The value of air plethysmography in predicting clinical outcome after surgical treatment of chronic venous insufficiency

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Purpose: **The role of air plethysmography (APG) as a predictor of clinical outcome after surgery in venous disease is yet to be defined. The purpose of this study was to investigate the value of APG in predicting clinical outcome after venous surgery for chronic venous insufficiency (CVI).**

Methods: **Seventy-three extremities in 71 patients with Class 3 through 6 CVI were assessed preoperatively with CEAP (*c*linical, *e*tiologic, *a*natomic, *p*athophysiologic) criteria, standing reflux duplex ultrasound scan, and APG with measurements of preoperative venous filling index (VFI), venous volumes, ejection fraction, and residual volume fraction. After surgical treatment of the affected limbs, repeat APG studies were obtained within 6 weeks. Established venous reporting standards were used for follow-up to calculate clinical symptom scores (CSSs) in each patient.**

Results: **Superficial venous reflux occurred alone in 24 limbs or in conjunction with perforator incompetence in 26 limbs. Deep and superficial reflux, with or without perforator incompetence, was found in 16 limbs, and seven limbs had isolated deep insufficiency. Follow-up was available in 60 of 71 patients (mean period, 44.3 months). Postoperative APG demonstrated significant hemodynamic changes after surgery as measured with VFI, venous volumes, ejection fraction, and residual volume fraction. Mean CSSs decreased from 7.35 ± 0.56 preoperatively to 1.79 ± 0.32 at late follow-up after surgery ($P < .001$). With the use of logistic regression, the parameter correlating most closely with clinical outcome was the VFI. A normal postoperative VFI (≤ 2 mL/s) predicted a good clinical outcome (CSS ≤ 2) in follow-up patients, with a positive predictive value of 94%, a specificity of 89%, and a sensitivity of 70%.**

Conclusions: **Normalization of the VFI after venous surgery for CVI is predictive of a good clinical outcome. This APG measurement may be a useful parameter to predict adequacy of surgery in patients with venous insufficiency. (J Vasc Surg 2000;32:961-8.)**

The role of corrective venous surgery for patients with symptomatic chronic venous insufficiency (CVI) has received increasing attention as techniques such as vein valve transplantation and subfascial endoscopic perforator surgery (SEPS) have been popularized. The proper selection of patients for venous surgery and evaluation of the adequacy of surgical correction require a demonstration of the anatomic and hemodynamic status of the patient before and after surgery. Using venous duplex scan examination or phlebography, the clinician can determine the anatomic and physiologic abnormalities that may be causing the patient's symptoms, allowing a rational selection of a procedure to correct or improve anatomic abnormalities.[1,2] However, quantitative assessment of the severity of these anatomic abnormalities is not obtained with these techniques.

Air plethysmography (APG) has been reported to provide hemodynamic data correlating with ambulatory venous pressures.[3,4] Criado et al[5] found that the

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Competition of interest: nil.

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Table I. CSS

Pain	0 = none; 1 = moderate, not requiring analgesics; 2 = severe, requiring analgesics
Edema	0 = none, 1 = mild/moderate, 2 = severe
Venous claudication	0 = none, 1 = mild/moderate, 2 = severe
Pigmentation	0 = none, 1 = localized, 2 = extensive
Lipodermatosclerosis	0 = none, 1 = localized, 2 = extensive
Ulcer: size (largest ulcer)	0 = none, 1 = < 2-cm diameter, 2 = > 2-cm diameter
Ulcer: duration	0 = none, 1 = < 3 mo, 2 = > 3 mo
Ulcer: recurrence	0 = none, 1 = once, 2 = more than once
Ulcer: number	0 = none, 1 = single, 2 = multiple

CSS is the sum of the values assigned to each of the nine categories. A maximum score is 18 (10).
CSS, Clinical symptom score.

venous filling index (VFI), as measured with APG, was an excellent predictor of the clinical severity of venous insufficiency. Several authors have reported the efficacy of APG in monitoring the early results of surgery.[6-8] However, correlation of the results of surgery with long-term clinical follow-up has not been reported in a significant number of patients. The purpose of this study was to determine whether improvement of the hemodynamic parameters measured with APG after corrective surgery for CVI was predictive of an improved long-term clinical outcome.

