# THE MEASUREMENT OF THE BLOOD FLOW THROUGH SKELETAL MUSCLE FROM THE LOCAL CLEARANCE OF $^{133}$XENON

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# INTRODUCTION

Nunquam quisquam ita bene subducta ratione ad vitam fuit,
Quin res, aetas usus aliquid appartet novi,
Aliquid admoneat, ut illa quae te scire credas, nescias,
Et quae tibi putaris prima in experiundo repudies.

(No life so perfect ever but that circumstance,
Increase of years, experience, can changes bring :
Your so-thought knowledge be but ignorance; those things
That you believed the finest fail to pass the test).

So William Harvey quoted in the first chapter of his book Exercitatio Anatomica de Motu Cordis which was published in 1628. In this work, Harvey postulated that the blood in the body travelled in a circular motion and in his own words stated

"I am obliged to conclude that in animals the blood is driven round in a circuit with an increasing, circular sort of movement, that this is an activity of function of the heart which it carries out by virtue of its pulsation, and that in sum it constitutes the sole reason for that heart's pulsatile movement."

This demonstration by Harvey that the blood in the body "circulated" opened a new field of investigation. A great deal of energy and thought has gone into the study of the circulation since that time and, in particular, the circulation to the various organs and vascular beds. Over the years, the concept that each organ and region of the body has its own particular blood supply with its own particular controls has now gained universal acceptance. The peripheral circulation is a term used to denote the blood flow occurring through skin, subcutaneous tissue and skeletal muscle and in many cases the term has been used as being synonymous with limb blood flow.

The measurement of circulation in a limb has provided many difficulties, especially with regard to the quantitative assessment of blood flow through the different compartments of the limb. The first real step forward was made by Brodie and Russell (1905) who suggested that a quantitative measure of blood flow through a limb could be made by immersing the limb in a water-filled, airtight container and occluding the venous return of the limb for a short period. The arterial blood would continue to enter the limb and produce an increase in pressure in the container and this could be recorded. The rate of rise of the recorder would be proportional to the amount of blood entering the limb; by calibrating the container with a known volume and knowing the area under study, a quantitative assessment of limb blood flow could be made. This apparatus is termed a plethysmograph and, until recent times, plethysmography has been the method most commonly used for the measurement of the peripheral circulation.

Hewlit and Zwaluwenburg (1909) were among the first to apply this principle to the study of the human limb and many clinical studies have been made by Abramson (1944) and by Barcroft and Swan (1953). Their work established the venous occlusion plethysmograph as a reliable method of measuring limb blood flow. One of the main limitations of the technique, however, is that it is a measure of the blood flow through an entire segment of a limb and therefore differentiation of blood flow occurring through the different compartments of the limb is impossible. To take a simple example, a manoeouvre which caused an increase in limb blood flow might imply an increase in skin blood flow, an increase in muscle blood flow or an increase in both. A comprehensive review of the use of this method and its limitations has been made by Landsdowne and Katz (1942). However, despite its limitations, it has remained the principal method of investigation of peripheral circulation until recent times. The technique requires cumbersome apparatus and in order to obtain accurate results, it requires careful control of environmental temperature; in practice, reliable results have been obtained only by individuals with a special interest in the method and who have devoted a great deal of their time to its study. The method therefore has not been widely used for clinical investigation.

These shortcomings led Whitney (1949) to introduce the strain gauge plethysmograph. This is a much simpler apparatus which consists of a mercury-filled rubber tube which is incorporated in an electrical circuit; variation in the diameter of the mercury column alters the resistance in the circuit, thus giving an electrical signal which may be amplified and recorded. When the venous return of a limb is occluded, as described for the water-filled plethysmograph, the diameter of the mercury column will be lessened when the tubing is stretched by the arterial blood entering the limb, and a measurement of limb blood flow may be made. However, as mentioned previously, this method is limited in that it cannot give reliable information as to blood flow occurring through the different compartments of the leg.

Kety (1949) described a method for the measurement of blood flow through skeletal muscle in man. His method was based on the hypothesis that a freely diffusible substance injected into a tissue will be carried away from the site of injection at a rate which is proportional to the effectiveness of the local circulation. In a tissue in which diffusion occurs rapidly, the rate of clearance of the substance will correlate closely with the local blood flow. He used $^{24}Na$ as the tracer and found a "mono-exponential" clearance following its injection into the gastrocnemius muscle. He calculated a clearance constant from a semi-logarithmic plot of the clearance curve, and concluded that this gave a quantitative assessment of the ability of the local circulation to remove or supply a freely diffusible substance. Various groups of workers have used this technique and the results found by these groups agreed closely (Cooper et al., 1949; Reese et al., 1951; McGirr, 1952; Walder, 1953).

Kety's basic assumption was that the "indicator" must be freely diffusible, and diffusion equilibrium maintained at all rates of blood flow. $^{24}$Na is defective, however, in that, although it is freely diffusible, it is physiologically active and its movement in tissue may be influenced by electrical potential gradients and by chemical combination. Thus, although the technique gave reliable information during the resting state, it was thought that the participation of the Na ion in the "sodium pump" phenomenon may interfere with its clearance. This would come into play especially at high rates of blood flow occurring during exercise, and the clearance would no longer accurately reflect the local blood flow. Thus, although the technique could reflect changes of flow such as produced by exercise, it would be a qualitative assessment only.

Despite these shortcomings, this technique was a major advance in the measurement of local tissue flow but it appeared that the indicator was not entirely satisfactory. This led Lassen (1964) to use the radioactive inert gas $^{133}$xenon as the indicator instead of $^{24}$Na. He chose this gas because it is physiologically inactive and on theoretical grounds its rate of clearance would have a more direct relationship to the tissue perfusion, thus allowing a quantitative measurement of local blood flow to be made.

At the same time as Lassen introduced this modification, work had begun in Glasgow using $^{133}$xenon for the measurement of muscle blood flow and the preliminary results were published in 1965 (Bell and Short). As mentioned previously, venous occlusion plethysmography has never been widely used for clinical investigative work and therefore relatively few studies on muscle blood flow have been carried out in patients undergoing surgical treatment for peripheral vascular disease. The $^{133}$xenon clearance technique appeared to be admirably suited for this purpose. The present thesis is concerned with -

1. An evaluation of the clinical usefulness of the $^{133}$xenon clearance technique as a measure of muscle blood flow.
2. The measurement of muscle blood flow in normal subjects.
3. The measurement of muscle blood flow in patients suffering from peripheral arterial disease.
4. An assessment of the effect of direct arterial surgery on muscle blood flow.
5. An assessment of the effect of sympathectomy on muscle blood flow.

# C H A P T E R I

## THE MEASUREMENT OF THE BLOOD FLOW THROUGH SKELETAL MUSCLE FROM THE LOCAL CLEARANCE OF $^{133}$XENON

1. The Advantages of $^{133}$Xenon as an Indicator

The use of $^{133}$xenon has certain advantages over $^{24}$Na as the indicator to measure local tissue perfusion :

(1) It is an inert substance which is chemically and physiologically inactive. Thus, its movement into tissue and removal from tissue will depend solely on diffusion gradients, solubility and blood flow.

(2) $^{133}$xenon has a much greater affinity for air than for tissue; $^{133}$xenon, removed from the site of injection by the venous blood, will, on reaching the alveolar capillaries, diffuse rapidly into the alveoli and be excreted by the lungs. It has been calculated that more than 90 per cent of $^{133}$xenon is removed from the circulation in one passage through the lungs (Harper et al., 1964). Also, the amount of $^{133}$xenon leaving the tissue at any time will be relatively small, depending on the local blood flow; this small quantity of $^{133}$xenon will be diluted many times in the general circulation by the time it has reached the alveolar capillaries.

Thus, there will be no effective recirculation of the isotope to distort the clearance curve.

(3) The half life of $^{133}$xenon is 5.2 days and it emits low energy gamma rays of 81 KeV. The radiation hazard to the patient will therefore be small. With 2 doses of 50 microcuries, the gonadal radiation exposure is 0.03 millirads (Lassen, 1964). This allows repeat estimations to be made with safety.

(4) Because of its high affinity for air, $^{133}$xenon will diffuse rapidly into the atmosphere and there will be little contamination of apparatus, and only routine precautions will be required on the part of the handler.

Derivation of Expressions for Muscle Blood Flow

The basic assumption made when deriving an expression for tissue blood flow from the clearance of an inert gas is that the tension of the gas in tissue is the same as that in venous blood. The tensions of the gas in tissue and in blood are related to their concentrations by the partition coefficient $\lambda$ , where

$$\lambda = \frac{C_m}{C_{vb}} \qquad 1.$$

and where $C_m$ is the amount of $^{133}$xenon (μCi) in 1 gm. muscle and $C_{vb}$ is the amount of $^{133}$xenon (μCi) in 1 ml. venous blood.

For $^{133}$xenon, the partition coefficient, $\lambda$, between muscle and blood has been shown to be 0.70 at a haematocrit of 40 (Conn, 1961).

If the flow of blood through muscle is F ml./gm./min., then the increase $dC_m$ in the amount of $^{133}$xenon in 1 gm. muscle in time dt is (according to the Fick Principle) the difference between the amount of $^{133}$xenon entering muscle ($F \times dt \times C_{ab}$) and the amount leaving muscle ($F \times dt \times C_{vb}$) where $C_{ab}$ is the amount of $^{133}$xenon (μCi) in 1 ml. arterial blood, and $C_{vb}$ is the amount of $^{133}$xenon (μCi) in 1 ml. venous blood.

That is $$dC_m = F(C_{ab} - C_{vb})dt$$

or

$$\frac{dC_m}{dt} = F(C_{ab} - C_{vb}) \qquad 2.$$

Normally, muscle blood flow (M.B.F.) is expressed in ml./100 gm./min. and is therefore related to F by

$$F = \frac{M.B.F.}{100} \qquad 3.$$

As the recirculation of $^{133}$xenon is negligible, one can assume that $C_{ab}$ is zero. Then, from equations 2 and 3 -

$$\frac{dC_m}{dt} = -\frac{M.B.F.}{100} \times C_{vb} \qquad 4.$$

but, from equation 1, $C_{vb} = \frac{C_m}{\lambda}$

$$\therefore \frac{dC_m}{dt} = -\frac{M.B.F.}{100} \times \frac{C_m}{\lambda} \qquad 5.$$

$$\text{i.e. } \frac{dC_m}{dt} = -\frac{M.B.F.}{100\lambda} \times C_m \qquad 6.$$

The solution of this standard differential equation is

$$C_m = C_{mo} e^{-\frac{M.B.F.}{100\lambda} t} \qquad 7.$$

where $C_{mo}$ is the amount of $^{133}$xenon in muscle at t = 0.

In practice, it is not necessary to determine the amount of the isotope $(\frac{\mu Ci}{g})$ in muscle at any time. This is related to the counting rate R (counts/sec.) in a collimated detector viewing the muscle by

$$C_m = K \times R \qquad 8.$$

where K is a constant depending on the counting geometry and the nature of the detector.

Differentiating equation 8 with respect to time, gives

$$\frac{dC_m}{dt} = K\frac{dR}{dt} \qquad 9.$$

Substituting in equation 6, gives

$$K\frac{dR}{dt} = -\frac{M.B.F.}{\lambda 100} \times KR$$

$$\therefore \quad \frac{dR}{dt} = -\frac{M.B.F.}{\lambda 100} \times R \qquad 10.$$

Equation 10 is of the same standard form as equation 6 and has solution

$$R = R_o e^{-\frac{M.B.F.}{100\lambda} t} \qquad 11.$$

where $R_o$ is the counting rate at time t = 0 and R is the counting rate at time t.

There are two common methods of calculating M.B.F. from the clearance curve when it is either plotted on semi-logarithmic paper or printed from the output of a logarithmic ratemeter.

The first method uses $T\frac{1}{2}$ which is the halving time of the exponential in minutes or, more simply, the time of the counting rate to be reduced by a factor 2.

In this case, equation 11 becomes

$$\tfrac{1}{2} R_o = R_o e^{-\frac{M.B.F.}{100} \cdot T\frac{1}{2}} \qquad 12.$$

Taking logarithms to the base e of both sides gives

$$\log_e \tfrac{1}{2} = - \frac{M.B.F.}{\lambda 100} \cdot T\tfrac{1}{2} \qquad 13.$$

$$\text{i.e.} \quad \log_e 2 = \frac{M.B.F.}{\lambda 100} \cdot T\tfrac{1}{2}$$

$$\text{Since} \quad \log_e 2 = 0.693,$$

$$M.B.F. = \frac{69.3 \lambda}{T\frac{1}{2}} \text{ ml/100 gm/min.} \qquad 14.$$

The second method is based on the decrease D, in the logarithm to the base 10 of the count rate in one minute.

Taking logarithms to the base 10 of both sides of equation 11 gives

$$\log_{10} R\,(t) = \log_{10} R_o - 0.4343 \frac{M.B.F.}{\lambda 100} \cdot t \qquad 15.$$

where R (t) is the count rate at t minutes and the factor 0.4343 which is $\log_{10} e$ arises from the conversion of the logarithms from the base e to the base 10.

The count rate one minute later R (t + 1) is given by

$$\log_{10}R(t+1) = \log_{10}R_o - 0.4343\,\frac{M.B.F.}{100\,\lambda}\,(t+1) \qquad 16.$$

Subtracting 15 from 16 gives

$$\log_{10}R(t) - \log_{10}R(t+1) = 0.4343\,\frac{M.B.F.}{100\,\lambda} \qquad 17.$$

If the left hand side of equation 17 is termed D, then

$$D = \frac{0.4343\ M.B.F.}{100\,\lambda} \qquad 18.$$

$$\text{i.e. } M.B.F. = \frac{100\,\lambda\,D}{0.4343} \qquad 19.$$

$$\text{i.e. } M.B.F. = 161\,D\ (\text{where } \lambda = 0.70) \qquad 20.$$

D can be obtained from a linear plot of the logarithm of the count rate against time. It is simply the decreases in the logarithm of the count rate in one minute and can, of course, be determined over a period lasting many minutes for greater accuracy.

## 2. The Method of Measuring Muscle Blood Flow

The procedure used for the estimation of muscle blood flow in all cases discussed in this thesis was the same. When resting blood flow was measured the subject was allowed to rest for a minimum period of half-an-hour in a quiet room, the temperature of which was approximately 70°F. The leg under study was placed in a cradle which brought the calf to heart level and minimized movement.

$^{133}$xenon was obtained from the Radio-Isotope Centre at Amersham and came in vials which contained 10 millicuries dissolved in 10 ml. of 0.9 per cent saline. 0.1 - 0.2 ml. of the solution containing 30-60 microcuries of $^{133}$ xenon was injected directly into the anterior tibial group of muscles. Firm pressure was applied over the injection site for approximately 2 minutes to minimize leakage along the needle track. The radioactivity was detected by a 1½ inch sodium-iodide scintillation crystal connected to a ratemeter and direct writing pen recorder. A diagramatic representation of this arrangement is shown in Fig.1.

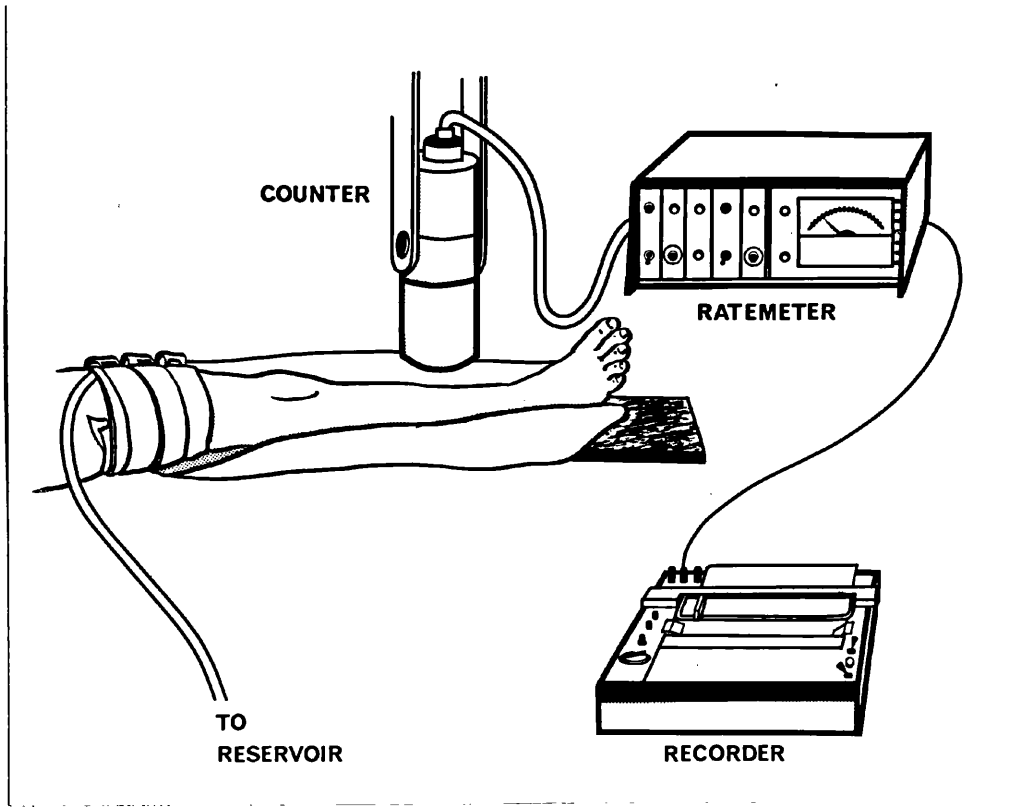


Fig. 1 : A schematic representation of the apparatus used to measure muscle blood flow.

After injection of the $^{133}$xenon, the clearance of the isotope was followed for 5-10 minutes as a measure of resting blood flow. A cuff, previously placed in position round the subject's thigh, was then inflated rapidly to 250 mm. Hg. from a reservoir containing air at 250 mm. Hg. By using this method, congestion of the limb was avoided. The subject was then asked to dorsiflex his ankle at 30 movements per minute until forced to stop on account of pain.

Each subject carried out at least 60 contractions and the minimum occlusion period was 2 minutes. The cuff was then released and a clearance curve obtained. The logarithmic plot of the clearance curve was transferred to graph paper and the "D" factor calculated. Each clearance curve was analysed for the following data :

1. The level of peak blood flow (P.B.F.)
2. The time taken from release of the cuff to atain P.B.F.
3. The duration of P.B.F.

By drawing a tangent to the clearance curve at any particular moment in time, D for that time may be calculated. In some cases D was calculated at minute intervals after release of the cuff.

3. Normal Results

A total of 110 limbs in 58 normal male subjects has been studied. This group consisted of student volunteers and patients admitted to hospital for minor surgical procedures. In none of these cases was there clinical evidence of peripheral arterial disease and all distal pulses were present. The ages of this group ranged from 20 years to 70 years with a mean of 43 years. A tracing after ischaemic exercise in a healthy young adult is shown in Fig. 2 and a logarithmic plot of this clearance curve is shown in Fig. 3.

In one subject an experiment was carried out to determine whether there was any diffusion laterally from the injection site, outwith the view of the collimator, which may influence the clearance curve. During the measurement of muscle blood flow after ischaemic exercise, the occluding cuff was re-applied for 3 minutes and then released. The result is shown in Fig. 4. When the occluding cuff is applied, the clearance of the $^{133}$xenon stops immediately. When the cuff is released, the clearance of the isotope continues.

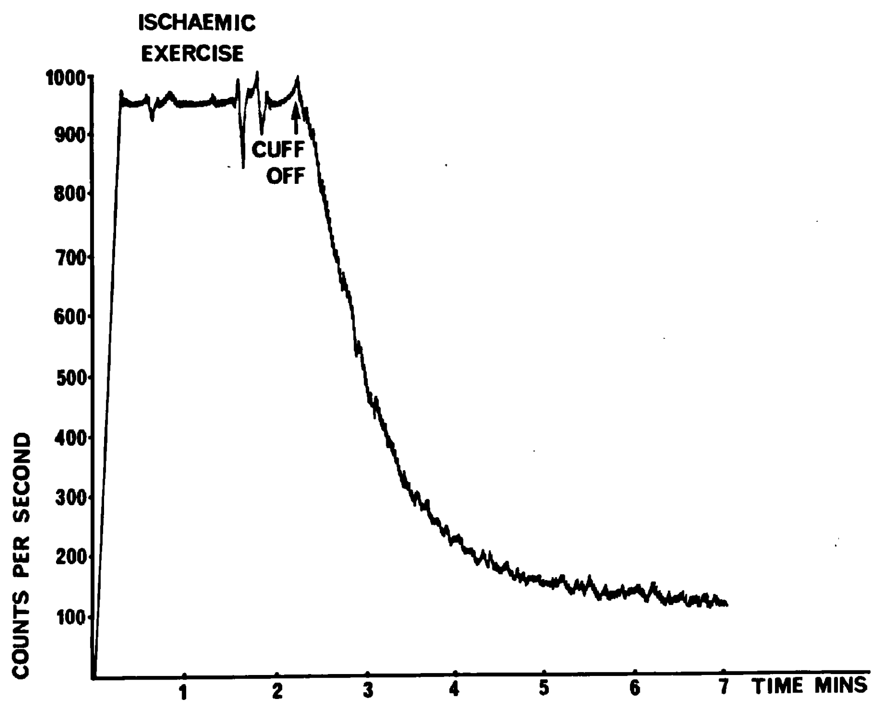


Fig. 2 : I. M. (20 years). Normal subject.
The cuff occluding the arterial inflow to the limb has been released after 2 minutes of ischaemic exercise.

