue spaces.[9]

Compression therapy partly supports, partly replaces the force necessary for propelling tissue fluid toward the root of the limb. Unfortunately, this treatment modality has so far not been based on the knowledge of hydraulic conditions in the interstitium of skin and subcutaneous tissue and blood perivascular spaces. The technical parameters of pneumatic compression devices are based on blood rheological data derived from textbooks. These are the capillary and venous blood pressure, venous blood flow and capacitance and capillary filtration. Unfortunately, there is little analogy between the blood and lymphatic system rheology at the tissue level. Pressures applied by pneumatic compression are set arbitrarily, because of lack of knowledge of skin and subcutis compliance (fibrosis), exact sites of lymphatic obstruction and accumulation of excess of tissue fluid as well as tissue fluid pressures and flow. The recommended compression pressures for pneumatic massage are around 50mmHg, timing of sleeve chamber inflation is usually 5 seconds and it is followed by a rapid deflation. Total compression time by an 8-chamber sleeve usually ranges between 20 to 40 seconds. It is not known whether this timing is sufficient to overcome tissue hydraulic resistance and move the stagnant tissue fluid.

What needs to be elaborated for clinical practice is how much external pressures should be applied either manually or by compression devices in order generate tissue pressures high enough to move the fluid to the non-swollen regions and how to measure the tissue fluid flow.

In this study, we measured tissue fluid pressure and flow under the skin in the subcutaneous tissue of lymphedematous limbs stage II to IV at rest and during manual and pneumatic compression under various applied pressures. The obtained data should be useful for physiotherapy and allow to set the compression parameters at levels corresponding to the physiological conditions.

MATERIAL AND METHODS

Patients.

Study was carried out on 25 patients with lymphedema of one lower limb, stage II to IV, duration of 2 to 15 years. Edema developed month to years after small foot abrasion, insect bite or soft tissue trauma. In 50% of cases edema was complicated by 1 to 3 attacks of dermato-lymphangio-adenitis. In 3 patients edema developed without any detectable reason. Cases with acute inflammation were excluded from the study. Five male volunteers with healthy legs served as controls. Staging was based on the level of edema starting from foot to groin, degree of skin keratosis and fibrosis and soft tissue tonometry.[9] Evaluation of lymphatic pathways was done on lymphoscintigraphic pictures. Color Doppler investigation was also carried out to exclude cases with the postthrombophlebitic changes. Calf and thigh circumference were measured in supine position 15cm below and 15 cm above the lower edge of patella. The study was approved by the Warsaw Medical University and the Indian Universities ethics committees.

Tissue fluid pressure measurement

The wick-in-needle technique was used. An 8 gauge injection needle with a polyethylene tubing

11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page146

(OD 1.34 mm) containing glass-wool wick protruding from the tubing tip at 5mm was introduced under the skin. The outer part of tubing was led outside the compression sleeve, connected to the pressure transducer (Honeywell, Elblinger, Poland) and recording was done using a 3 channel device, pressure range -20 to 150 mmHg (Telsoft, Warsaw, Poland) and LabView software (National Instruments, Austin, TX, USA). The position of transducer was zeroed and pressure recording was started simultaneously with manual compression or sequential inflation of sleeve chambers. The data were collected using Microsoft Excel program and were presented graphically on a pressure/time scale.

Continuous limb girth (volume) measurement

Strain gauge plethysmography was used to measure girth changes in the calf and thigh. The plethysmograph (Hokanson, Bellevue, WA, type EC6) recording vein mode was applied. The girths of mid-calf and mid-thigh were measured and a 2 cm shorter mercury strain gauges were put around limb at chamber levels 3 to 8. Elongation was read off on the recorder graph scale in mm as a change in limb circumference. Inflation of chambers located distally to the strain gauge propelled mobile tissue fluid in proximal direction. Once fluid reached the limb region with strain gauge, its volume increased and so did the girth. Increase in girth was recalculated into volume by multiplying cross area of limb at the studied level by the length of the compressing chamber. Subtracting the volume value before compression from that during compression provided data on the transferred volume.

Manual massage

Limb massaging started distally from the level of pressure sensor and strain gauge, slowly approached them, then it was continued over the site of recording in proximal direction to the groin. Tissue fluid pressure and girth changes were recorded continuously.

Pneumatic compression appliance

We used such a device designed for us by Biocompression (Moonachie, NJ). It was built of 8 segments 9 cm long each, sequentially inflated, inflation pressures were regulated from 50 to 125 mmHg, gradient pressures was proximally decreasing by 20%, inflation time of each chamber was 50 sec, there was no deflation of distal chambers, the deflation time at the end of the cycle was 50 sec. The long inflation time was based on our observations that manual squeezing of tissue fluid from the wound during debulking surgery took a minimum of 50 to 100 sec. No deflation prevented venous return to the distal parts of the limb and venous stasis with increased filtration rate. Sites of pressure and flow recordings have been shown on *Figure 1*.

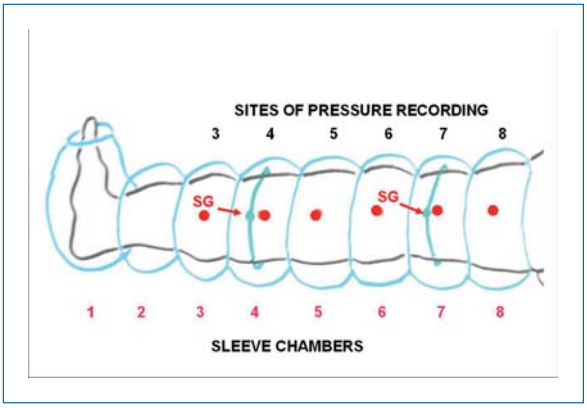

Figure 1. *Schematic presentation of lower limb in a pneumatic sleeve with 8 chambers 9 cm wide each. Tissue fluid pressure was measured at 6 points indicated by large dots. The lines encircling calf and thigh show the site of strain gauge location for continuous measuring of girth changes.*

RESULTS

Subcutaneous tissue fluid pressures at rest

Tissue fluid pressure measured under the skin in lymphedematous calfs ranged between – 1.5 and 10 mmHg (mean 2.5±3.0) and in controls between -1.8 and

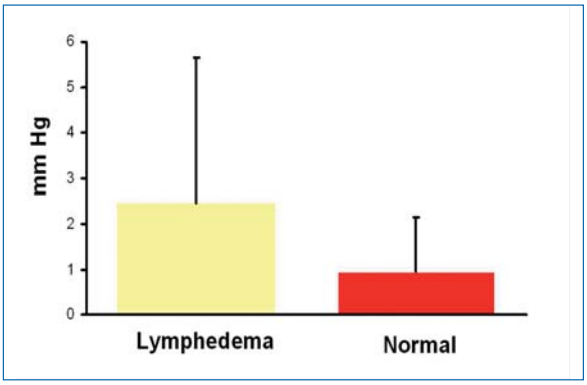

Figure 2. *Tissue fluid pressure measured under the calf skin in a horizontal position in 15 patients with lymphedema stage II to IV and 5 healthy subjects. No significant differences between lymphedema and normal limbs. There were no differences depending on the stage of the disease. Data are means +-SD.*

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3.0mmHg (mean 0.8±1.2) (*Figure 2*). There were no statistically significant differences between the groups. These reading corroborate our previous clinical and experimental findings.[10,11] The mechanism of low pressure can be explained by high skin compliance in the early stages of edema formation leading to expansion of the subcutaneous space absorbing excess of capillary filtrate not drained away by lymphatics.