METHODS

From December 1991 to September 1999 at University of North Carolina Hospitals, 71 patients with CVI who underwent corrective surgical procedures in 73 extremities were identified. The presence of greater or lesser saphenous varices and the incompetence of the superficial, deep, or perforating venous systems were established 2 to 6 weeks before surgery with the techniques described below. Open ulcers were treated with four-layer, sustained compression wraps (Profore, Smith and Nephew, Hull, United Kingdom) or Unna's paste boots (Medicopaste, Graham-Field, Hauppauge, NY) until healed before surgery. Arterial insufficiency was excluded by the presence of palpable pedal pulses or an ankle-brachial index greater than 0.8.

Extremities were classified with CEAP (*c*linical, *e*tiologic, *a*natomic, *p*athophysiologic) criteria in accordance with the most recent update of reporting standards in venous disease[9] and contained moderate to severe venous disease with clinical classifications 3 through 6. Clinical symptom scores (CSSs) were assigned on a scale of 0 to 2 (0, asymptomatic and 2, severe) for the nine items listed in Table I as suggested by the American Venous Forum Ad Hoc Committee on Reporting Standards in Venous Disease.[10] Scores were totaled preoperatively and postoperatively from a patient's direct history and physical examination results, which were based on clinic notations. A postoperative total CSS of 2 or less was established as a good clinical outcome, indicating complete ulcer healing along with significant improvement in limb pain and edema while allowing incomplete resolution of deep dermal scarring or pigmentation.

Each patient underwent a complete three-part CVI evaluation by an experienced, registered vascular technologist. A lower extremity duplex ultrasound scan examination with a 5-MHz linear array B-mode ultrasound scan probe with a 3-MHz pulsed Doppler scan (Acuson 128 XP 10 color flow ultrasound scanner, Mountain View, Calif) comprised the initial study. This evaluation was performed with the patient in the supine position with 30 degrees of reverse Trendelenburg's position. Compression maneuvers and examination of flow patterns with augmentation allowed identification of acute or chronic venous obstruction and identification of incompetent perforating veins. Commencing at the saphenofemoral junction, the deep, superficial, and perforating veins were assessed with Doppler scan flow patterns and B-mode imaging as previously described.[5]

Venous reflux in the deep and superficial venous systems was evaluated with a rapid inflation/deflation system (Hokanson E20 Rapid Cuff Inflator and AG101 Cuff Inflator Air Source, Issaquah, Wash) and duplex ultrasound scan while the patient stood. This system allowed measurement of valvular closure times with a cutoff valve closure period of 0.5 second as the criterion for significant venous reflux. Systematic interrogation of the common femoral, superficial femoral, popliteal, greater saphenous, and lesser saphenous veins was conducted.

Finally, venous hemodynamics were assessed in all limbs with an air plethysmograph (ACI Medical, Inc, Sun Valley, Calif) both before surgery and within 6 weeks after surgery. Reflux into the calf was determined with measurement of the VFI, and calf pump function was assessed with measurement of the ejection fraction (EF) and the residual volume fraction (RVF) through determination of venous volume (VV), as previously described by Christopolous et al.[11]

Surgical correction of patients with superficial and combined deep and superficial venous insufficiency involved division and flush ligation of the saphenous vein at the saphenofemoral or saphenopopliteal junc-

Table II. Distribution of venous abnormalities and associated surgical procedures in patients with clinical follow-up

Anatomy	*Surgical procedure*
Deep, superficial, and perforator incompetence (n = 6)	SV and perf (n = 6)
Deep and superficial incompetence (n = 5)	SV (n = 5)
Superficial and perforator incompetence (n = 23)	SV and perf (n = 23)
Deep incompetence (n = 6)	Axillary vein/valve transplant (n = 6)
Superficial incompetence (n = 22)	SV (n = 22)
	Total (n = 62)

SV, Greater or lesser saphenous vein stripping with tributary ligation; *SV and perf,* greater or lesser saphenous vein stripping combined with subfascial perforating vein interruption.

