CONSENSUS

Expert consensus document on direct ambulatory venous pressure measurement

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Venous hypertension during walking, that is increased ambulatory venous pressure (AVP), is the major characteristic of disturbed venous hemodynamics. Determining the exact AVP is therefore very valuable in expressing the severity of chronic venous disease (CVD).[1] For this purpose, direct AVP measurement is the "gold standard" up till now.[2-6]

At the beginning of the twentieth century, Von Recklinghausen (1906) was already able to measure venous pressure.[7] He was followed by Roulson (1911) and Beecher (1936).[8] The latter two introduced compression of the superficial venous system to distinguish superficial from deep venous insufficiency.

The technique of AVP measurement that is still used was developed in 1925 by Barber and Shatara.[9] McPheeters and Rice as well as Pollack and Wood demonstrated that venous pressure drops during walking.[10-11] Seiro showed that the venous pressure drop in patients with varicose veins is lower compared to healthy individuals.[12] Höjensgard and Stürup as well as Arnoldi proved the existence of a similarity between superficial and deep venous pressure.[13, 14] A correlation between the calf muscle pump function and venous pressure exists.[5]

Although AVP measurement is considered to be the "gold standard" functional test for quantifying venous hypertension, it has largely been replaced by duplex ultrasound (DUS). However, DUS is not a real functional test that is able to give information on the quality of the venous pump expressed as pressure decrease in ambulatory condition. In daily practice DUS has become the gold diagnostic tool for all routine therapy decisions in phlebology, but AVP measurement still has its diagnostic importance and supplementary value in complex cases of CVD.

Despite the use of AVP measurement for almost a century it has never been fully standardised.[15] The following document results from a consensus meeting of experts on AVP measurement during the UIP World Congress in Monaco, August-September 2009. The aims were to agree about the technique, interpretation of the results and indications, which may lead to standardisation of AVP measurement.

Materials and methods

A few months before the UIP World Congress in Monaco, August-September 2009, S.W.I.R., O.W. and H.A.M.N. invited six experts on AVP measurement to discuss the pitfalls, whereby standardisation on AVP measurement was not fully reached so far. All invited experts agreed on participating in this project. Next, S.W.I.R. sent all the experts the protocol that describes the way in which AVP measurement is performed in Rotterdam, the Netherlands. Together with the protocol five statements and questions on AVP measurement were sent. These statements and questions were formulated by S.W.I.R., O.W. and H.A.M.N. and included the main bottlenecks in standardising AVP measurement.

During the meeting in Monaco the experts discussed the protocol statements and the answers to the questions. After the meeting the minutes were sent to all experts and their comments were processed in order to come to this final consensus document.

First, the statements and questions will be outlined. Subsequently, the standardised protocol on AVP measurement is reported.

Questions and statements

1. AVP measurement is an important functional parameter to characterize the severity of insufficiency of the venous pump, i.e. CVD.

— Revised statement: AVP measurement is the "gold standard" for assessing the severity of hemodynamic abnormality of CVD in the lower extremities.

2. Technique of AVP measurement: We use tiptoe and knee bend exercises, but these exercises do not mimic walking. During tiptoe movements the gastrocnemius veins do not empty.[16] Should a treadmill be used to copy a normal walking pattern? If we decide to do so, what should be the walking speed and for how long should the patient do this exercise?

— Revised statements: The only way to get correct information is to mimic the normal walking pattern. This can be reached by performing the investigation on a treadmill;

— The ideal speed to perform AVP measurement on a treadmill is 1 Hz (= 1 step/second) but the speed using the treadmill is expressed in km/h. 4 km/h would correspond to normal walking, but not all patients will be able to reach this speed. Therefore we recommend 2 km/h with an elevation of 8°;

— Walking should be continued at the same speed until a stable phase of the pressure curve is reached;

— Only if a treadmill is not available, alternatively tiptoe or knee-bending exercises may be used.

3. Interpretation of AVP measurement: Until now, we determined AVP as the deepest point of pressure after 10 tiptoe/knee bend exercises.

— A significant relation between the deepest point of pressure after 10 exercises and the clinical score of CEAP has been shown;[17]

— Revised statement: It has to be questioned if this deepest pressure alone is the best representative value.

