The aims of special investigations into the peripheral vascular system are to assist in the establishment of the nature and degree of any disorder of the circulation, to determine the treatment indicated in a particular case, and especially to evaluate the progress of disease on the effects of therapy in any one patient.

Many of the tests give results of little value unless they are applied when the circulation in the part to be tested is at its maximum. In a cool room, for example, with a normal limb at rest, the metabolic demands are small and the difference between the blood flow in a normal limb and one which is severely ischaemic is not significant. It is therefore important that there should be the maximum blood flow through a part at the time of the test. This can be achieved in muscle quite simply as the circulation through the muscle is controlled almost completely by the action of local metabolites, and therefore exercise with an occluding tourniquet placed proximally will produce the maximum flow on release of the tourniquet. As regards the blood flow in the skin and subcutaneous tissues the problem is not so simple. Various methods of achieving vasodilatation and therefore maximum flow have been used such as reflex heating, induction of fever by vaccines, paravertebral block, spinal anaesthesia, peripheral nerve block and chemical paralysis of junctional tissues by Priscol and the hexamethonium compounds. Reflex heating is simple and has been used largely by us, but it sometimes requires to be prolonged even up to an hour or more and to such an extent as to be unpleasant and even exhausting to an elderly person to secure maximal vasodilatation and, in fact, it may not achieve this at all. Failure to secure vasodilatation is more common when the lower rather than the upper limbs are being tested. Also in our experience a greater degree of vasodilatation is always achieved by peripheral nerve block which, of course, results in a temporary sympathectomy of the part, and this is in keeping with the fact that blood flow following operative sympathectomy is always greater than that induced by reflex heating. Furthermore, if the room temperature is too low, e.g. 17°C., full vasodilatation may not be obtained, whereas in a relatively warm room, e.g. 23°C., the vessels of the same limb on this occasion may dilate readily (Fig. 1). With these reservations in mind reflex heating is, we believe, the most generally useful method of estimating the results of sympathetic

**Fig. 1.—** The results obtained from reflex heating depend to a large extent on the room temperature.
release. If, however, complete vasodilatation is required, a peripheral nerve block as of the ulnar nerve or, preferably, the ulnar and the median nerves at the elbow or the posterior tibial nerve at the ankle should be done and the effect so achieved will be similar to that following sympathectomy. Spinal anaesthesia, paravertebral block, vaccines and drugs have not been used by us owing to associated alterations of blood pressure, difficulty or uncertainty of technique and discomforts or even risks of the method.

The methods of estimating the circulation which we have used extensively are: (1) Skin temperature tests; (2) plethysmography; (3) oscillometry; (4) circulation time by injection of fluorescin; (5) arteriography. Skin temperature tests are simple and useful, but particularly at the extremes of temperature they are inaccurate. For example, Lewis pointed out that a difference of temperature between 33° C. and 33.5° C. may indicate an increase of blood flow of 100 per cent. in the hand. Also a limb which is obviously nearly gangrenous may on occasions have a high skin temperature in an area adjacent to the dead tissue, especially if there is superficial inflammation in the skin and subcutaneous tissues. However, the temperatures of each digit of a normal hand during reflex vaso-

---

**Fig. 2.**—The upper part shows a normal response to reflex heating in the right leg, and in the left leg a response indicative of arterial obstruction. The lower curves show the plethysmographic readings of the same limbs.

---

**Fig. 3.**—The curve of the left calf is normal. The curve of the right calf diminished and delayed in reaching its maximum, and returning to normal.

---

**Fig. 5.**—The skin temperature shows a difference of .75° C. only, whereas the plethysmograph shows a marked difference of 4 c.c. per 100 c.c. tissue per minute.
digits of either leg or arm following reflex heating are highly significant indicating obstruction of the vessels of one limb (Fig. 2). The apparatus we have used and which we have found completely satisfactory is the copper-constantan multiple lead thermocouple supplied by the Cambridge Instrument Company. It is important to note here that the patient should be comfortably lying at rest in the room where the tests are to be undertaken for at least half an hour before measurements are begun.

