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Tussen polspalpatie en aortografie. Diagnostische betekenis van enkele onbloedige meetmethoden bij ontoereikende bloedvoorziening van de benen

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SUMMARY, CONCLUSIONS, RECOMMENDATIONS

'BETWEEN PULSE-PALPATION AND AORTOGRAPHY'

The significance of some non-invasive measuring methods for the diagnosis of arterial insufficiency in the lower extremities.

General part

The aim of the present study is to draw attention to the significance of non-invasive instrumental examination for the diagnosis of arterial insufficiency in the legs. The significance of this examination is studied, particularly in relation with angiography. Finally, an attempt has been made at defining which method(s) and parameters yield the best information.

Chapter 1 contains the introduction and a general definition of the problem, while Chapter 2 presents a survey of the literature on the several techniques existing. In Chapter 3 the methods used in the present study are described (photo-electric plethysmography of the big toes, at rest and after arterial occlusion; mechanic oscillography of the calves and the thighs, at rest; measurement of the systolic ankle and thigh pressure, at rest and after calf- and thigh-exercise respectively; measurement of the calf flow, at rest and during hyperemia, with venous occlusion plethysmography and with plethysmography without venous occlusion).

Chapter 4 deals with the results of the measurements carried out on 117 patients who also underwent an aortographic examination. The group consisted of 73 patients with unilateral, and 44 patients with bilateral arterial obliterations (occlusion or severe stenosis). In all the cases the results of the non-invasive measurements were compared with those of the aortography. On the basis of the aortograms a classification of 5 categories was drawn up:

- Category O : no significant narrowing of the arterial lumen, 'good' legs;
- Category I : obliteration of the femoro-popliteal arteries;
- Category II : obliteration of the aorto-iliac arteries;
- Category III : combined obliteration (I+II at the same side);
- Category IV : obliteration of the crural arteries.

In contrast with aortography, the non-invasive methods can be applied in an out-patient clinic; they cause the patients little discomfort and are without risk. They can be repeated easily during follow-up studies. These methods differ from aortography in so far as their results yield information about the *functioning* of the arterial circulation, not about the *anatomy* of the arterial circulation.

It is obvious that the non-invasive examination should be carried out previously to the aortographic examination, provided that there are no (or hardly any) false-negatives found at the non-invasive examination. This condition can be fulfilled, particularly by the measurement of the systolic ankle pressure at rest. Therefore, this latter measurement forms the best method for defining whether there is arterial disease of clinical significance or not.

It is impossible to avoid false-positives altogether, due to the continuous scale from light atherosclerotic wall-lesions to obliterations. However, practically these false-positives are not unacceptable; for instance, in the case of the ankle pressure measurement or in the case of photo-electric plethysmography the false-positive legs appear to be in a worse arterial condition than the other legs without obliterations, in view of the clinical course, the angiogram and the results of other measurements. Actually, these false-positives might even have been false-negatives of the angiogram.

The aim of aortography is not: to define whether there are any obliterations, but to gain anatomical information so that the vascular surgeon can decide whether the obliterated vessels are fit for reconstruction and, if so, which technique should be chosen.

There is an *indication for aortography* if

- 1: obliteration from the infra-renal aorta to the popliteal artery is proved (or: not excluded) by the physical examination and by non-invasive instrumental measurements;
- 2: the severity of the complaints justifies a possible reconstructive operation;
- 3: the patient's general condition is such that, in relation with the severity of the complaints, the risks of an operation are acceptably low;
- 4: the patient has a positive attitude towards a possible reconstructive operation.

All these four conditions have to be fulfilled.

In a number of cases the indication for aortography can be based on the case-history and the physical examination, without a non-invasive instrumental examination being needed. Yet in these cases it would be advisable to start with this non-invasive instrumental examination for the following reasons:

- 1: from the clinically simple cases one may gain a lot of experience with regard to both the measurements and their interpretation;
- 2: if the aortogram leaves the examiner in doubt concerning e.g. the severity of a

- stenosis (particularly in the case of multilevel and of bilateral vascular disease) or concerning the condition of the crural arteries ('outflow-tract'), the measurement may yield important additional information;
- 3: if the clinical results of a reconstructive arterial operation are unsatisfactory (for the patient, for the surgeon or for both), an objective evaluation is desirable; re-angiography, as a rule, is not indicated. In this case the non-invasive measurement enables the examiner to evaluate the results of the operation, provided that a pre-operative report is available for comparison;
 - 4: when the results of the operation are clinically satisfactory, it is important to record the situation by means of measurements, in order to obtain an objective evaluation of the short and long term surgical results and to have an objective report in the case of a relapse or of recurring complaints.