Subcutaneous tissue fluid pressures and flow during manual massage

The manual force for massage is set arbitrarily and never seems to be too high. However, our measurements showed that hands generated tissue fluid pressures ranging as high as 140 mmHg (*Figure 3*). This was observed in stages II and III. In stage IV high skin rigidity limited the force transfer to subcutis and lower pressures were observed. To investigate whether the manual force is transferred to proximal regions of the limb, we measured pressures at different distances from the massaging hand. Compression 3 cm from the sensor did not show any transfer pressure through this distance . This could be explained by skin rigidity and low hydraulic conductivity of subcutis.

Tissue fluid flow during manual massage was seen only during compression of tissues, to stop immediately after removal of the pressing hand (*Figure 4*). The calculated flow per compression values were around 5 ml. The skin indentation by the massaging hand usually disappeared within 10-15 sec. This indicated that the displaced fluid returned to its site of origin.

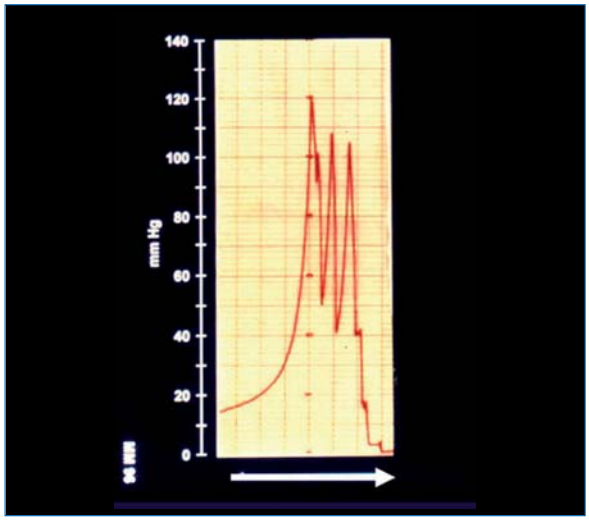

Figure 3. *Tissue fluid pressure measured under the skin in a lymphedematous calf in a horizontal position during manual massage. Note the short-lasting high pressure waves at each manual compression and zero level immediately after stopping of massage. The blinded physiotherapeutist used such a force during each massage session.*

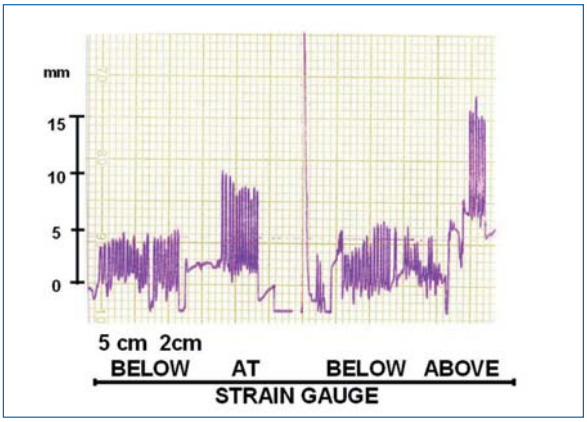

Figure 4. *Change in circumference (volume) in a lymphedematous calf during manual massage recorded at two levels 10 cm apart. Note that hand compression caused only a short-lasting increase in circumference with immediate return to the initial level. There was no increase of circumference when the massaging hand was put 5 and 2 cm away from the strain gauge. Pressing tissues directly at the site of strain gauge brought about an increase in circumference with a fast drop after hand removal. Pressing above the strain gauge caused increase of circumference below. This indicated retrograde flow of fluid. 15 mm on scale = 5 mm of calf girth increase = 10-15 ml of calculated tissue fluid flow.*

Subcutaneous tissue pressures and flow during pneumatic massage

The pressures generated in tissue fluid during the first inflation of asleeve chamber were in all cases lower than those in the chamber itself. (*Figure 5, 6A, 6B*). This high gradient was most likely caused by skin rigidity (fibrosis) and dissipation of the applied force to the proximal non-compressed regions. Interestingly, there was also little tissue fluid pressure transmission in subcutis from the compressed to the non compressed proximal segments for a distance of 9 cm (width of the chamber). In advanced stages IV limited pressure transmission in proximal direction could be seen. An interesting finding was building up pressure in the distal parts of the limb during sequential inflations of proximal chambers. This could be due to flow obstruction at the inguinal level. We also noticed that tissue fluid pressures reached lower levels in the popliteal and upper thigh than in other limb regions. These two regions are usually less swollen and

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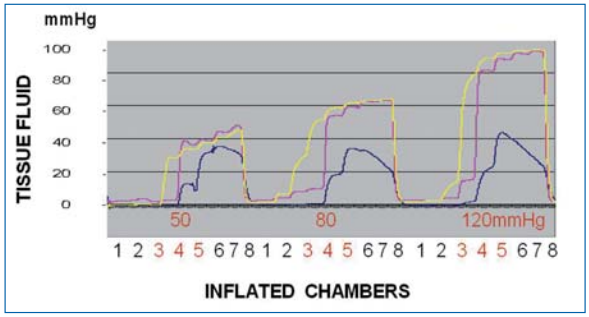

Figure 5. *Tissue fluid pressure recording in a normal calf subcutaneous tissue at the level of compression sleeve chambers 3, 4 and 5. Inflation pressures 50, 80 and 120 mmHg. Inflation time of each chamber 55 sec, no deflation. Number 1 to 8 denote consecutive sleeve chambers. Pressures recorded under chambers 3 (yellow line), 4 (red line) and 5 (blue line). Note that pressures were always lower than those in chambers. Inflation of chambers 1,2 and 3 to 50 mmHg did not generate pressures at level 3. Inflation of chamber 4 produced pressure of 30 mmHg at level 3 stepwise rising during inflation of consecutive chambers to 45 mmHg. Inflation of chamber 4 also produced tissue fluid pressure rise to 40 mmHg and of chamber 5 to 12 mmHg, to increase during inflation of consecutive chambers to 45 and 38, respectively. Similar pressure curves were observed during inflation of chambers to 80 and 120 mmHg. Blue line (level 5) represents pressure at the medial aspect of calf just below the knee usually with less edema.*

