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Association of Venous Volume and Diameter of Incompetent Perforator Veins in the Lower Limb—Implications for Perforator Vein Surgery

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Purpose. *To define the association between venous volume as measured with air-plethysmography and the duplex ultrasound measured diameter of incompetent perforator of the lower limb.*
Patients and methods. *Thirty-six patients with chronic venous disease were investigated with air-plethysmography and duplex ultrasound. Venous volume and venous filling time was measured. Venous filling index was calculated. The findings were correlated with the diameter of the largest incompetent perforator vein of the lower limb.*
Results. *Twenty-six patients with venous volume in the normal range (80–170 ml) had a median perforator diameter of 3. 5 mm (IQR 3.2–4.3). Ten patients with venous volume above 170 ml had median perforator diameter of 5.5 mm (IQR 4.6–7.7). (*$p = 0.001$*, Mann–Whitney). There was a correlation between the venous volume and diameter of the largest incompetent perforator vein. (Pearson correlation factor 0.69,* $p = 0.01$*).*
Conclusion. *Limb volume correlates to the diameter of the largest incompetent perforator of the calf. Increase in venous limb volume could be partly responsible for an increase in the size of calf perforators thereby promoting incompetence.*

Keywords: Chronic venous disease; Incompetent perforator veins; Plethysmography; Venous volume; Duplex ultrasound.

Introduction

Poor venous function, caused by venous reflux, obstruction or calf muscle pump failure, will ultimately lead to an increase in ambulatory venous pressure. It is well known that high venous blood pressure over time leads to skin changes and ulceration.[1] Compression therapy has been the cornerstone in treatment of patients who develop these complications. Despite optimal medical therapy the healing process is often long and the risk for ulcer recurrence is high. Surgical therapy has been the alternative for patients with reflux in the great and/or small saphenous vein while the role of perforator ligation is less well defined.[2,3] Standardisation of methods to locate the site of calf perforators and to measure their size accurately and studies that confirm the causative role of incompetent perforator veins (IPV) in progression of chronic venous disease are lacking. Several recent publications on IPV have been focused on the clinical success of subfascial endoscopic perforator surgery (SEPS), in combination with superficial venous surgery, regarding ulcer healing and recurrence.[4,5] A clear advantage compared to the open procedure has been shown, mainly in form of less wound complications.[5–7] Other reports have shown that IPV often regain competence (~80%) after ablation of the superficial venous incompetence without the need for ligation.[8,9] The only clear indication for perforator interruption, according to a recent published analysis, is primary deep venous incompetence with concomitant perforator incompetence.[10]

Non-invasive venous studies such as plethysmography give information about the overall venous function of the limb, information that is not gained by duplex ultrasound scanning. Venous filling index (VFI) as measured by air-plethysmography (APG) has been evaluated in great detail. It is calculated from two parameters; the venous volume (VV) and venous filling time. It represents the amount of blood (in ml) accumulating in the veins of the leg when rising from recumbent to upright position and the time taken in seconds.[11] VFI is regarded normal when below 2 ml/s.

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Values above this range indicate valve failure and an increasing value is a sign of more severe reflux.

This study was conducted to investigate the possible association between VV as measured with APG and the duplex ultrasound measured diameter of incompetent perforator veins.

Patients and Methods

Thirty-six patients (26 men) aged 34–81 years (mean 57 years) with perforator incompetence and severe venous disease (CEAP clinical class 4–6) were investigated with APG (ACI Medical Inc., Sun Valley, CA, USA) and duplex ultrasound (Ultramark-9, Advanced Technology Laboratories, Bothell, WA, USA) by an experienced vascular technician. In cases of bilateral disease, the limb more severely affected was included. Veins piercing the fascia (directly) connecting the superficial (above fascia) and deep (below fascia) veins was regarded as perforators. Incompetence was defined as outward flow >0.5 s. The diameter of the perforator was measured deep to the muscle fascia. Measurements were made in 15° of reverse Trendelenburg position. Reflux was elicited by distal manual calf compression and release. APG was performed according to the technique described by Christopoulos.[11] VV and venous filling time were measured and VFI calculated. VV between 80–170 ml and VFI <2 ml/s was considered normal. The findings of APG were correlated to the diameter of the largest incompetent perforator vein of the lower limb. The anatomical distribution of reflux was confirmed with duplex ultrasound but the diameter of other veins in superficial or deep system was not measured.

In this paper, data are represented by the median and inter-quartile range. Statistical significance of between group differences was assessed using the Mann–Whitney *U*-test (software from SPSS Inc, version 10.1, USA) with a p-value <0.05 considered to be significant.