Table III. APG changes after venous surgery

APG measurements	*Preoperative (mean ± SE)*	*Postoperative (mean ± SE)*	P *value, paired* t *test*
VV (mL)	155.2 (± 7.9)	125.9 (± 5.9)	< .001
VFI (mL/s)	7.0 (± 0.6)	3.2 (± 0.4)	< .001
EF (%)	58.7 (± 2.6)	63.8 (± 2.4)	.018
RVF (%)	42.4 (± 2.2)	32.8 (± 2.8)	.002

APG, Air plethysmography; *EF,* ejection fraction; *RVF,* residual volume fraction; *VFI,* venous filling index; *VV,* venous volume.

tion, followed by stripping from the groin with ligation of tributaries. Two patients required lesser saphenous vein stripping. All patients with combined superficial and perforator incompetence received superficial stripping combined with subfascial ligation of one to five perforating veins. Subfascial ligation of perforating veins was initially accomplished by direct incision (n = 24) and later by an endoscopic (SEPS) approach (n = 10). Finally, seven patients had isolated deep venous insufficiency and underwent autogenous axillary vein to deep venous valve transplants as previously described.[12]

The statistical differences between the preoperative and postoperative APG scores were evaluated with paired *t* tests with two-sided significance assigned through the Bonferroni-Holm method for multiple comparisons at an overall 0.05 level. Values are expressed as mean ± SE. Logistic regression was used to examine the relationship between the various APG parameters and clinical outcome. The Kruskal-Wallis test was used for further assessment of the association between clinical outcome as a continuous variable and postoperative VFI values. Analyses were performed with FREQ, UNIVARIATE and LOGISTIC from SAS System software (SAS Institute, Cary, NC).

RESULTS

In this group, 73 extremities in 71 patients were operated on. The mean age of the patients was 50.6 years (range, 25-77 years), and 54% of the patients were female. Of the 71 patients studied, clinical follow-up was available in 62 extremities (85%) at a mean period of 44.3 months after surgery. Eighty percent of the patients studied had clinical follow-up evaluations more than 24 months after surgery. Sixty-six extremities were classified as having primary CVI, and seven with isolated deep venous insufficiency limbs were determined to have secondary CVI. The distribution of the venous abnormalities recognized on preoperative duplex scan examination and the corresponding surgical procedures in the 71 patients studied are summarized in Table II.

Postoperative APG demonstrated significant changes in hemodynamic function after surgery as measured with VFI, VV, EF, and RVF (all $P < .02$). Preoperative and postoperative value comparisons are illustrated in Table III. In the 62 extremities available for follow-up, mean CSSs decreased significantly from 7.35 ± 0.56 preoperatively to 1.79 ± 0.32 at late follow-up after surgery (Fig 1). The only APG parameter to correlate independently with clinical outcome was the VFI. A normal postoperative VFI (≤ 2 mL/s) predicted a good clinical outcome (CSS ≤ 2) in patients at late follow-up, even after correcting for preoperative VFI ($P = .04$). The positive predictive value of a normal postoperative VFI for a CSS of 2 or less was 94%, the specificity was 89%, and the sensitivity was 70%.

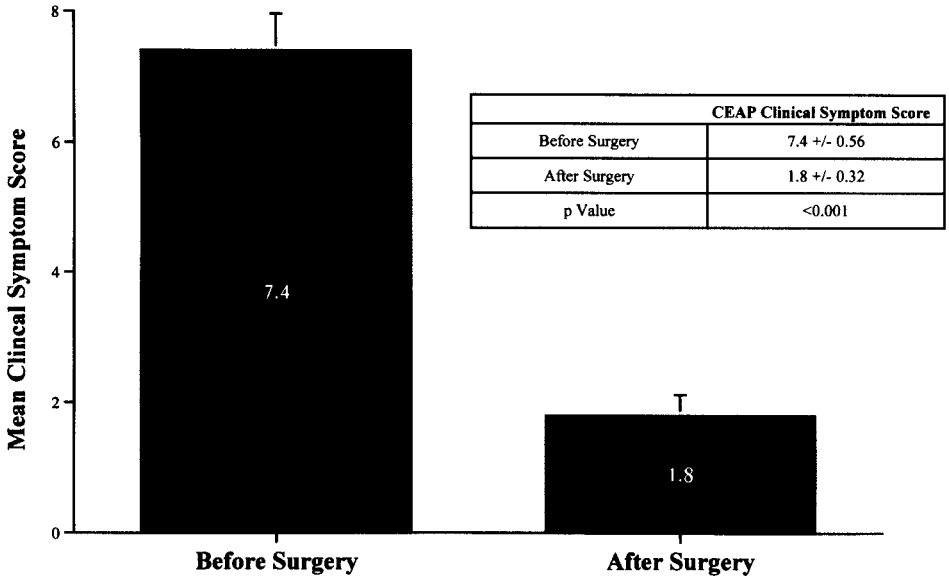

Fig 1. CEAP scores were assigned from nine categories to establish a CSS (Table I), for a maximum of 18 in each limb. In extremities with late follow-up (n = 62), significant improvement in mean CSS was observed in all extremities after corrective venous surgery. A postoperative CSS of 2 or less was established as good clinical outcome.