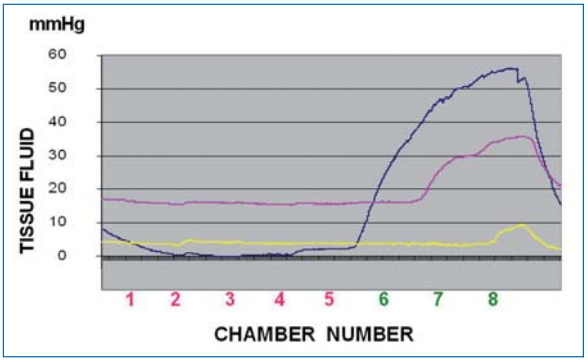

Figure 6b. *Tissue fluid pressure in the thigh lymphedematous subcutis stage IV during pneumatic compression of 50 mmHg). Pressures recorded at level 6 (blue line), 7 (red line) and 8 (yellow line). Note that as in the calf, tissue fluid pressures during first inflation of all chambers were lower than those in the chambers. Inflation of chambers 1 to 5 to 50 mmHg did not generate pressures at level 6. Inflation of chamber 6 produced at level 6 pressure of 35 mmHg (blue), stepwise rising during inflation of consecutive chambers to 55 mmHg. Inflation of chamber 7 produced tissue fluid pressure rise at level 6 to 50 mmHg and at level 7 to 30 mmHg to increase during inflation of consecutive chambers to 55 and 35 mmHg. The yellow line represents pressure at level 8 close to the groin usually with less edema and low flow resistance.*

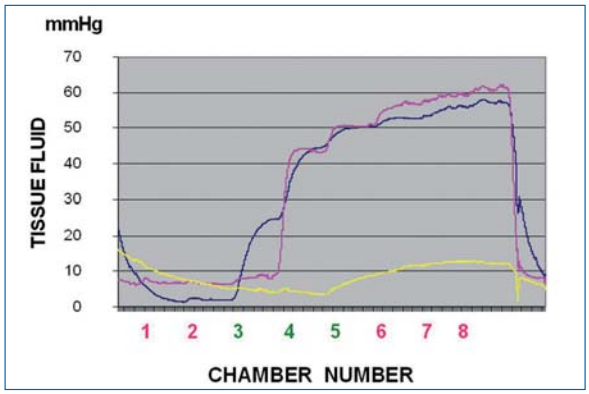

Figure 6a. *Tissue fluid pressure in the calf lymphedematous subcutis stage III during pneumatic compression of 50 mmHg (inflation time of each chamber 55 sec, no deflation). Pressures recorded at level 3 (blue line), 4 (red line) and 5 (yellow line). Note that tissue fluid pressures during first inflation of chambers at level 3, 4 and 5 were lower than those in the chambers themselves. Inflation of chambers 1 and 2 to 50 mmHg did not generate pressures at level 3. Inflation of chamber 3 produced at level 3 pressure of 25mmHg (blue), stepwise rising during inflation of consecutive chambers to 55 mmHg. Inflation of chamber 4 produced tissue fluid pressure rise at level 3 and 4 to 45 mmHg to increase during inflation of consecutive chambers to 60. The yellow line represents pressure the medial aspect of calf just below the knee (level 5) usually with less edema and low flow resistance.*

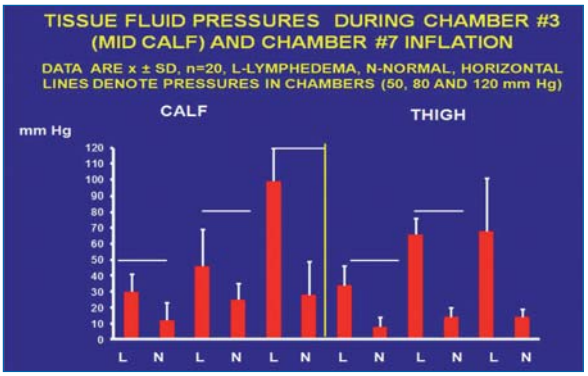

Figure 7. *Summarized data of tissue fluid (TF) pressures in calf and thigh subcutaneous tissue in patients with lymphedema (n=15) and healthy subjects (n=5) during the first inflation of pneumatic sleeve to 50, 80 and 120 mmHg. L- lymphedema, N- normal, horizontal line denotes pressure in the sleeve, mean values ± SD. Note that TF pressure was in all cases lower than in the sleeve both in the lymphedema cases and healthy subjects (for explanation see text). There were also evident differences between lymphedema and control cases.*

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slowly accumulate fluid translocated during sequential massage. Summarized data of 15 patients have been presented on *Figure 7*.

Circumference (volume) changes during pneumatic massage

Continuous recording of circumference changes during sequential compression gave indirect insight into the volumes of fluid translocated from the compressed segments to the proximal ones. Following inflation of a chamber, increase of limb circumference occurred proximally to this chamber. Sequential inflations of chambers from 1 to 8 resulted in stepwise increase of circumference in consecutive segments of the limb (*Figure 6*). The increase in circumference at each level was recalculated into increase in volume. Summarized data of 15 patients are presented on *Figure 7*. The calculated proximally transferred volume was evident in the calf but much more in the thigh containing large volumes of fluid and fat.

Continuous recording of circumference changes during sequential compression gave insight into the volumes of fluid translocated from one pressed segment to another. Following inflation of a chamber there was increase of circumference in limb segment above this chamber. When the segment with strain gauge was compressed, the girth decreased. Further sequential inflation of proximal chambers brought about girth decrease (*Figure 8*). This was observed in cases with low resistance to tissue fluid flow. In case of flow obstruction, girth rose to high values. The increase in girth was recalculated into increase in volume. The total volume accumulating fluid volume in the proximal parts of the limb could also be calculated. Summarized data have been presented of *Figure 9*.

