

Venous surgery for the treatment of chronic venous insufficiency with respect to global venous haemodynamics and clinical symptoms

The value of dynamic venous function tests for predicting the success

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Keywords

Dynamic venous function tests, CVI, surgical treatment, clinical outcome

Summary

Our goal was to document changes in venous drainage function ΔV and venous refill times t_0 and t_h achieved with venous surgery and compare them with preoperative measurements acquired using a variety of venous function tests. Preoperative measurements were performed with two pressure cuffs to predict postoperative outcome; they were compared with actual postoperative measurements made without a pressure cuff. In addition we also analyzed whether the postoperative improvement in venous haemodynamics was correlated with an improvement in clinical findings and symptoms. **Patients, methods:** 64 patients (14 men and 50 women) were enrolled into the study. Inclusion criteria were Doppler sonographic evidence of insufficiency of the saphenous veins and impaired venous haemodynamics, which form the medical indication for venous surgery. Before and after surgery a variety of diagnostic tests of venous function were carried out simultaneously with the patient in a seated position and performing dorsal extensions: mercury strain gauge plethysmography

(MSGP) at the forefoot and calf, phlebodometry (PDM), light reflection rheography (LRR), digital photoplethysmography (DPPG) with Elcat measuring head and with Laumann Elcat measuring head, universal light reflection plethysmography (ULP). **Results:** All the examined methods are suitable for monitoring progress and evaluating therapeutic success after the selective surgical removal of insufficient vein segments. All examination methods showed that refill times t_0 and t_h were significantly improved 6 weeks after venous surgery. The postoperative results of ΔV , t_0 and t_h were most reliably predicted by MSGP (forefoot). ΔV , t_0 and t_h values determined with MSGP at the calf differed significantly from those acquired with PDM, so MSGP (calf) should not be used for preoperative screening. **Conclusions:** A close correlation between improvement of clinical symptoms and improvement in venous haemodynamics was found. Selection of the suitable preoperative measurement method makes it possible to accurately predict postoperative outcome.

Schlüsselwörter

Dynamische Venenfunktions-tests, CVI, chirurgische Therapie, klinisches Resultat

Zusammenfassung

Ziel der Studie war die Erfassung von venöser Abpumpfunktion ΔV und den venösen Wiederauffüllzeiten t_0 und t_h mittels verschiedener Venenfunktions-tests, die durch einen chirurgischen Veneneingriff erzielt wurden. Diese wurden mit den präoperativen Messungen verglichen. Präoperative Messungen wurden mit 2 Tourniquets durchgeführt, um das postoperative Ergebnis vorherzusagen, postoperative Messungen erfolgten ohne Tourniquet. Zusätzlich wurde analysiert, ob die postoperative Verbesserung der venösen Hämodynamik mit einer Verbesserung des klinischen Bildes und der Symptome korrelierte. **Patienten, Methoden:** 64 Patienten (14 Männer, 50 Frauen) wurden in die Studie aufgenommen. Einschlusskriterium war der dopplersonographische Nachweis insuffizienter Hautstammvenen und eine Einschränkung der venösen Hämodynamik, die die medizinische Indikation zu einem phlebochirurgischen Eingriff bedingte. Vor und nach phlebochirurgischem Eingriff wurde die venöse Funktionsdiagnostik mit folgenden Messmethoden simultan in sitzender Körperposition unter Durchführung von Dorsalextensionen erfasst: Hg-Dehnungsstreifen-PG Vorfuß, Hg-Dehnungsstreifen-PG Wade, PDM, LRR, DPPG (Elcat Messkopf), DPPG (Laumann Elcat Messkopf), ULP. **Ergeb-**

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Venenchirurgie in der Therapie der chronisch venösen Insuffizienz in Anbetracht der globalen venösen Hämodynamik und der klinischen Symptome – Wertigkeit der dynamischen Venenfunktion zur Vorhersage des operativen Erfolges
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Chirurgie veineuse de l'insuffisance veineuse chronique en considération de l'hémodynamique veineuse globale et des symptômes cliniques – Évaluation des tests fonctionnels veineux pour prévoir le succès d'une opération

