Ambulatory Venous Pressure: Correlation with Skin Condition and Role in Identifying Surgically Correctible Disease

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Objectives: (1) To evaluate the full spectrum of venous skin damage with respect to ambulatory venous pressure. (2) To determine whether the ambulatory venous pressure / tourniquet test can be used to select patients for superficial venous surgery (e.g. long or short saphenous stripping).

Design: Prospective study.

Setting: Vascular studies unit.

Materials and Methods: Ambulatory venous pressure was measured in a large sample of limbs (360) with a wide spectrum of venous disease. In addition the effect of a tourniquet placed below the knee on ambulatory venous pressure and venous refilling time was assessed in 234 limbs. This was compared with Duplex assessment of deep and superficial venous reflux at this site.

Results: There was a linear trend towards more severe skin damage with increasing ambulatory venous pressure. Ulceration was associated with more severe calf muscle pump dysfunction (higher ambulatory venous pressure) than were lipodermatosclerosis, eczema or pigmentation. The tourniquet test was not able to distinguish between deep and superficial reflux as determined by Duplex scanning.

Conclusions: Ambulatory venous pressure should be used to quantify venous insufficiency and remains the reference standard test of the venous calf muscle pump. The tourniquet test should not be used to select patients for surgery since it cannot distinguish deep from superficial venous incompetence. Venous reflux is best localised using Duplex ultrasound.

Key Words: Ambulatory venous pressure; Venous insufficiency; Duplex ultrasound.

Introduction

The venous calf muscle pump has been likened to a “peripheral heart”. It is responsible for maintaining venous return from the leg, overcoming the effects of the upright posture which Man has adopted. Failure of the pump results in distension of the veins in the leg and an increase in the pressure within them. The measurement of venous pressure after exercise, ambulatory venous pressure (AVP) is accepted as the reference standard test of venous insufficiency.¹⁻⁷ It provides an overall assessment of the efficiency of the venous calf muscle pump and has been shown to correlate well with the incidence of venous ulceration. No previous study examined the spectrum of skin changes from normal through to ulceration with respect to the AVP.

It has also been suggested that patients who show normalisation of the AVP on application of a narrow tourniquet (to obstruct superficial but not deep venous reflux) show similar improvement following superficial venous surgery (e.g. long saphenous stripping).⁸⁻¹¹ This test might therefore be used to identify those patients with superficial venous reflux and who would benefit from superficial venous surgery.

Duplex scanning has been hailed as “the second sight of the vascular surgeon”¹² and is a valuable tool in the assessment of venous reflux. It is particularly useful in evaluating venous disease, since individual veins may be examined both anatomically, using the ultrasound modality and functionally, using the pulsed Doppler analysis.

The aims of this study are firstly to establish, in our referral population with venous disease, the relationship between AVP and the clinical severity of their venous disease assessed on a four point scale from normal skin through to ulceration, and secondly to...
examine (using Duplex scanning as a reference) whether the AVP/tourniquet test can differentiate between deep and superficial venous reflux.

**Methods**

Two hundred and twelve patients attending the vascular clinic of a university teaching hospital with a diagnosis of either varicose veins or chronic venous insufficiency were studied. Three-hundred and sixty limbs were assessed, patients who were diabetic or had coexistent arterial disease were excluded from the study. Twenty eight limbs included in the study had previously had a deep venous thrombosis (DVT) proven on phlebography. Clinical examination was performed by one observer (SPKP) in order to divide them into four groups:

1. Varicose veins but healthy skin.
2. Mild skin changes (eczema or pigmentation).
3. Severe skin changes (lipodermatosclerosis).
4. Ulceration (either active or a history of recurrent ulceration).

Eczema, pigmentation and lipodermatosclerosis were as defined by Browse and Burnand. 13

Ambulatory venous pressure was recorded using a standard technique. 5 A pedal vein was cannulated with a 21 gauge cannula connected to a pressure transducer, amplifier and chart recorder. The ambulatory venous pressure was recorded after a short, standardised exercise regimen (10 tiptoe exercises performed at the rate of one/second). The time taken for the pressure to return to 90% of the initial resting pressure on cessation of exercise was also recorded (RT90). The lowest of three repeated measurements of AVP was recorded. These measurements were repeated with a 2.5 cm wide cuff inflated just below the knee to a pressure of 140 mmHg. This has been shown on phlebographic examination to occlude superficial veins but not deep veins. 5

One hundred and forty three patients had both limbs assessed. In many cases it was not possible to cannulate a vein on both feet, therefore in 74 cases only one limb entered the study.