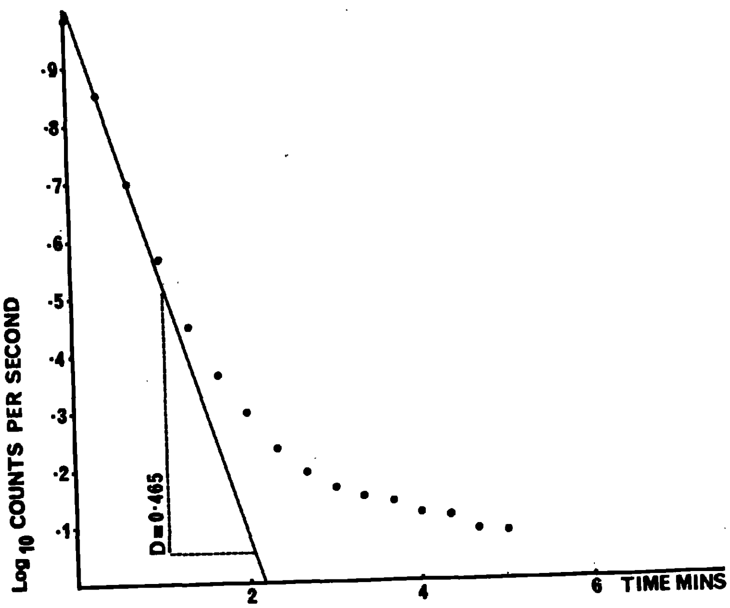


Fig. 3 : A logarithm plot of the clearance curve illustrated in Fig. 2. D = 0.465; peak muscle blood flow = 74.9 ml./100 gm./min.

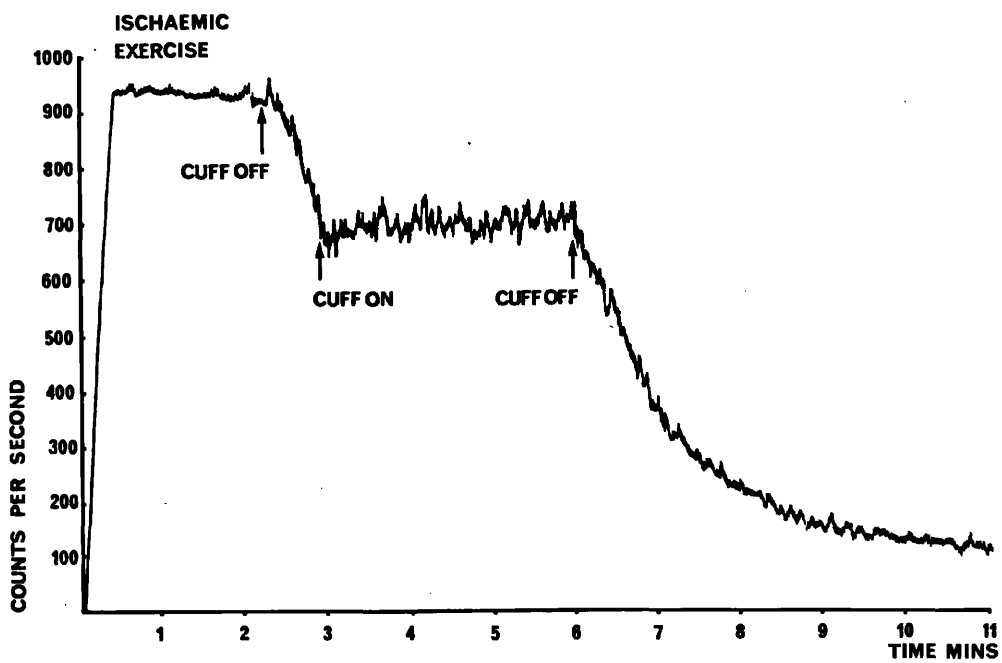


Fig. 4 : The subject has undergone 2 minutes of ischaemic exercise and, during the clearance of 133-xenon, the cuff has been re-applied for 3 minutes. During this 3-minute period, the clearance of 133-xenon virtually stops.

The resting blood flow ranged between 0.64 ml./100 gm./min. to 5.47 ml./100 gm./min. with a mean of 2.28 ml./100 gm./min. (S.D. $\pm$ 0.92).

Peak blood flow following ischaemic exercise varied between 37.0 ml./100 gm./min. and 127.2 ml./100 gm./min. with a mean of 62.0 ml./100 gm./min. (S.D. $\pm$ 17.7). Mean time taken to attain peak blood flow following release of the occluding cuff was 0.46 min. (Range 0.1 min. to 1.1 min. : S.D. $\pm$ 0.21). Mean duration of the peak blood flow was 1.08 min. (Range 0.3 min. to 2.0 min. : S.D. $\pm$ 0.37).

A histogram showing the distribution of the peak blood flow results is shown in Fig. 5.

The repeatability of the peak blood flow estimations was assessed in two different ways. In three subjects, two estimations of peak blood flow were made in the same leg with an interval of 15 minutes between them. Both estimations were made from approximately the same site. These results are given in Table 1. It can be seen that there is an extremely good correlation between the first and the second readings.

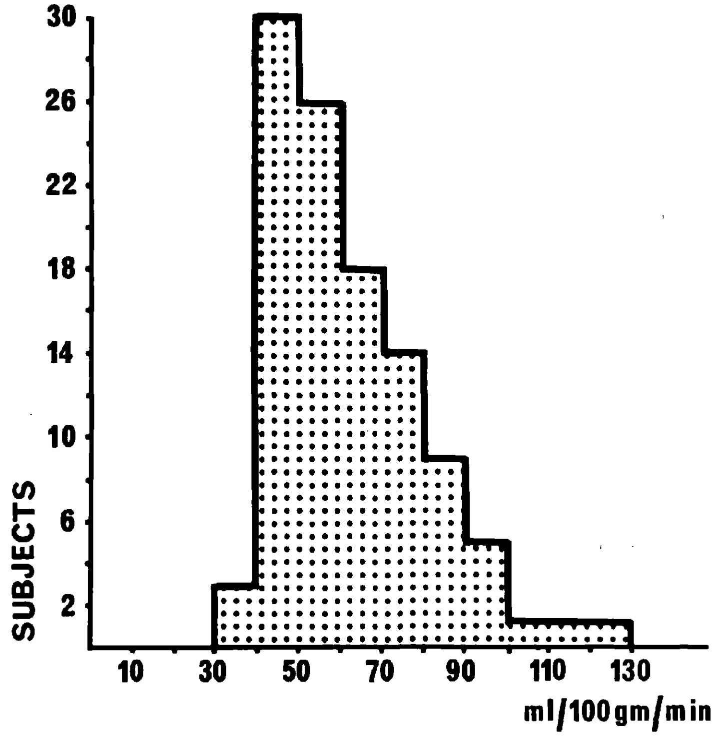


Fig. 5 : Distribution histogram of the peak blood flow results from the normal subjects.

| Name | Age | Peak Blood Flow ml/100 gm/min (1) | Peak Blood Flow ml/100 gm/min (2) |
|---|---|---|---|
| J.B. | 20 | 87.7 | 90.2 |
| W.A. | 23 | 98.2 | 100.2 |
| A.D. | 24 | 111.9 | 112.9 |

Table 1 : Repeat estimations of peak muscle blood flow at intervals of 15 minutes.

In 7 normal subjects, repeat estimations of peak blood flow were made at longer time intervals. At each visit, one estimation of peak muscle blood flow was made from both limbs. The time interval between estimations was quite random and depended on the availability of the subject for the estimation rather than on selection of a particular time. The number of estimations in any one subject varied from 2 to 5; in the case of the duplicate estimations, the time interval was 2 to 4 weeks and in the case of the more frequent estimations, anything from 4 weeks to 3 months.

The coefficient of variation ranged between 2.6 per cent and 24 per cent with a mean of 10 per cent (S.D. $\pm$ 5.4 per cent). These results are given in Table 2.

| Name | No. of Estimations | Mean and S.D. | Coefficient of Variation % |
|---|---|---|---|
| A.B. | 3 | 85.1 ± 5.7 | 6.7 |
| | 3 | 68.4 ± 5.1 | 7.5 |
| I.B. | 3 | 45.4 ± 6.2 | 13.7 |
| | 3 | 46.7 ± 2.9 | 6.2 |
| I.C. | 2 | 86.9 ± 2.3 | 2.6 |
| | 2 | 80.8 ± 9.5 | 11.8 |
| K.G. | 5 | 86.1 ± 20.7 | 24.0 |
| | 5 | 70.1 ± 6.7 | 9.6 |
| I.McD. | 5 | 61.7 ± 4.9 | 7.9 |
| | 5 | 66.6 ± 7.3 | 11.0 |
| A.T. | 5 | 88.2 ± 8.2 | 9.3 |
| | 5 | 89.3 ± 12.2 | 13.7 |
| J.W. | 2 | 61.7 ± 1.6 | 2.6 |
| | 2 | 56.6 ± 7.6 | 13.4 |

Table 2 : Normal group. Repeat estimations over periods of time varying from 2 weeks to 3 months.

In order to determine whether the blood flow results were influenced by the age of the patient, the results obtained in the normal group were divided into three age groups, i.e. 20-40 years, 40-60 years and over 60 years of age. The results are are given in Table 3.

| Age Group (years) | No. of Patients | No. of Limbs | Resting Blood Flow ml/100 gm/min (mean & S.D.) | Peak Blood Flow ml/100 gm/min (mean & S.D.) | Time to Peak Blood Flow (mins) (mean & S.D.) | Duration of Peak Blood Flow (mins) (mean & S.D.) |
|---|---|---|---|---|---|---|
| 20 - 40 | 22 | 42 | 2.08 $\pm$ 0.88 | 72.0 $\pm$ 20.0 | 0.39 $\pm$ 0.17 | 1.05 $\pm$ 0.31 |
| 40 - 60 | 26 | 50 | 2.35 $\pm$ 0.94 | 54.4 $\pm$ 12.1 | 0.55 $\pm$ 0.26 | 1.16 $\pm$ 0.41 |
| Over 60 | 10 | 18 | 2.42 $\pm$ 0.99 | 60.1 $\pm$ 13.8 | 0.43 $\pm$ 0.22 | 0.94 $\pm$ 0.37 |

Table 3 : Normal group. Muscle blood flow in different age groups.

The results were analysed by the student 't' test. There is no statistically significant difference between the groups with respect to resting blood flow. Peak blood flow was found to be significantly higher in the 20-40 group than in the 40-60 age group ($p < 0.01$) and the over-60 age group ($p < 0.05$). Time to peak blood flow was significantly shorter in the 20-40 age group than in the 40-60 age group ($p < 0.001$) but not than in the over-60 age group. There was no significant difference between any of the groups with respect to duration of peak blood flow.

One of the objects of studying the normal subjects was to obtain a control group for comparison with patients suffering from peripheral arterial disease. This disease usually occurs in people over the age of 40 years and so to provide a more appropriate comparison, the results from the normal subjects over 40 years of age have been grouped together. It is these results which will be used when comparing normal to abnormal. The mean results for this group were :

| | |
|---|---|
| Resting blood flow | 2.37 ml./100 gm./min. (SD $\pm$ 0.94) |
| Peak blood flow | 55.9 ml./100 gm./min. (SD $\pm$ 12.7) |
| Time to peak blood flow | 0.52 min. (SD $\pm$ 0.25) |
| Duration of peak blood flow | 1.10 min. (SD $\pm$ 0.41) |

Blood flow results at minute intervals following release of the occluding cuff were calculated for this group and are shown in Fig. 6. At one minute, the blood flow had reached its maximum level and by two minutes, this had passed off.

## Discussion

The figures reported here agree well with those given by Lassen (1964) in his original article. In a similar age group, he found a peak blood flow of 51.8 ml./100 gm./min. (SD $\pm$ 11.5) and in the present series, peak blood flow was 55.9 ml./100 gm./min. (SD $\pm$ 12.7). Lindbjerg (1965) found a peak blood flow of 52.1 ml./100 gm./min. (SD $\pm$ 11.5) in control subjects over 50 years of age. There is therefore a good correlation between the present findings and those of other groups of workers using the $^{133}$xenon clearance technique.

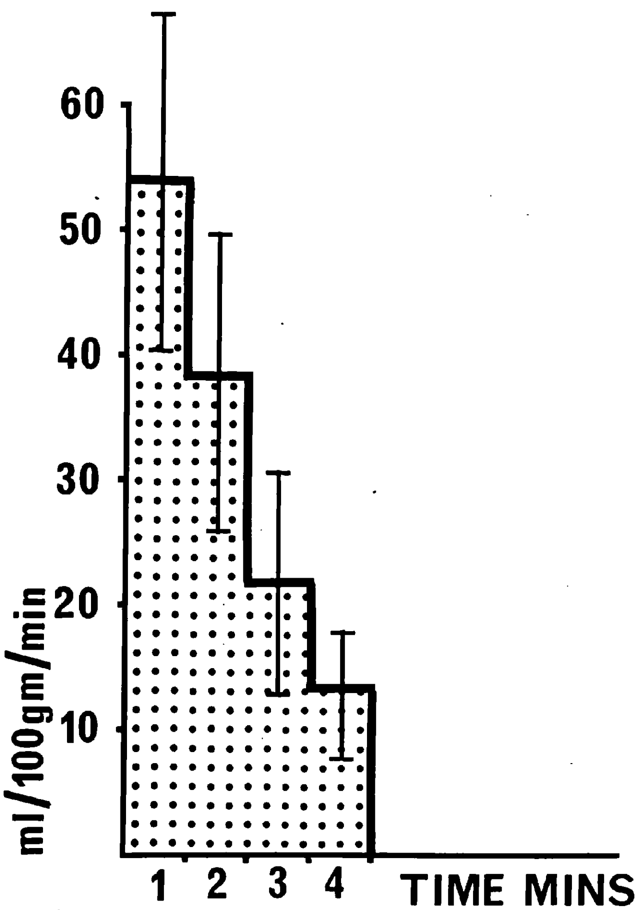


Fig. 6 : Muscle blood flow calculated at minute intervals following release of the occluding cuff. Control group over 40 years of age.

It is difficult to compare the results obtained by the $^{133}$xenon clearance technique to results obtained by other methods. Venous occlusion plethysmography measures the blood flow destined for all the tissue in the area under study, whereas the clearance technique is a measure of blood flow at capillary level in muscle alone. Landsdowne and Katz (1942), using venous occlusion plethysmography, reported a resting blood flow in normal subjects ranging between 0.6 and 7.0 cc./min./100 cc. limb volume: in the present series, resting blood flow ranged from 0.64 to 5.47 ml./100 gm./min. Pollock, Bell and Ledingham (1968), while studying the effect of hyperbaric oxygen on muscle blood flow, found that the resting blood flow measured by the clearance of $^{133}$xenon was systematically lower than that measured by strain gauge plethysmography. Lassen et al (1965) and Perovsky et al. (1966) also found that the $^{133}$xenon clearance technique gave lower results than the classical venous occlusion plethysmograph method. This is to be expected as the plethysmograph technique will measure the blood flow destined for all the tissues in the area under study, including the non-distenable ones (i.e. bone); the clearance technique measures only the capillary flow in muscle and would be expected to be smaller under resting conditions. Plethysmography will also measure blood flow which is occurring through arterio-venous shunts, whereas the $^{133}$xenon clearance technique will not; again this may partly explain why the plethysmographic methods give higher results.

It was interesting to note that peak blood flow in the over-40 age group was significantly lower than the under-40 age group. This finding agrees with that of Lindbjerg (1965) who found that peak blood flow after ischaemic exercise was significantly higher in controls less than 50 years of age than it was in persons more than 50 years of age. Lassen and Kamp (1965) also observed this fact. Using the $^{133}$xenon clearance technique during walking, they found that the younger control group had significantly higher flows. Wagner and Riccardi (1966) have shown that, on autopsy specimens over 40 years of age, atherosclerotic changes were present in every case and these became more extensive the greater the age. Presumably the presence of such lesions has been responsible for this observed decrease in peak blood flow.

The mean coefficient of variation for peak blood flow over various time intervals ranging from 2 weeks to 3 months was 10 per cent. This is quite an acceptable degree of variation and would allow the technique to be used for both acute and long-term studies.

<u>Disadvantages of the Technique</u>

One of the main considerations of any technique is to know how accurately it is measuring what it is intended to measure. Kjellmer et al. (1967) studied the relationship between the total blood flow in an isolated cat muscle with the $^{133}$xenon clearance technique. The found that the blood flow calculated from the intramuscular injection of $^{133}$xenon represented 62 per cent of the total muscle flow. At first sight this may appear disappointing; however, further consideration shows that the two methods would not necessarily be expected to correlate particularly closely. The clearance technique is a measure of flow at capillary level and would not be influenced by arteriovenous anastomoses; thus, the clearance would only correlate with that fraction of the blood supply to muscle that is not shunted through these anastomoses. They did find that the clearance technique reflected changes in blood flow in the same direction as the total muscle blood flow and that it agreed most closely with the total blood flow during conditions of maximum dilatation. Thus the technique would be expected to be of most value when muscle blood flow is maximal, i.e. following ischaemic exercise. However, Sejerson and Tonnesen (1966), using an atraumatic tissue labelling technique, found a much closer correlation between total flow measured by drop recorder technique and the clearance of $^{133}$xenon. They suggested that the trauma caused by the local injection was responsible for the poor correlation between $^{133}$xenon clearance and total flow reported by Kjellmer et al. (1967). This would appear to be reasonable as they were injecting between 0.05 ml. to 0.15 ml. into the muscle of the cat (cf. 0.1 ml.-0.2 ml. into anterior tibial group of muscles) and quite marked tissue distortion may be expected. However, as pointed out by Lassen (1965), the trauma caused by local injection in the anterior tibial group of muscles will be so small (i.e. small injection, large muscle mass) that it will not influence the clearance curve to any significant degree. Despite these criticisms, it must be remembered that the important factor as far as nutrition and function are concerned is the blood flow at capillary level, and theoretically the $^{133}$xenon method will accurately give information concerning this.

One of the advantages of $^{133}$xenon as the indicator for the measurement of blood flow is that it moves freely in tissue as it is quite inert. Therefore, it would be reasonable to expect some diffusion of $^{133}$xenon away from the injection site. If it diffused outwith the view of the collimator, this would cause an overestimation of blood flow. In order to prevent this from happening, the counter was never put closer than 2-3 inches from the leg so that a large area of muscle was in view of the collimator. However, it is readily seen in Fig. 4 that, as soon as the circulation is stopped, the effective clearance of the isotope ceases. The circulation was occluded for 3 minutes without any appreciable drop in the counting rate and therefore it may be concluded that any diffusion in tissue is so small that it will not interfere with the clearance curve. Gillespie (personal communication) has measured the diffusion coefficient of $^{133}$xenon in muscle <u>in vitro</u> and found it to be $0.7 \times 10^{-5}$ cm.$^{2}$ sec.$^{-1}$. This means that $^{133}$xenon will diffuse in the order of 1 cm. in 1 hour.

Barlow, Haigh and Walder (1961) have suggested that there is a dual circulation through muscle; one through muscle proper and one through the connective tissue. If an injection were placed in the connective tissue in the resting state, this would be very difficult to detect as resting muscle blood flow is usually so low and the range of values so great. However, during reactive hyperaemia, an abnormally low flow in a normal person would make one suspicious that the injection had been placed in connective tissue. In the series reported here, no curve fell into this category; however, recent work on the effect of vasodilator drugs on muscle blood flow in normal subjects (Bell, 1969) did reveal an abnormally low curve in one subject. This was a repeat estimation in a subject receiving a placebo, and was so unlike the previous tracing that it was thought justifiable to ascribe this to an injection into connective tissue. However, this is a very unusual finding and has occurred only once in well over 500 estimations.

Reflux of $^{133}$xenon along the needle track following intra-muscular injection would not only lead to loss of counting rate and a falsely high flow rate but would also result in contamination of subcutaneous tissue and skin. A multi-exponential clearance curve would then be obtained which would be extremely difficult to analyse. In an attempt to prevent this, firm pressure was always applied over the needle track for approximately 2 minutes after the injection.

Distortion of the tissue and the presence of a small haematoma could interfere with the resting blood flow. This is kept to a minimum by injecting a small quantity of the solution (i.e. 0.1-0.2 ml.). Also, during the hyperaemic period, these factors would tend to be minimal owing to the large volume of blood flowing through the muscle.

Tonesson (personal communication) has said that on a few occasions acute thrombosis may be caused by the occluding cuff. However, the author has carried out well over 500 estimations using this technique and has not observed this complication.

Most normal subjects tolerate the test well and it is no more than a numb and paralysed feeling in the leg which forces them to stop exercising. Occasionally, patients with severe peripheral arterial disease find that the pain of the ischaemic exercise is so great that they cannot finish the test. This applies to very few cases, and more often the patient will complain of the pain from the occluding cuff rather than the ischaemic pain. The technique therefore does require patient co-operation and on occasion cannot be used because of the discomfort it causes.

## SUMMARY OF CHAPTER I

The advantages of the use of $^{133}$xenon as an indicator for the measurement of muscle blood flow and the mathematical derivation of the expressions for muscle blood flow have been described.

The local clearance of $^{133}$xenon has been used to estimate resting muscle blood flow and blood flow following ischaemic exercise in normal subjects. The technique was found to have a mean coefficient of variation of 10 per cent when repeat estimations were carried out over time intervals ranging from 2 weeks to 3 months. The range of peak blood flow in normal subjects was from 37.0 ml/100 gm./min. to 127.2 ml./100 gm./min. with amean of 62.0 ml./100 gm./min. (SD $\pm$ 17.7)

The effect of increasing age on muscle blood flow was investigated. There was no change in resting muscle blood flow in the different age groups. Peak blood flow following ischaemic exercise was found to be significantly reduced in subjects over 40 years of age.

The accuracy of the local clearance of $^{133}$xenon as a measure of muscle blood flow has been discussed and the advantages and disadvantages of the technique assessed.

It is concluded that the $^{133}$xenon clearance technique is a useful method for the estimation of local muscle blood flow and that it is suitable for the investigation of patients with abnormalities of the circulation.