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nisse: Als postoperative Verlaufskontrolle zur Beurteilung des Therapieerfolges nach selektiver operativer Entfernung der insuffizienten Venenabschnitte sind nach den vorliegenden Ergebnissen alle Verfahren einsetzbar. Die Wiederauffüllzeiten t_0 und t_h besserten sich statistisch signifikant 6 Wochen nach phlebochirurgischem Eingriff bei allen Untersuchungsmethoden. **Schlussfolgerung:** Zwischen der Verbesserung klinischer Symptome und der Verbesserung der venösen Hämodynamik wurde eine enge Korrelation gefunden. Die Auswahl der geeignetsten präoperativen Messmethode macht es möglich, das postoperativ zu erwartende Ergebnis bereits präoperativ sicher vorauszusagen.

Mots clés

Tests dynamiques fonctionnels veineux, insuffisance veineuse chronique, traitement chirurgical, étude clinique

Résumé

Nous avons voulu documenter la fonction veineuse de drainage ΔV et le temps de remplissage veineux de T_0 à T_h obtenu par chirurgie veineuse et le comparer avec les mesures préopératoires acquises par une variété de tests fonctionnels. Les mesures préopératoires ont été effectuées avec deux manchons gonflables en prévision du résultat postopératoire; ceci a été comparé avec la mesure postopératoire faite avec seulement un manchon gonflable. En outre, nous avons cherché à savoir si l'amélioration postopératoire de l'hémodynamique veineuse était en corréla-

tion avec une amélioration clinique et symptomatique. **Patients et méthode :** 64 patients (14 hommes et 50 femmes) ont été inclus dans l'étude. Les critères d'inclusion ont été l'évidence ultrasonographique de l'insuffisance saphénienne et l'altération de l'hémodynamique veineuse qui donne donc l'indication à une chirurgie veineuse. Avant et après l'intervention, toute une série de tests diagnostics de la fonction veineuse ont été effectués simultanément avec le patient en position assise et effectuant des extensions dorsales : Une pléthysmographie par jauge de contrainte (PJC) à l'avant-pied et au mollet, une phlébodynamométrie (PDM), une réographie par réflexion lumineuse (RRL), une photopléthysmographie digitale (PPGD) avec une tête de mesure Elcat et avec une tête de mesure Laumann Elcat, et finalement une pléthysmographie par réflexion lumineuse (PRL). **Résultats :** Toutes les méthodes utilisées conviennent pour le monitoring et l'évaluation thérapeutique après chirurgie sélective de veines insuffisantes. Toutes les méthodes d'examen ont montré que le temps de remplissage de T_0 à T_h a été amélioré de manière significative après six mois. Le résultat postopératoire de ΔV , T_0 à T_h a été prévu de manière fiable par PJC (avant-pied). ΔV , de T_0 à T_h déterminée par PJC au mollet et a montré une différence significative avec la PDM. Ainsi, la PJC au mollet ne devrait pas être utilisée pour le bilan préopératoire. **Conclusions :** Une corrélation serrée entre l'amélioration des symptômes cliniques et de l'hémodynamique veineuse a été mise en évidence. La sélection des méthodes de mesures préopératoires rend possible une prévision du résultat postopératoire.

Impaired venous haemodynamics can be quantified with a variety of dynamic venous function tests. Earlier studies showed that both the choice of examination method and the movement sequence have a major effect on the degree of correlation between non-invasive venous function tests and phlebodynamometry (13).

Venous function tests it make is possible to quickly screen patients to evaluate the efficacy of a phlebosurgical procedure. In addition, they allow us to make an accurate preoperative prognosis of postoperative success with respect to venous haemodynamics and, indirectly, subjective symptoms. Thus, venous function tests

- reveal the extent of haemodynamic dysfunction and
- indicate the probable benefit of the operation, which we have to monitor postoperatively.

For these reasons it is of decisive importance to determine which method most reliably predicts postoperative outcome even before surgery. In order to make such a methodological evaluation, we subjected a group of patients to dynamic venous function tests, comparing the prognostic value of the data collected in simultaneous measurements.