Of these 212 patients, 234 limbs of 141 patients were also assessed using Duplex scanning (22 of these had a history of deep venous thrombosis). The scans were performed using an Hitachi™ scanner with a 7.5 MHz probe and pulsed Doppler signal analysis. Each patient sat with legs relaxed and dependent over the side of a couch. The popliteal, short saphenous and long saphenous veins were all interrogated just below-knee level. Significant reflux was defined as reverse flow on valsala manoeuvre, or on release of manual calf compression lasting longer than 0.5 s. On the basis of the Duplex scan limbs were classified into four groups: 1. No reflux in these three veins; 2. Superficial reflux only (long or short saphenous reflux but popliteal vein competent); 3. Deep reflux only (popliteal reflux but both long and short saphenous veins competent); 4. Deep and superficial reflux (long or short saphenous reflux with popliteal incompetence). All three assessments were performed on the same day.

**Statistical analysis**

Statistical analysis was by non-parametric methods (Mann-Whitney U (two tailed), Wilcoxon and Chi squared tests). All quoted ranges in parentheses are 95% confidence intervals derived using a Wilcoxon test.

**Results**

One hundred and thirty three limbs had varicose veins and healthy skin with no evidence of eczema, pigmentation, lipodermatosclerosis or ulceration. Seventy one limbs had evidence of eczema or pigmentation but no lipodermatosclerosis. Fifty eight limbs had lipodermatosclerosis but no ulceration and 98 limbs had either active ulceration or a history of recurrent ulceration.

In those cases with unilateral ulceration we found a median AVP of 68 mmHg (57–80) in the ulcerated limbs and 56.5 mmHg (42.5–68.5) in the non-ulcerated limbs (p < 0.05). Therefore analysis has been by limb rather than by patient.

The median ambulatory venous pressure in the group with healthy skin was 47.5 mmHg (43.5–51), compared to 62 mmHg (57.5–64) in the eczema/pigmentation group, 65 mmHg (61–68) in the lipodermatosclerosis group and 69 mmHg (65–73) in the ulcerated group. Figure 1 shows this graphically, with 95% confidence intervals for each group. Significant differences in ambulatory venous pressure were found between the group with healthy skin and the group with mild skin changes (p < 0.0001) and between the group with mild skin changes and the ulcerated group (p < 0.01). The differences obtained between the group with mild skin changes and those with more severe skin changes and between those with severe skin
changes and those with ulceration were not statistically significant. This analysis is also illustrated as in Fig. 2. This shows the clinical severity of venous disease with increasing AVP (grouped in bands of 10 mmHg).

The median venous refilling time (RT90) in the limbs with healthy skin was 12 s, compared to 5.25 s in the group with eczema or pigmentation, 4.9 s in the group with lipodermatosclerosis and 5 s in the ulcerated group. The difference in RT90 between the limbs with healthy skin and those with mild skin changes was statistically significant ($p < 0.0001$). Other differences between groups were not significant.

The Duplex scan revealed that 134 limbs had superficial venous reflux, 23 deep reflux, 39 had reflux in none of these three veins examined at the knee level and 38 had venous incompetence in both superficial and deep systems. All scanned limbs had patent popliteal veins with no evidence of outflow obstruction on calf compression. The incidence of ulceration was 8% in the group with no reflux at this level, 20% in those with superficial reflux, 39% in those with deep reflux and 53% in those with both deep and superficial reflux (Table 1).

The relationship between the distribution of venous reflux on duplex and ambulatory venous pressure is illustrated in Table 2. Limbs with superficial venous reflux have a higher ambulatory venous pressure (61 mmHg) than those without reflux (47 mmHg) ($p < 0.01$). The median AVP in limbs with superficial reflux alone was 61 mmHg (57.5–64) compared to 60 mmHg (49–69.5) in those with deep reflux alone. Limbs with both deep and superficial reflux had a median AVP of 66 mmHg (60–72) compared to 60 mmHg (49–69.5) in those with deep reflux alone.