— Systolic pressure peaks during walking exceeding the standing pressure are an important parameter characterising severe reflux and/ or obstruction. Both, maximal systolic pressure and minimal diastolic pressure are taken into account if the mean venous pressure during walking is given.[3] In analogy to the mean arterial pressure (MAP) as used in cardiovascular physiology mean venous pressure is defined by the formula: (systolic pressure + 2x diastolic pressure)/3 (Formula 1).[18]

4. Interpretation of AVP measurement: AVP is normal if less than one half of standing venous pressure (SVP) is reached during exercise.

— Revised statement: Instead of giving exact values of AVP it might be better to draw one of the following conclusions for the individual patient: normal, intermediate venous hypertension or severe venous hypertension (Table I);

Table I.—*Tentative interpretation of mean AVP values in percentages. AVP is expressed as a percentage of SVP to adjust for patient's height (these values for the proposed mean venous pressure have not yet been validated in clinical series).*

	AVP (%)
Normal	10-30
Intermediate venous hypertension	31-45
Severe venous hypertension	>45

— It has been shown that there is a correlation between the clinical severity and the range of ambulatory venous hypertension for the CEAP classes C3- C6 whereas patients with uncomplicated varicose veins usually present with no or mild ambulatory venous hypertension.[19] Interpretation of AVP measurement: If venous refill time (RT) is used, 90% of venous refill time (RT90) should be used.[19]

— Revised statement: Although the relation between RT90 and the clinical score of CEAP is significant, RT is dependent on several factors, i.e. temperature, arterial flow and vein diameter, and should therefore not be used as a primary outcome for AVP measurement,[17] even though no significant influence of ambient temperature within normal limits has been demonstrated.[20]

Technique of AVP measurement revised

The present report concentrates entirely on measuring venous pressure in a dorsal foot vein. One of the patients' feet is placed in a bucket filled with warm water. This is done for about 5 minutes to warm the foot and consequently cause vasodilatation of the foot veins. A (22 Gauge) syringe is inserted in a dorsal vein of the foot with the patient in sitting position with both legs depending. When the syringe is placed in the right position, it can be fixed like an infusion needle. Subsequently, a three-way tap (single (electronic pressure) transducer in combination with the connecting tube) is placed and the system is connected to a 0.9% saline infusion. Small amounts of heparin may be used to prevent clotting in the needle. The pressure transducer should be kept at the same height as the tip of the needle (zero calibration). The electronic pressure transducer is connected to the recorder, which is connected to a computer. After flushing possible air bubbles out of the system, the system should be calibrated for pressure increase with the patient in lying position, with the legs horizontal and the upper body at an angle of about 30° to the legs. In this position the puncture site is at the same height as the right atrium. When the three-way tap is switched, the pressure transducer is in direct communication with the superficial veins and the system can be calibrated for the zero level. The three-way tap is switched again to prevent blood to flow into the connection tube and the transducer. The patient is then asked to move the foot, by means of moving the toes towards the nose and back. This procedure is done to demonstrate that the system is in working order. After this measurement, the patient is helped in standing position on the treadmill (which has an 8° elevation) and standing venous pressure (SVP) can be recorded. The patient will walk at a pace of 2 km/h until the venous pressure has reached a plateau phase (=AVP). The treadmill is then stopped and the patient will stand still until SVP has been reached (=RT). Then again, the patient is disconnected from the recorder and is asked to lie down on the bed. After reconnecting the patient, zero calibration takes place and the patient is asked to move the foot a few times to check that the system is still in working order.

Interpretation of AVP measurement revised

In supine position venous pressure should be between 5 and 10 mmHg, which is mainly determined by the exact position of the needle in relation to the pressure in the right atrium. In upright position venous pressure in a foot vein is defined by the hydrostatic pressure. SVP is therefore dependent on the person's height. This value will be between 80 and 100 mmHg in an adult of average height.