Patients, methods

Study design

The study is a prospective, one centre open label clinical trial.

Patients

64 patients (14 men and 50 women) were enrolled in the study. The average age was 49.7 years (SD 12.7 years). Inclusion criteria for this study were the medical indication for venous surgery and a written declaration of consent from the patient. The distribution of valvular incompetence sites is shown in ► Table 1.

Examination methods

Before and after venous surgery, venous function was measured simultaneously with the

The great socioeconomic impact of venous disease has been documented in numerous studies (1, 7, 15). Much of the expense associated with hospital stays, outpatient treatment or invalidity can be avoided by early, rigorous therapy, because for the most part such costs are caused by damage resulting from long years of inadequately treated venous disease. Our goal should be the early detection of dysfunctional venous haemodynamics in the legs through patient education and suitable diagnostic procedures in order to begin appropriate and effective therapy as soon as possible. Simple, non-invasive and cost-effective examination methods are

needed which can be used for large-scale screening and follow-up.

In addition to the stripping or sclerotherapy of venous segments with valvular incompetence, a key role is also played by complex physical decongestive therapy (14), including

- compression,
- physical therapy,
- manual lymph drainage and
- physical exercise.

Doppler and duplex sonography are used for the topographic detection and mapping of vein segments with valvular incompetence (9, 12, 16).

following examination methods while the patient sat and performed dorsal extensions:

- mercury strain gauge plethysmography (MSGP)
 - forefoot,
 - calf,
- phlebodynamometry (PDM),
- light reflection rheography (LRR),
- digital photoplethysmography (DPPG),
- universal light reflection plethysmography (ULP).

Venous drainage function ΔP (mmHg) and refill times t_h (s) and t_o (s) were determined. Dynamic venous function tests were carried out while the patients performed a standardized sequence of movements: ten dorsal extensions in 15 seconds timed with a metronome, with the patient in a seated position.

These diagnostic tests were supplemented by next measuring venous function with the extrafascial veins occluded with a 7 cm wide pressure cuff. In each patient the measurements were made without pressure cuff, with a cuff at the groin (120 mmHg) and additionally with a second cuff below the popliteal fossa (80 mmHg). An overview of the analyzing methods of the venous function parameters is given in ► Figure 1.

Because of the simultaneous measurements, all of the sensors had to be fixed on the patient's leg at the same time. The measuring heads for LRR and DPPG lay immediately next to each other 10 cm above the medial malleolus; interference between the two sensors was ruled out in pre-trial tests. The strain gauge sensors were applied to the center of the calf at the level of greatest calf circumfer-

ence, and the butterfly needle for PDM was applied to the forefoot.

Preoperative function tests were carried out without pressure cuffs or with one or two pressure cuffs. Six weeks after surgery for the removal of incompetent veins identified with Doppler sonography or colour duplex sonography, the identical function tests performed preoperatively were repeated without pressure cuffs.

Surgical treatment

After skin incision the saphenofemoral junction, including side branches, was dissected. Vicryl 2.0 was used to ligate the GSV and its branches. The saphenous vein was subsequently disconnected from the deep venous system and cannulated by the stripper that was retrieved via an infragenual stab incision in the area of competent valves.

In the case of insufficiency of the short saphena vein, cryostripping was performed (3).

All operations were performed in automatized tumescence local anesthesia.(10)

Statistical analysis

For each method (MSGP forefoot, MSGP calf, PDM, LRR, DPPG, ULP) we determined whether the values for venous drainage function and refill times t_o and t_h measured preoperatively without pressure cuffs differed from the postoperative values measured without pressure cuffs (t-test for dependent samples).

For all methods the preoperative values venous drainage and refill times t_o and t_h measured with two pressure cuffs were compared with the corresponding postoperative values without pressure cuffs (t-test for dependent samples).

For each measuring method the variance of the differences (before and after) was determined. The variances found with the different measuring methods were compared using Morgan's test.