# CHAPTER II

## THE MEASUREMENT OF MUSCLE BLOOD FLOW IN PATIENTS WITH PERIPHERAL VASCULAR DISEASE

The clinical and radiological assessment of a patient suffering from peripheral arterial disease is of paramount importance in the management of any case and cannot be replaced by measurements of muscle blood flow. Intermittent claudication, which is often the presenting symptom of peripheral arterial disease, is however a subjective phenomenon and, in theory, an objective measurement of the blood flow through muscle may be expected to provide a more reliable index for the assessment of patients suffering from it. Estimations of muscle blood flow were therefore carried out on patients admitted to hospital for investigation of peripheral arterial disease.

## Method

The meth od used was identical with that described in Chapter I. Over a period of approximately 2 years, estimations of muscle blood flow were made in all patients admitted for investigation of intermittent claudication.

## Results

A total of 177 limbs in 109 patients suffering from peripheral arterial disease have been studied. All these patients were considered to have atherosclerosis as the cause of their arterial disease and, in over 95 per cent of the cases, the diagnosis was confirmed by lumbar aortography. The ages of the patients ranged from 36 years to 75 years, with a mean of 56 years.

Mean resting blood flow was 1.84 ml./100 gm./min. (SD $\pm$ 0.89). Mean peak blood flow was 29.3 ml./100 gm./min. (SD $\pm$ 12.0). Mean time to peak blood flow was 1.67 min. (SD $\pm$ 1.0) and mean duration of peak blood flow was 2.41 min. (SD $\pm$ 1.27). There is no significant difference in resting blood flow between the diseased group and the normal group. However, peak blood flow is significantly reduced ($p < 0.001$), time to peak blood flow and duration of peak blood flow are significantly prolonged ($p < 0.001$) in both cases.

A typical tracing from a patient with an occlusion of the superficial femoral artery is shown in Fig. 7, and a logarithmic plot of this tracing is shown in Fig. 8. A distribution histogram of the peak blood flow results in the diseased group is shown in Fig. 9.

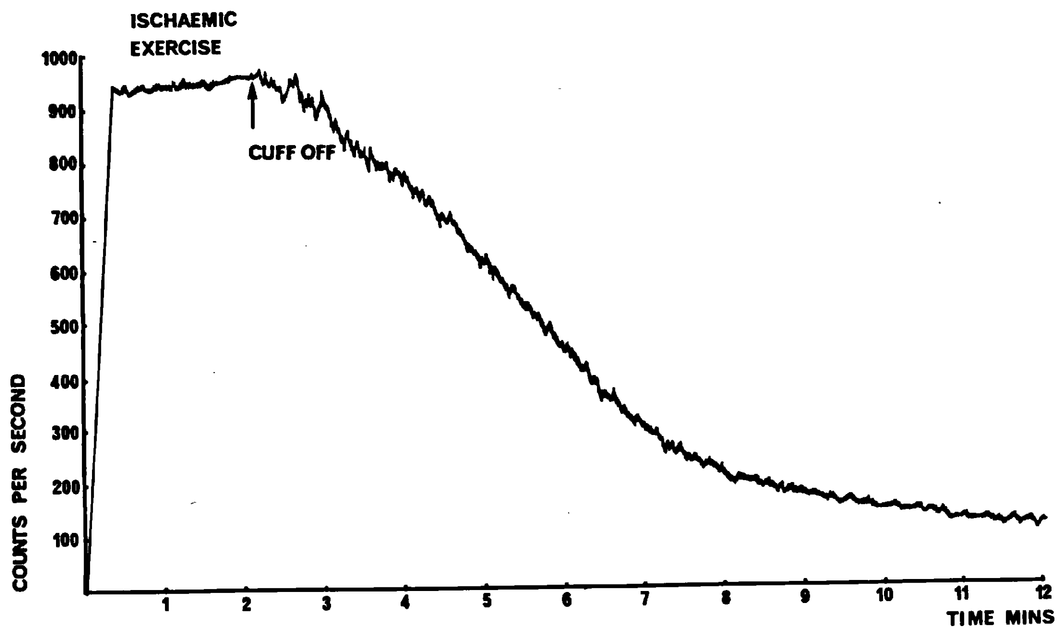


Fig. 7 : K. B. (66 years). Clearance curve obtained from a patient with a 3-inch occlusion of the femoral artery at the opening in adductor magnus.

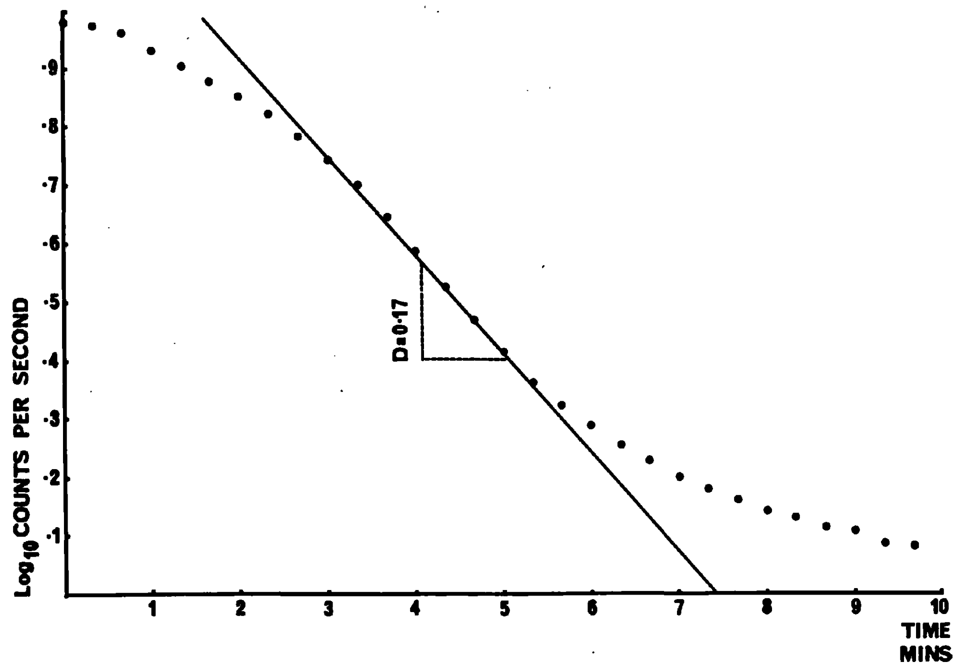


Fig. 8 : A logarithmic plot of the clearance curve illustrated in Fig. 7. D = 0.17; peak muscle blood flow = 27.4 ml./100 gm./min.

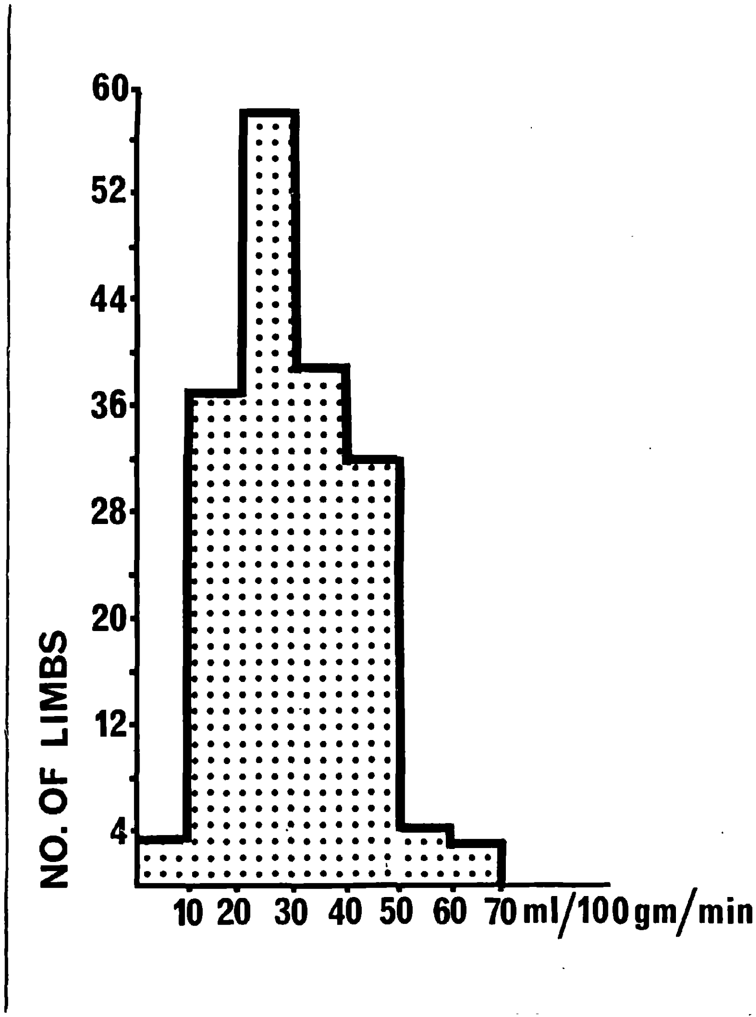


Fig. 9 : A histogram showing the distribution of the peak muscle blood flow results in patients suffering from peripheral arterial disease.

To determine whether the site or extent of the disease influenced the blood flow response to ischaemic exercise, the group was divided into three :

1. Those patients with an occlusive lesion proximal to the inguinal ligament. Patients with aorto-iliac occlusions were excluded from this group; these patients have particularly severe claudication and too few of them have been studied to allow satisfactory analysis.
2. Those patients with occlusive lesions distal to the inguinal ligament.
3. Those patients with generalized atherosclerotic changes throughout the vascular tree but with no main vessel occlusion proximal to the popliteal bifurcation.

Patients with both proximal and distal occlusive lesions have been excluded as again too few cases in this category have been studied. The results from these groups are shown in Table 4.

| | No. of Limbs | Resting Blood Flow ml/100 gm/min | Peak Blood Flow ml/100 gm/min | Time to Peak Blood Flow (min) | Duration of Peak Blood Flow (min) |
|---|---|---|---|---|---|
| Generalised | 74 | $1.79 \pm 0.68$ | $35.5 \pm 11.0$ | $1.37 \pm 0.72$ | $1.78 \pm 0.74$ |
| Proximal Occlusion | 21 | $1.85 \pm 0.75$ | $34.1 \pm 12.1$ | $1.52 \pm 1.10$ | $2.28 \pm 1.35$ |
| Distal Occlusion | 82 | $1.88 \pm 1.08$ | $22.5 \pm 8.9$ | $1.97 \pm 1.12$ | $3.05 \pm 1.35$ |

Table 4 : The effect of the site of atherosclerotic disease on muscle blood flow.

Comparison of the generalized and proximal groups shows that peak blood flow and time to peak blood flow are not significantly different but that the duration of the peak blood flow in the proximal group is significantly prolonged ($p < 0.05$).

When the generalized and distal groups were compared, peak blood flow was significantly lower ($p < 0.001$), time to peak blood flow significantly delayed ($p < 0.001$) and the duration of peak blood flow significantly prolonged ($p < 0.001$) in the distal group.

Comparison of the proximal and distal groups shows that the peak blood flow in the distal group is lower ($p < 0.001$) and that the duration of the peak blood flow is prolonged ($p < 0.025$). There is no significant difference between the groups in the time taken to reach peak blood flow.

Muscle blood flow was calculated at minute intervals after release of the occluding cuff for each patient in the 3 groups. The results are shown in Figs. 10, 11 and 12. Study of these figures readily demonstrates the different flow patterns in each group. The reduction in peak blood flow, delay in reaching peak blood flow and prolonged duration of peak blood

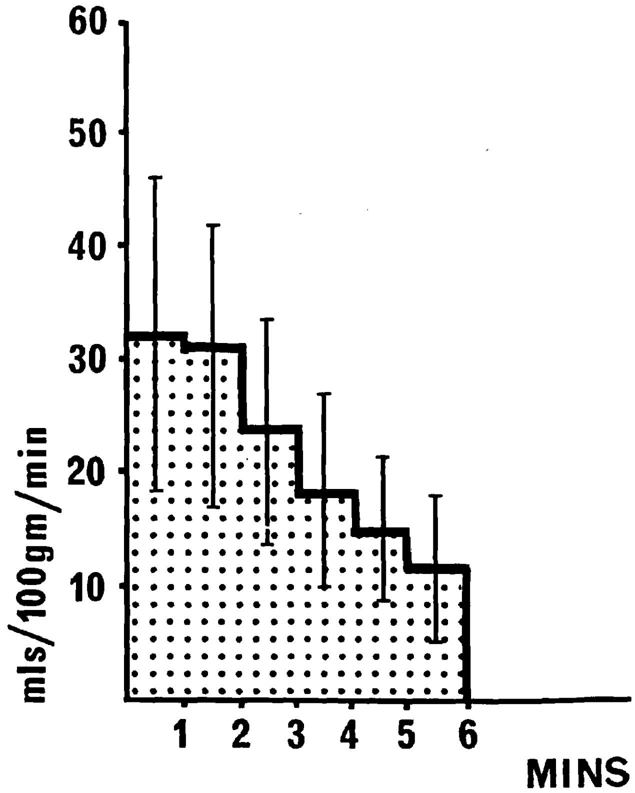


Fig. 10 : Muscle blood flow calculated at minute intervals following release of the occluding cuff. Patients with generalised disease and no main vessel occlusion.

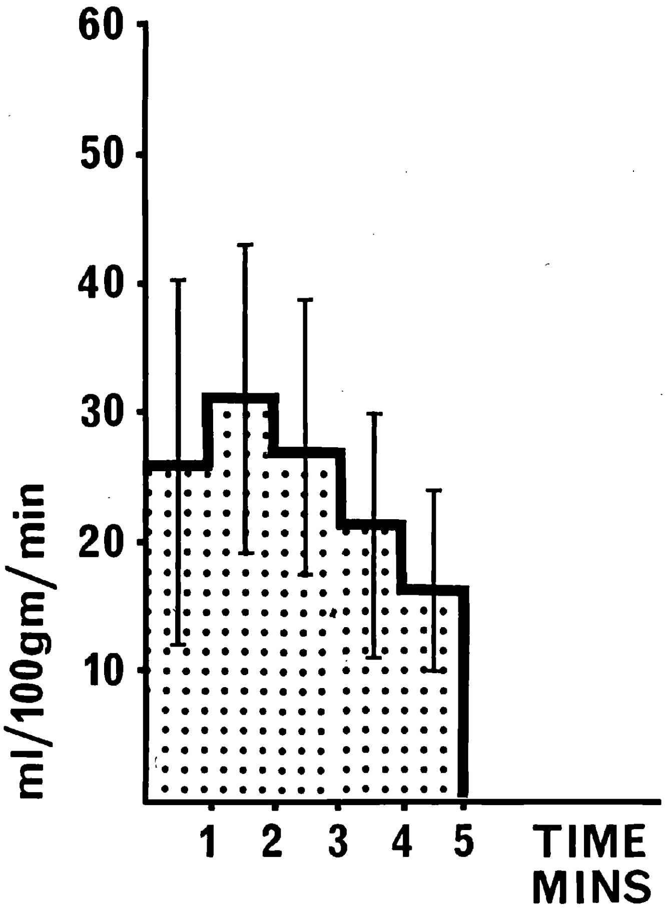


Fig. 11 : Muscle blood flow calculated at minute intervals following release of the occluding cuff. Patients with occlusive lesions proximal to the inguinal ligament.

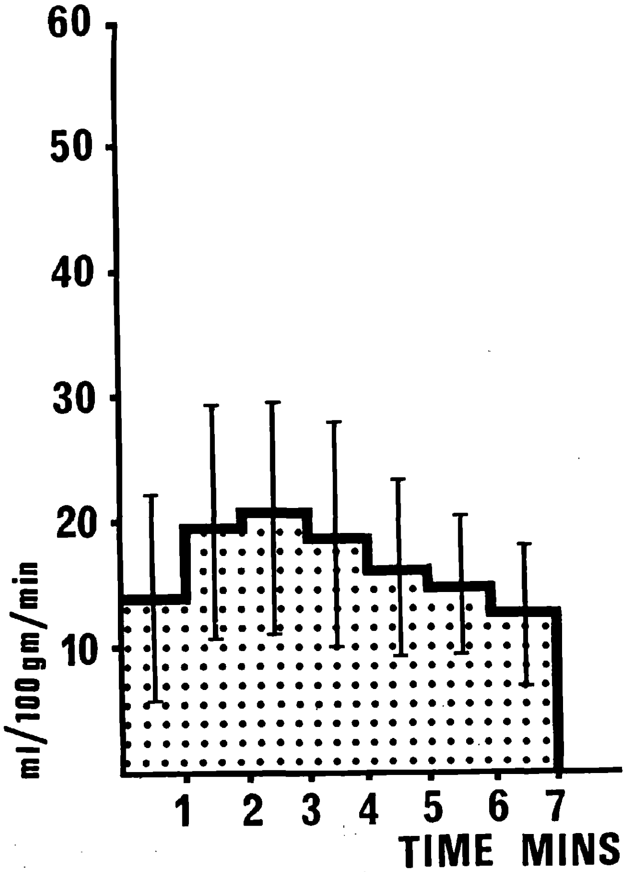


Fig. 12 : Muscle blood flow calculated at minute intervals following release of the occluding cuff. Patients with occlusive lesions distal to the inguinal ligament.

flow are more markedly abnormal in the distal group (Fig. 12), less so in the proximal group (Fig. 11) and least of all in the generalized group (Fig. 10).

There is a considerable overlap between the results obtained in the normal and abnormal groups. If arbitarily one standard deviation from the mean is taken and this is assumed to be the diagnostic level, then any peak blood below 42.3 ml./100 gm./min., any time to peak blood flow longer than 0.8 min., and any duration of peak blood flow longer than 1.5 min. may be taken as being indicative of arterial disease.

Nine normal limbs (8.2 per cent) had a peak blood flow below 42.3 ml./100 gm./min.: 6 limbs (5.5 per cent) had a duration of peak blood flow longer than 0.8 min.: and 8 limbs (7.3 per cent) had a duration of peak blood flow longer than 1.5 min. If all three parameters are considered together no normal person studied had all 3 outwith control levels.

The same 3 criteria were used in assessing the diseased group. Taking the group as a whole 30 limbs (16.9 per cent) had a peak blood flow above 42.3 ml./100 gm./min.: 57 limbs (32.2 per cent) had a time to peak blood flow of 0.8 or less minutes: 54 limbs (30.5 per cent) had a duration of peak blood flow of 1.5 minutes or less. If those patients in the generalized group who did not suffer from intermittent claudication are excluded from the group, then these figures become 7.3 per cent, 15.3 per cent and 19.8 per cent respectively.

Taking all 3 parameters together into consideration 16 limbs (9.0 per cent) had all 3 within the normal range. Looking at each group separately, 1 limb in the distal group and 2 in the proximal group had all 3 parameters within the control levels. In the generalized group 13 limbs had all 3 parameters within the normal range. Only 2 patients in the generalised group with all 3 parameters within the normal range complained of intermittent claudication.

## Discussion

It has been reported previously that there is no difference in resting muscle blood flow between normal subjects and people suffering from peripheral arterial disease (Edholm et al., 1951: Landowne, 1942: Tonnesen, 1965). The findings in the present study confirm this. In an experimental study on dogs, Van de Berg et al. (1964) found that an arterial stenosis which did not alter blood flow at rest caused a reduction in the hyperaemic response. This presumably explains why muscle blood flow is usually adequate at rest in patients with arterial disease but inadequate during exercise.

In 1950, Shepherd first described the typical changes which occur in muscle blood flow in peripheral arterial disease. Using venous occlusion plethysmography, he described a reduced level of peak blood flow following ischaemic exercise, a delay in reaching this level and a prolongation of the hyperaemic response. His findings have been confirmed by other workers using venous occlusion plethysmography (Hillestad, 1965) and strain gauge plethysmography (Myers, 1964). The results reported in this thesis agree well with those other workers using different techniques. Lassen (1964), Lindbjerg (1965) and Bell (1968) described the same reduced peak blood flow, delay in attaining it and lengthened duration of peak blood flow following ischaemic exercise using the $^{133}$xenon clearance method.

It was interesting to see how the site or extent of the lesion in the vessels affected the response to ischaemic exercise. Shepherd (1950) reported 2 types of response in peripheral arterial disease; Group A in which the blood flow gradually subsided from a maximum on release of the cuff and Group B in which the flow built up gradually to a peak over a period of minutes after release of the cuff. In this series of patients, those with the generalized type of disease appear to fall into Group A and those with the distal occlusive lesions into Group B. Those patients with proximal occlusive lesions appear to fall in between the 2 groups and, if anything, resemble Shepherd's Group B. Unfortunately, Shepherd did not give details of angiography in his report.

The use of the $^{133}$xenon clearance technique as a means of diagnosing peripheral arterial disease appears to be satisfactory. Taking one standard deviation from the mean in the control group for peak blood flow, time to reach peak blood flow and duration of peak blood flow, no normal subject lay outwith these levels when all 3 parameters were studied together, although there was some overlap when individual parameters were studied. There were no false positives in this series and the technique may be of value in excluding peripheral vascular disease in patients complaining of muscle pain.

In the diseased group 9.0 per cent of the limbs studied fell within the normal range for peak blood flow, time to reach peak blood flow and duration of peak blood flow. Of this group intermittent claudication was complained of in 5 limbs. Thus, of the 177 limbs studied, only 5 in which intermittent claudication was present gave false negative results when all 3 parameters are considered together.

It would appear that the reduction in peak blood flow after ischaemic exercise is the most reliable of the 3 parameters studied when examining established cases of peripheral arterial disease. However, it would seem necessary to consider all 3 parameters studied together in order to minimize the number of false negative results.

Lassen (1964) also reported an overlap between normal and abnormal persons; he found that 2 out of 13 patients gave false negative results. Webster (1966) found that 50 per cent of problem patients investigated for muscle pain fell within the normal range. In this series, over 95 per cent of the patients studied have had radiologically proven atherosclerotic arterial disease and presumably this is why such a clear-cut difference was found between normal and abnormal.