Results

Twenty-eight patients had active venous ulcers (C6) and eight had skin changes (C4). The aetiology (according to history and duplex ultrasound findings) was primary disease in 20 patients (Ep) and secondary (post-thrombotic) in 16 patients (Es). At least one incompetent medial perforator was present in all limbs. Superficial venous incompetence was present in 29 limbs (83%) and deep venous incompetence in 31 limbs (89%). No patient had isolated perforator incompetence. All limbs had reflux according to the APG with VFI >2 ml/s. The median value for VFI was 6.5 (IQR 4.3–8.2). The median VV was 150 ml (IQR 122–174). There was a significant correlation between VV and the diameter of the largest incompetent perforator vein, irrespective of anatomical location of reflux in superficial or deep veins. (Pearson correlation factor 0.69, $p=0.01$) (Fig. 1). There was a significant difference between 26 patients with VV in the normal range (80–170 ml) with a median perforator diameter of 3.5 mm (IQR 3.2–4.3) and 10 patients with VV above 170 ml with a median perforator diameter of 5.5 mm (IQR 4.6–7.7) ($p=0.001$, Mann–Whitney *U*-test) (Fig. 2). There was no significant difference in VV or perforator diameter between patients with primary or secondary disease. There was no correlation between VFI and the diameter of the incompetent perforator vein.

Discussion

APG has been used during the last 13 years with variable findings regarding the value of this investigation.[12–16] APG indicates VV changes indirectly, by measuring pressure changes in an air chamber covering the area from the ankle to the knee. The test is performed after emptying the limb veins by elevating the leg, during changes in position from recumbent to standing and during heel-raise manoeuvres. The test gives some information on the function of the calf muscle pump (ejection volume and ejection fraction), the presence or absence of outflow obstruction (outflow fraction) and the amount of reflux (VFI). By using a tourniquet, some differentiation between superficial and deep venous incompetence can be made. All these parameters are based on VV. The value of interpreting VV measurements directly and how VV correlates to venous pathology is less defined. Neglen *et al.*[17] used APG and venous pressure measurements to investigate the pressure/volume relationship to the compliance of popliteal vein. They showed a relationship between VV and venous pressure. However, the relationship is not exactly linear.[18]

In this series there is a correlation between venous volume and the diameter of the largest incompetent perforator of the calf. A possible mechanism in formation of incompetent veins is shown in Table 1, which suggests a process in which an increase in VV precedes incompetence in the perforator veins, and may actually cause the incompetence of the perforator. According to this theory, the increase in venous limb volume could be partly responsible for the dilatation

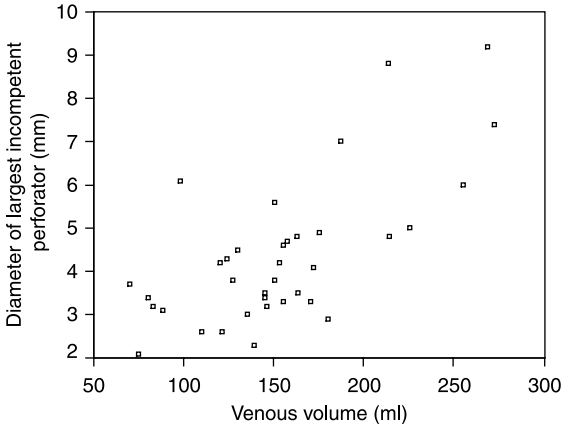

Fig. 1. Scatter gram showing the association between venous volume and diameter of the largest incompetent perforator in 36 patients. Pearson correlation coefficient 0.69, correlation significant at the 0.01 level (two-tailed).

of calf perforator in turn promoting incompetence. In support of this, the VV has been shown to decrease following stripping and ablation of varicose veins[15] and incompetent perforators have been shown to regain competence following stripping of the great saphenous vein.[8,9] In this scenario, an important goal with surgical treatment might be to reduce the VV in order to restore the perforator veins to a normal competent state. Our findings are not unexpected; an increase in VV should be reflected by an increase in the diameter of all veins in the limb. Our assumption that this is important for perforating veins is based on hypothesis, but further research in the form of sequential studies of the perforator veins is needed to understand the role of incompetent perforators in both primary and secondary chronic venous disease.

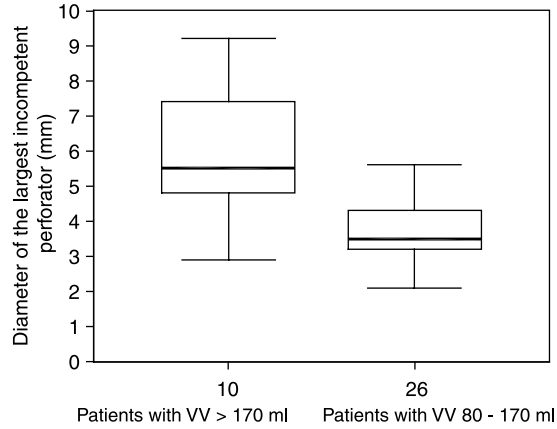

Fig. 2. Boxplot showing the difference in diameter of the largest perforator of the calf in patients with normal and abnormal venous volume (the boxes show the median, lower and upper quartiles and the whiskers indicate the maximum and minimum values) ($p=0.001$, Mann–Whitney *U*-test).

Table 1. Possible mechanism in formation of incompetent perforator veins

Primary or secondary valve destruction in saphenous or deep veins → Valve incompetence → Axial reflux → Increase in venous volume (increased venous pressure) → Dilatation in diameter of perforator → Valve incompetence in perforator vein → Outward flow in perforator

From this analysis we can learn what can be achieved by treating them.

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