Results

Changes in venous drainage achieved with venous surgery

With ULP, DPPG, LRR and MSGP (forefoot) we were able to demonstrate a statistically sig-

Tab. 1 Frequency distribution of sites of incompetence

number of patients	location of valvular incompetence	
1	lateral branch varicosis, perforating veins	
1	long saphenous vein	I°, lateral accessory saphenous vein
1		I°, lateral branch varicosis
1		II°, lateral branch varicosis
1	long saphenous vein II°, short saphenous vein III°	lateral branch varicosis
4	long saphenous vein	III°
3		III°, perforating veins
3		III°, lateral branch varicosis
3		III°, lateral branch varicosis, perforating veins
1	long saphenous vein III°, short saphenous vein I°	Giacomini vein
5	long saphenous vein	IV°
8		IV°, lateral branch varicosis
3		IV°, perforating veins
15		IV°, lateral branch varicosis, perforating veins
3	long saphenous vein IV°, short saphenous vein I°	perforating veins
4	long saphenous vein IV°, short saphenous vein III°	perforating veins
4	long saphenous vein, IV°, lateral branch varicosis	
1	short saphenous vein II°, lateral branch varicosis	
2	short saphenous vein III°	

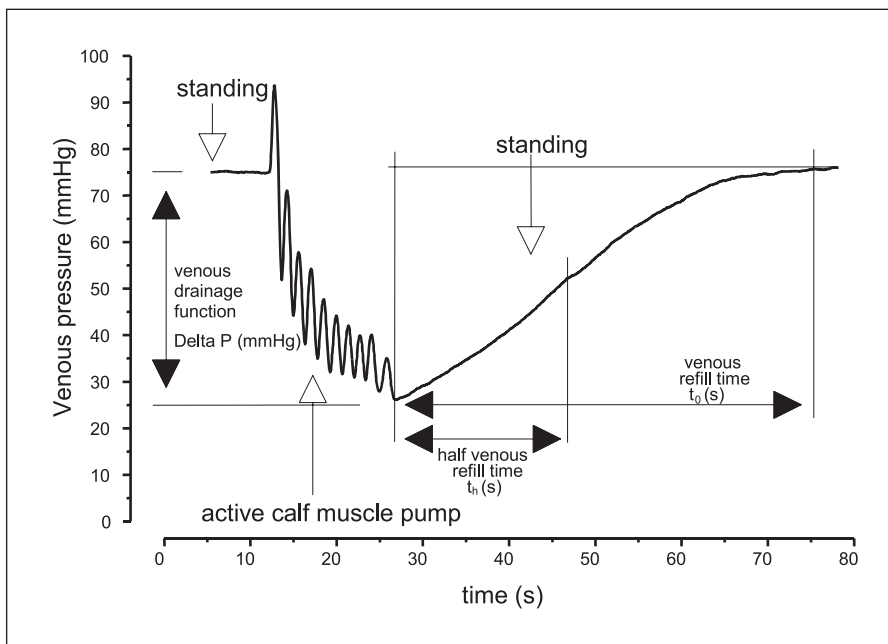


Fig. 1 Venous pressure measured intravenously at the dorsum of the foot with activated calf muscle pump in a standing position (PDM). During exercise a reduction of venous pressure was observed in venous systems with incompetent valves (venous drainage function ΔP in mmHg). At rest the pressure slowly rose again. The time needed to return to the initial pressure is termed venous refill time (s), while the time needed to reach half of the initial pressure is called half venous refill time t_h (s).

Change in venous refill times t_0 and t_h achieved with phlebosurgery

Measured increases in refill times t_0 and t_h achieved with venous surgery were highly significant with all of the investigated methods.

Differences in refill times t_0 and t_h (s) are given in ► Figure 2b as the difference between the values measured without pressure cuff before venous surgery minus the value measured without pressure cuff after surgery.

Comparison of function parameters simulated before surgery with post-operation outcome

The venous function parameters drainage volume and refill times were measured pre-operatively using two pressure cuffs and compared with the same values measured post-operatively without pressure cuffs. Changes were determined by subtracting the preoperative values from postoperative results. In the following we give the means of the differences with the standard deviation.

nificant increase in venous drainage. MSGP (calf) and PDM did not show statistically significant improvement in venous drainage

function. A comparison of drainage function before and after surgery (in both cases without pressure cuffs) is shown in ► Figure 2a.