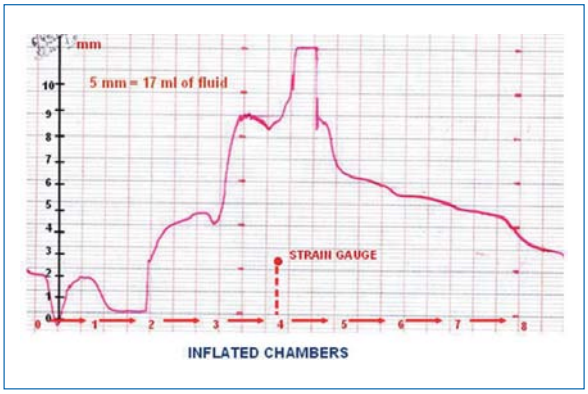

Figure 8. *Circumference changes in lymphedematous calf stage IV during sequential compression at 120 mmHg. Strain gauge underneath chamber 4. Inflation of chamber 1 brought about decrease of girth due to halting of venous inflow. Inflation of chamber 2 caused increase at level 3 by 5 mm, of chamber 3 by 5 mm, of chamber 4 by another 3 mm do decrease sharply (compression by sleeve chamber 4). Inflation of chambers distal to 4 was followed by decrease in girth at level 4 most likely due to an easy proximal drainage of tissue fluid. The values of girth changes in mm were used for volume computing. Five mm increase corresponded to 15-17 ml.*

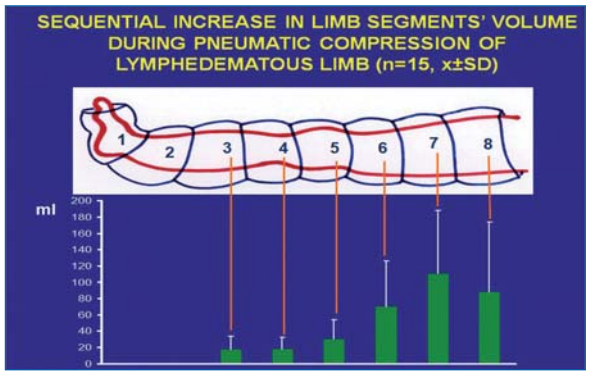

Figure 9. *Calculated volumes of tissue fluid (TF) moved sequentially from distal parts of lymphedematous limb toward the groin by pneumatic compression of chambers 1 to 7. The volume increases in consecutive limb segments to reach highest values in the mid-thigh. Note that although edema is clinically most visible above the ankle level, bulk of the fluid is moved from the thigh. Values are means ± SD, n=15. Note high SD caused by differences in accumulation of TF in individual patients.*

Correlation between pressure and girth changes during sequential compression

Correlating pressure and flow data provides information of whether there is a high resistance to tissue fluid flow. High fluid pressures and low flow would suggest major flow obstruction, usually at the groin level, whereas, low pressures and low flows would point to low efficacy of compression due to high skin rigidity. High flows and low pressures were usually seen in early stages of lymphedema without fibrotic changes of skin and subcutaneous tissue. There was no correlation between tissue fluid pressure generated by external compression and flow in proximal direction in tissue fibrosis and scars after surgery and radiotherapy. There could be high pressure but practically no flow . This resistance could only be overcome by strong external compression generating very high tissue fluid pressures.

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DISCUSSION AND CONCLUSIONS

Taken together, in obstructive lymphedema of lower limbs tissue fluid pressures in the subcutaneous tissue were low and did not differ from those measured in normal subjects. During manual massage the applied force is set arbitrarily and it generated pressures ranging from 100 to 150 mmHg. Compression at a distance of 3 cm from location of the pressure sensor didn't not show any rise in pressure what could be explained by skin rigidity and low hydraulic conductivity of subcutis. Tissue fluid flow appeared during manual compression only when the hand was pressing, but stopped immediately after cessation of massage. The calculated flow values during manual massage were low.

Pressures generated in tissue fluid by pneumatic compression chambers were lower than those measured in the inflated chamber. The gradient depended most likely on skin rigidity (fibrosis) and dissipation of the applied force in the subcutaneous tissue to the proximal non-compressed regions. There was little tissue fluid pressure transmission in subcutis to the noncompressed proximal segments. Interestingly, building up pressure in the distal parts of the limb during inflation of proximal chambers was observed. This was presumably the consequence of flow obstruction at the inguinal level. Strain gauge put around the limb provided data on circumference changes during compression and allowed to calculate the approximate volume of displaced fluid. This volume ranged in our studies from 10 to 30 ml per inflated chamber, to reach above 100 per the whole sleeve in the groin region.

Interestingly, there was no direct correlation between tissue fluid pressure generated by external compression and flow in proximal direction. This was presumably caused by fibrosis of the subcutaneous tissue and scars after radiotherapy creating mechanical resistance to flow. It could only be overcome by external compression generating very high tissue fluid pressures.

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11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page151

The plantar venous pump: Anatomy and physiological hypotheses

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foot anatomy, venous pump, plantar veins

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SUMMARY

An anatomical study of 200 (cadaveric) feet injected with latex demonstrated that Lejars' concept of the venous sole of the foot is incorrect: the true plantar venous pump consists of the plantar veins, located deep between the plantar muscles and compressed by weight bearing during walking. The normal venous sole (Bourceret) is a thin network and its dilatation (Lejars) is pathological, attributed to severe distal venous stasis.

The blood reservoir of the foot, which moves upwards as the result of manual compression of the plantar venous pump or weight bearing during walking, is located in the plantar veins.

This is the reason why, in patients with venous disease, it is so important to make sure that the static anatomy of the foot is normal. In fact, the venous pump of the foot is the first step in venous return of blood during walking, just before the calf pump.

INTRODUCTION

Background

1861: Sucquet: observed taut channels in the thickness of the skin going from a pre-capillary arteriole to a post-capillary venule. This structure shunts the capillary blood and facilitates passage into the arteriovenous anastomoses. These channels are observed in areas of high pressure in the sole of the foot and the palm of the hand.

1885: Bourceret[1] demonstrated a fine plexus of dermal and subdermal veins along the entire plantar surface of the foot. This venous network drains directly into the medial and lateral marginal veins, and into the medial and lateral plantar veins via fine perforators in fatty tissue.

11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page152

1889: Braune[2] observed an arch—the anterior part of the plantar venous network by the interdigital veins and which opens into the dorsal veins. He confirmed the existence of the fine plexus described by Bourceret.

1890: F. Lejars[3] was the first to describe a venous pump activated by walking: the plantar venous pump. He described large superficial vessels which form a true plantar reservoir. But these large superficial veins were injected by an arterial approach under high pressure and, in fact, Lejars' observation is a technical artifact.

1993: J. H. Scurr,[4] using plethysmography, recorded changes in volume and estimated the quantity of blood ejected from the sole of the foot as 20-30 ml during contraction.

1993: Gardner and Fox[5] proposed the hypothesis which states that it is the stretching of the medial and lateral plantar veins which, with each step, pushes the blood into the saphenous veins and the deep venous network and that the pump of the foot and that of the calf function sequentially.