In the subgroup of seven patients with isolated deep venous incompetence, the preoperative VFI was 10.1 ± 0.57. After vein transplant procedures, the postoperative VFI improved to 6.4 ± 1.2 but did not normalize. A subgroup of 16 limbs contained combined venous reflux involving the deep and superficial or superficial/perforator systems. In patients with combined deep venous system disease, seven limbs underwent saphenous vein stripping alone, and eight limbs received saphenous vein stripping combined with perforator ligation. One patient had saphenous vein stripping combined with a popliteal vein transplant. Of the 15 patients with combined deep and superficial disease treated with saphenous vein stripping with or without perforator ligation, the VFI changed from 9.3 ± 1.2 preoperatively to 4.6 ± 1.0 postoperatively. Eight of the 15 patients had normalization of their VFI postoperatively. The CSS averaged 7.2 ± 1.0 preoperatively and improved to 2.4 ± 0.9 postoperatively in patients with follow-up. In the subgroup of patients whose VFI normalized, the postoperative CSS was 1.1 ± 0.5.

The CSSs in patients whose VFI normalized are compared with patients whose VFI did not normalize (< 2 mL/s) in Fig 2. A linear relationship was observed between the CSS and postoperative VFI. A moderately abnormal postoperative VFI (2 mL/s < VFI < 4 mL/s) was associated with a good clinical outcome in 53% of patients and rarely occurred (n = 3) when the VFI was 4 or more. Patients with extremities that had a normal postoperative VFI (n = 33) were six times more likely to have a good clinical outcome than those whose VFI did not normalize (n = 29). Unlike the VFI, postoperative changes in VV, EF, and RVF were not predictive of improvement in CSS (Fig 3).

DISCUSSION

Noninvasive venous testing has contributed significantly to the understanding of the venous abnormalities underlying CVI. Duplex scanning has been reported to be as accurate as invasive phlebography in identifying venous reflux produced by valvular incompetence of the deep, superficial, or perforating veins of the lower extremities.[13,14] Using this technique, the skilled examiner can determine the anatomic abnormalities contributing to CVI. However, duplex scanning provides no indication of the hemodynamic importance of these abnormalities. It identifies pathologic sites, but does not provide quantitative hemodynamic information (this is similar to arterial lesions revealed with arteriography). Photoplethysmography (PPG) has been used as a screening method in many laboratories because the venous refill times provided by PPG have been shown to be sensitive, although

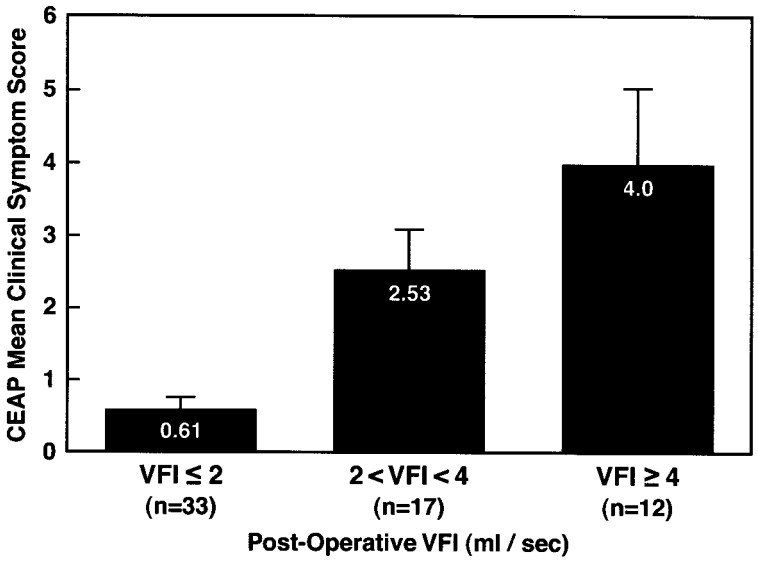

Fig 2. Comparison of mean CSS in patients who had normal postoperative VFI with mean CSS in those whose values did not normalize (> 2 mL/s). Mean values and numbers in each group are shown. A linear relationship is observed. *VFI,* Venous filling index.