A difference in the blood flow pattern between these patients with diffuse atherosclerotic changes and those with distal occlusions is to be expected. The first type of disease causes intermittent claudication only occasionally whereas the latter almost invariably does.

Comparison of the proximal and distal groups showed that the proximal group had a higher peak blood flow and of shorter duration than the distal group. This is probably due to the fact that, in the proximal group, there may be a good collateral circulation across the pelvis, allowing good distal filling.

It appears then that the response to ischaemic exercise is most severely affected in these patients with distal occlusive lesions, not so severely affected in patients with proximal occlusive lesions and least severely affected in the generalized type of lesion. If one does not include aorto-iliac occlusion, this agrees well with the clinical situation as it is those patients with the femoral and popliteal occlusions who usually have the most severe intermittent claudication.

The typical symptom of intermittent claudication occurs in the calf of the leg and therefore the question arises as to whether it is appropriate to draw conclusions regarding this symptom by studying muscle blood flow in the anterior tibial group of muscles. The blood supply to the anterior and posterior aspects of the leg is derived directly from the popliteal artery and therefore any lesion proximal to the popliteal bifurcation would be expected to influence both groups of muscles in the same way. When intermittent claudication arises from a localised occlusion in the posterior tibial artery, then the $^{133}$xenon clearance technique would be unable to detect this. Such patients are relatively few and are not suitable for direct arterial surgery. Presumably the reason that intermittent claudication occurs so frequently in the calf is that, when walking, the main action is that of plantar flexion as the line of the body weight in the erect attitude lies in front of the axis of the ankle joint. The gastrocnemius is one of the most powerful plantar flexors and not surprisingly is one of the first muscles affected by lack of blood supply.

## SUMMARY OF CHAPTER II

Muscle blood flow has been studied in a group of patients suffering from peripheral arterial disease. Resting blood flow in this group was not significantly different from that of the normal group. The typical response to ischaemic exercise in patients with peripheral arterial disease is a reduction in the level of peak blood flow, a delay in reaching peak blood flow and a prolongation of the duration of peak blood flow. Those patients with distal arterial occlusive disease have the most abnormal response, those with generalized atherosclerotic disease the least abnormal and those patients with proximal arterial occlusion have a response somewhere in between.

As a method of diagnosing peripheral arterial disease, the $^{133}$xenon clearance technique appears to be reasonably accurate. If all three parameters of the ischaemic response are considered together then no false positives were found in the present series. In t he patients with peripheral arterial disease only 2.8% of the limbs in which intermittent claudication was present gave false negative results.

# C H A P T E R  I I I

# THE BLOOD FLOW THROUGH SKELETAL MUSCLE FOLLOWING DIRECT ARTERIAL SURGERY

The assessment of the results of direct arterial surgery for peripheral arterial disease is usually based upon clinical examination. This takes into account the nutrition of the skin, palpation of the pulses, oscillometry and the effect of surgery on intermittent claudication. As far as the patient is concerned, intermittent claudication is by far the most troublesome symptom of peripheral arterial disease and the improvement in this symptom is the most significant measure of the success of any operation. However, intermittent claudication is a subjective symptom and is often found to vary quite considerably with time. There is thus a need for an objective method for the evaluation of surgical procedures used in the treatment of peripheral arterial disease. Intermittent claudication is due to deficient blood supply at cellular level (capillary blood flow) during exercise, and a method which gives a measure of tissue perfusion would be most suitable for its assessment. The $^{133}$xenon technique is a measure of capillary blood flow or tissue perfusion in skeletal muscle and thus fulfils this need. Accordingly, the technique has been used to assess patients before and after direct arterial surgery.

This chapter will be presented in two parts. In the first part the results from those patients having surgical procedures carried out to the vascular tree proximal to the inguinal ligament will be discussed and in the second part those having surgery to the arterial tree distal to the inguinal ligament.

## AORTO-ILIAC SURGERY

### Method

Muscle blood flow measurements were made following ischaemic exercise as described in Chapter I. As it was found that there was no difference in resting blood flow between the normal and diseased groups, the resting measurements were omitted.

Muscle blood flow was measured in each patient immediately before operation and at 2 and 3 months following operation. During the follow-up of these patients, blood flow measurements were carried out 6 months and 1 year after operation. From each measurement, an estimation of peak blood flow, time to peak blood flow and duration of peak blood flow was made.

## Results

A total of 31 patients were studied. The indication for operation was intermittent claudication in 30 cases and incipient gangrene in one. The diagnosis was established in each case by translumbar aortography. Twenty-two patients in this group had thrombo-endarterectomy of the aorta and/or iliac arteries and 9 had a prosthetic fabric tube inserted, either as a replacement or to bypass the diseased segment.

### THROMBO-ENDARTERECTOMY

Twenty-seven limbs of the 22 patients who had a thrombo-endarterectomy carried out have been studied. Those patients who suffered from intermittent claudication in both limbs had blood flow estimations made in each limb. The lesions operated on are given in Table 5.

| Lesion | No. of Patients |
|---|---|
| Diffuse aorto-iliac disease | 5 |
| Occlusion of aortic bifurcation | 1 |
| Common iliac artery occlusion | 5 |
| Common iliac artery stenosis | 6 |
| Common iliac and external iliac artery occlusion | 1 |
| External iliac artery occlusion | 4 |

Table 5 : Aorto-iliac thromboendarterectomy group. Distribution of the lesions treated surgically.

The muscle blood flow results before and after operation are shown in Table 6. There was an increase of 44.8 per cent in peak blood flow and a reduction of 35.3 per cent in the duration of peak blood flow after operation ($p < 0.005$ in both cases). Time taken to reach peak blood flow was reduced by 31.9 per cent but this was not to a statistically significant level.

| | Peak Blood Flow ml/100 gm/min | Time to Peak Blood Flow (mins) | Duration of Peak Blood Flow (mins) |
|---|---|---|---|
| Before operation | 30.1 ± 13.7 | 1.59 ± 1.37 | 2.52 ± 1.29 |
| After operation | 43.6 ± 17.7* | 1.09 ± 1.11 | 1.63 ± 0.66* |

Table 6 : Muscle blood flow results before and after thrombo-endarterectomy to the aorta and iliac arteries.
* $p < 0.005$.

The group was reviewed to determine the effect of surgery on intermittent claudication. All but one of these patients (A.S.) were regarded as technically satisfactory in that a previously absent or diminished femoral pulse returned or improved in volume. Twenty of the limbs studied (74.1 per cent) had an improvement or complete absence of intermittent claudication when seen at approximately 3 months after operation. There was no improvement in claudication in 7 limbs (25.9 per cent). The results for the muscle blood flow estimations in these two groups are shown in Table 7.

| | Improvement | | | No Improvement | | |
|---|---|---|---|---|---|---|
| | Peak Blood Flow ml/100 gm/min | Time to Peak Blood Flow (min) | Duration of Peak Blood Flow (min) | Peak Blood Flow ml/100 gm/min | Time to Peak Blood Flow (min) | Duration of Peak Blood Flow (min) |
| Before Operation | 30.6 ± 13.3 | 1.43 ± 1.01 | 2.63 ± 1.34 | 28.6 ± 15.8 | 2.04 ± 1.98 | 2.23 ± 1.18 |
| After Operation | 49.3 ± 15.4 | 0.69 ± 0.47 | 1.54 ± 0.64 | 27.3 ± 14.0 | 2.23 ± 1.61 | 1.87 ± 0.73 |

Table 7 : Aorto-iliac thromboendarterectomy group. Comparison between muscle blood flow in patients with and without improvement in intermittent claudication.

In the group showing improvement in claudication distance, the post-operative peak blood flow was significantly higher ($p < 0.001$), the time taken to and the duration of peak blood flow were significantly shorter ($p < 0.001$) in both cases. Four limbs showed no improvement in muscle blood flow, yet the patients claimed absence of intermittent claudication in those limbs.

Study of the muscle blood flow figures shows that the mean time taken to attain peak blood flow was reduced from 1.30 min. pre-operatively to 0.63 min. post-operatively. This reduction in time is significant at the 2 per cent level.

In the group showing no improvement in claudication, there was no significant difference in any of the parameters studied and no individual patient showed an improvement in muscle blood flow.

Muscle blood flow estimations were made at minute intervals following release of the cuff pre-operatively and post-operatively in the group with improvement in claudication distance and the flow patterns compared in Fig. 13.

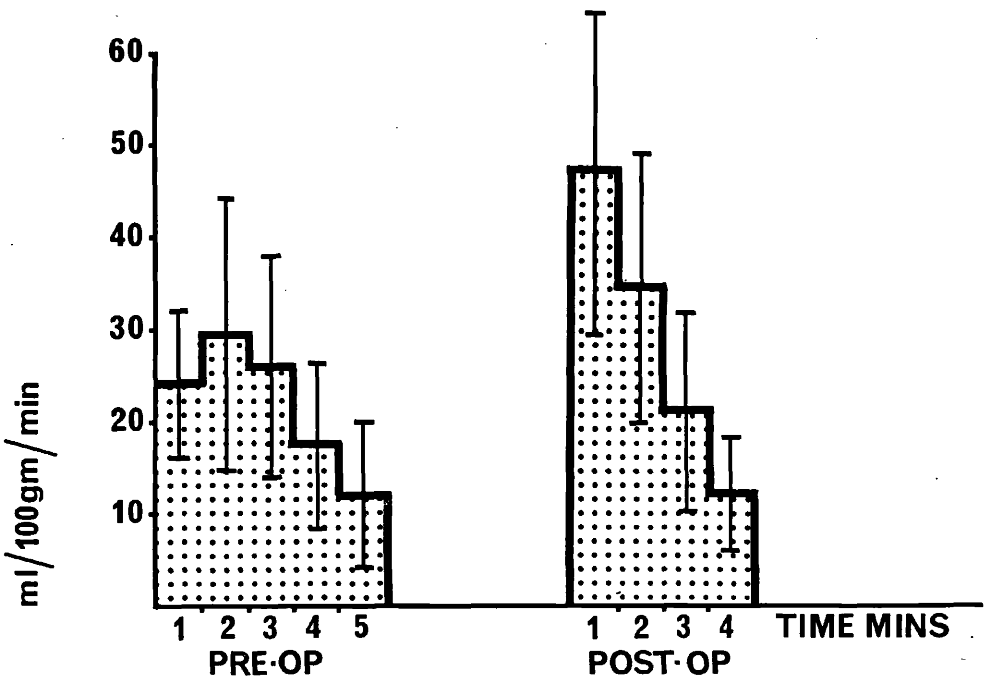


Fig. 13 : Aorto-iliac thromboendarterectomy group. Muscle blood flow calculated at minute intervals following release of the occluding cuff before and after surgery.

The lower limits of the 'normal' range were defined arbitarily in Chapter I as one standard deviation from the mean of all the results from the normal subjects over 40 years of age. These values were :

| | |
|---|---|
| Peak blood flow | 42.3 ml./10 gm./min. |
| Time to peak blood flow | 0.8 min. |
| Duration of peak blood flow | 1.5 min. |

Eleven (55 per cent) of the 20 successful limbs fell within the normal range in all three respects.

The results were reviewed to determine whether the presence of an occlusive lesion distal to the inguinal ligament in addition to the proximal lesion influenced the results of surgery. Eight limbs had an additional distal lesion and the muscle blood flow results before and after surgery are given in Table 8. The post-operative peak muscle blood flow results were not significantly higher than the pre-operative values. In the entire aorto-iliac thromboendarterectomy group, 7 of the limbs studied were regarded as being unsuccessful on clinical grounds; 4 had a distal occlusive lesion and 3 did not. Thus, 57 per cent of the failures in this group were patients with a distal occlusive lesion as well as the disease in the aorto-iliac segment.

| Additional Lesion | Patient | Preoperative Peak Blood Flow ml/100 gm/min | Postoperative Peak Blood Flow ml/100 gm/min |
|---|---|---|---|
| Superficial femoral occlusion | J.B. | 11.3 | 19.3 |
| " " " | T.E. | 46.6 | 53.9 |
| " " " | F.K. | 29.8 | 51.5 |
| " " " | S.P. | 11.2 | 22.5 |
| " " " | T.P. | 45.7 | 61.2 |
| " " " | T.P. | 43.0 | 56.0 |
| Popliteal occlusion | W.L. | 24.2 | 20.9 |
| " " | J.M. | 10.5 | 16.9 |
| Mean and S.D. | | 27.8 $\pm$ 15.9 | 37.8 $\pm$ 19.4 |

Table 8 : Aorto-iliac thromboendarterectomy group. The influence of a distal occlusive lesion on muscle blood flow results following surgery.

Two of the 16 patients regarded as having had successful surgery died within 6 months of the operation from myocardial infarction. Ten of the remaining patients have been followed up for one year (13 limbs).

Muscle blood flow estimations were carried out at 3, 6 and 12 months. The results are illustrated in Fig. 14. The rise in muscle blood flow achieved at 3 months was well maintained during the period of follow-up. Although individual patients

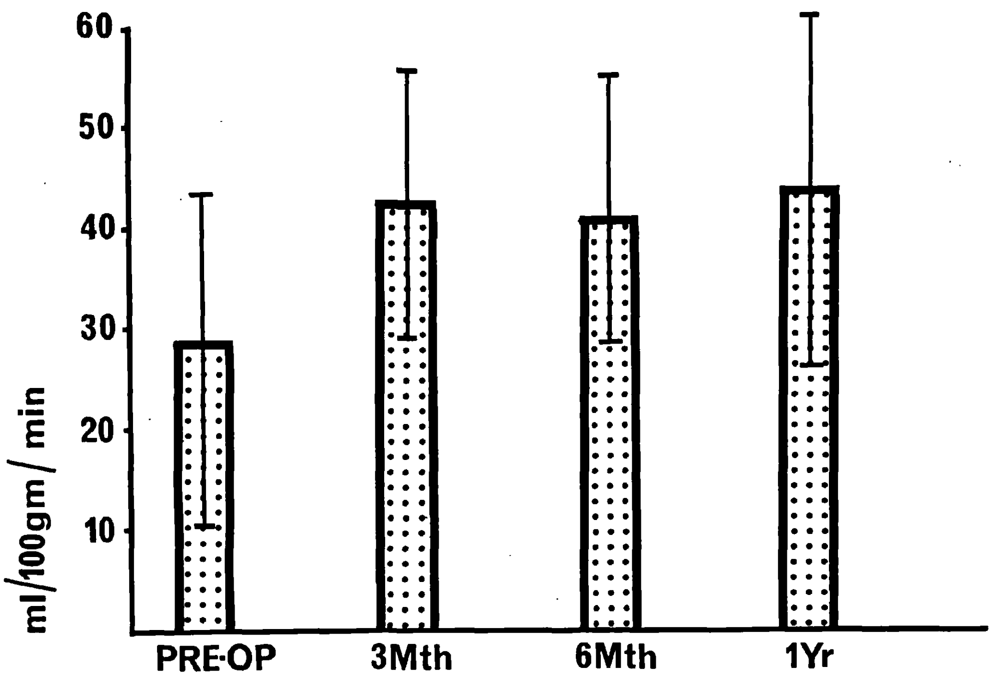


Fig. 14 : Aorto-iliac thromboendarterectomy group. Muscle blood flow results in the successful group over the first post-operative year.

sometimes showed variation in the level of peak blood flow, the improvement in muscle blood flow was well maintained. There was no statistically significant difference in the peak muscle blood flow during the post-operative follow-up.

## AORTO-ILIAC GRAFT

Nine patients had an aorto-iliac graft inserted and 18 limbs have been studied. The lesions operated upon are given in Table 9.

| Lesion | No. |
|---|---|
| Diffuse aorto-iliac disease | 5 |
| Occlusion of aorto-iliac bifurcation | 3 |
| Common iliac occlusion | 1 |

Table 9 : The lesions present in those patients with an aorto-iliac prosthetic graft.

One patient developed an occlusion of one limb of the graft in the immediate post-operative period and required amputation of the limb. Five of the remaining 8 patients said that they had an improvement in claudication distance and 3 did not. The results are shown in Table 10.

| | Improvement | | | No Improvement | | |
|---|---|---|---|---|---|---|
| | Peak Blood Flow ml/100 gm/min | Time to Peak Blood Flow (min.) | Duration of Peak Blood Flow (min.) | Peak Blood Flow ml/100 gm/min | Time to Peak Blood Flow (min.) | Duration of Peak Blood Flow (min.) |
| Before Operation | 26.7 ± 12.4 | 1.54 ± 1.23 | 2.64 ± 1.44 | 27.6 ± 16.5 | 2.12 ± 1.99 | 2.07 ± 1.16 |
| After Operation | 41.1 ± 19.5 | 0.77 ± 0.45 | 1.89 ± 0.96 | 25.4 ± 18.7 | 1.77 ± 1.69 | 2.48 ± 1.08 |

Table 10 : Aorto-iliac graft group. Comparison between muscle blood flow in patients with and without improvement in intermittent claudication.

In this group the muscle blood flow estimations did not agree so closely with the clinical picture: 2 of the patients who claimed improvement in intermittent claudication showed no increase in peak blood flow. However, in those patients without improvement in walking distance, there was no increase in muscle blood flow following operation. The increase in peak blood flow in the improved group was not statistically significant. Only 2 limbs studied had peak blood flow, time to and duration of peak blood flow within the normal limits.

The influence of a distal occlusive lesion was again investigated. There was no improvement in muscle blood flow in any limb with a distal occlusion. Two patients had a unilateral distal occlusion (1 short superficial femoral and 1 popliteal occlusion). Although both patients said that their claudication was relieved, there was no improvement in the values obtained for muscle blood flow following operation.

## DISCUSSION

The overall success rate for this group was 61 per cent, as gauged by an improvement in or complete relief of intermittent claudication. The thromboendarterectomy group had a success rate of 68 per cent. Gomes et al. (1967) reported a success rate of 69 per cent for both thromboendarterectomy and graft replacement but unfortunately did not give the figures for each group. Dickinson et al. (1967) reported 71 per cent of cases improved or symptom-free.

One of the striking features of both groups was the deleterious effects of a distal occlusive lesion combined with the proximal lesion. In this series, 16 limbs had combined lesions and only 5 (31 per cent) of these showed an improvement in peak muscle blood flow and relief of claudication. Dickinson (1967) found that 44 per cent of failures in aorto-iliac surgery were due to deterioration in associated femoro-popliteal diseases. The real problem, of course, is deciding whether the proximal lesion is significant in the production of the intermittent claudication. Obviously, if it is not, then the profunda femoris artery is carrying as much blood as it can and no surgery proximal to this will help. Strandess and Bell

(1965) also make this point and claim that, on comparing the systemic blood pressure (measured in the arm) with the femoral arterial pressure, the presence of a pressure gradient denotes a significant lesion. The muscle blood flow measurements in the leg do not seem to be able to solve this particular problem. This, of course, is to be expected for, as Vonruden et al. (1964) have pointed out, in the presence of two stenoses in a vessel, the resulting flow will be that of the more significant and not the summation of the stenoses. Thus, the alleviation of the lesser stenosis will not result in an increase in blood flow.

Only 13 out of the 30 successful limbs fell within the normal range for peak blood flow, time to peak blood flow and duration of peak blood flow. An improvement in intermittent claudication was therefore found despite the fact that the muscle blood flow results had not returned to normal in all respects.

In Chapter II it was shown that patients without main vessel occlusion - that is, 'generalised' disease - may have muscle blood flow outwith the normal range and yet might not complain of intermittent claudication. It may be that some of these patients fall into this category following removal of a main vessel occlusion. Also, some patients had an improvement but not complete relief of claudication and in their cases the muscle blood flow would not be expected to be within the normal range.

It is more difficult to explain why patients showing no improvement in peak muscle blood flow should have an improvement in claudication distance. Larsen and Lassen (1966) also found an improvement in claudication distance following a course of regular exercises but found no improvement in peak muscle blood flow. It may be, of course, that a localised lesion in the anterior tibial artery has not permitted any real improvement to the leg as a whole to be manifest. In the present series, 6 patients claimed relief of claudication but had no improvement in peak muscle blood flow. Review of the aortograms of these cases showed that 4 had a good run-off through the anterior and posterior tibial arteries and that 2 showed atheromatous changes without occlusion in both tibial vessels. Therefore, a localised lesion in the anterior tibial artery did not appear to be the explanation. Another explanation may be that in fact these patients have not become fully ambulant following the operation and that they did not have a true improvement in intermittent claudication. The simple instruction of telling a patient to slow down his walking pace may relieve claudication completely (Semple, 1953). The muscle blood flow results would suggest that the latter explanation is possibly the reason for this paradoxical finding.

Study of the individual figures during the period of follow-up showed that occasional wide fluctuations occurred in peak muscle blood flow with respect to time. This confirms the concept that peripheral arterial disease does not follow an inexorably downward course but is a dynamic disease. Thus, a thrombosis or embolus in a vessel may cause deterioration in intermittent claudication but, with the opening up of the collateral circulation or even the main channel, there is an improvement in this symptom. As Stein (1964) says with regard to this subject, there is "a continuous process of enlargement of existing pathways or the formation of new ones."

SUMMARY

Measurements of muscle blood flow have been made before and after surgical procedures carried out on the lower aorta and iliac vessels.

The muscle blood flow measurements reflect accurately the success or failure of the operation in that patients who had an improvement in intermittent claudication had an improvement in muscle blood flow. Those patients with no improvement in intermittent claudication had no improvement in muscle blood flow. It was also found that, where surgery was successful, it was possible for the muscle blood flow to return to a normal type of pattern.

The most striking finding was that those patients with an occlusion distal to the inguinal ligament in addition to the proximal lesion had very little improvement in muscle blood flow following surgery.

When the surgical procedure was successful, the increase in peak muscle blood flow was well maintained in the first post-operative year.