MATERIAL AND METHODS

We used 200 non-selected, non-embalmed cadaveric subjects (with a high average age).

After exposing the medial marginal vein, a no. 19 butterfly venous catheter was inserted and directed towards the toes (countercurrent therefore to blood flow). The common femoral vein was approached and a tube was inserted to perform lavage-irrigation with soapy water, repeated several times, until a clear liquid was obtained. Then undiluted latex with neoprene was injected, which stained green (120 - 150 ml per limb), for 30 minutes. Dissection was started the next day.

RESULTS

I/ Demonstration of the plantar venous pump

The existence of a plantar venous pump is an unquestionable reality. It is confirmed every day by phlebologists who carry out what they erroneously refer to as "Lejars' plantar compression maneuver".

With the patient's foot immobile, manual compression exerted on the plantar venous arch triggers frank acceleration of blood flow in the posterior tibial veins, revealed in the ankle by Doppler scanning. Therefore, this acceleration of deep blood flow is immediate, intense, and repeated. This is a deep blood reservoir, mobilized by manual pressure exerted on the sole of the foot, corresponding to the lateral (and medial) plantar veins included between two fleshy muscles.

II/ Anatomical description of the veins in the foot

A-Superficial venous network

1-Veins in the sole of the foot

The superficial veins in the sole of the foot form a fine network which drains into the marginal veins via small, valve-bearing veins. These valves prevent the passage of blood into the superficial area. In the event of total or partial absence of valves in these superficial plantar veins, moderate dilation of the plantar venous network

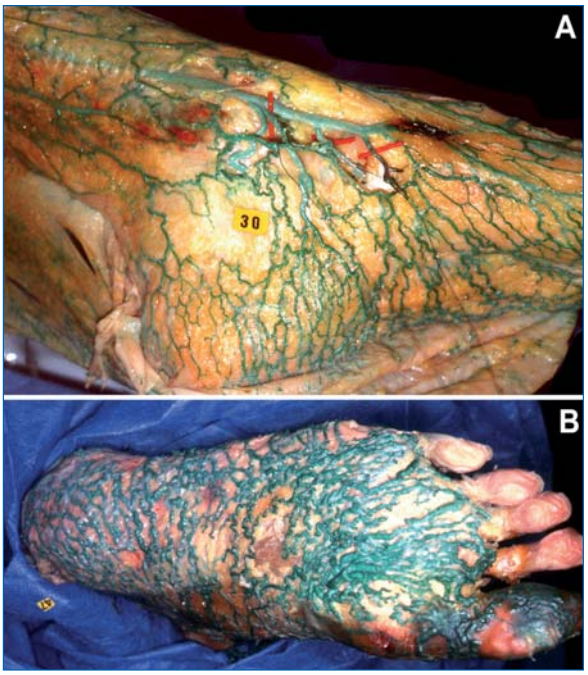

Figure 1. *1A: Non-valvular veins of the cutaneous network visible in the totality of the sole of the foot.*
Reflux by the small terminal collector veins (red lakes): Bourceret venous sole, plexus of small veins, 1 to 2 mm in diameter.

1B: A case of plantar superficial reflux, abnormal.
Reflux with major dilation of the plantar cutaneous veins.

11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page153

is observed (the so-called "Bourceret sole" *Figure 1A*). In contrast, in the event of abnormal reflux, major dilation of this network occurs, leading to "Lejars' plantar venous sole" (*Figure 1B*). This venous dilation is produced by severe venous stasis, most often by a superficial and/or deep vein reflux.

2-Marginal veins

The superficial venous network also comprises medial and lateral marginal veins. *The medial marginal vein* arises from the perforator of the first metatarsal interspace and continues, giving rise to the great saphenous vein. This vein forms a functional unit with the medial plantar veins which we will discuss later. *The lateral marginal vein* also arises from the perforator of the first metatarsal interspace and ends in the short saphenous vein.

3-The interdigital veins drain into Braune's arch from the dorsal veins

B-The deep venous network of the foot

This network comprises two layers of veins as seen in this frontal section (*Figure 2*).

1- The deep "bony" veins, located in contact with the tarsal bones in the concavity of the bony arch, which drain cancellous bone.

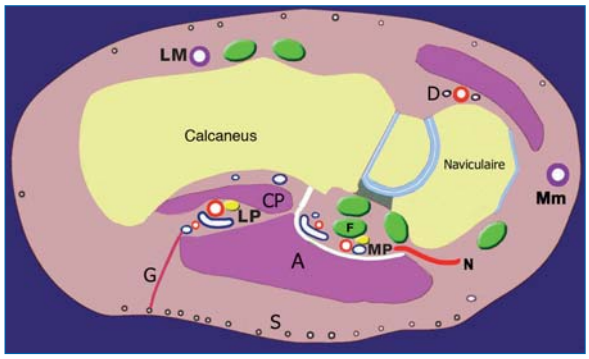

Figure 2. *Medial longitudinal section of the foot showing the muscle topography of the large plantar veins.*

LP: lateral plantar veins, intermuscular, located in the slit which separates the fleshy body of the plantar quadratrus (PQ) from that of the abductor hallucis (A): effective muscular action

MP: medial plantar veins: fibrous and tendinous relations: tendon-long flexor of the hallux (F) and deep fascia of the abductor muscle: rigid structure with no great direct action on the veins.

N: navicular perforator, G: perforator in fatty tissue, Mm: medial marginal vein, LM: lateral marginal vein

2- The network of large collecting veins, the musculotendinous veins (*Figure 3*).

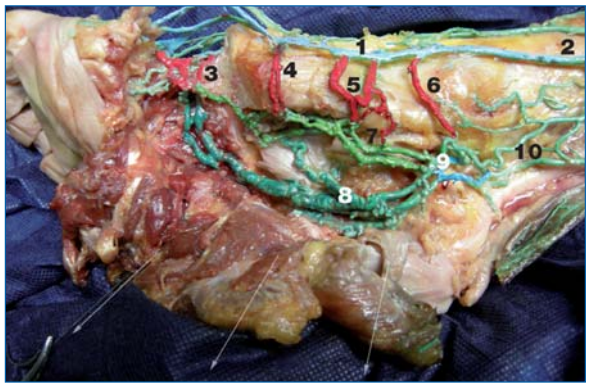

Figure 3. *The two venous systems of the foot (the first metatarsal is partially resected). The medial system: the plantar and marginal veins communicating by many perforators. The lateral system, the lateral plantar veins, a true venous pump in the foot. 1=the medial marginal vein, 2=the great saphenous vein, 3=the perforator of the 1st metatarsal interspace, 4=the cuboidal perforator, 5=the navicular perforator, 6=the malleolar perforator, 7=the medial plantar veins (light green) have low capacities and communicate via the medial perforators, 8=the lateral plantar veins (dark green), with their large diameter and length form a true blood reservoir in the plantar venous pump, 9=the calcaneal plexus, 10=the posterior tibial veins.*

This network comprises the medial and lateral plantar pedicles, which join together posteriorly to form the calcaneal confluent of the plantar veins.