For diagnosis and follow-up, non-invasive measurement is indispensable also in the case of patients who will not undergo an aortography because the indications 2, 3 or 4 for aortography are not fulfilled or because a primary 'blind' lumbar sympathectomy is being considered. Non-invasive measurement may contribute to the indication for sympathectomy, because the presence or absence of a sufficient inflow in the whole leg, i.e. the condition of the aorto-iliac arteries, affects the results of the sympathectomy.

Special part

Photo-electric plethysmography

Photo-electric plethysmography on the big toe is a technique which can be applied without difficulty and which meets the requirements of a screening method satisfactorily. The most important information is yielded by the shape of the pulse-wave:

concave catacrotic wave	: obliteration very unlikely;
straight catacrotic wave	: obliteration likely;
convex catacrotic wave	: obliteration practically certain;
no pulsations	: obliteration certain.

The quantitative parameters, however, should not be neglected, because by means of them the number of false-negatives is reduced substantially.

amplitude-ratio (right to left):

between 0.5 and 2.0	: no conclusion can be drawn;
<0.5, or >2.0	: obliteration likely.

propagation-time of the pulse-wave:

<0.35 s	: no conclusion can be drawn;
0.35 - 0.37 s	: obliteration likely;
>0.37 s	: obliteration practically certain.

crest-time of the pulse-wave:

<0.27 s	: no conclusion can be drawn;
0.27 - 0.29 s	: obliteration likely;
>0.29 s	: obliteration practically certain.

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sum propagation-time + crest-time:

<0.61 s	: no conclusion can be drawn;
≥0.61 s	: obliteration practically certain.

A practical disadvantage of photo-electric plethysmography is the necessity of warming-up the patient indirectly. Its great advantage, however, is that the pulsations of the most distant periphery are recorded and in this way information is gained both about the part of the arterial tree distal from the part which can be defined by means of the aortogram, and about the cutaneous circulation. This is important in cases of night- and rest-pain, trophic changes or defects due to atherosclerosis, diabetes mellitus and Buerger's disease. Recordings of the pulsations of the toes and of the skin of thigh and calf may elucidate the extent to which the circulation is insufficient and may help the examiner to fix the level of a possible amputation.

Photo-electric plethysmography carried out after arterial occlusion (above the knee) is a simple test for measuring the circulatory reserve capacity. The amount of time after which, subsequently to arterial occlusion during 2 minutes, pulsations reappear (i.e. the time of latency) indicates the absence or presence of hemodynamically important impediments of the bloodstream.

Time of latency: <12 s	: no conclusions can be drawn;
12-16 s	: obliteration likely;
>16 s	: obliteration practically certain.

If the profile of the hyperemic response is examined also, the large number of false-negatives — particularly in the aorto-iliac category — may be reduced substantially.

In contrast with the measuring of the systolic ankle blood pressure after exercise, with photo-electric plethysmography after arterial occlusion the examiner is relatively independent of the patient's cooperation; besides, the legs lie still, the muscles are relaxed and the detector remains in situ so that recording can take place without any interruption.

When pulsations are recorded after arterial occlusion, part of the false-negatives of the photo-electric plethysmography at rest are recognised.

Mechanic oscillography

Mechanic oscillography enables the examiner to get useful information about the condition of the arterial supply in the legs in a simple, rapid way. The oscillogram can be read without difficulty. It indicates the quality of the pulsations in both legs (particularly the differences between the two legs). Moreover, it often enables the examiner to localise the obliteration approximately. At first sight, therefore, oscillography seems to be an ideal method both for screening and for selecting

patients for aortography, and for setting up a functional classification as complementary information to angiography. However, no conclusions can be drawn from the absolute amplitude of the oscillogram — except beyond a certain limit — so that one can rely on left-right differences only. Consequently it is often impossible to make any interpretation when there are no evident left-right differences, when the oscillations are slight or when there is more or less symmetrical bilateral arterial disease.