## MUSCLE BLOOD FLOW FOLLOWING SURGERY TO THE FEMORAL AND POPLITEAL ARTERIES

Most of the blood flow studies carried out to assess the results of surgery to the femoral and popliteal arteries have been done using an electro-magnetic flowmeter (Golding and Cannon, 1966; Cappelen and Hall, 1963; Little et al., 1968; Renwick et al., 1968). This method will measure the blood flow occurring through major arteries and will give information on whether the immediate surgical procedure has been satisfactory. This is very important as it indicates whether further operative surgery should be carried out. However, with respect to intermittent claudication, it is of little value as it measures blood flow through a major vessel and gives no information about blood flow at capillary level. It has also been pointed out that the blood flow measured through grafts in the resting state have little bearing on what subsequently happens to muscle blood flow during exercise (Mannick, 1966). It is that latter measurement which is important in the evaluation of the success of any surgical procedure.

Although hyperaemia in calf blood flow following direct arterial surgery has been demonstrated by Eastcott (1953) and Wellington et al. (1966), few studies have been carried out on muscle blood flow during exercise. No long-term studies have been carried out on muscle blood flow following surgery and, accordingly, the $^{133}$xenon clearance technique has been used to measure muscle blood flow before and after reconstructive surgery to the femoral and popliteal arteries.

## Method

Muscle blood flow was measured following ischaemic exercise as described previously. The flow measurements were made pre-operatively and approximately 3 months after operation. The patients were seen at intervals of 6 months and 1 year after operation and muscle blood flow studies were again carried out. All patients had translumbar aortography carried out to determine the extent of the disease.

## Results

A total of 47 limbs in 45 patients have been studied. Twenty-seven limbs in 25 patients had thromboendarterectomy of the superficial femoral artery and/or popliteal artery, and 20 limbs in 20 patients had a bypass vein graft inserted. The indication for surgery was intermittent claudication in every case. Three patients had a bypass vein graft in one limb and a thromboendarterectomy in the other.

## SUPERFICIAL FEMORAL AND POPLITEAL THROMBOENDARTERECTOMY

Twenty-seven limbs in 25 patients have been studied. The lesions operated on are given in Table 11.

| Lesion | No. of Legs |
|---|---|
| Total occlusion of the superficial femoral artery | 8 |
| Short occlusion at the adductor magnus hiatus | 5 |
| Stenosis at the adductor magnus hiatus | 10 |
| Occlusion of the popliteal artery | 4 |

Table 11 : Femoral and popliteal thromboendarterectomy group. The lesions operated on.

The results are given in Table 12. The peak blood flow increased by 76 per cent following operation. Time to peak blood flow and duration of peak blood flow were reduced by 68.3 per cent and 44.3 per cent respectively. ($p < 0.001$ in all cases).

| | Peak Blood Flow ml/100 gn/min | Time to Peak Blood Flow (min.) | Duration of Peak Blood Flow (min.) |
|---|---|---|---|
| Before Operation | 28.3 ± 11.3 | 1.80 ± 0.79 | 2.96 ± 1.43 |
| After Operation | 49.8 ± 19.8* | 0.57 ± 0.47* | 1.65 ± 0.96* |

Table 12 : Femoral and popliteal thromboendarterectomy group. Muscle blood flow results before and after surgery (mean and 1 S.D.).
* $p < 0.001$

Of the group, 5 limbs (18.5 per cent) derived no benefit with respect to claudication and did not have a return of previously absent pulses. Two of the patients had further arteriography and this confirmed that the operated segment had undergone occlusion. The peak blood flow results from this group are shown in Table 13. Three patients showed a slight rise in peak blood flow but there was no significant increase in muscle blood flow in the group as a whole.

| Patient | Age | Peak Blood Flow (ml/100 gm/min) | |
|---|---|---|---|
| | | Before Operation | After Operation |
| R.B. | 62 | 20.9 | 20.9 |
| J.L. | 51 | 26.3 | 29.8 |
| J.McA | 51 | 21.7 | 14.9 |
| J.S. | 59 | 13.7 | 20.1 |
| M.D. | 48 | 26.5 | 33.0 |
| Mean & SD | | 21.8 ± 5.2 | 23.7 ± 7.5 |

Table 13 : Femoral and popliteal thrombo-endarterectomy group. Peak muscle blood flow before and after surgery in patients without improvement in intermittent claudication.

This left 22 limbs which were considered successful on clinical grounds, with a return of previously absent pulse and an improvement in oscillometry. Intermittent claudication was improved or relieved in every case. Twenty-one of the limbs showed an improvement in peak blood flow. One patient (T.H.) claimed that his claudication had improved yet showed only a slight increase in peak muscle blood flow. Study of his results showed that the time taken to reach peak blood flow was reduced from 1.7 min. to 0.3 min. following operation.

Fourteen (64 per cent) of the 22 successful limbs fell within the normal range for peak blood flow, time to peak blood flow and duration of peak blood flow.

Muscle blood flow was calculated at minute intervals following release of the cuff for the 22 successful limbs, both pre-operatively and post-operatively. These are compared in Fig. 15. It can readily be seen that, following successful surgery, the muscle blood flow returns to a normal type of pattern. In 14 patients, measurements of muscle blood flow were made in the non-operated limb and the mean results are given in Table 14.

| | Peak Blood Flow ml/100 gm/min | Time to Peak Blood Flow (min.) | Duration of Peak Blood Flow (min.) |
|---|---|---|---|
| Before Operation | 41.0 ± 10.7 | 0.59 ± 0.42 | 1.64 ± 0.81 |
| After Operation | 41.8 ± 15.5 | 0.61 ± 0.41 | 1.57 ± 0.64 |

Table 14 : Femoral and popliteal thromboendarterectomy group. Muscle blood flow results from 14 non-operated limbs.

It can be seen that there is no difference in the muscle blood flow following successful surgery to the opposite limb. The flow patterns before and after operation are almost identical in this control group. They are compared in Fig. 16.

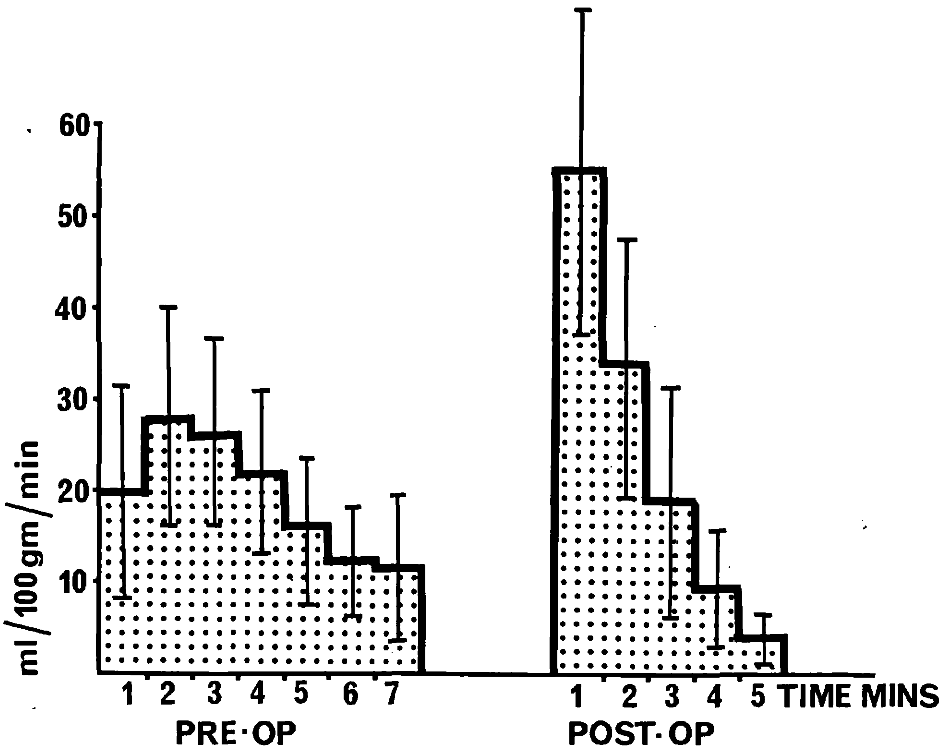


Fig. 15 : Femoral and popliteal thromboendarterectomy group. Muscle blood flow at minute intervals following release of the occluding cuff. Patients with an improvement in intermittent claudication.

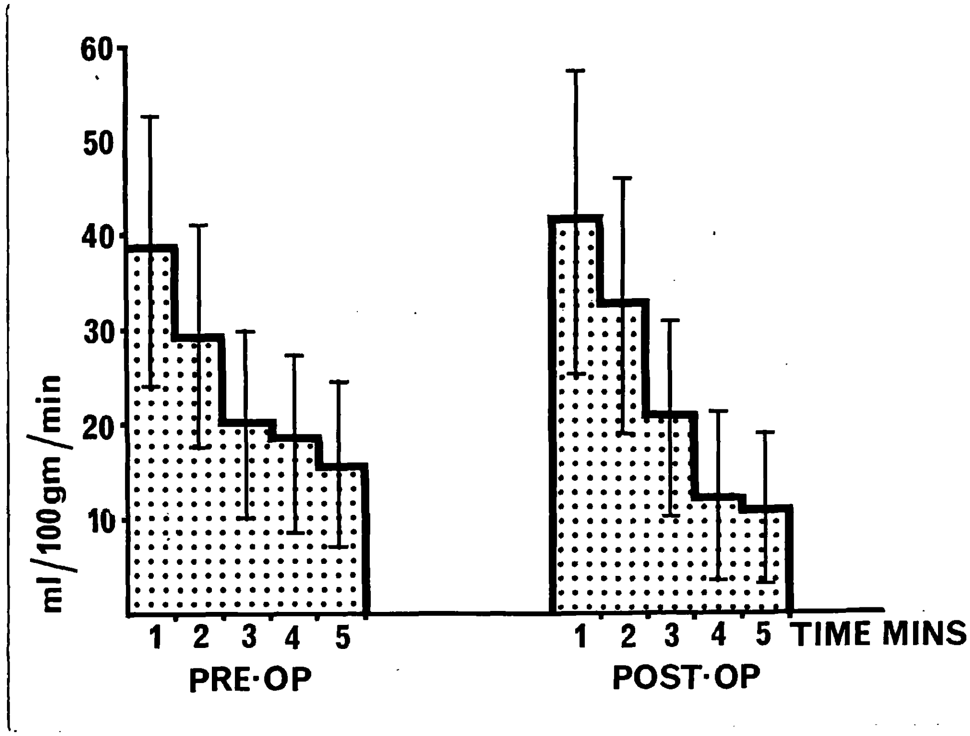


Fig. 16: Femoral and popliteal thromboendarterectomy group. Muscle blood flow at minute intervals following release of the occluding cuff. Non-operated limbs.

One of this group died of coronary artery disease within 6 months of operation. Eighteen of the remaining 20 have been followed up for one year. On clinical grounds, one patient (T.M., 2 limbs) had evidence of occlusion, and this was confirmed by aortography.

The muscle blood flow studies in the 16 limbs at 3 months, 6 months and 1 year showed that the post-operative level achieved at 3 months was well maintained at 1 year (Fig. 17). Although there tended to be a slight fall at 1 year, this was not statistically significant. However, further study of the individual figures showed that there were 2 clear-cut types of response (termed A and B). Eight patients showed response A in that the muscle blood flow showed a marked improvement at 3 months but then began to decline and return towards the pre-operative level. This is illustrated in Fig. 18. Although the peak muscle blood flow is significantly higher than the pre-operative level at 3 months and 6 months ($p < 0.001$ and $< 0.02$ respectively), it is not statistically significantly higher at 1 year. Also, the peak muscle blood flow at 1 year is significantly reduced from that at 3 months ($p < 0.01$).

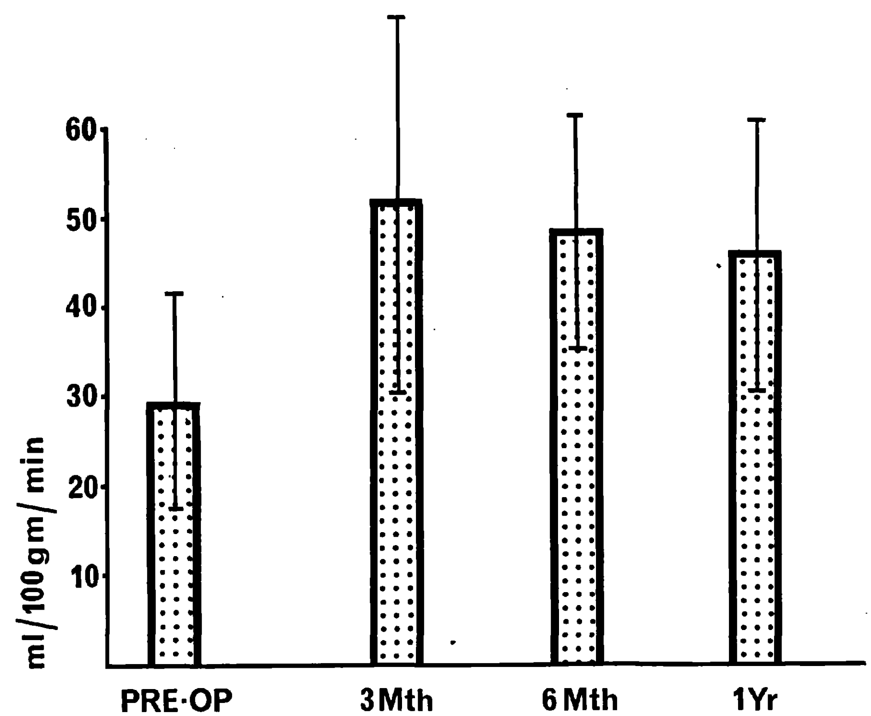


Fig. 17 : Femoral and popliteal thromboendarterectomy group. Muscle blood flow studies over the first post-operative year.

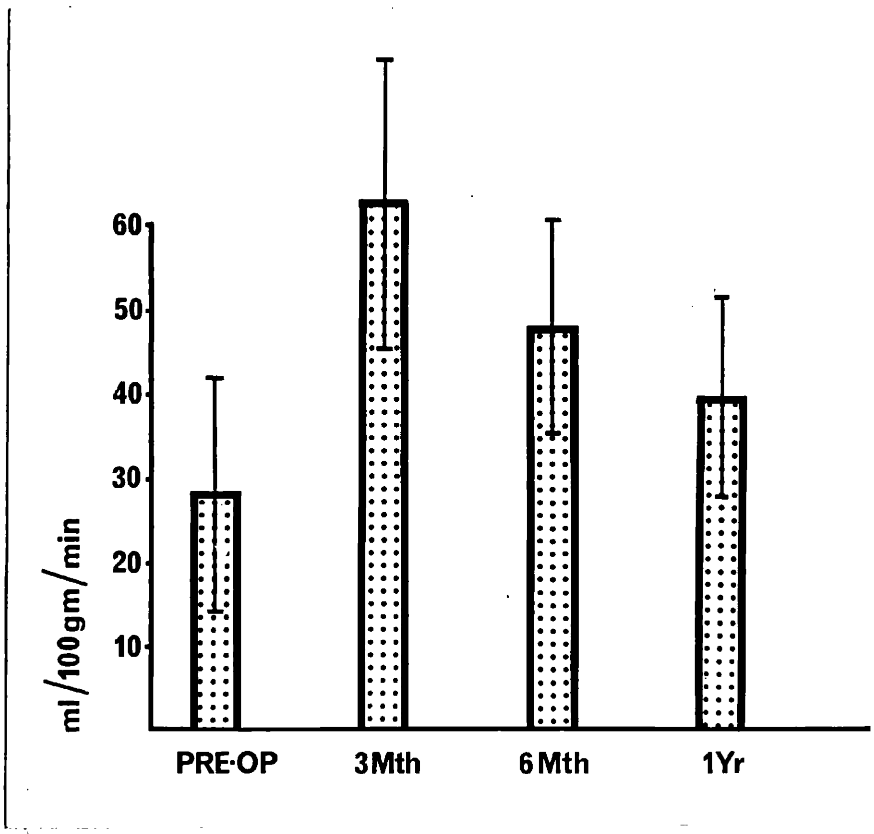


Fig. 18 : Femoral and popliteal thromboendarterectomy group. Eight patients who showed a rise in peak muscle blood flow 3 months after operation. Thereafter the peak muscle blood flow gradually declined towards the pre-operative level (Response A).

One of the patients who showed this response illustrates the point. L.D., aged 47 years, had suffered from intermittent claudication for 2 years in his left leg and had a thrombo-endarterectomy with vein patch carried out for this. His pre-operative peak blood flow was 29.7 ml./100 gm./min. Three months following surgery, the peak blood flow was 63.6 ml./100 gm./min. Nine months later, he began to complain of intermittent claudication and the peak muscle blood flow was found to be 35.4 ml./100 gm./min. At 3 months and 1 year after surgery, arteriography was carried out and Fig. 19 shows the films. It can be seen that at 3 months the endarterectomised segment of the femoral artery is fully patent but at 9 months there is marked narrowing proximal to this.

In the other type of response, B, the muscle blood flow remained at the improved level found at 3 months and in some cases continued to improve during the period of follow-up. This is illustrated in Fig. 20. At 3 months, 6 months and 1 year after operation, the peak muscle blood flow is significantly higher than pre-operatively ($p < 0.02$, 0.02 and 0.01 respectively).

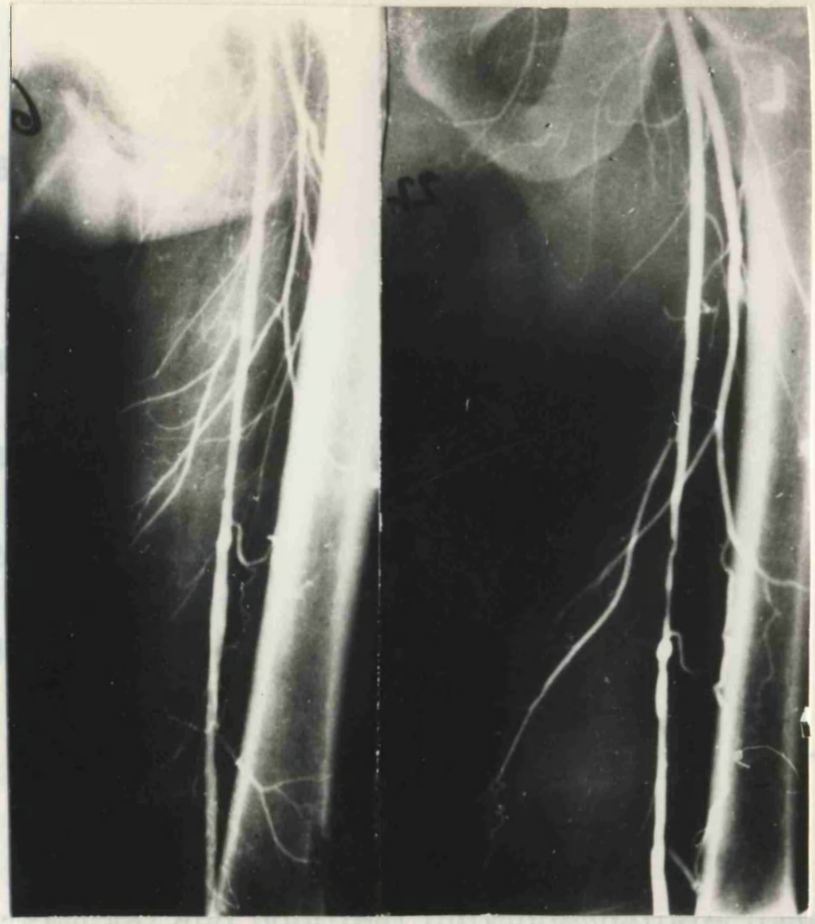

Fig. 19: L.D. (47) Aortograms at 3 months and 1 year following operation.

| | |
|---|---|
| Pre-op. P.B.F. | 29.7 ml/100 gm/min |
| 3 months post-op. P.B.F. | 63.6 ml/100 gm/min |
| 1 year post-op. P.B.F. | 35.4 ml/100 gm/min |

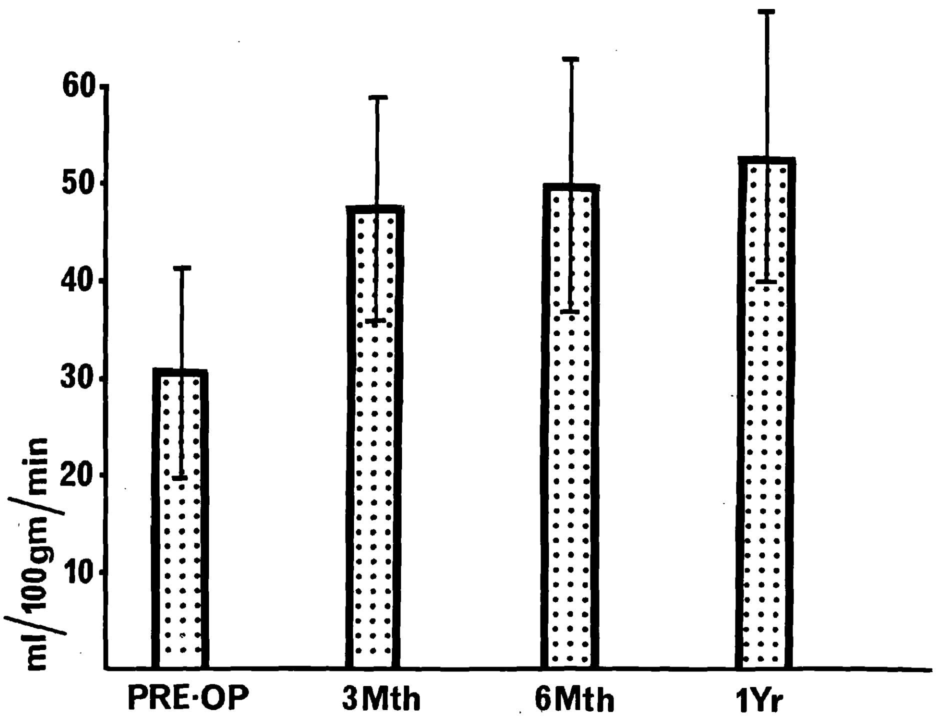


Fig. 20 : Femoral and popliteal thromboendarterectomy group (8 patients). Once the post-operative peak muscle blood flow is achieved, it is well maintained over the year of follow-up (Response B).