- **The medial** (or internal) **plantar pedicle** is short, about 5 cm in length, and relatively rectilinear. It occupies only the posterior part of the sole of the foot, behind the tendon of the lateral fibular vein. It comprises two veins and in some cases is plexiform:
  - it extends along the medial border of the foot and receives the perforators of the medial marginal vein.
  - laterally, it receives blood from the adjacent muscles: the abductor hallucis, the flexor digitorum brevis and the plantar quadratus muscle.

These two veins are small and project on tendons and so are ineffective for the plantar venous pump.

The lateral (or external) **plantar pedicle** is longer (12 cm), curved, and larger because it is located between the two muscle layers of the sole of the foot, and thus is compressed during contraction. It arises opposite the 1st

11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page154

metatarsal interspace from the venous arch of the 1st interspace.

It emerges laterally, and then is rectilinear and empties into the calcaneal confluent vein where it joins with the medial plantar veins. This plexus joins the posterior tibial veins. The plantar pedicle generally is formed of two veins that parallel the artery but sometimes only one collecting vein exists along part of its pathway. Along their pathway, the lateral plantar veins sometimes present fusiform dilations, the plantar sinuses, comparable to those of the medial head of the gastrocnemius muscle and the soleus muscle. This is evidence in support of a venous pump.

The lateral plantar pedicle receives perforators from the lateral marginal vein, perforators in fatty tissue, the inter-metatarsal veins (in particular from the 1st and 4th metatarsal interspaces), the calcaneal veins and the veins in the adjacent large plantar muscles.

3-The calcaneal confluent of the plantar veins lies in the calcaneal groove. It is formed by the medial and lateral plantar veins and appears as a fine venous plexus which condenses to form the posterior tibial veins.

The calcaneal confluent of the plantar veins (*Figure 3*) is semi-plexiform, multi-valvular, and connects to the great saphenous vein by the tibial malleolar perforator vein (sometimes the navicular). This calcaneal confluent lies at the distal end of the plantar muscle pump. It distributes blood both into the posterior tibial and into the great saphenous vein via the malleolar and navicular perforators.

The terminal valves of the medial and lateral plantar veins are competent in normal subjects.

C-The perforator veins

4.1-*The perforator of the 1st metatarsal interspace , generally of large diameter, is a relay because it is connected to the venous arch* from the 1st interspace, which is the starting point of all venous networks in the foot, superficial and deep. The anterior tibial veins, the lateral plantar pedicle, and the medial plantar pedicle arise from it. This arch is situated in relation to the superficial dorsal arch which joins the medial marginal vein and the lateral marginal vein.

4.2-*The medial marginal perforator veins* (*Figures 3 and 4*) open into the medial marginal vein and provide the three-root origin of the great saphenous vein. They differentiate into plantar and dorsal veins.

4.2.1 There are three **plantar perforators** (*Figure 4*):

- the malleolar (or talus): close to the malleolus, it joins the confluent of the plantar veins
- the navicular: it is close to the tubercle of the scaphoid bone
- the cuneiform: it crosses the 1st cuneiform bone

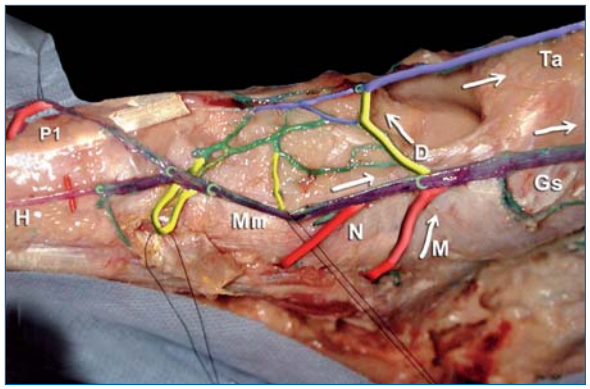

Figure 4. *Dorsal and plantar medial perforators, connected to the medial marginal (Mm) vein at the origin of the great saphenous (Gs) vein.*

Note the three-root origin of the great saphenous vein: it arises from the medial marginal vein Mm, the dorsal communicator which opens into the anterior tibial veins aT, and the malleolar communicating vein connected to the calcaneal plexus.

Note the large diameter of the communicating vein of the 1st metatarsal interspace P1. Note also the abrupt change in diameter of the dorsal vein of the foot after receiving the dorsal perforator vein D, thus becomes the anterior tibial vein.

-Mm: Medial marginal (or internal) vein
-Gs: Great saphenous vein.
H: Dorsal vein of the hallux
Ta: anterior tibial veins

The dorsal perforator veins are shown in yellow:
-D= Dorsal perforator vein which communicates anteriorly with the anterior tibial veins (Ta).

The plantar perforator veins are shown in red: anteriorly to posteriorly
-P1=Perforator of the first metatarsal interspace
-N navicular -M malleolar or the talus

11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page155

4.2.2 **The dorsal medial perforator veins (shown in yellow)**

The dorsal perforator vein (D) communicates in front with the anterior tibial veins (Ta).

4.3-*The lateral marginal perforator veins* (*Figure 5*): there are two—the calcaneal and the cuboidal which join the lateral marginal vein. They cross the lateral fibular tendons (inter-tendinous and subtendinous perforator).