Determination of AVP has always been a point of discussion, since the introduction of AVP measurement.[15] Usually the deepest point of the pressure curve (= plateau phase) was taken as the deciding parameter (Figure 1).[17] In order to respect also the systolic pressure peaks the group suggests to define AVP as (systolic pressure + 2 x

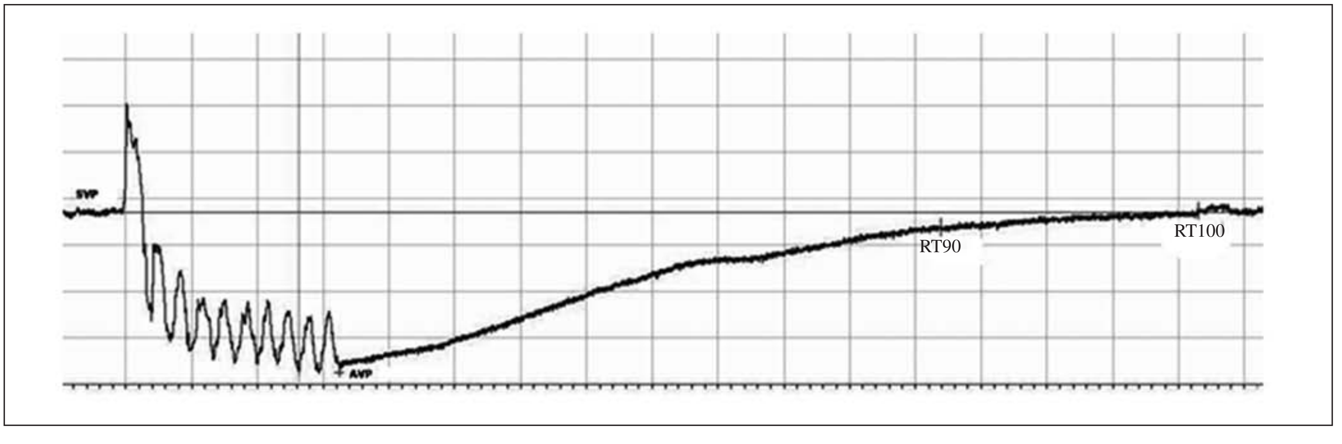

Figure 1.—AVP measurement and definitions (normal individual). X-axis: time (seconds) ; Y-axis: venous pressure (mmHg); SVP: standing venous pressure; AVP: ambulatory venous pressure, as used up till now (deepest point of pressure drop); RT90: venous refill time to 90% of SVP; RT: venous refill time to SVP.

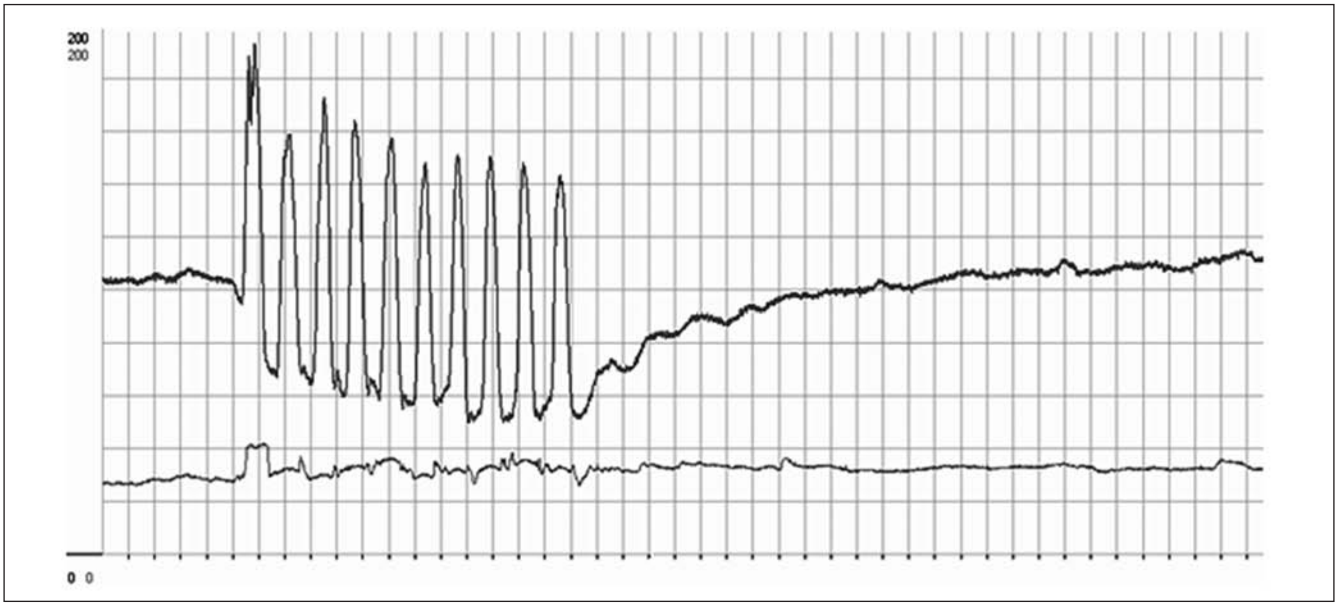

Figure 2.—AVP curve in a patient with a severe postthrombotic syndrome. AVP defined as (systolic pressure + 2 x diastolic pressure)/3=98.