## VEIN BYPASS GRAFT

Twenty limbs in 20 patients have been assessed in this group. The lesions are shown in Table 15.

| Site of Occlusion | No. |
|---|---|
| Total occlusion of the superficial femoral artery | 9 |
| Occlusion at the adductor hiatus | 7 |
| Short occlusion of the popliteal artery | 4 |

Table 15 : Bypass vein graft group. The distribution of the lesions operated on.

The saphenous vein was used for the graft in 19 cases and the cephalic vein in 1. All had the bypass graft inserted from the common femoral artery to the popliteal artery. Three patients in this group (15 per cent) had clinical evidence of graft occlusion at 3 months in that their claudication had not improved and the pulses were the same as before operation. No patient in the failed group showed an improvement in peak muscle blood flow after operation. However, one of the patients claimed that his claudication had improved, yet his muscle blood flow fell from 29.2 ml./100 gm./min. to 16.9 ml./100 gm./min. Arteriography was carried out on this patient and this confirmed occlusion of the graft.

The remaining 17 had relief of claudication and there was no clinical evidence of graft failure. The results are shown in Table 16.

| | Peak Blood Flow ml/100 gm/min | Time to Peak Blood Flow (min) | Duration of Peak Blood Flow (min) |
|---|---|---|---|
| Before Operation | $24.0 \pm 8.6$ | $1.70 \pm 0.84$ | $3.22 \pm 1.15$ |
| After Operation | $51.5 \pm 14.3$ | $0.38 \pm 0.17$ | $1.42 \pm 0.60$ |

Table 16 : Vein bypass graft group. Muscle blood flow during first post-operative year.

The peak blood flow increased by 114.6 per cent following operation. Time to peak blood flow was reduced by 76.5 per cent, and duration of peak blood flow by 55.9 per cent. The post-operative peak blood flow was significantly higher, the time to reach peak blood flow and duration of peak blood flow significantly shorter ($p < 0.001$ in all cases).

One patient (K.B.) had a minimal rise in peak blood flow following operation but had relief of his symptoms. In this patient, the time taken to achieve peak muscle blood flow after ischaemic exercise was reduced from 3.3 minutes to 0.5 minutes. Four patients had relief of claudication and a marked improvement in muscle blood flow, yet the peak blood flow was not within the normal range as defined in Chapter I.

Readings at minute intervals following release of the occluding cuff were calculated for the 17 successful limbs and the results are shown in Fig. 21. After operation, the blood flow pattern is strikingly different and has returned to a normal type of pattern.

In 13 patients in this group, muscle blood flow measurements were carried out on the non-operated limb and the results are given in Table 17. When the flow patterns are studied, it can be seen that they are almost identical before and 3 months after surgery to the opposite limb. The flow patterns in the non-operated limb are illustrated in Fig. 22.

| | Peak Blood Flow ml/100 gm/min | Time to Peak Blood Flow (min) | Duration of Peak Blood Flow (min) |
|---|---|---|---|
| Before Operation | 46.4 ± 14.6 | 0.38 ± 0.37 | 1.49 ± 0.89 |
| After Operation | 49.2 ± 16.6 | 0.40 ± 0.34 | 1.32 ± 0.70 |

Table 17 : Bypass vein graft group. Peak muscle blood flow results in the non-operated limb.

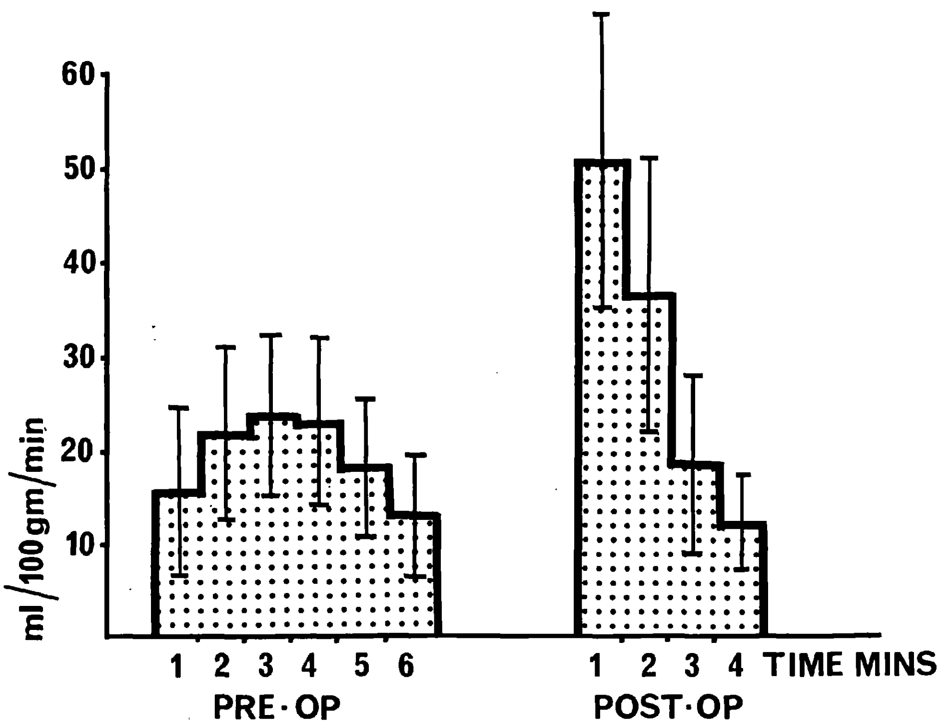


Fig. 21 : Vein bypass graft group. Muscle blood flow calculated at minute intervals following release of the occluding cuff. Patients with an improvement in intermittent claudication.

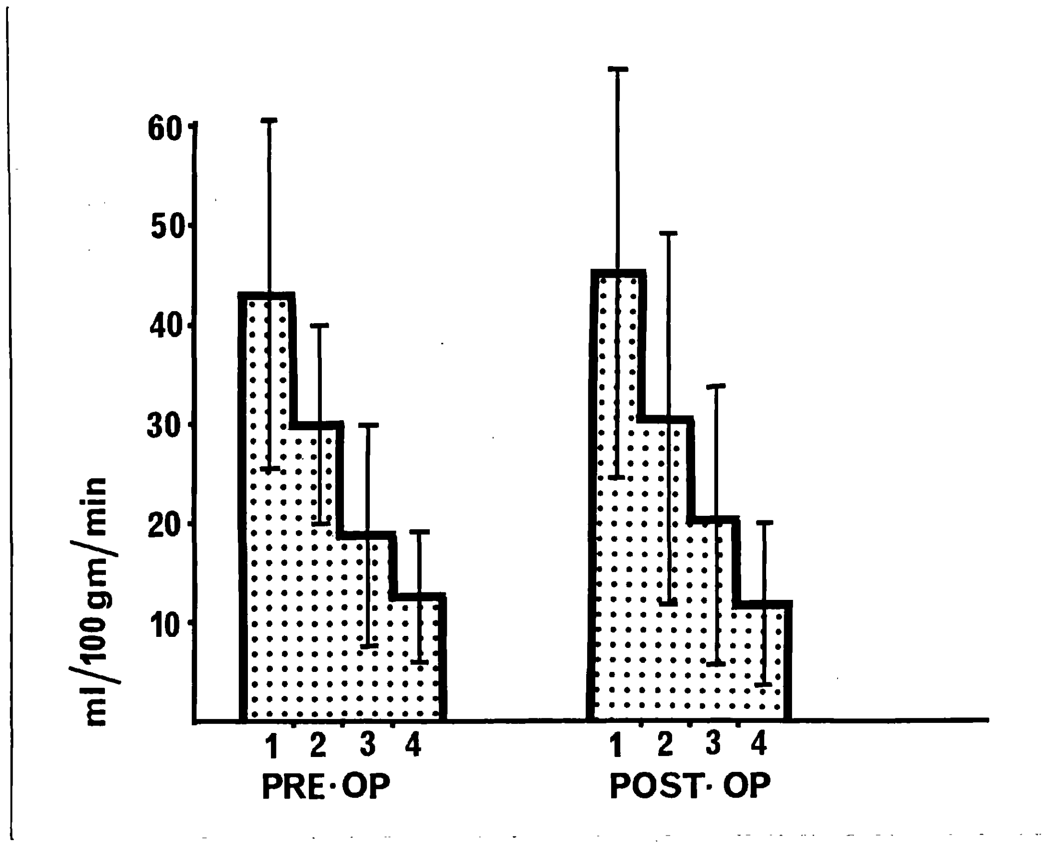


Fig. 22 : Vein bypass graft group. Muscle blood flow calculated at minute intervals following release of the occluding cuff. Non-operated limbs.

During the follow-up of these patients, one developed an occlusion at 5 months (confirmed by arteriography). Muscle blood flow estimations have been carried out at 3 months, 6 months and 1 year on 8 patients. Once the post-operative level has been achieved, this is well maintained (Fig. 23). The rise in peak muscle blood flow following operation was significantly higher at 3 months ($p < 0.01$), 6 months ($p < 0.001$) and 1 year ($p < 0.005$). There was no statistically significant change in the level of muscle blood flow during the period of follow-up (Fig. 23). One of these patients showed the Type A response seen in the group who had thromboendarterectomy, that is a rise in muscle blood flow at 3 months and thereafter a gradual reduction in muscle blood flow. Two patients showed a gradual increase in peak muscle blood flow during the first post-operative year.

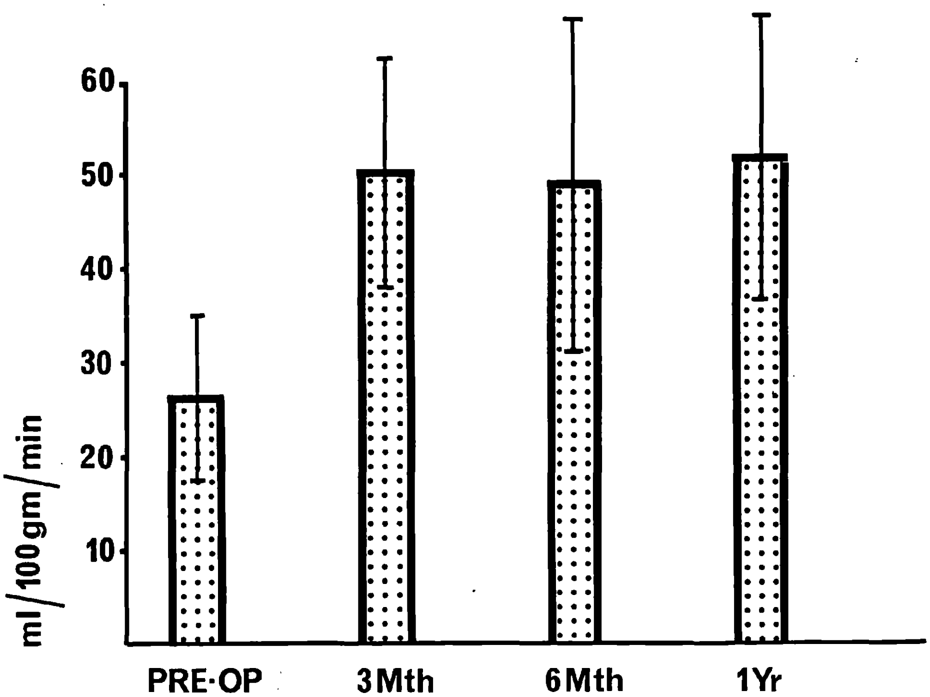


Fig. 23 : Vein bypass graft group. Peak muscle blood flow results in the first year after operation.

## DISCUSSION

Taking the group as a whole, 8 patients had evidence on clinical grounds of failure of the operative procedure when reviewed at 3 months and in each case the blood flow estimations confirmed this. This gives an overall failure rate of 16.7 per cent.

In the femoral and popliteal thromboendarterectomy group, 25.9 per cent of the limbs operated on had re-occluded at 1 year. Spencer and Reinhoff (1963), operating on a similar series of patients, reported a failure rate of 29 per cent.

After 1 year, 15 per cent of the patients with saphenous vein bypass grafts had evidence of occlusion. Again, this was reflected extremely well in the muscle blood flow studies as no patient who had failed showed an improvement in blood flow. Linton and Darling (1962) reported a failure rate of 9 per cent in a series followed for between 6 months and 2 years. Little et al. (1968) reported an early failure rate (3 months) of 27.5 per cent and Mannick et al. (1967) reported an early failure rate of 29 per cent and a late failure rate of 35 per cent on patients operated on for severe peripheral ischaemia.

In both groups studied, the post-operative blood flow measurements correlated well with the clinical situation and in particular with the diagnosis of failure. No patient who did not have an improvement in claudication had a significant improvement in blood flow. However, 2 patients stated that there was an improvement in claudication distance yet the peak muscle blood flow showed no improvement. In both these cases, the onset to peak blood flow was markedly reduced from the pre-operative value. (This was also observed in 4 limbs in the aorto-iliac thromboendarterectomy group).

Using $^{24}$Na as the local indicator, Walder (1958) has shown that, during walking, there is a gradual build-up of muscle tension. In patients with arterial disease, owing to reduced arterial perfusion pressure distal to an occlusion, the muscle tension may be greater than the perfusion pressure. This will result in muscle blood flow falling to zero and severe claudication. The rise in inflow pressure following surgical removal of a proximal occluding lesion may allow the peak muscle blood flow to be achieved more rapidly and allow adequate blood to perfuse the muscle, thus preventing the muscle pressure from rising above the inflow pressure.

Another explanation may be that, as a result of the more rapid inflow of arterial blood after removal of the obstruction, the accumulation of metabolites responsible for intermittent claudication (Lewis and Grant, 1925) does not occur.

Also, it must be remembered that intermittent claudication is a subjective symptom and to assess improvement solely on this symptom can on occasion be misleading. To illustrate this fact, one patient claimed cure of his claudication following operation but the peak muscle blood flow showed no improvement. Arteriography confirmed that the operated segment was occluded. Presumably the patient had not returned to his pre-operative walking speed and his improvement in claudication was not real.

Harrison and Preez (1964) noted that, following an occlusion after direct arterial surgery, the claudication on occasion was not as severe as it was pre-operatively. They suggested that this may be due to the increased arterial perfusion pressure during the successful period resulting in the opening up of the collaterals which remain patent when the main vessel becomes occluded. This is an attractive argument but the results found in the present series do not support it as the muscle blood flow did not increase.

In those cases in which surgery is successful, the blood flow sometimes returns to a pattern normal in every respect (Chapter I, p. 30). Mannick et al. (1966), using the local clearance of sodium labelled with $I^{131}$, found that the clearance after exercise returned to normal following successful surgery. Snell et al. (1960), using venous occlusion plethysmography, also found that the pattern of reactive hyperaemia tended toward normal following successful removal of an arterial occlusion.

The sequential blood flow studies provided useful information. In 50 per cent of the thromboendarterectomy group, followed up for 1 year after operation, it was noted that, after a marked rise in blood flow at 3 months, the blood flow gradually decreased to pre-operative levels. This led to an occlusion in one case and to a recurrence of symptoms in another. This is not a surprising finding as the vessel is still subject to the same disease process as before operation, and presumably the recurrence of atherosclerotic lesions has been responsible for the decrease in peak blood flow. This was actually observed in the patient illustrated in Fig. 19. This, of course, does not necessarily imply that every case will eventually fail. The disease process may remain static. In fact, many of the cases remain well and symptom-free for many years following surgery.

Following a bypass operation with the saphenous vein, it appears that the blood flow in some cases gradually increased with time. Mannick and Jackson (1966) noted that there was a gradual build up in blood flow through saphenous vein bypass grafts over several days following surgery. Strandess and Bell (1966) also described a gradual build up of limb blood flow over a period of months after surgery. This may be due to the opening up of the collateral circulation in the distal arterial tree, as a result of the increased head of pressure.

The diagnosis of failure of direct arterial surgery is usually straightforward on clinical examination in that peripheral pulses are absent and there is no improvement in intermittent claudication. In 2 patients, the muscle blood flow estimations failed to increase in the post-operative period, yet the patients claimed relief of claudication. Arteriography was carried out and this confirmed that the operated segment had in fact occluded. Thus, muscle blood flow studies can be of value in selecting those patients who require post-operative arteriography.

## SUMMARY OF CHAPTER III

Muscle blood flow studies have been carried out before and after direct arterial surgery. The pattern of muscle blood flow following ischaemic exercise was found to return towards normal in those cases in whom surgery was successful. In no case in which surgery failed was there any significant improvement in muscle blood flow. Occasionally patients with an improvement in intermittent claudication had no improvement in muscle blood flow but in each case there was a significant reduction in time taken to reach peak blood flow.

In the thromboendarterectomy group, several patients showed a marked improvement in muscle blood flow at the 3-month period but thereafter the blood flow began to return to the pre-operative level.

In the saphenous vein bypass group, only one patient showed this tendency and some of the patients had a gradual improvement in muscle blood flow over the year that they were followed up.

# CHAPTER IV

# MUSCLE BLOOD FLOW FOLLOWING LUMBAR SYMPATHECTOMY

Lumbar sympathectomy has been used in the management of peripheral arterial disease for many years but there has been considerable controversy as to its exact role (Smithwick, 1957). Many studies have been made of the effect of lumbar sympathectomy on the resting blood flow through the skin and the increase in blood flow following this operation is well-documented (Stein et al., 1948; Barcroft and Walker, 1949; Duff, 1951; Tice et al., 1963). Studies which have been carried out on the effect of lumbar sympathectomy on muscle blood flow were made, using venous occlusion plethysmography and, although when it is used on the calf it is largely a measure of muscle blood flow, the technique cannot differentiate between blood flow occurring through skin or muscle. Most workers are agreed that sympathectomy does not improve muscle blood flow (Grant and Pearson, 1938; Stein et al., 1948; Barcroft et al., 1952). There is no doubt, however, that on occasion a marked improvement in intermittent claudication seems to occur following this operation. The problem is to explain the successes rather than the failures (Dornhorst, 1950). One of the main problems in evaluating the effect of sympathectomy is the lack of a reliable post-operative yardstick to measure any improvement (Mavor, 1955). Accordingly, the $^{133}$xenon clearance technique has been used to measure muscle blood flow before and after lumbar sympathectomy. As no long-term studies in muscle blood flow have been made after sympathectomy, the technique has been used to measure muscle blood flow during the first year after operation.

## Method

Each patient was rested for a minimum of half an hour before any measurements were made. The resting blood flow was measured for 10 minutes as described previously. The patient underwent a period of ischaemic exercise and the level of the peak blood flow, time taken to peak blood flow and duration of peak blood flow estimated. All patients had measurements made approximately 2-3 days before surgery. Post-operatively, muscle blood flow studies were carried out at 7-10 days, 1 month, 3 months, 6 months and 1 year. It was not possible to carry out the estimations at each of these time intervals in every patient but an attempt was made to do so as far as possible.

The indications for lumbar sympathectomy in these cases are given in Table 18. Those patients operated on for intermittent claudication had atherosclerotic occlusive disease so severe and extensive that they were regarded as unsuitable for direct arterial surgery. Although intermittent claudication was the main indication for operation in 26 limbs, 38 patients included this symptom among their complaints.

| Complaint | No. of Limbs |
|---|---|
| Intermittent claudication | 26 |
| Severe ischaemic changes or gangrene of toes | 14 |
| Cold foot | 6 |
| Raynaud's disease | 1 |
| Rest pain | 4 |

Table 18 : Indications for lumbar sympathectomy

<u>Results</u>

A total of 51 limbs in 50 patients have been studied. The mean resting blood flow was 1.67 ml./100 gm./min. (S.D. ± 0.97) before operation and 1.40 ml./100 gm./min. (S.D. ± 0.59) after operation. There was no statistically significant difference in resting blood flow.

The results for muscle blood flow in response to ischaemic exercise before and after lumbar sympathectomy are given in Table 19. There was no statistically significant difference in any of the parameters studied following operation.

| | Peak Blood Flow ml/100 gm/min | Time to Peak Blood Flow (min) | Duration of Peak Blood Flow (min) |
|---|---|---|---|
| Before Operation | 22.8 ± 11.2 | 1.84 ± 1.23 | 3.23 ± 1.33 |
| After Operation | 23.9 ± 12.8 | 1.57 ± 1.23 | 2.79 ± 1.37 |

Table 19 : Muscle blood flow before and after lumbar sympathectomy in 51 limbs (mean and 1 S.D.)

Claudication distance was assessed before and after operation. This was done on a subjective basis by simple questioning of the patient. Care was taken to ask each patient whether his walking pace was the same as before operation. Twenty-seven (71.1 per cent) stated that they had no improvement in claudication; 8 (21.1 per cent) had improvement; 3 (7.9 per cent) said that their claudication distance had deteriorated. The muscle blood flow results for each of these groups are shown in Table 20. There was no statistically significant difference between any of the groups for the 3 parameters studied.

| | Peak Blood Flow ml/100 gm/min (mean and SD) | Time to Peak Blood Flow (mins) | Duration of Peak Blood Flow (mins) |
|---|---|---|---|
| | Intermittent Claudication Improved | | |
| Before Operation | 22.1 ± 11.4 | 1.69 ± 1.29 | 3.45 ± 1.66 |
| After Operation | 23.1 ± 13.6 | 1.96 ± 1.39 | 2.83 ± 1.03 |
| | Intermittent Claudication Unimproved | | |
| Before Operation | 21.0 ± 11.5 | 2.20 ± 1.78 | 3.38 ± 1.28 |
| After Operation | 22.0 ± 13.6 | 1.73 ± 1.27 | 2.62 ± 1.67 |
| | Intermittent Claudication Worse | | |
| Before Operation | 20.0 ± 3.7 | 2.23 ± 1.55 | 3.23 ± 1.76 |
| After Operation | 20.4 ± 8.7 | 1.60 ± 0.64 | 2.27 ± 1.14 |

Table 20 : Sympathectomy group.