not specific indicators of reflux.[15] However, PPG is a poor quantitative measure of venous incompetence because of its inability to differentiate grades of clinical severity of disease.[16]

APG was introduced by Christopoulos et al[11] as a tool for assessing global venous reflux. APG measures various parameters of lower extremity venous function including the VFI, EF, and RVF. The VFI measures the venous refilling rate of the calf, thereby assessing the overall degree of calf venous reflux, whereas the EF and RVF assess the function of the calf muscle pump. The RVF has been reported to have a high correlation with ambulatory venous pressures.[4] In previous studies it has been suggested that the VFI is a good predictor of venous reflux and the best APG parameter correlating with the clinical severity of venous disease.[5]

In recent years, APG testing has been used to objectively measure changes in venous hemodynamics after therapeutic intervention in patients with CVI. Improvements in these parameters have been documented in lower extremities treated with compression therapy[4,17] and in patients undergoing surgery for venous disease.[6-8] The clinical application of noninvasive venous testing is still evolving, and it remains unknown whether noninvasive venous testing can predict clinical outcome. Objective ulcer healing has been investigated in several studies, but there has been little correlation with noninvasive venous studies. Cordts et al[18] found no association between the number of incompetent valves identified by venous duplex scan examination and ulcer healing. Likewise, Mayberry et al[19] examined several clinical and hemodynamic variables in patients with venous leg ulcers and found no correlation with venous refill time as measured with PPG.[19]

In this study, we attempted to address the question of whether noninvasive venous testing with APG can assist in predicting clinical outcome. Hemodynamic improvement was observed after venous surgery in all APG variables studied (VFI, VV, EF, and RVF). Although skin changes such as pigmentation remained, significant clinical improvement occurred on the basis of summary symptom scores incorporating ulcer healing and patients' perception of improvement. We found that of the above parameters, normalization of the VFI postoperatively was the most highly predictive of a good late clinical outcome with a positive predictive value of 94%.

Patients with a VFI less than 2 mL/s after surgery were six times more likely to have minimal symptoms associated with venous insufficiency. In extremities where the postoperative VFI did not normalize but was only moderately abnormal (VFI between 2 and 4 mL/s), the CSS was occasionally 2 or less (9 of 17 extremities), but this rarely occurred (3 of 12 extremities) when postoperative VFI was greater than 4. There was no correlation between postoperative EF

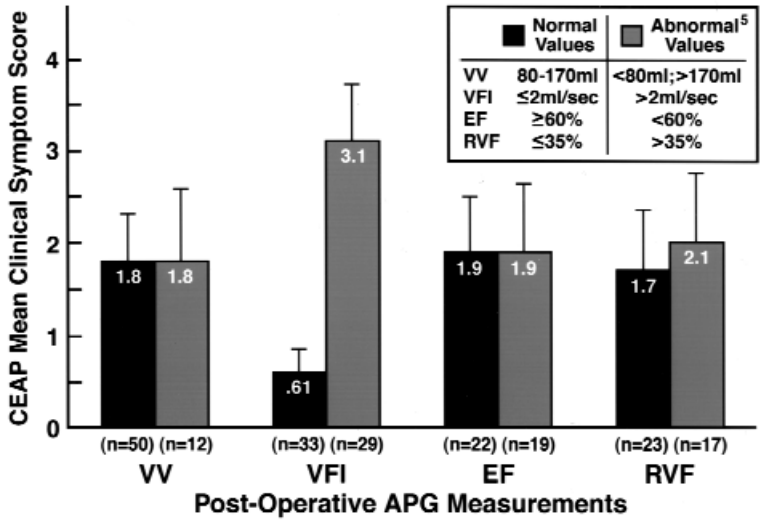

Fig 3. Comparison of postoperative CSS in limbs with normal and abnormal APG measurements. Normal values are shown. *EF,* Ejection fraction; *RVF,* residual volume fraction; *VFI,* venous filling index; *VV,* venous volume.

and RVF and late clinical outcome (Fig 3). The reason for this is unclear, but one could postulate two reasons. First, the determination of these APG parameters requires significant patient compliance with tiptoe maneuvers, and some patients in our population have difficulty performing these exercises correctly. Additionally, these values are more associated with ambulatory venous pressure and calf pump function than with venous reflux. Thus, patients with a normalized VFI may perceive more improvement in their overall CVI symptoms such as pain, edema, and venous claudication than those who normalized their EF and RVF.