Plethysmography with the technique and apparatus described by Barcroft and Edholm (1943) can be applied to the calf or forearm measuring predominantly the muscle flow or to the hand or foot measuring predominantly the skin flow. The apparatus is complicated and difficult to use but it does give the results precisely in cubic centimetres per 100 cc. of tissue per minute. With reference to muscle flow it is found in the normal limb that following exercise with a tourniquet in situ this increases from 1 or 2 cc. per 100 cc. of tissue per minute up to 15 cc. or more immediately on release of the tourniquet and within two minutes or so is back to normal, whereas in the presence of arterial obstruction the rise is much less in extent, is delayed in reaching the maximum and is much later in returning to normal. This is well shown in Fig. 3. Plethysmography is probably the most valuable method of estimating improvement or otherwise following some specific treatment, for example Fig. 4 shows the return of the curve to near normal following the grafting of a femoro-popliteal artery. Clinically the patient also lost his intermittent claudication.

With regard to skin flow Fig. 5 is interesting in that it shows after reflex heating an increase of flow in the left foot from 2 to 6 cc and in the right foot from 2 to 3 cc per 100 cc of tissue per minute, whereas the skin temperatures rise from 25°C. to 32.25°C. and 31.5°C. respectively—a not very great difference in temperature between the two sides and not sufficiently significant considering the actual difference in flow. As a routine in clinical practice, however, we do not recommend plethysmography owing to its difficult and complicated technique, although on occasions it is useful, for example in an oedematous limb where oscillometry and skin temperatures are inaccurate and also when records of improvement following treatment are required.

Oscillometry using a Pachon oscillometer will often indicate the level of arterial obstruction in a limb. It will not record the difference between an organic arterial obstruction and an obstruction of the vasomotor type. It gives no indication of the efficiency of the collateral circulation, as the small collaterals resulting from a major arterial block absorb the vast majority of pulsation recordable by this method and a limb with a perfectly healthy skin distally may often show minimal readings by the Pachon oscillometer. Swelling of a limb similarly masks recordable pulsations, and oscillometry is of little value in such cases, often when an estimate of the arterial side of the circulation is mostly required. However digital oscillometry may be a useful and important investigation, recording as it does pulsation in the terminal part of the limb. It will record increase of pulsation resulting from reflex heating, and the shape of the
curve is indicative of the state of the arterial wall. Fig. 6 is a tracing from the distal phalanx of a male, aged 81, before and after reflex heating, at no time showing a dicrotic notch indicating rigid but unobstructed arteries, and Fig. 7 is a tracing from a healthy female of 19 with elastic vessels shown by a prominent dicrotic notch. Let us consider a hand in a woman of 40 with a recent onset of a Raynaud phenomenon in the middle two fingers. If, following reflex heating or peripheral nerve block, the oscillometric records of all the fingers give a similar amplitude, the obstruction is vasmotor in origin, but if the amplitude in the affected fingers is considerably less than that in the unaffected fingers, there is organic obstruction present. If it was shown that the amplitude of the oscillations bears a direct relationship to the flow of blood through the part, it would be a very simple, useful and valuable instrument. We are investigating this particular point at the present time and, in fact, there is some evidence that this is so.

A simple digital oscillometer can be constructed by a perspex tube into which the terminal phalanx snugly fits without constriction, the junction between the finger and tube being completed and rendered airtight by means of Seelastik. The other end of the tube is sealed to the diaphragm of an ear piece of an ordinary earphone. The pulsation of the finger thus moves the diaphragm of the earphone inducing in the coil a current which is passed through a galvanometer, the deflexions from which are recorded on a sensitive plate. Very simply the leads from the earphones can be connected to and recorded on a clinical electrocardiograph (Fig. 8). Suitable perspex tubes are available to fit different digits, and can be readily attached to the earphone. Other methods based on the same principle are, of course, available for recording oscillations, and with some of these and the incorporation of a transducer valve it is hoped soon to have an accurate digital plethysmograph, an instrument which so far has been very difficult to achieve.