On occasion, an improvement in muscle blood flow was seen but this had no constant relationship to the improvement or lack of improvement in walking distance. There was no correlation between muscle blood flow and the improvement or deterioration in the symptom of intermittent claudication. Measurements of muscle blood flow were carried out in the non-operated limb in 35 patients and the results are given in Table 21. There was no significant difference in the level of peak blood flow, the time to achieve peak blood flow or the duration of peak blood flow.

| | Peak Blood Flow ml/100 gm/min | Time to Peak Blood Flow (min) | Duration of Peak Blood Flow (min) |
|---|---|---|---|
| Before Operation | 34.2 ± 13.8 | 1.04 ± 0.90 | 2.03 ± 1.00 |
| After Operation | 34.6 ± 15.4 | 1.21 ± 1.33 | 1.84 ± 0.88 |

Table 21 : Sympathectomy group. Muscle blood flow results from the non-operated limb.

Of the 38 patients assessed with respect to claudication, 35(24 limbs) have been followed for 1 year. The blood flow measurements were carried out at 7 - 10 days, 1 month, 3 months

6 months and 1 year post-operatively. Again, those who had an improvement in claudication distance were compared with those who did not. Some of the patients whose walking distance improved after operation showed a gradual improvement in blood flow over the period of follow-up but, taking the group as a whole, there was no statistically significant difference between the peak blood flow before operation compared to that at 1 year. The results are shown in Figs. 24 and 25.

The patients who did not have an improvement in claudication showed no fixed trend; some patients showed a gradual increase in muscle blood flow during the period of observation, others did not and others showed a gradual deterioration. There was no statistically significant change in muscle blood flow over the period of follow-up.

In 20 patients, muscle blood flow estimations were made in the non-operated limb before operation and 3 months, 6 months and 1 year after operation. The results are shown in Fig. 26. Taking the mean results of this group, the blood flow estimations remained very steady over the year and there was no statistically significant change at any time.

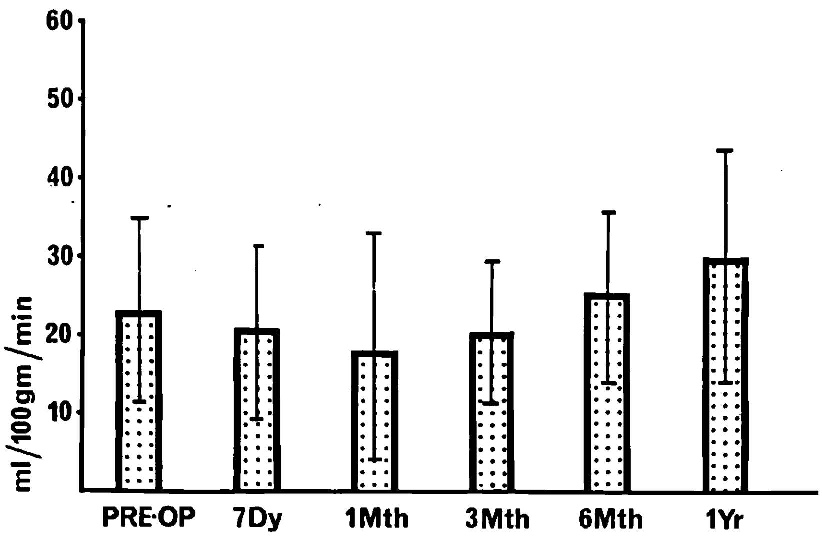


Fig. 24 : Sympathectomy group. Peak muscle blood flow in patients without an improvement in intermittent claudication.

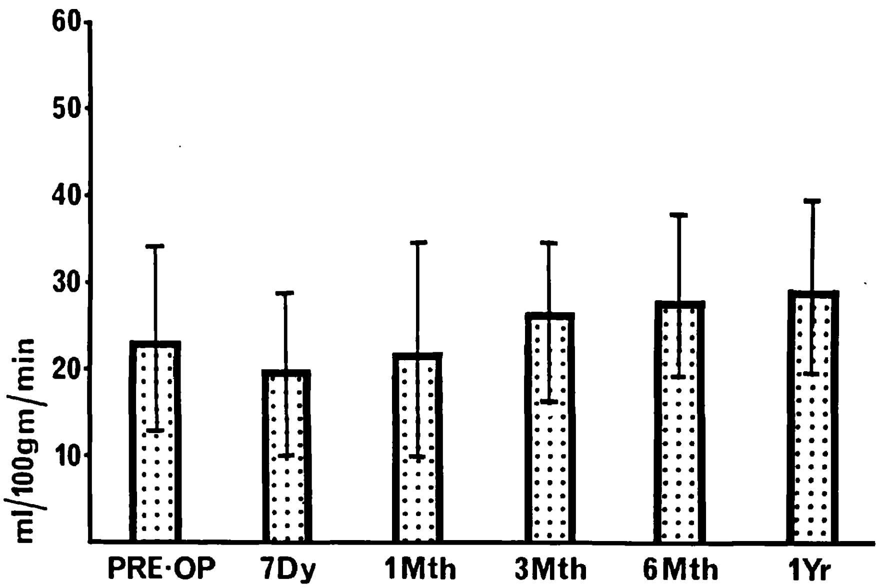


Fig. 25 : Sympathectomy group. Peak muscle blood flow results in patients with an improvement in intermittent claudication.

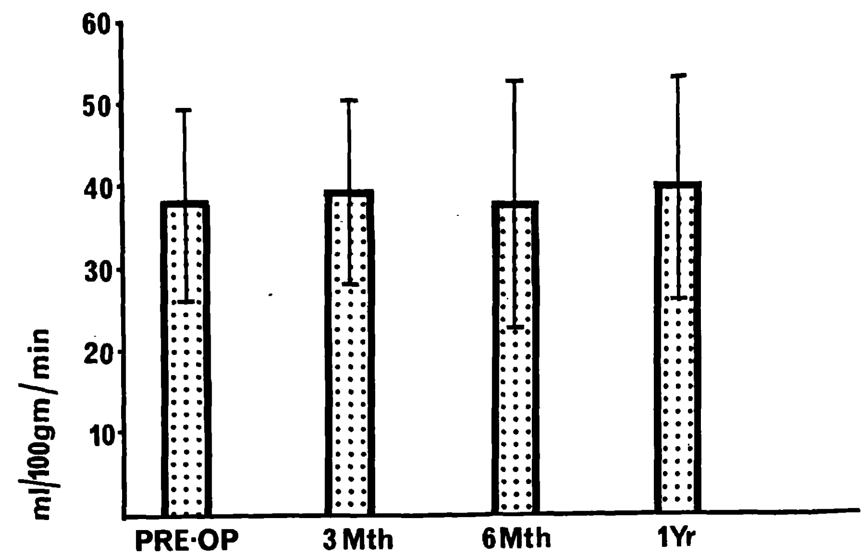


Fig. 26 : Sympathectomy group. Non-operated limb : peak muscle blood flow results over 1 year.

However, study of the individual figures (Table 31, Appendix 1) shows that in some cases there was a marked variation in muscle blood flow. In 14 limbs studied, the muscle blood flow remained fairly steady: in 3 of these 14 limbs, a marked decrease in muscle blood flow was noted at 6 months but in each case muscle blood flow had returned to the baseline level when seen 6 months later. Four of the group showed a gradual improvement in muscle blood flow over the year and 2 patients showed a gradual deterioration, one of whom in addition experienced an increase in the severity of his intermittent claudication.

## DISCUSSION

Despite a great deal of writing concerning the value of lumbar sympathectomy in the treatment of peripheral arterial disease, there are relatively few studies on muscle blood flow. Moreover, an increase in resting muscle blood flow is unlikely to influence intermittent claudication and only studies on muscle blood flow during exercise will be directly relevant (Shepherd, 1950). In the present study, it was found that lumbar sympathectomy produced no improvement in resting muscle blood flow, a finding previously reported by Stein et al. (1948) and Tice et al. (1963). The peak blood flow following ischaemic exercise was not improved following sympathectomy and thus no improvement in claudication would be expected. Grant and Pearson (1938) also reported that muscle blood flow following exercise did not improve after operation. Shaw et al. (1964) came to the conclusion, in an extensive survey of the effect of sympathectomy, that the previous claims for the beneficial effect of the operation were due to inadequate controls. There is no doubt, however, that some people do have an improvement in intermittent claudication following operation. Berry et al. (1955) reported that 49 per cent of patients who had a sympathectomy for intermittent claudication had improvement in this symptom. However, the question remains - is the benefit due to the operation? In the present study, those patients who had benefit from the operation were separated from those who did not. In the group with improved symptoms, there was a tendency for a gradual increase in the muscle blood flow with time. This increase, however, was not to a significant level. Study of the group who did not improve also showed that there was no significant increase in muscle blood flow with time.

Study of the blood flow in the non-operated limb provided extremely useful information. Three types of pattern evolved when the blood flow was measured over a period of time. In the first type (70 per cent of this series), the muscle blood flow remained constant and fluctuated only a little over the year of follow-up. In these patients, intermittent claudication remained fairly uniform; Richards (1957) reported that 60 per cent of patients studied over a 5-year period had no deterioration in their claudication. This supports the concept of a fairly large number of patients in whom the disease is static and there is no serious deterioration in muscle blood flow. In the second type there may be a gradual deterioration in blood flow; this often accompanies an increase in the severity of the claudication. In the third group, there is a gradual improvement in muscle blood flow with time. In this series, a gradual improvement in muscle blood flow in the non-operated limb occurred in 20 per cent of the cases studied; in the operated group the "success" rate was 21.1 per cent. Abramson et al. (1965) also found that the improvement in walking ability was the same in non-operated controls as that in a group treated by lumbar sympathectomy. In view of these findings, it would appear that any improvement in intermittent claudication following lumbar sympathectomy is due to spontaneous improvement in muscle blood flow and not due to the operation *per se*. Shaw et al. (1964) and Gillespie (1967) also came to this conclusion.

When the results from all the limbs were reviewed, it was seen on occasion that there were dramatic falls in the blood flow estimations and equally dramatic rises over a period of time. In many instances these changes in blood flow closely paralleled the clinical picture; the fall in blood flow being accompanied by a deterioration and the rise by an improvement in intermittent claudication. It would appear then that the manifestations of peripheral arterial disease do not follow a steadily progressive downhill course in every case. The disease may be arrested at any stage and the symptoms remain static for long periods of time or they may improve quite dramatically. Thus a lesion which has been of little significance may encroach sufficiently into the arterial supply of the limb to produce a reduction in muscle blood flow and intermittent claudication. The increase in resistance caused by this will stimulate the opening up of the collateral circulation with an improvement in muscle blood flow. Following an acute main vessel thrombosis, the collateral circulation may improve for as long as 6 months (Silbert, 1938). There are many cases presented in the present thesis which illustrate this point. This study also implies that in the management of these cases a prolonged course of conservative treatment is worthwhile to determine the amount of spontaneous improvement. Learmonth (1950) also concluded that a long period of conservative management should be carried out following an acute episode before undertaking sympathectomy.

In conclusion, it appears that any improvement in intermittent claudication following lumbar sympathectomy is due to spontaneous improvement in muscle blood flow, presumably due to the opening up of the collateral circulation, and not due to the operation *per se*. These results support the concept that lumbar sympathectomy should not be carried out for intermittent claudication but should be reserved for those cases which have skin ischaemia.

SUMMARY OF CHAPTER IV

Measurements of muscle blood flow have been made before and after lumbar sympathectomy. Resting muscle blood flow was not increased following operation. The response to ischaemic exercise following operation has also been studied; the level of peak muscle blood flow, the time taken to achieve peak blood flow and the duration of it were not significantly improved after operation.

Peak muscle blood flow studies carried out in the first year after operation showed that in 21.1 per cent of the cases there was a gradual increase in muscle blood flow and an improvement in intermittent claudication. Peak muscle blood flow studies in the non-operated limb showed a gradual increase over a similar period of time in 20 per cent of cases. From these findings, it is suggested that the alleviation of intermittent claudication following lumbar sympathectomy is due to the opening up of the collateral circulation over a period of time and not to the operation *per se*.

## GENERAL SUMMARY AND CONCLUSIONS

A technique for the measurement of the blood flow through skeletal muscle, from the local clearance of the radio-active inert gas $^{133}$xenon has been described. The muscle blood flow estimations had a mean coefficient of variation of 10 per cent over time intervals up to 3 months and from this it was concluded that the technique would be of value for long-term studies.

In a group of 58 normal subjects, the mean resting blood flow was 2.28 ml./100 gm./min. (S.D. $\pm$ 0.92). Muscle blood flow was studied following ischaemic exercise and the mean peak blood flow was 62.0 ml./100 gm./min. (S.D. $\pm$ 17.7): mean time to peak blood flow was 0.46 min. (S.D. $\pm$ 0.37). In this normal group, it was found that the peak muscle blood flow was significantly reduced in the over 40-60 and over 60 age groups.

A group of 109 patients suffering from atherosclerotic peripheral arterial disease have been studied. There was no difference between resting blood flow in this group and that in the normal group.

There was a clear-cut difference in muscle blood flow following ischaemic exercise between the normal subjects and the patients suffering from arterial disease. The typical finding in the diseased group was a reduction in the level of peak blood flow, a delay in reaching the level of peak blood flow and a prolongation of the peak blood flow. These changes were found to be greatest in patients with occlusive lesions distal to the inguinal ligament and least in patients with generalised disease without main vessel occlusion.

The technique has been used in the study of patients who had direct arterial surgery for atherosclerosis of the peripheral vessels. It has been shown that following successful surgery the muscle blood flow may revert to a normal pattern. In all cases the muscle blood flow results correlated well with the success or failure of the surgical procedure, and was important objective corroborative evidence of the result. In particular, it was found that in some cases the muscle blood flow showed no improvement following operation and the patient found an improvement in symptoms, yet arteriography confirmed that the operated segment had undergone occlusion; the muscle blood flow measurements therefore may be of value in selecting those patients who should have post-operative arteriography.

In the first post-operative year, peak muscle blood flow studies were carried out at 3 months, 6 months and 1 year. In most cases the improvement in peak muscle blood flow was well maintained during this period. However, in 50 per cent of the patients having thromboendarterectomy to the femoral and popliteal arteries, there was a gradual return towards the pre-operative level following an initial improvement. This suggests that these patients should have continued long-term follow-up as they appear to be at risk of late failure.

A study has been made of muscle blood flow before and after lumbar sympathectomy. There was no change in resting blood flow, peak blood flow, time to achieve peak blood flow or duration of peak blood flow following operation. 21.1 per cent of patients claimed improvement in the symptom of intermittent claudication when followed up over the first post-operative year. Peak muscle blood flow in the non-operated limb showed a gradual increase in 20 per cent of cases over a similar period of time. It has been concluded that the improvement in intermittent claudication occasionally found following lumbar sympathectomy is due to the opening up of the collateral circulation rather than to the operation itself.

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# A P P E N D I X I

## T A B L E S

Table 1. A.

Normal Group

Age Range 20-40 Years.

| Name | Age | Leg | Resting Blood Flow (ml/100gm/min.) | Peak Blood Flow (ml/100gm/min.) | Time to Peak Blood Flow (mins.) | Duration of Peak Blood Flow (mins.) |
|---|---|---|---|---|---|---|
| C.B. | 28 | Left | 1.29 | 53.1 | 0.1 | 0.9 |
| A.B. | 20 | Right | 2.74 | 90.2 | 0.3 | 0.8 |
| | | Left | 2.58 | 72.5 | 0.5 | 0.9 |
| A.B. | 26 | Right | 2.15 | 127.2 | 0.3 | 0.7 |
| | | Left | 1.61 | 82.9 | 0.3 | 1.0 |
| I.B. | 23 | Right | 2.42 | 52.3 | 0.5 | 1.0 |
| | | Left | 1.29 | 45.9 | 0.7 | 1.8 |
| J.C. | 40 | Right | 0.81 | 70.8 | 0.4 | 1.0 |
| | | Left | 1.45 | 76.5 | 0.3 | 1.3 |
| W.C. | 21 | Right | 1.77 | 94.2 | 0.5 | 0.8 |
| | | Left | 1.77 | 93.4 | 0.3 | 1.0 |
| R.C. | 35 | Right | 1.29 | 66.0 | 0.7 | 0.7 |
| | | Left | 1.77 | 48.3 | 0.3 | 0.7 |
| I.C. | 20 | Right | 3.37 | 88.5 | 0.3 | 0.8 |
| | | Left | 2.42 | 87.5 | 0.3 | 1.0 |
| C.F. | 20 | Right | 1.93 | 40.3 | 0.5 | 1.5 |
| | | Left | 1.61 | 55.6 | 0.5 | 1.3 |

Table 1. A.

| Name | Age | Leg | Resting Blood Flow (ml/100gm/min.) | Peak Blood Flow (ml/100gm/min.) | Time to Peak Blood Flow (mins.) | Duration of Peak Blood Flow (mins.) |
|---|---|---|---|---|---|---|
| K.G. | 20 | Right | 1.61 | 119.1 | 0.1 | 0.8 |
| | | Left | 2.07 | 66.0 | 0.4 | 1.2 |
| J.G. | 20 | Right | 0.97 | 107.9 | 0.3 | 0.9 |
| | | Left | 1.61 | 91.8 | 0.2 | 0.9 |
| J.L. | 20 | Right | 2.09 | 59.6 | 0.5 | 0.8 |
| | | Left | 1.61 | 53.1 | 0.7 | 0.8 |
| D.McD. | 25 | Right | – | 45.1 | 0.3 | 1.0 |
| | | Left | 1.29 | 51.5 | 0.1 | 1.2 |
| I.McD. | 20 | Right | 1.61 | 68.4 | 0.3 | 1.3 |
| | | Left | 2.42 | 72.5 | 0.3 | 1.4 |
| M.McM. | 22 | Right | 1.61 | 63.5 | 0.3 | 0.7 |
| | | Left | 3.37 | 71.5 | 0.3 | 0.8 |
| G.M. | 22 | Left | 1.77 | 56.4 | 0.7 | – |
| I.S. | 24 | Right | 5.47 | 98.2 | 0.2 | – |
| | | Left | 3.22 | 85.3 | 0.3 | 1.0 |
| R.S. | 39 | Right | 2.74 | 68.4 | 0.5 | 0.8 |
| | | Left | 3.22 | 69.2 | 0.5 | 0.5 |
| A.T. | 21 | Right | 0.97 | 74.1 | 0.5 | 1.0 |
| | | Left | 1.13 | 72.5 | 0.6 | 1.2 |
| J.W. | 28 | Right | 2.09 | 62.8 | 0.3 | 1.3 |
| | | Left | 2.82 | 51.2 | 0.2 | 1.3 |

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Table 1. A.

| Name | Age | Leg | Resting Blood Flow (ml/100gm/min.) | Peak Blood Flow (ml/100gm/min.) | Time to Peak Blood Flow (mins.) | Duration of Peak Blood Flow (mins.) |
|---|---|---|---|---|---|---|
| A.W. | 20 | Right | 2.90 | 51.5 | 0.7 | 2.0 |
| | | Left | 1.77 | 57.2 | 0.7 | 1.3 |
| W.W. | 26 | Right | 2.90 | 83.7 | 0.3 | 1.3 |
| | | Left | 1.93 | 78.9 | 0.3 | 1.2 |
| | | Mean | 2.08 | 72.0 | 0.39 | 1.05 |
| | | | ± | ± | ± | ± |
| | | 1 S.D. | 0.88 | 20.0 | 0.17 | 0.31 |

Table 1. B.

Normal Group.