Drainage function

A significant difference was found only with MSGP (calf) (► Fig. 3a).

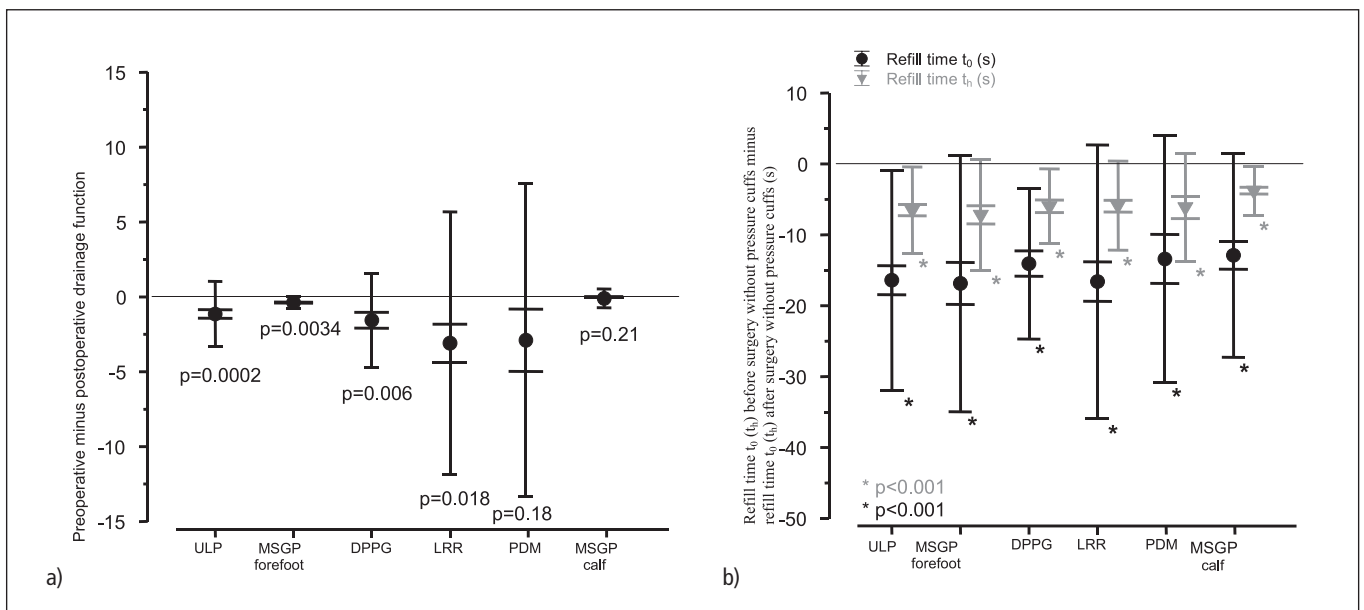


Fig. 2 Change achieved with venous surgery (means with standard deviations and standard errors) a) in venous drainage function b) in refill time t_0 (t_h) determined with the different examination methods