The circulation time has been estimated by the fluorescin test in a large number of cases at Hammersmith Hospital. In this test 4 cc. of a 20 per cent. aqueous solution of sodium fluorescin is rapidly injected into the veins of the right elbow. After the needle is in situ and before the injection is made, the room is darkened and the part under observation is observed under ultra violet light. A delay in the appearance of the fluorescin in the right foot as opposed to the left foot would indicate arterial obstruction in the former. In order to establish the end point more accurately MacGregor and Wayne (1951) and Goodwin and Kaplon (1951) suggested raising introdermal wheals with 1:1000 histamine on the dorsa of both feet. Wheals are also raised in the left antecubital fossa and the

Fig. 6.—Oscillometric recordings from the distal phalanx of a male aged 81.

Fig. 7.—Oscillometric record from the distal phalanx of a healthy female of 19. There is a marked dicrotic notch.

Fig. 8.—A simple digital oscillograph.
circulation rate in the legs is determined by subtracting the arm-to-arm time from the arm-to-foot time. Goodwin and Kaplon demonstrated increased circulation rate in lower limbs following the use of Priscol. The results though interesting have not been particularly helpful in the diagnosis and treatment of peripheral vascular disorders and give little information which is not obtainable clinically.

With increasing experience it becomes more and more apparent that a careful clinical examination with attention to the cardiovascular system as a whole will to a large extent eliminate the use of many of the tests which have been evolved for the estimation of peripheral blood flow. On the other hand graphic records which record improvement or deterioration in the state of the circulation are of great value, and a useful addition to clinical impression, and for this purpose it seems to us that the most useful methods that we have are muscle and digital plethysmography. The perfection of an accurate and simple digital plethysmograph would be a most useful addition to our armamentarium, and if it is found that digital oscillations bear a direct relationship to digital flow, the problem of useful investigation may be rendered much more simple. With the increase in our knowledge and experience in the treatment of major vascular obstruction by direct surgical attack on diseased vessels such as artery grafting or possibly in some cases disobliterating procedures, precise evaluation and records are important, and the most important of all procedures for this purpose is arteriography. The value, scope and technique of this will be discussed elsewhere in this journal, and this measure, coupled with plethysmography and possibly oscillometry with full sympathetic release, gives an accurate evaluation of the circulation, a precise diagnosis, an indication for any particular treatment and, what is so often demanded, reasonably accurate prognosis.

BIBLIOGRAPHY

OXFORD MEDICAL PUBLICATIONS

OPERATIVE SURGERY
by VARIOUS AUTHORS
Edited by the late ALEXANDER MILES
Sometime Consulting Surgeon to the Edinburgh Royal Infirmary
and SIR JAMES LEARMONTH, K.C.V.O., C.B.E., Ch.M., F.R.C.S.
Regius Professor of Clinical Surgery and Professor of Surgery in the University of Edinburgh
Third edition 572 pages 235 illustrations 30s. net

MANAGEMENT OF PERIPHERAL ARTERIAL DISEASES
by SAUL S. SAMUELS, A.M., M.D.
Chief of the Clinic for Peripheral Arterial Disease, Bellevue Hospital, New York
364 pages 112 illustrations 63s. net

OXFORD UNIVERSITY PRESS
The Investigation of Peripheral Vascular Disorders

Peter Martin

*Postgrad Med J* 1953 29: 436-440
doi: 10.1136/pgmj.29.335.436

Updated information and services can be found at:
http://pmj.bmj.com/content/29/335/436.citation

These include:

**Email alerting service**
Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

Notes

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/