TABLE II.—*Legends of Figures 1-3. Outcome differences between the various ways of interpretation.*

	Figure 1	Figure 2	Figure 3A	Figure 3B
SVP (mmHg)	80	106	100	100
Diastolic venous pressure (mmHg)	11	51	15	20
Systolic venous pressure (mmHg)	40	145	75	130
AVP (mmHg)*	21	82	35	57
Interpretation**	normal	severe	intermediate	severe

The diastolic venous pressure is a misleading parameter to characterize AVP. * AVP=(systolic blood pressure + 2 x diastolic blood pressure)/3; ** Interpretation according to Table I.

diastolic pressure)/3. In case a treadmill is used, the subject will walk with a speed of 1 Hz during a maximum period of 30 seconds.

We suggest not using RT or RT90 for routine practice. AVP remains the primary outcome. If RT90 is, for some reason, taken into account as secondary outcome it should be longer than 25 seconds to be normal.

The conclusion of AVP measurement may be: normal (no venous hypertension), intermediate venous hypertension or severe venous hypertension. Possible cut-off values are shown in Table I. It needs to be considered that the proposed way to define AVP will shift up the pressure values in comparison to taking the minimal diastolic values (Figures 1-3, Table II). Therefore, the values given in Table I need to be validated by future studies including clinical and Duplex outcome (CEAP).

It needs to be stressed that it is problematic to reduce the information contained in a pressure curve to one single numeric value (AVP). An interobserver variation study has shown the large systematic and random errors in estimating AVP from AVP measurement graphs, especially in extraordinary cases (Figure 3A, B).[15] Experienced investigators may also look for the speed of pressure fall and on a possible pressure increase after exercise, pointing to a proximal venous obstruction. In general reflux, obstruction or both can not be differentiated by measuring peripheral venous pressure. The same is also true for a differentiation between superficial or deep venous pathology.

A limitation of AVP measurement is that the patient should be capable of walking. In case a patient is not able to walk but is able to stand upright, it is possible to use an external footpump or tiptoe exercise. However, this alternative of measuring AVP has never been validated with regard to the treadmill.