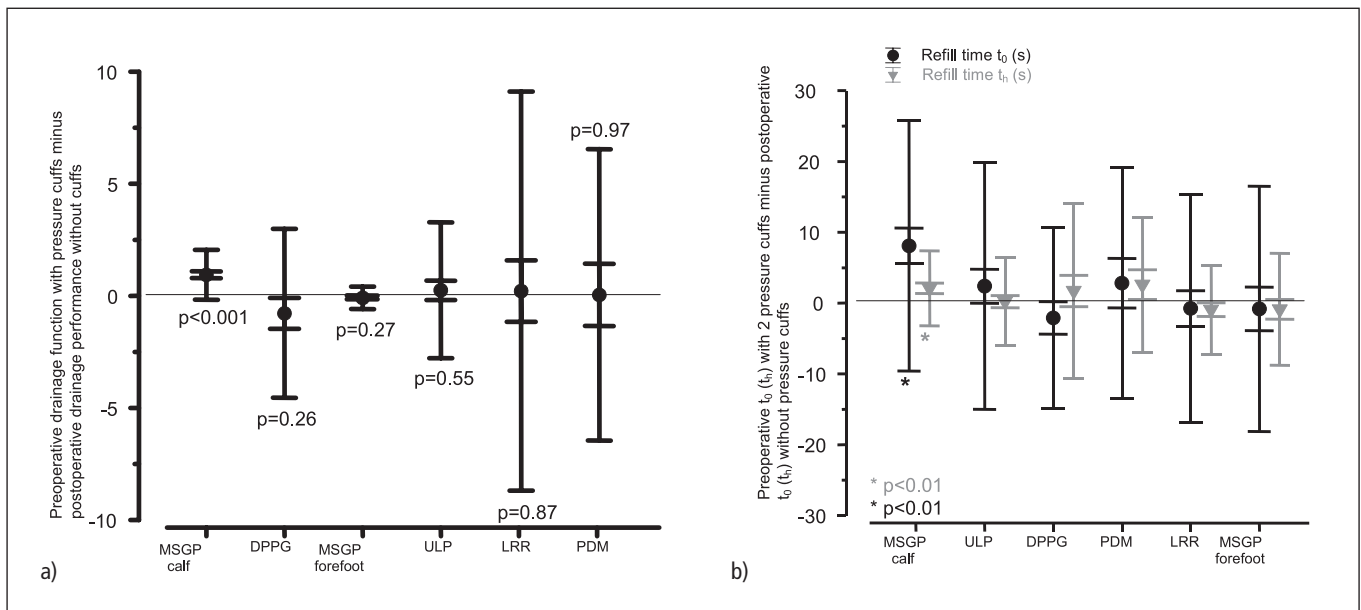


Fig. 3 Differences of values measured preoperatively with two pressure cuffs and postoperatively without pressure cuffs (means, standard deviation and standard error): A t-test for dependent samples was used to determine whether the values measured with two tourniquets before the operation differed from values measured postoperatively without tourniquets.

- a) venous drainage function ΔV
- b) refill times t_0 and t_1

Venous refill times t_0 and t_1

A significant difference was found only with MSGP (calf) (► Fig. 3b).

Since the various methods yielded in part strongly diverging results, we then used variance analysis to determine which methods are best suited for comparison with each other.

Comparison of preoperative and postoperative measurements

Drainage function/ refill time t_0 / refill time t_1

The difference between preoperative drainage function, refill time t_0 , and refill time t_1 with two pressure cuffs and the correspond-

ing postoperative values without pressure cuffs were calculated for each test method. The variance of the differences was calculated for each test method. All of the resulting variances were compared with each other. Those combinations whose variances did not differ from each other are marked in dark gray. (► Tab. 2–4). We conclude that these blue-tagged combinations can be compared with each other with various degrees of quality.

Tab. 2 Comparison of variability of measured differences in drainage function. We compared the variance of the differences between measurements before the operation with two pressure cuffs and those taken after surgery without pressure cuffs. The dark gray fields mark those pairs of methods whose variances did not differ from each other with statistical significance.

	MSGP calf (SD 1.1)	MSGP (SD 0.5)	PDM (SD 6.5)	LRR (SD 8.9)	DPPG (SD 3.8)
MSGP forefoot (SD 0.5)					
PDM (SD 6.5)					
LRR (SD 8.9)					
DPPG (SD 3.8)					
ULP (SD 3.0)					

Correlation between postoperative measurements and clinical symptoms

Out of the total patient collective, 30 patients (25 women and 5 men) were examined more closely. Their pre- and postoperative clinical symptoms were analyzed for correlations with the changes in measured values (► Tab. 5). After venous function tests were carried out the patients were divided into two groups. In the first patient group (n = 19) the values normalized postoperatively, while in the second patient group (n = 11) the same values improved, but did not return to normal. In the group with normalized postoperative venous function parameters 72% were symptom-free, while only 32.5% of the patients

were symptom-free in the second group that still had pathological values after the operation. However, all of the patients showed at least an improvement in symptoms and venous parameters. In the group of patients who improved but did not normalize, the proportion of patients with advanced CVI and long duration of disease was markedly higher than in the group with normalized measurements.