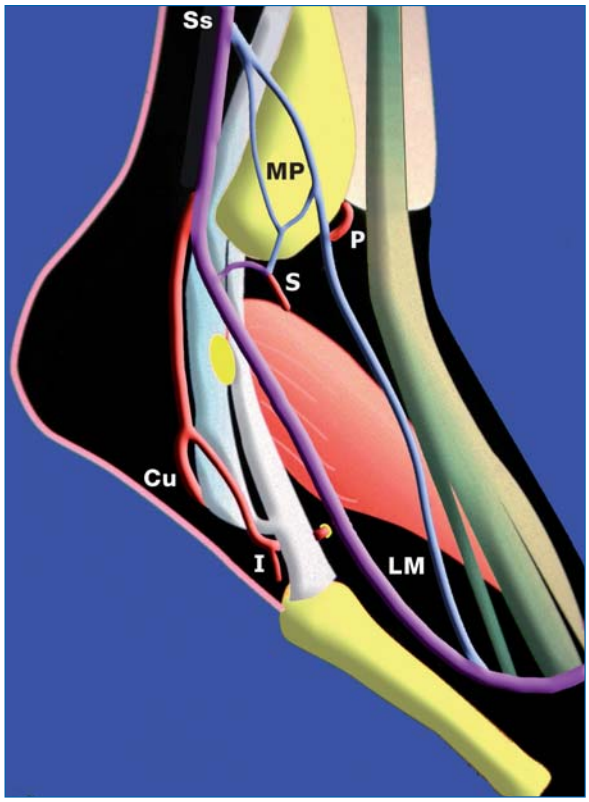

Figure 5. *The lateral perforator veins of the foot. Origin of the main portion of the short saphenous vein (Ss)*
- the lateral marginal (LM) vein is not a constant finding, but often is large.
- the lateral malleolar plexus MP, on the contrary, is a constant finding. It gives rise to perforator veins:
P= premalleolar S= submalleolar.
- A common C vessel of the lateral perforators of the foot exists, a true third root of the short saphenous vein;
it crosses the fibular long flexor tendons: the intertendinous (I), and cuboidal (Cu) perforator veins

REMINDER

Therefore, this is the overall organization of the veins in the foot, which traditionally differentiates the superficial veins, mainly the dorsal and marginal veins, and the medial and lateral plantar veins, deep veins. We have decided to revise the classification of these veins:

In fact, anatomically ***2 very different sets of veins*** *can be differentiated and, functionally emerging, as clearly shown in* Figure 3.

First, a ***medial network*** *which includes the marginal vein and the medial plantar veins. They are well connected by 3 or 4 well-developed medial perforator veins.*

Second, a ***lateral network****, which consists practically of a single lateral pedicle, comprising the lateral plantar veins. They are long and of large diameter, with few perforators and thus without a major connection with the lateral marginal superficial venous system.*

According to this classification, the venous pump is mainly deep and intermuscular, confined to the lateral plantar veins which supply the posterior tibial blood flow.

Only the perforator of the first metatarsal interspace is common to the 2 venous compartments of the foot.

COMMENTS

A/ Review of the steps in lower limb venous return[4-14]

- *At rest*, the venous pump is not active, as we shall subsequently see, therefore the system is necessary and sufficient in itself to provide specific continuity of venous return.

- *When a subject goes from the seated to the standing position*, under the influence of gravity, the weight of the column of blood exerts a pressure of about 80 mm of mercury.

- *After a certain number of steps* (ie, about 10 - 25 m), ankle pressure falls to 30 mm of mercury. This decrease is related to mobilization of the volume of blood, due to activation of the different venous pumps in the lower limb during walking.

11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page156

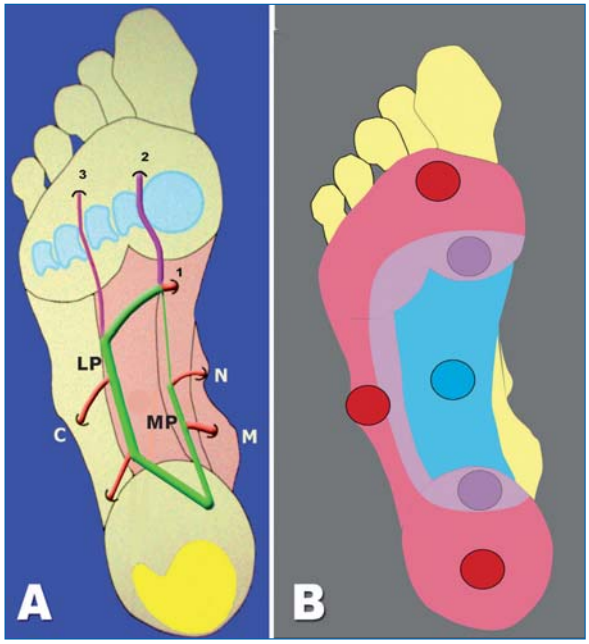

Figure 6. *A: Projection of the plantar venous axes. The plantar compression maneuver shows that while ejection is very effective in the plantar arch on which the venous axes project, normally it is zero in the weight-bearing area. This is also evidence that contradicts Lejars' theory. The principal perforators: C =cuboidal, N =navicular, M =malleolar 1°E=perforator of the 1st metatarsal interspace 3°E=perforator of the 3rd interspace*

B: relations with the weight-bearing area. Red circular patch = weight-bearing area on the ground. Blue circular patch= manual compression area of the plantar veins.

A well-known mechanism in the calf and in the thigh, where the intramuscular veins of the triceps and of the quadriceps act as a blood reservoir, in particular, those of the soleus muscle and the medial head of the gastrocnemius muscle, and those of the vastus lateralis muscle.

Contraction ejects the volume of blood and muscle relaxation allows filling of this reservoir.

A series of valves channels the blood propelled to the root of the limb and prevents any reflux.

B/ Where is the plantar venous pump located?

In fact, different lines of evidence confirm that the plantar venous pump is located deep, intermuscularly:

- The plantar venous axes are connected directly to the posterior tibial veins, which are extensions of them.

- The direction of the valves indicates that blood flows from the deeper part to the superficial part.

- The volume of blood ejected by the pump is 20 to 30 ml, which corresponds to the capacity of the lateral and medial plantar veins. These veins are primarily inter-muscular, thus pointing to the intervention of a motor apparatus for venous ejection during walking, which adds to the pressure exerted by the foot on the ground.

REMINDER

The venous sole according to fine plexus presentation, Bourceret = the physiological state

The venous sole according to dilated venous lakes; Lejars = the pathological stasis state

Site of venous pump in the foot =Lateral plantar veins

The anatomical description of the lateral plantar veins shows the 3 components of this pump which determine its functioning: (*Figure 7*)

1- Anteriorly, the **suctioning pole,** directed towards the toes**.** There are many supply pathways: the highly vascularized toes, the highly developed metatarsal muscles, the large metatarsal perforator vein (arising from the superficial network of the medial marginal vein)

2- The middle portion comprises the **body of the reservoir** of the pump, whose average volume is 15 to 25 ml. It is enhanced at this level by bony and muscular veins, the medial and lateral perforators. Weight bearing and the action of walking produce a massage effect on the plantar vascular area.