No conclusions can be drawn from an absence of left-right differences unless the maximal amplitude on the calves is ≥ 5 mm (obliteration unlikely) or the maximal amplitude on the calves is ≤ 3 mm and/or on the upper leg ≤ 2 mm (obliteration likely). A side-difference with a ratio between the worse leg and the better leg $< 2/3$, on one of the two levels, points at an obliteration.

A ratio between the maximal amplitude on the calf and the maximal amplitude on the upper leg > 1 does not prove that there is an obliteration; the opposite is not true either.

A comparison of pre-and post-operative oscillograms is often of doubtful value, particularly in the case of bilateral aorto-iliac reconstructions and of reconstructions with clinically moderate results.

From a scientific point of view, it is more difficult to compare the oscillograms of various patients and to classify them than is the case with the results of other measuring methods.

As for the functional classification (particularly in the case of a femoro-popliteal occlusion combined with an angiographically 'moderate' iliac stenosis), it is often impossible to determine, on the basis of the oscillogram of the upper leg, whether there is a hemodynamically significant impediment of the blood stream proximal of the bifurcation of the a.femoralis.

A right-left ratio between the maximal amplitudes on the upper legs $\leq 2/3$ does not prove that there is an obliteration proximal of the bifurcation of a. femoralis on the worse side.

If the limitations of the oscillogram as mentioned above are accepted, mechanic oscillography at rest is a good method, which often yields sufficient information (particularly in the case of a unilateral obliteration). The present writer has no experience with post-exercise oscillography.

Measurement of blood pressure

With the Doppler ultrasound technique it is possible, as a rule, to detect useful signals of the posterior tibial artery and of the dorsalis pedis artery, even in those cases in which the photo-electric plethysmography did not reveal a pulsatile flow in the big toe. Sometimes a signal is detected on only one of the two foot arteries. In this case one may assume the other one to be obliterated. In the present study no signals could be traced in a small number of patients in whom there was an arterial insufficiency in an advanced state with rest-pain, night-pain, trophic changes,

defects or incipient gangrene. These data in themselves are important.

Measurements of the systolic ankle blood pressure at rest, carried out with the help of the Doppler-probe as a detector placed on the foot arteries, form a good method for screening and for selecting patients for aortography; for this purpose it is preferable to photo-electric plethysmography as there are hardly any false-negatives and the patients need not be warmed up.

As a rule the systolic ankle pressure at rest (cuff-width 12 cm) in normal subjects is above 100% of the systolic arm blood pressure, practically always above 90%.

In patients with atherosclerosis without significant narrowing of the arterial lumen, the ankle pressure is usually in the normal range.

If the ankle pressure is above 100%, obliteration of the great arteries is excluded.

If the ankle pressure is below 90%, it is highly probable that there is an obliteration.

It is disappointing that hardly any quantitative correlation is found between the ankle pressure at rest and the measured exercise tolerance (claudication distance) so that the severity of the complaints cannot be objectivated. However, complaints of rest- and night-pain are objectivated by the finding of an ankle pressure below 50%; nevertheless, a higher ankle pressure does not exclude rest- or night-pain, particularly in the case of diabetes mellitus and Buerger's disease.

The practical significance of measurements of the ankle blood pressure after calf exercise is of limited value, because their correlation with the exercise tolerance is comparable with the correlation of the ankle blood pressure at rest with the exercise tolerance. When measurement at rest yields marginal results, the measurements after exercise do not contribute much to a better distinction between 'good' and 'bad' legs.

Systolic blood pressure at the distal thigh is a very interesting additional information.

Measurement of the systolic thigh pressure at rest (cuff-width 15 cm) yields important information about the level(s) of obliteration.

In normal subjects values of 100–130% of the systolic arm blood pressure are reported in the literature.

In subjects with atherosclerosis without significant narrowing of the arterial lumen, the systolic thigh pressure is nearly always above 90%.