Using these data would allow the practitioner to determine the adequacy of corrective surgery for patient counseling and for consideration of further surgery. Padberg et al[8] found that in patients with a combination of venous reflux involving deep and superficial or superficial/perforator systems, partial correction of only the superficial system may be performed with significant hemodynamic and clinical improvement in most patients. Similar results were observed in the group of 16 patients in our study with combined venous reflux involving the deep and superficial or superficial/perforator systems. Correction of the superficial or superficial/perforator systems alone resulted in an improvement in the VFI and a general improvement in the CSS. Thus, it appears that postoperative VFI measurements in these patients could predict whether superficial surgery alone is likely to result in a good clinical outcome before deep venous reconstruction is considered.

In summary, reflux and calf pump function, as measured with APG, were significantly improved after venous surgery. Normalization of VFI after venous surgery for CVI is predictive of a good clinical outcome with the use of the CSS classification system. Use of this APG measurement after venous surgery may be a useful clinical parameter to determine adequacy of surgery in patients with venous insufficiency.

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REFERENCES

1. Lundstrom B, Osterman G. Assessment of deep venous insufficiency by ascending phlebography. Acta Radiol Diagn 1982;24:375-9.
2. Myers KA, Ziegenbein RW, Zengh GH, et al. Duplex ultrasonography for chronic reflux disease: patterns of venous reflux. J Vasc Surg 1995;21:605-12.
3. Nicolaides AN, Zukowski A, Lewis P, Kyprianou P, Malouf M. The value of ambulatory venous pressure measurements. In: Bergan JJ, Yao JST editors. Surgery of the veins. 1st ed. Orlando: Grune & Stratton Inc; 1985. p. 111-9.
4. Christopoulos DG, Nicolaides AN, Szendro G, et al. Air plethysmography and the effect of elastic compression on venous hemodynamics of the leg. J Vasc Surg 1987;5:148-59.
5. Criado E, Farber MA, Marston WA, Danniel PF, Burnham CB,

Keagy BA. The role of air plethysmography in the diagnosis of chronic venous insufficiency. J Vasc Surg 1998;27:660-70.
6. Gillespie DL, Cordts PR, Hartono C, et al. The role of air plethysmography in monitoring the results of venous surgery. J Vasc Surg 1992;16:674-8.
7. Christopoulos DG, Nicolaides AN, Galloway JMD, Wilkison A. Objective noninvasive evaluation of venous surgical results. J Vasc Surg 1998;8:683-7.
8. Padberg FT, Pappas PJ, Araki CT, et al. Hemodynamic and clinical improvement after superficial ablation in primary combined venous insufficiency with ulceration. J Vasc Surg 1996;24:711-8.
9. Porter JM, Moneta GL, International Consensus Committee on Chronic Venous Disease. Reporting standards in venous disease: an update. J Vasc Surg 1995;21:635-45.
10. Nicolaides AN. Classification and grading of chronic venous disease in the lower limbs: a consensus statement. In: Gloviczki P, Yao JST, editors. Handbook of venous disorders: guidelines of the American Venous Forum, 1st ed. London: Chapman & Hall; 1996. p. 652-60.
11. Christopoulos DG, Nicolaides AN, Szendro G. Venous reflux: quantification and correlation with the clinical severity of chronic venous disease. Br J Surg 1988;75:352-6.
12. Raju S, Fredericks R. Valve reconstruction procedures for nonobstructive venous insufficiency: rationale, techniques, and results in 107 procedures with two-to eight-year follow-up. J Vasc Surg 1988;7:301-10.
13. Szendro G. Nicolaides AN, Zukowski AJ, et al. Duplex scanning in the assessment of deep venous incompetence. J Vasc Surg 1986;4:237-42.
14. Labropoulos N, Delis K, Nicolaides AN, et al. The role of the distribution and anatomic extent of reflux in the development of sign and symptoms in chronic venous insufficiency. J Vasc Surg 1996;23:504-10.
15. Abramowitz HB, Queral LA, Flinn WR, et al. The use of photoplethysmography in the assessment of venous insufficiency: a comparison to venous pressure measurement. Surgery 1979;86:434-41.
16. Bays RA, Dean HA, Atnip RG, et al. Validation of air plethysmography, photoplethysmography, and duplex ultrasonography in the evaluation of severe venous stasis. J Vasc Surg 1994;20:721-7.
17. Noyes LD, Rice JC, Kerstein MD. Hemodynamic assessment of high-compression hosiery in chronic venous disease. Surgery 1987;102:813-5.
18. Cordts PR, Hanrhan LM, Rodriguez AA, et al. A prospective, randomized trial of Unna's boot versus Duoderm CGF hydroactive dressing plus compression in the management of venous leg ulcer. J Vasc Surg 1992;15:480-6.
19. Mayberry JC, Moneta GL, Taylor LM, et al. Fifteen-year results of ambulatory compression therapy for chronic venous ulcers. Surgery 1991;109:575-81.