3- Posteriorly, the calcaneal confluent, which corresponds to the **ejection pole**, empties with full diameter into the posterior tibial veins. This is confirmed in everyday phlebological practice by the high elevation of posterior tibial blood flow after manual compression of the plantar surface, confirmed by many authors.[4,8-10]

11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page157

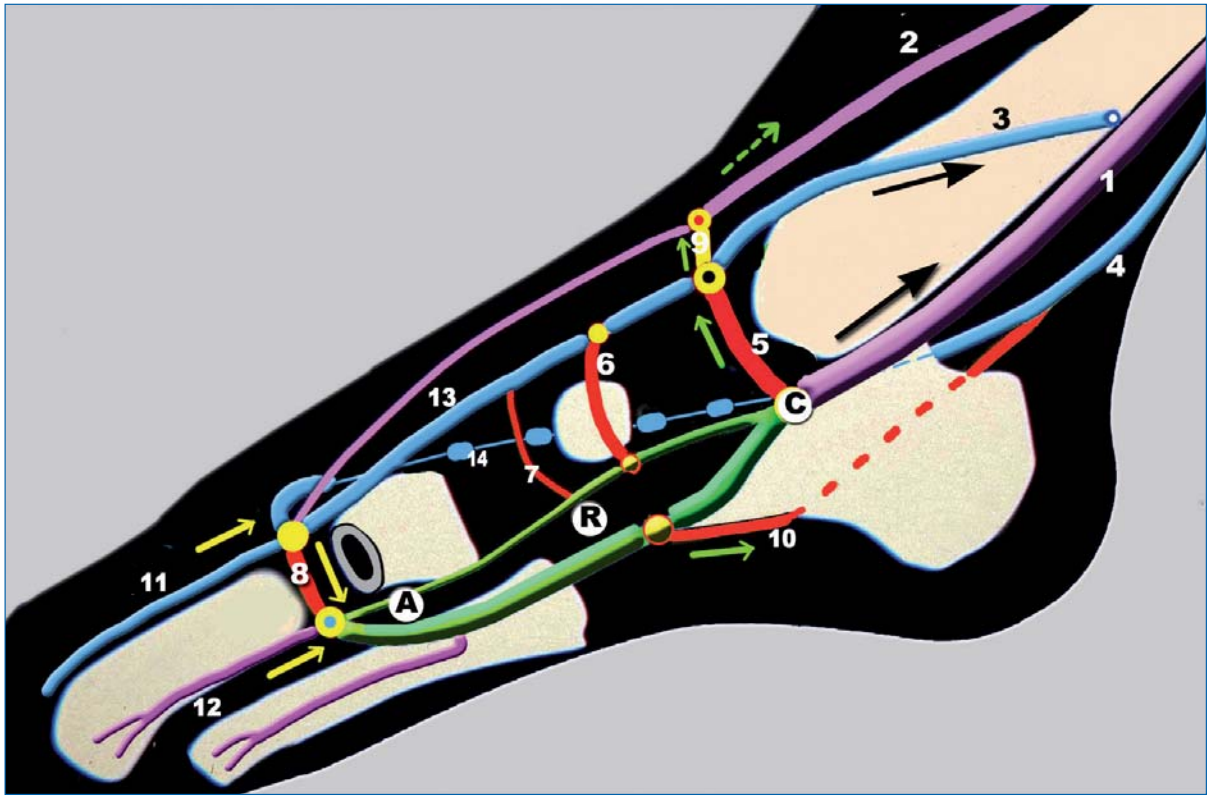

Figure 7. *Hypotheses on functioning of the venous pump in the foot*

The pump (shown in green) comprising the plantar veins is polarized and contains 3 parts going from front to back: A suction pole (A), a reservoir (R), and an ejection pole (C) the calcaneal confluent.

Anteriorly, the distal pole (directed towards the toes) or aspiration A: blood enters the pump during raising of the foot in plantar flexion by relaxation of the plantar muscles.

The pump is supplied by the highly vascularized toes and the highly developed metatarsal muscles. The pump is supplied with superficial blood carried by the communicator vein of the 1st interspace (8).

The body of the pump or reservoir R is enhanced by the bony and muscular veins, but also by superficial blood by the medial and lateral perforator veins of the foot (in red).

The distal or ejection pole is represented by the calcaneal confluent C.

Blood is supplied to the posterior tibial veins (1), but also the great saphenous vein (3), by the malleolar perforator vein (5), and to the anterior tibial veins (2) by the dorsal perforator vein (9).

1: Posterior tibial veins
2: Anterior tibial veins
3: Great saphenous vein
4: Short saphenous vein
5: Malleolar perforator vein
6: Navicular vein
7: Cuneiform perforator vein
8: Perforator vein of 1st metatarsal interspace
9: Dorsal perforator vein
10: Calcaneal perforator vein
11: Dorsal vein of the hallux, very large
12: Intermetatarsal vein
13: Medial marginal vein
14: Lateral marginal vein

Three phases can be described during walking:

1- The weight-bearing phase: contact of the foot on the ground produces direct compression of the reservoir in the sole of the foot between weight-bearing areas.

2- The impulse phase: Weight bearing on the forefoot with flexion of the toes which fix the foot on the

11_DN_1007_BA_int_ok_Daflon_int_ok_Phlebo 17/06/10 16:12 Page158

ground, resulting in compression of the pump in the musculotendinous plane by muscle contraction;

3- The suspension phase of the foot, lifted off the ground, allows filling of the pump.

During walking, the pump reloads cyclically when the foot is lifted up and empties when weight bearing is applied.

As just described, the plantar venous pump is the only one effective up to the calf, where its action is taken over by the calf pump of the soleus muscle. Its dual action, on both the deep and the superficial saphenous vein circulation, underlines the unimpeded circulation of blood between the two vascular compartments. In fact, the perforator veins of the foot have an important specific anatomical feature, that of not having any effective valves.

CONCLUSIONS

The blood reservoir, mobilized by manual pressure on the sole of the foot and emptied during weight bearing during walking, is not a superficial one in "Lejars' sole", but rather is deep. It corresponds to the lateral plantar veins between the two fleshy muscles and is compressed at each step of walking.

These anatomical data explain why it is important to check for normal static posture of the foot in a patient with chronic venous disease, to ensure proper emptying of the plantar venous pump during walking.

Similarly, the utility of stimulation of the plantar venous pump in the prevention of post-surgical deep vein thrombosis should be emphasized[15-17] in high-risk patients. This can be done by manual massage going upwards, by intermittent pneumatic compression, or by simple elastic compression starting at the root of the toes.

This venous pump of the human foot is the first step in venous return from the lower extremity to the heart. The calf pumping mechanism, produced by contraction of the soleus muscle and of the gastrocnemius muscle, then takes over.[4,5,14]

This work was granted the Prize for the 'best abstract' at the XVIth World Meeting of the Union Internationale de Phlébologie, Principality of Monaco, 31 August-4 September 2009.

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