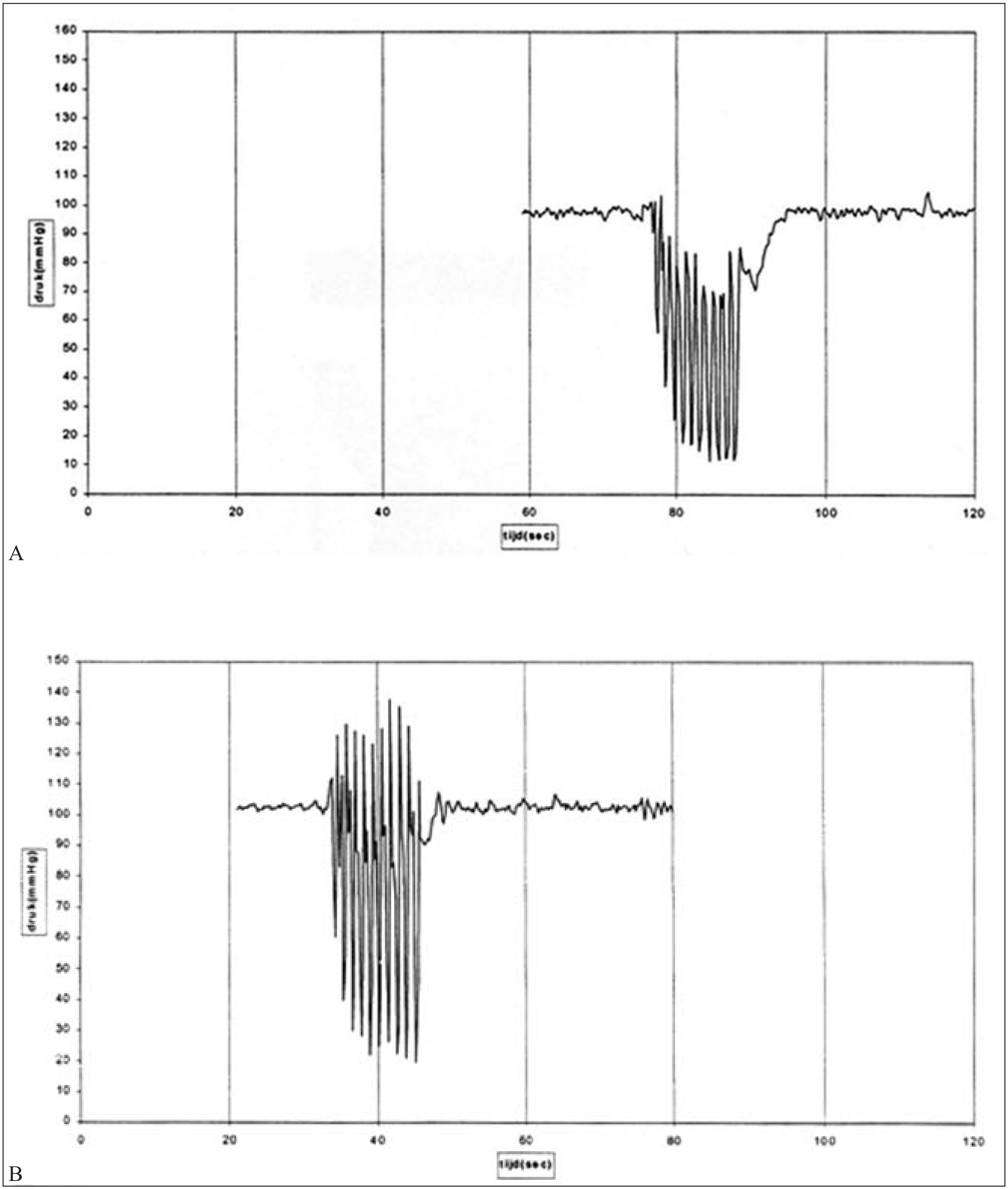

Figure 3.—A, B) These graphs from patients with severe CVD showed a high interobserver variability in a previous study.[15] The deepest pressure readings (diastolic pressures) are 15 mmHg (A) and 20 mmHg (B), simulating "normal venous function". By calculating the mean venous pressure also the high systolic pressure peaks (caused by venous reflux) are taken into consideration (values see Table II) putting both cases into the category of an intermediate (A) or severe (B) category of venous hypertension (Table I). Figures 3A and 3B are reproduced with permission from: Kolbach DN *et al.*[15]

Indications for AVP measurement

Although AVP measurement is the "gold standard" functional test in patients with CVD, in daily practice it has largely been replaced by DUS. However, AVP measurement is still very useful for the following indications:

— to support diagnosis. For example, a patient with clinical signs (and symptoms) of CVD without abnormalities on DUS;

— (congenital) venous anomalies, *i.e.*, vena cava anomaly, to objectify venous hypertension;

— to select and follow-up therapeutic interventions. For example, in case of venous (partial) venous obstruction, *i.e.*, venous anomaly or after a deep vein thrombosis, venous desobstruction (and stenting) may be indicated in patients with venous hypertension. The therapeutic effect after the intervention can also be monitored by AVP measurement. After the intervention AVP should be improved;

— to follow up of spontaneous course. For example, patients who have had a deep vein thrombosis. AVP measurement may be performed to assess the indication for medical elastic compression stockings, which is ambulatory venous hypertension;

— to assess the influence of interventions in the acute experiment (*e.g.*, body position, compression, temperature).[16-20]

Conclusions

AVP measurement is the "gold standard" for assessing the severity of hemodynamic abnormality of CVD in the lower extremity. Since AVP measurement has not been standardised so far, we revised AVP measurement and made some proposals how to evaluate venous pressure curves in the future.

AVP measurement will take place on a treadmill with standardised speed. Final readings are based on the mean venous pressure that is defined by the formula: (systolic pressure + 2x diastolic pressure)/3. After calculating the mean venous pressure, patients may be categorised into one out of three categories (normal (AVP 10-30 mmHg), intermediate venous hypertension (31-45 mmHg), severe venous hypertension (AVP >45 mmHg).

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Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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