If the systolic thigh pressure is above 100%, there is no hemodynamically significant impediment of the blood stream proximal of the bifurcation of the a. femoralis.

When there is an obliteration proximal of the bifurcation of the a. femoralis, the thigh pressure is usually below 90%.

The expectation, that the systolic thigh pressure would enable the examiner to differentiate in all cases between the absence and the presence of hemodynamically significant impediments of the blood stream proximal of the bifurcation of the a. femoralis, did not come true. An approach to this problem appeared to be possible with measurement of the thigh pressure after thigh exercise; still, for practical use it is of limited value.

Measurement of the flow

A simple and attractive method for measuring the calf flow is venous occlusion plethysmography with mercury-in-rubber strain gauges. From a technical and methodical point of view, however, this method requires more skill than the other techniques. If failures and false results are to be avoided, the person who carries out this measurement must be well-trained in applying the method and he needs proper technical assistance. This is the reason why venous occlusion plethysmography is a method which can only be applied in specialised units.

The calf flow at rest does not have any significance for the diagnosis of arterial obliteration. The maximal calf flow after arterial occlusion and the profile of the hyperemic response give useful information about the functional capacity of the arterial system. However, in normal individuals the range of the maximal flow is wide and no sharp distinction can be made between pathological and normal conditions.

A maximal calf flow > 20 ml/100 ml.min indicates patent arteries, < 10 ml/100 ml.min indicates obliteration. Between 10 and 20 ml/100 ml.min there is usually no obliteration if the maximal flow is reached within 20 s; a longer peak flow time or a ratio to the maximal flow of the other calf < 0.75 indicates obliteration.

The measurement is most useful for the purposes of follow-up – after an arterial reconstruction, after a lumbar sympathectomy or in cases where no therapy is applied – and for judging the effect of training or drugs. Besides, venous occlusion plethysmography contributes to a more fundamental knowledge about the circulation of the legs.

Like the ankle pressure at rest or after exercise, the maximal calf flow is no index for the severity of claudication. The claudication distance cannot be surmised on the basis of the maximal flow supplied to the calf by the arterial system.

A new and reliable method, introduced in this thesis, is the measurement of the calf flow without venous occlusion ('lifting- laying down' plethysmography) after arterial occlusion or after calf exercise. This method increases our insight into several aspects of venous occlusion plethysmography. It is also an alternative examination, in cases of low arterial pressure at the level of the thigh or in the case of patients who have undergone an operation of the femoropopliteal arteries recently.

This method showed that in a number of the patients with low thigh pressure the low values found by venous occlusion plethysmography were false.

The question arises whether a population screening for peripheral atherosclerosis could be recommended or whether an examination of the arterial circulation of the legs should be included in the existing screening programmes.

This screening would be useful

1. if it is possible to recognise individuals with a propensity for developing obliterations of the arterial system of the legs and/or other less accessible organs (provided that atherosclerosis of the leg arteries is an index for atherosclerosis of arteries of other organs), and
2. if it is feasible to postpone or prevent the complications of atherosclerosis in these individuals, by means of a regimen or by surgical or drug therapy applied at an early stage.

It is beyond the scope of the present study to judge of the latter aspect. As for the first aspect, with none of the methods described can a sharp distinction be made between legs with 'normal' arteries and legs with a slight to severe atherosclerosis without obliteration.

Beside a number of individuals with an asymptomatic obliteration, one might find subjects with 'marginal' values on one or both legs and subject them to a closer investigation. Still a much larger group of subjects with a serious atherosclerosis, who run a great risk to get problems due to this disease might not be discovered. This is illustrated by the finding that in 73 patients of the present group who had an obliteration in one leg, the 'good' leg usually showed normal values during measurement.

It is clear that at present a population screening for peripheral atherosclerosis would only be useful in the context of a research programme. This programme would be, one should realise, a time-consuming and labourious enterprise, in view of the methods to be used, i.e. photo-electric plethysmography - after warming up - at rest and after arterial occlusion, and ankle blood pressure measurements at rest and after exercise, and in view of the requirements for a proper investigation: a close examination and long-term follow-up of both the selected individuals and a control group.