Table 3 shows the median venous refilling times (RT90) with 95% confidence limits in each of the four groups. This shows a clear difference in RT90 between limbs with either deep or superficial reflux and those

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Table 1. Distribution of venous incompetence and skin ulceration

<table>
<thead>
<tr>
<th>Condition of skin</th>
<th>Number (%)</th>
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<tbody>
<tr>
<td>Normal skin</td>
<td>60 (8%)</td>
</tr>
<tr>
<td>Pigmentation/eczema</td>
<td>25 (4%)</td>
</tr>
<tr>
<td>Lipodermatosclerosis</td>
<td>24 (4%)</td>
</tr>
<tr>
<td>Ulceration</td>
<td>39 (6%)</td>
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</tbody>
</table>

Table 2. Distribution of venous incompetence and ambulatory venous pressure

<table>
<thead>
<tr>
<th>Ambulatory venous pressure (95% confidence limits)</th>
<th>No reflux (n=39)</th>
<th>Superficial reflux (n=134)</th>
<th>Deep reflux (n=23)</th>
<th>Superficial and deep (n=38)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulceration</td>
<td>3 (8%)§</td>
<td>27 (20%)§‡</td>
<td>9 (39%)‡§</td>
<td>20 (53%)§</td>
</tr>
</tbody>
</table>

*p = 0.19; †p = 0.04; §p = 0.2; ¶p = 0.7.

*p < 0.01; †p < 0.01 (Mann - Whitney).
Table 3. Distribution of venous incompetence and venous refilling times obtained without tourniquet

<table>
<thead>
<tr>
<th></th>
<th>Venous refilling time 90% (RT90) (95% confidence limits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No reflux (n=39)</td>
<td>14 s (11-19.2)†‡§</td>
</tr>
<tr>
<td>Superficial reflux (n=134)</td>
<td>6.6 s (5.75-7.7)†‡</td>
</tr>
<tr>
<td>Deep reflux (n=23)</td>
<td>7.6 s (5.9-9.85)†</td>
</tr>
<tr>
<td>Superficial and deep (n=38)</td>
<td>4.75 s (3.45-6.25)§</td>
</tr>
</tbody>
</table>

*,†p < 0.01; †p < 0.05; §p < 0.01 (Mann-Whitney).

Table 4. Distribution of venous incompetence and reduction of AVP with below-knee tourniquet

<table>
<thead>
<tr>
<th></th>
<th>Reduction in AVP with tourniquet (95% confidence limits)</th>
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<tbody>
<tr>
<td>No reflux (n=39)</td>
<td>1.25 mmHg (-2.0-5.5)</td>
</tr>
<tr>
<td>Superficial reflux (n=134)</td>
<td>2 mmHg (0.3-5.5)</td>
</tr>
<tr>
<td>Deep reflux (n=23)</td>
<td>3 mmHg (-0.5-7)</td>
</tr>
<tr>
<td>Superficial and deep (n=38)</td>
<td>2.5 mmHg (0.5-5)</td>
</tr>
</tbody>
</table>

Table 5. Distribution of venous incompetence and increase in venous refilling time with below-knee tourniquet

<table>
<thead>
<tr>
<th></th>
<th>Increase in refilling time with tourniquet (95% confidence limits)</th>
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</thead>
<tbody>
<tr>
<td>No reflux (n=39)</td>
<td>1.35 s (-0.15-2.65)</td>
</tr>
<tr>
<td>Superficial reflux (n=134)</td>
<td>0.75 s (0.3-1.2)</td>
</tr>
<tr>
<td>Deep reflux (n=23)</td>
<td>1.25 s (0.75-2.3)</td>
</tr>
<tr>
<td>Superficial and deep (n=38)</td>
<td>0.2 s (-0.35-0.7)</td>
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Discussion

The skin changes and ulceration associated with venous disease are accepted to be due to failure of the venous calf muscle pump. This pump mechanism is responsible for emptying the veins of the leg, thus reducing the pressure within them. The measurement of venous pressure in a pedal vein after a standardised exercise (AVP) thus provides a global assessment of the efficacy of the calf muscle pump.

These data show a clear association between AVP and different skin condition in a large sample of limbs with a wide spectrum of venous disease. Previous studies have assessed fewer patients and have only examined the incidence of ulceration. Fig. 2 shows that the likelihood of venous ulceration and skin damage increase in a linear fashion with increasing AVP. There is, however, some overlap between AVP measurements in limbs grouped by their clinical condition as shown in Fig. 1. There are a number of explanations why this may be so.