Discussion

Since dynamic venous function tests are used, not only to evaluate global venous hemodynamics but also to determine whether phlebosurgical measures are indicated (5) and to monitor postoperative outcome, we examined their prognostic value and reproducibility in this context. Since the early 1970's, PDM has become established as the most important, reliable and prognostically valuable method for the quantitative evaluation of global hemodynamics in the venous system of the leg in patients with chronic venous insufficiency (6, 11). For this reason it remains the gold standard for testing phlebological function. Its invasive nature is a disadvantage, however, so there is a need for new, non-invasive methods that offer the same accuracy as PDM (2, 8). Any such new method would have to provide information on global hemodynamics as good as that provided by PDM, and these measurements must not be falsified by the use of pressure cuffs for therapy planning.

Our results indicate that all of these methods are suitable for postoperative follow-up to evaluate the success of therapy after selective surgical removal of incompetent vein segments. All of the methods showed statistically significant improvement in refill times t_0 and t_h 6 weeks after venous surgery. The postoperative improvement in drainage function ΔV and refill times t_0 and t_h was predicted most reliably by MSGP (forefoot). Similarly reliable prognoses were provided by LRR for refill times t_0 and t_h . The differences between the results gathered with PDM and those obtained with MSGP (calf) were statistically significant, so MSGP (calf) should not be used for preoperative screening.

It is vital that both the movement program and the measurement method be identical before and after surgery.

Tab. 3 Comparison of variability of measured differences in t_0 . We compared the variance of the differences between measurements taken before the operation with two pressure cuffs and those taken after surgery without pressure cuffs. The dark gray fields mark those pairs of methods whose variances did not differ from each other with statistical significance.

	MSGP calf (SD 17.7)	MSGP fore-foot (SD 17.4)	PDM (SD 16.3)	LRR (SD 16.1)	DPPG (SD 12.8)
MSGP forefoot (SD 17.4)					
PDM (16.3)					
LRR (SD 16.1)					
DPPG (SD 12.8)					
ULP (SD 17.4)					

Tab. 4 Comparison of variability of measured differences in t_h . We compared the variance of the differences between measurements taken before the operation with two pressure cuffs and those taken postoperatively without pressure cuffs. The dark gray fields mark those pairs of methods whose variances did not differ from each other with statistical significance.

	MSGP calf (SD 5.3)	MSGP fore-foot (SD 7.9)	PDM (SD 9.5)	LRR (SD 6.3)	DPPG (SD 12.3)
MSGP forefoot (SD 7.9)					
PDM (SD 9.5)					
LRR (SD 6.3)					
DPPG (SD 12.3)					
ULP (SD 6.2)					

Tab. 5 Number of patients and disease stage according to Widmer and CEAP classification in the groups with normalized and non-normalized postoperative parameters.

CVI°		group with postoperative parameters	
Widmer	CEAP	normalized	non-normalized
I	C2-C3	11 (58%)	2 (18%)
II	C _{4a} -C _{4b}	4 (21%)	4 (36%)
III	C ₅ -C ₆	4 (21%)	5 (45%)

The correlations between the preoperative values in the tourniquet test and postoperative improvement measured without pressure cuffs make it clear that if a suitable diagnostic method is selected it is possible to reliably predict postoperative outcome. An improvement in measurements found in a tourniquet test is correlated with postoperative improvement in symptoms. It is important to note that the majority of patients that still had non-normalized postoperative values despite an improvement in clinical symptoms had advanced stages of CVI (82%) and had suffered from venous disorders over an extended period of time. The correlation makes it clear just how important it is to make an early diagnosis and begin therapy as soon as possible (4).

Conclusion

The sooner phlebosurgical action is taken, the more likely it is that venous haemodynamics normalize and physiological integrity can be restored.

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