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DISCUSSION

Dr Andrew Nicolaides (London, England). I very much enjoyed the paper and your presentation, and I congratulate the authors for an excellent study. Certainly the aim of the study has been achieved very well, but what I am going to say is because I believe there should be a lot more additional and useful information buried in the data we have just heard and I will try and unravel it. I will ask three questions.

The authors have shown that the APG measurements change with surgery, and in fact, they have shown that the VFI, which is a measurement of reflux, decreases by 60%. This is a measure of how effectively they have done the ligation and the surgery. Now I suspect this reduction in VFI is the result of mainly the effect in the patients with superficial venous incompetence, and I expect to have little change in the patients who have deep venous incompetence. I would very much like to see the data presented separately.

There is a reduction in venous volume of about 16%, and this, if you really think about it, represents the veins that have been removed. It is all the blood that is no longer there. Now the ejection fraction increased by 10%, and this is probably the effect of ligation of the incompetent perforating veins. I would expect if the author presented the results of the patients with incompetent perforating veins separately, this 10% would probably be 20% or 30% because we know that from some other data we have.

Finally, the residual volume fraction decreased by 25%. Now if I see such a decrease in patients with leg ulceration, I can be convinced, and I can tell the patients with certainty that the ulcers will heal because this corresponds to approximately a 25% decrease in ambulatory venous pressure. I suspect there has not been that much decrease in residual volume fraction if we take the patients with chronic venous insufficiency. Therefore, my first question is can the author give us any information if he has done the analysis of these groups separately and the three groups are the patients with varicose veins alone, the patients with varicose veins and incompetent perforating veins, and the patients with deep venous incompetence? There are 26 patients with varicose veins and incompetent perforating veins. Therefore, we should have some useful information out of that.

The second area I would like to address is that the authors have shown that there is a reduction in the CEAP clinical symptom score after surgery from 7.4 to 1.8, and there was an associated reduction in the VFI, the reflux, as an independent predictor in a multivariate analysis. Now in a multivariate analysis if you have an independent predictor, all the authors are thrown out, but what we are trying here is to understand the contribution and what the various measurements mean. My second question to the authors is, have they repeated a multivariate analysis having thrown out the VFI to see if the others have any correlation or contribute at all?

Finally, we come to the last comment. Although the aim of the paper has been very well fulfilled and you have identified a very good predictor of the results of surgery, an additional aim of all this work is to find out what exactly is going on and what these measurements mean. My third question is, where do you go from here? I would like to know what other plans you have to improve on this work.

I very much enjoyed the paper again, and thank you for the privilege of the floor.

Dr Lewis V. Owens. Thank you, Dr Nicolaides. It is an honor to have you review our data as the premier expert in this area.

Your first question addressed specific subcategories of the patients as well as improvements of their ejection fraction, venous volumes, and their residual volume fraction. Probably the main problem with that is we have a series of about 73 patients and we do not have enough subcategories to assess this. I do know that the patients with the incompetent perforators, their ejection fraction, did improve about 12% to 15% following their procedures, which is near in line with what your estimated area was, but as we get more numbers and we continue our database, it will be very important to see what the prediction is going to be.

As far as the multivariate analysis and whether or not we threw out the VFI as an individual variable, we did not do that. I agree; I think it will be very important to go back and do that because that will be valuable data as well.

The final question was where do we go from here? There is no doubt that buried within these patients as far as with their clinical follow-up there is a lot of useful data that will help guide us in our treatment. As Dr Padberg has shown in his study of patients who had combined superficial and deep venous incompetence, their clinical symptoms did significantly increase following superficial stripping. Well, there would certainly be subcategories of patients with these combined diseases that we can follow along. As our database increases we will be able to focus specifically on these patients and how to manage them.