The effect of the tourniquet placed below the knee on AVP was calculated thus: Effect of tourniquet = (AVP without tourniquet) – (AVP with tourniquet). Similarly for refilling times the effect of the tourniquet was calculated in the same way.

Table 4 shows the change in AVP produced by the below-knee tourniquet in each of the four groups. Limbs with incompetence only in the superficial veins had a median reduction in AVP when the tourniquet was placed of 2 mmHg compared to 1.25 mmHg at this level of superficial reflux alone at this level was 6.6 s (5.75-7.7) compared to 4.75 s (3.45-6.25) in those with both deep and superficial reflux. The limbs with deep reflux alone had a median refilling time of 7.6 s (5.9-9.85) compared to 4.75 s (3.45-6.25) in those with reflux in both the deep and superficial systems.

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The effect of a below-knee tourniquet on venous refilling time (RT90) in each of the four groups is shown in Table 5. Limbs with no incompetence showed a median increase in RT90 of 1.35 s, those with superficial reflux 0.75 s, those with isolated deep reflux 1.35 s and those with both deep and superficial reflux 0.2 s. None of these differences were statistically significant except that between isolated deep reflux and those with both deep and superficial reflux (p < 0.05).
neutrophil function and fibrinolysis may determine which limbs develop ulceration in the presence of an elevated AVP.15-20

This study also shows a relationship between decreasing venous refilling time and deterioration in skin condition. This trend is not linear however, as has been highlighted already by Nicolaides et al.7 who suggests that RT90 be used as a screening test to identify limbs likely to have an abnormal AVP. There is a significant difference between limbs with healthy skin and those with skin changes, but the more severely affected limbs do not appear to have any further significant deterioration in refilling time.

It is interesting to note that the highest incidence of ulceration was found in limbs with both deep and superficial venous reflux, and that deep venous reflux was associated with a higher incidence of ulceration than superficial reflux (although not statistically significant) and that the lowest incidence of ulceration was found in limbs with no reflux in the three veins examined at the knee level. These findings are in agreement with all other analyses of the distribution of venous incompetence and skin ulceration. Ambulatory venous pressure and RT90 also follow this trend (Tables 2 and 3) although the limbs with deep venous reflux had a median AVP slightly lower and an RT90 slightly longer than those with superficial reflux alone.

The hypothesis that superficial reflux can be distinguished from deep reflux by the application of a tourniquet during AVP and RT90 measurement is not borne out by Tables 4 and 5. There was no greater reduction in AVP with the application of a tourniquet in the patients with superficial reflux, compared either with those who had deep venous reflux or those who had no reflux. Similarly there was no greater increase in RT90 in the patients with superficial reflux compared with the others. This might be because the tourniquet either fails to obstruct the superficial veins or compresses the popliteal vein (reducing reflux flow and potentially restoring an incompetent valve to competence). A similar problem with using tourniquets has been noted by McMullin et al.21 Another explanation would be that reflux through perforating veins below the tourniquet may influence the AVP to such an extent that the effect of the tourniquet on the veins at knee level is irrelevant. This seems unlikely, however the study has not addressed perforating vein incompetence.

This study therefore demonstrates that ambulatory venous pressure correlates well with the clinical condition of the skin in patients with venous disease. Limbs affected by the skin changes of eczema / pigmentation or lipodermatosclerosis are associated with calf muscle pump failure as measured by AVP. Ulceration is associated with further deterioration of calf pump function.

The tourniquet test in combination with AVP measurement is not helpful in determining whether superficial venous reflux is present, and therefore cannot be used as a means of selecting patients for superficial venous surgery.

We suggest that the ambulatory venous pressure measurement should be used as the reference standard test when it is necessary to quantify the degree of venous calf muscle pump failure (and therefore severity of venous disease), for example when evaluating or comparing treatments for venous disease. When planning surgery however the test cannot indicate the site of incompetence; this function is served admirably by Duplex scanning.

Acknowledgements

We are grateful to Mr M.I. Asher for help in performing ambulatory venous pressure measurement and to Mrs J. Brookes for assistance with Duplex scanning.

This work was supported by a grant from Medi-U.K. Ltd.

References


Accepted 15 June 1995