Age Range 40-60 years

| Name | Age | Leg | Resting Blood Flow (ml/100gm/min.) | Peak Blood Flow (ml/100gm/Min.) | Time to Peak Blood Flow (mins.) | Duration of Peak Blood Flow (mins.) |
|---|---|---|---|---|---|---|
| A.B. | 52 | Right | 2.58 | 49.1 | 0.5 | 1.5 |
| | | Left | 1.77 | 46.7 | 0.7 | 1.7 |
| C.B. | 58 | Right | 2.74 | 44.3 | 0.5 | 0.7 |
| | | Left | 2.58 | 60.8 | 0.7 | 0.5 |
| R.B. | 44 | Right | 1.61 | 46.7 | 0.3 | 1.9 |
| | | Left | 1.61 | 40.3 | 0.7 | 1.8 |
| B.C. | 57 | Right | 1.77 | 60.4 | 0.2 | 0.8 |
| | | Left | 3.70 | 72.5 | 0.5 | 1.1 |
| E.C. | 44 | Right | 1.61 | 43.5 | 0.7 | 0.5 |
| | | Left | 1.13 | 59.8 | 0.5 | 0.8 |
| A.G. | 45 | Right | 3.22 | 49.9 | 0.5 | 1.0 |
| | | Left | 3.22 | 62.0 | 0.3 | 0.8 |
| J.G. | 43 | Right | 3.54 | 46.7 | 0.7 | 1.5 |
| | | Left | 3.06 | 53.9 | 0.8 | 1.0 |
| E.H. | 41 | Left | 0.97 | 56.4 | 0.3 | 1.5 |
| A.H. | 42 | Right | 1.61 | 54.7 | 0.5 | 1.2 |
| | | Left | 1.61 | 60.4 | 0.5 | 0.5 |

Table 1. B.

| Name | Age | Leg | Resting Blood Flow (ml/100gm/min.) | Peak Blood Flow (ml/100gm/min.) | Time to Peak Blood Flow (mins.) | Duration of Peak Blood Flow (mins.) |
|---|---|---|---|---|---|---|
| J.H. | 57 | Right | 1.61 | 51.2 | 1.1 | 1.0 |
| | | Left | 1.29 | 59.6 | 1.1 | - |
| T.H. | 46 | Right | 2.09 | 45.9 | 0.7 | 1.5 |
| | | Left | 2.09 | 49.9 | 0.7 | - |
| H.K. | 44 | Right | 1.61 | 49.1 | 1.0 | 1.0 |
| | | Left | 2.25 | 45.9 | 1.0 | 1.0 |
| J.L. | 53 | Left | 3.46 | 45.9 | 0.3 | 1.3 |
| N.McL. | 56 | Right | 0.64 | 49.1 | 0.2 | 1.5 |
| | | Left | 1.13 | 48.3 | 0.2 | 0.9 |
| T.McG. | 41 | Right | 2.25 | 48.3 | 0.5 | 1.3 |
| | | Left | 1.77 | 57.3 | 0.5 | 1.4 |
| J.McM. | 55 | Right | 4.03 | 71.6 | 0.4 | 1.4 |
| | | Left | 4.35 | 65.2 | 0.5 | 1.5 |
| W.McL. | 41 | Right | 3.38 | 83.7 | 0.5 | 1.3 |
| | | Left | 3.22 | 88.6 | 0.7 | 1.0 |
| I.McL. | 47 | Right | 2.42 | 68.4 | 0.3 | 0.7 |
| | | Left | 3.22 | 80.5 | 0.2 | 0.7 |
| H.McG. | 58 | Right | 2.25 | 82.1 | 0.7 | 1.2 |
| | | Left | 1.77 | 50.7 | 0.7 | 1.5 |
| J.McD. | 56 | Right | 3.22 | 58.0 | 0.2 | 0.6 |
| | | Left | 3.06 | 57.2 | - | - |

Table 1. B.

| Name | Age | Leg | Resting Blood Flow (ml/100gm/min.) | Peak Blood Flow (ml/100gm/min.) | Time to Peak Blood Flow (mins.) | Duration of Peak Blood Flow (mins.) |
|---|---|---|---|---|---|---|
| W.M. | 50 | Right | 3.38 | 37.0 | 1.0 | 1.0 |
| | | Left | 2.25 | 38.6 | 0.3 | 0.7 |
| H.M. | 60 | Right | 2.42 | 54.7 | 0.3 | 1.5 |
| | | Left | 1.45 | 49.9 | 0.5 | 1.9 |
| H.R. | 44 | Right | 2.90 | 40.3 | 0.8 | 1.5 |
| | | Left | 4.03 | 40.3 | 0.8 | 1.7 |
| H.R. | 42 | Right | - | 56.4 | 1.0 | 1.0 |
| | | Left | - | 55.4 | 0.6 | 0.8 |
| H.S. | 57 | Right | - | 52.3 | 0.3 | 0.5 |
| | | Left | - | 44.3 | 0.3 | 1.0 |
| T.T. | 46 | Right | 1.45 | 46.7 | 0.3 | 2.0 |
| | | Left | 0.97 | 37.0 | 0.3 | 1.5 |
| | | Mean & one S.D. | 2.35 ± 0.94 | 54.4 ± 12.1 | 0.55 ± 0.26 | 1.16 ± 0.41 |

Table 1. C.

Normal Group.

Age Range Over 60 Years.

| Name | Age | Leg | Resting Blood Flow (ml/100gm/min.) | Peak Blood Flow (ml/100gm/min.) | Time to Peak Blood Flow (mins.) | Duration of Peak Blood Flow (mins.) |
|---|---|---|---|---|---|---|
| G.B. | 72 | Right | 2.42 | 72.5 | 0.5 | 0.9 |
| | | Left | 2.42 | 66.8 | 0.5 | 0.7 |
| A.C. | 61 | Right | 2.42 | 65.2 | 0.8 | 1.2 |
| | | Left | 3.54 | 72.5 | 0.3 | 0.8 |
| J.D. | 61 | Right | 0.97 | 41.1 | 0.5 | 1.5 |
| | | Left | 0.97 | 48.3 | 0.5 | 1.5 |
| W.McM. | 65 | Right | 1.29 | 43.5 | 0.1 | 0.8 |
| J.McK. | 69 | Right | 3.22 | 90.2 | 0.7 | 0.3 |
| | | Left | 4.19 | 67.6 | 0.7 | 0.5 |
| J.McI. | 65 | Right | 3.54 | 50.7 | 0.7 | 1.2 |
| | | Left | 2.42 | 40.3 | 0.3 | 1.5 |
| J.O. | 66 | Right | 4.03 | 62.8 | 0.7 | 1.0 |
| | | Left | 2.09 | 62.8 | 0.3 | 0.5 |
| R.S. | 68 | Right | 1.93 | 54.7 | 0.3 | 0.7 |
| J.W. | 63 | Right | 1.77 | 70.8 | 0.1 | 1.0 |
| | | Left | 3.06 | 74.1 | 0.3 | 0.5 |
| J.W. | 62 | Right | 1.77 | 49.9 | 0.2 | 1.3 |
| | | Left | 1.45 | 47.5 | 0.3 | 1.0 |
| | | Mean & one S.D. | 2.42 ± 0.99 | 60.1 ± 13.8 | 0.43 ± 0.22 | 0.94 ± 0.37 |

Table 2

Normal Group

Repeat Estimations

| Name | Age | Leg | Estimation | P.B.F. ml/100gm/min. | Period of time over which estimations were made. |
|---|---|---|---|---|---|
| A.B. | 20 | Right | 1 | 90.2 | 10 weeks |
| | | | 2 | 78.9 | |
| | | | 3 | 86.1 | |
| | | Left | 1 | 72.5 | |
| | | | 2 | 62.8 | |
| | | | 3 | 70.0 | |
| I.B. | 23 | Right | 1 | 40.3 | 5 weeks |
| | | | 2 | 43.5 | |
| | | | 3 | 52.3 | |
| | | Left | 1 | 44.3 | |
| | | | 2 | 49.9 | |
| | | | 3 | 45.9 | |
| I.C. | 20 | Right | 1 | 88.5 | 2 weeks |
| | | | 2 | 85.3 | |
| | | Left | 1 | 87.5 | |
| | | | 2 | 74.1 | |

Table 2

| Name | Age | Leg | Estimation | P.B.F. ml/100gm/min. | Period of Time over which estimations were made. |
|---|---|---|---|---|---|
| K.G. | 20 | Right | 1 | 119.1 | 6 weeks |
| | | | 2 | 77.3 | |
| | | | 3 | 64.4 | |
| | | | 4 | 78.4 | |
| | | | 5 | 91.3 | |
| | | Left | 1 | 66.0 | |
| | | | 2 | 79.0 | |
| | | | 3 | 74.1 | |
| | | | 4 | 62.0 | |
| | | | 5 | 69.2 | |
| I.McB. | 20 | Right | 1 | 68.4 | 24 weeks |
| | | | 2 | 58.8 | |
| | | | 3 | 56.4 | |
| | | | 4 | 59.9 | |
| | | | 5 | 65.2 | |
| | | Left | 1 | 72.5 | |
| | | | 2 | 62.8 | |
| | | | 3 | 55.5 | |
| | | | 4 | 70.8 | |
| | | | 5 | 71.6 | |

Table 2

| Name | Age | Leg | Estimation | P.B.F. ml/100gm/min. | Period of Time over which estimations were made. |
|---|---|---|---|---|---|
| A.T. | 21 | Right | 1 | 93.4 | 16 weeks |
| | | | 2 | 74.1 | |
| | | | 3 | 93.0 | |
| | | | 4 | 91.8 | |
| | | | 5 | 88.7 | |
| | | Left | 1 | 82.6 | |
| | | | 2 | 72.5 | |
| | | | 3 | 98.0 | |
| | | | 4 | 90.2 | |
| | | | 5 | 103.2 | |
| J.W. | 28 | Right | 1 | 60.5 | 2 weeks |
| | | | 2 | 62.0 | |
| | | Left | 1 | 62.8 | |
| | | | 2 | 51.2 | |

Table 3

Muscle Blood Flow Readings at Minute Intervals

Following Release of the Occluding Cuff

Normal Group

Age Range 40 - 80

| Time (mins.) | | | |
|---|---|---|---|
| 1 | 2 | 3 | 4 |
| 49.1 | 49.1 | 29.8 | - |
| 46.7 | 46.7 | 25.8 | 12.9 |
| 44.3 | 28.2 | 8.1 | - |
| 60.8 | 32.2 | 16.1 | - |
| 46.7 | 46.7 | 33.8 | 15.3 |
| 40.3 | 40.3 | 17.4 | 14.5 |
| 72.5 | 36.7 | - | - |
| 66.8 | 33.8 | - | - |
| 60.4 | 33.0 | 16.9 | 8.1 |
| 72.4 | 41.9 | - | - |
| 43.5 | 21.7 | - | - |
| 59.8 | 31.4 | - | - |
| 65.2 | 65.2 | 31.4 | 22.5 |
| 72.5 | 26.6 | 8.9 | - |
| 41.1 | 24.2 | 13.7 | 9.7 |
| 48.3 | 48.3 | 18.5 | 8.9 |
| 49.9 | 30.6 | 20.1 | - |
| 62.0 | 35.4 | 18.5 | - |

Table 3

Muscle Blood Flow Readings at Minute Intervals

Normal Group

Age Range 40 - 80

| Time (mins.) | | | |
|---|---|---|---|
| 1 | 2 | 3 | 4 |
| 46.7 | 46.7 | 29.0 | 12.9 |
| 53.9 | 41.1 | 24.2 | 9.7 |
| 54.7 | 41.9 | 23.4 | 12.9 |
| 60.4 | 28.2 | 8.1 | - |
| 45.9 | 51.2 | 39.5 | - |
| 45.9 | 45.9 | 35.0 | 20.9 |
| 49.1 | 49.1 | 25.8 | 7.4 |
| 45.9 | 45.9 | 26.6 | - |
| 45.9 | 35.4 | 25.8 | 14.5 |
| 33.0 | 16.9 | 8.9 | 3.9 |
| 49.1 | 33.0 | 20.1 | 10.5 |
| 48.3 | 13.1 | 6.1 | 4.0 |
| 65.2 | 53.1 | - | - |
| 83.7 | 58.0 | - | - |
| 88.6 | 58.0 | - | - |
| 68.4 | 43.5 | 20.9 | - |
| 66.8 | 26.6 | - | - |
| 90.2 | 48.3 | - | - |
| 67.6 | 51.5 | - | - |

Table 3

Muscle Blood Flow Readings at Minute Intervals

Normal Group

Age Range 40 - 80

| Time (mins.) | | | |
|---|---|---|---|
| 1 | 2 | 3 | 4 |
| 50.7 | 43.5 | 28.2 | - |
| 40.3 | 29.8 | 16.9 | - |
| 82.1 | 65.2 | 41.9 | 25.0 |
| 50.7 | 50.7 | 27.4 | - |
| 52.3 | 30.6 | 10.5 | - |
| 37.0 | 37.0 | 24.2 | 12.1 |
| 38.6 | 30.6 | 19.3 | - |
| 54.7 | 39.4 | - | 19.3 |
| 49.9 | 49.9 | 30.6 | 16.1 |
| 62.8 | 41.9 | 29.0 | - |
| 30.6 | 18.5 | - | - |
| 40.3 | 40.3 | 36.2 | - |
| 40.3 | 40.3 | 24.2 | - |
| 56.4 | 56.4 | 33.8 | - |
| 56.4 | 37.8 | 29.0 | - |
| 38.6 | 14.5 | - | - |
| 44.3 | 27.4 | 20.9 | - |

Table 3

Muscle Blood Flow Readings at Minute Intervals

Normal Group

Age Range 40 - 80

| | Time (Mins.) | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| | 54.7 | 33.8 | 20.9 | 12.9 |
| | 46.7 | 46.7 | 29.8 | 13.7 |
| | 37.0 | 28.2 | 18.5 | 14.5 |
| | 70.8 | 33.8 | 15.3 | - |
| | 49.9 | 27.4 | 9.7 | - |
| | 49.9 | 25.0 | 7.3 | - |
| | 47.5 | 27.4 | 13.2 | 7.3 |
| Mean | 54.0 | 38.3 | 22.1 | 12.9 |
| one S.D. | ± 13.4 | ± 11.9 | ± 9.1 | ± 5.3 |

Table 4. A.

Peripheral Arterial Disease Group

Generalised Disease Without Main Vessel Occlusion

| Name | Age | Leg | Intermittent Claudication | Resting Blood Flow (ml/100gm/min.) | Peak Blood Flow (ml/100gm/min.) | Time to Peak Blood Flow (mins.) | Duration of Peak Blood Flow (mins.) |
|---|---|---|---|---|---|---|---|
| D.A. | 58 | Right | Yes | 1.61 | 24.2 | 2.0 | 3.5 |
| R.B. | 62 | Left | No | 2.25 | 30.6 | 0.7 | 1.6 |
| T.B. | 63 | Right | No | 1.77 | 35.4 | 0.3 | 1.5 |
| S.B. | 45 | Right | Yes | 0.81 | 45.9 | 0.1 | 1.8 |
| | | Left | Yes | - | 25.0 | 0.7 | 3.0 |
| A.B. | 66 | Left | No | 1.61 | 30.6 | 0.3 | 1.5 |
| J.B. | 57 | Left | No | 1.13 | 37.8 | 0.5 | 2.0 |
| W.B. | 64 | Right | No | 1.61 | 43.5 | 0.8 | 1.3 |
| T.C. | 53 | Right | No | 1.77 | 39.4 | 0.1 | 1.9 |
| D.C. | 74 | Left | Yes | 3.70 | 30.6 | 1.0 | 2.0 |
| J.D. | 60 | Left | No | 1.93 | 46.7 | 0.6 | 2.0 |
| M.D. | 53 | Right | Yes | 1.61 | 29.8 | 2.5 | 1.8 |
| | | Left | Yes | 2.25 | 12.1 | 2.0 | 4.0 |
| R.D. | 64 | Left | Yes | 0.81 | 22.5 | 0.5 | 2.0 |
| J.E. | 57 | Left | No | 3.54 | 30.6 | 1.5 | 2.5 |
| P.F. | 43 | Left | No | 2.90 | 40.3 | 0.5 | 1.7 |
| A.F. | 61 | Right | Yes | 1.13 | 31.0 | 0.9 | 2.1 |
| J.F. | 56 | Right | No | 1.77 | 44.3 | 0.7 | 1.5 |

/...

Table 4. A.

| Name | Age | Leg | Intermittent Claudication | Resting Blood Flow (ml/100gm/min.) | Peak Blood Flow (ml/100gm/min.) | Time to Peak Blood Flow (mins.) | Duration of Pea Blood Flow (mins) |
|---|---|---|---|---|---|---|---|
| J.G. | 62 | Right | No | 2.09 | 27.4 | 0.3 | 1.3 |
| J.G. | 56 | Right | No | 2.58 | 64.4 | 0.7 | 1.1 |
| | | Left | Yes | 1.61 | 49.1 | 1.2 | 1.8 |
| J.G. | 55 | Right | No | 1.77 | 25.8 | 0.7 | 1.0 |
| | | Left | Yes | 0.97 | 16.1 | 2.0 | 2.0 |
| J.B. | 61 | Right | Yes | 0.97 | 27.4 | 0.5 | 1.5 |
| W.H. | 52 | Right | Yes | 1.29 | 36.2 | 1.0 | 3.0 |
| | | Left | No | 1.61 | 45.9 | 0.3 | 1.5 |
| A.H. | 42 | Left | Yes | 3.06 | 32.2 | 0.5 | 2.1 |
| G.H. | 52 | Right | No | 3.22 | 49.8 | 0.7 | 1.8 |
| | | Left | Yes | 2.89 | 41.8 | 0.8 | 1.5 |
| C.H. | 61 | Right | Yes | 2.74 | 23.3 | 0.5 | 0.7 |
| R.K. | 66 | Left | Yes | 1.77 | 20.1 | 0.4 | 1.0 |
| C.K. | 46 | Right | No | 2.90 | 51.5 | 1.0 | 0.6 |
| I.K. | 54 | Left | Yes | 1.29 | 45.1 | 1.7 | 2.4 |
| A.K. | 58 | Right | Yes | 1.93 | 42.7 | 0.3 | 0.6 |
| T.K. | 61 | Right | Yes | 1.29 | 36.2 | 1.0 | - |
| | | Left | Yes | 2.25 | 20.9 | 1.3 | 1.5 |
| J.L. | 51 | Right | No | - | 38.6 | 0.5 | 2.3 |
| | | Left | Yes | - | 26.3 | 3.5 | 3.5 |

/...

Table 4. A.

| Name | Age | Leg | Intermittent Claudication | Resting Blood Flow (ml/100gm/min.) | Peak Blood Flow (ml/100gm/min.) | Time to Peak Blood Flow (mins.) | Duration of Pea[k] Blood Flow (mins.) |
|---|---|---|---|---|---|---|---|
| F.L. | 53 | Right | No | 1.45 | 49.1 | 1.3 | 1.0 |
| W.L. | 53 | Right | No | 2.25 | 40.3 | 1.5 | - |
| J.McK. | 53 | Left | Yes | - | 35.4 | 0.8 | 1.2 |
| C.McK | 65 | Right | Yes | 2.09 | 26.6 | 1.0 | 1.5 |
| C.McC. | 50 | Right | No | 1.29 | 31.4 | 0.7 | 2.0 |
| J.McA. | 51 | Left | No | 1.13 | 42.7 | 0.7 | 1.3 |
| M.McL. | 58 | Right | No | 1.45 | 28.2 | 1.3 | 2.0 |
| H.McH. | 45 | Right | Yes | 1.61 | 45.6 | 0.8 | 1.5 |
| A.McL. | 66 | Left | Yes | 1.93 | 14.5 | 1.0 | 1.0 |
| J.McL. | 43 | Right | No | 0.97 | 33.0 | 1.0 | 2.0 |
| D.M. | 39 | Right | Yes | 1.77 | 31.4 | 1.0 | 2.7 |
| | | Left | No | 2.09 | 32.2 | 1.0 | 2.0 |
| J.M. | 59 | Right | No | 1.61 | 35.2 | 1.0 | 2.5 |
| J.O'N | 48 | Right | Yes | 1.93 | 29.8 | 1.5 | 1.5 |
| | | Left | Yes | 3.22 | 32.2 | 1.0 | 1.3 |
| L.P. | 51 | Right | No | 0.97 | 42.7 | 1.3 | 2.5 |
| W.P. | 62 | Right | No | 1.29 | 25.0 | 0.2 | 0.8 |
| J.L. | 59 | Right | No | - | 61.0 | 0.4 | 1.3 |
| R.M. | 67 | Right | No | 2.42 | 35.4 | 0.3 | 2.3 |
| W.M. | 56 | Right | Yes | 1.29 | 21.7 | 2.3 | 2.9 |
| | | Left | Yes | 1.61 | 30.6 | 1.0 | 2.6 |

/...

Table 4. A.

| Name | Age | Leg | Intermittent Claudication | Resting Blood Flow (ml/100gm/min.) | Peak Blood Flow (ml/100gm/min.) | Time to Peak Blood Flow (mins.) | Duration of Peak Blood Flow (mins.) |
|---|---|---|---|---|---|---|---|
| A.Q. | 65 | Left | No | 0.97 | 48.3 | 0.7 | 1.3 |
| J.R. | 49 | Left | No | 1.93 | 49.0 | 0.4 | 1.0 |
| T.S. | 50 | Right | Yes | 1.29 | 28.9 | 2.0 | 1.0 |
| | | Left | Yes | 2.09 | 20.1 | 1.2 | 0.7 |
| J.S. | 67 | Left | No | - | 20.1 | 0.3 | 1.7 |
| W.S. | 50 | Right | No | 1.13 | 42.7 | 0.7 | 0.9 |
| W.S. | 54 | Left | Yes | 1.29 | 49.1 | 2.0 | 2.0 |
| H.S. | 61 | Right | Yes | 1.61 | 29.0 | 4.0 | 1.5 |
| J.S. | 58 | Left | No | 1.77 | 53.9 | 0.3 | 1.3 |
| D.W. | 62 | Right | No | - | 30.6 | 0.3 | 3.6 |
| A.A. | 64 | Right | Yes | 0.97 | 39.4 | 0.5 | 2.1 |
| A.H. | 63 | Left | No | 1.61 | 52.3 | 0.3 | 2.3 |
| J.T. | 54 | Left | No | 1.45 | 41.9 | 0.3 | 1.0 |
| K.B. | 66 | Left | No | 1.29 | 51.5 | 0.3 | 1.0 |
| F.W. | 58 | Right | No | - | 26.6 | 0.4 | 1.6 |
| | | Mean ± one S.D. | | 1.79 ± 0.68 | 35.5 ± 11.0 | 1.37 ± 0.72 | 1.78 ± 0.74 |

## Table 4B

## Peripheral Arterial Disease Group

## Proximal Occlusive Lesions

| Name | Age | Site of Occluding Lesion | Leg | Resting Blood Flow (ml/100gm/min.) | Peak Blood Flow (ml/100gm/min.) | Time to Peak Blood Flow (mins.) | Duration of Peak Blood Flow (mins.) |
|---|---|---|---|---|---|---|---|
| T.B. | 63 | C.I. | Left | 1.29 | 25.0 | 0.8 | 1.5 |
| J.B. | 57 | C.I. | Right | 1.61 | 18.5 | 3.0 | 5.0 |
| G.C. | 27 | E.I. | Left | 1.61 | 46.7 | 1.2 | 2.5 |
| R.C. | 51 | E.I. | Right | 3.22 | 61.2 | 1.0 | 1.5 |
| R.C. | 43 | E.I. | Right | 2.42 | 41.1 | 3.0 | 1.5 |
| | | E.I. | Left | 3.62 | 42.7 | 0.3 | 0.7 |
| S.D. | 64 | E.I. | Left | 1.45 | 27.4 | 0.8 | 1.3 |
| A.E. | 56 | C.I. & E.I. | Left | 0.81 | 29.8 | 1.0 | 3.0 |
| J.T. | 54 | C.I. | Right | 0.81 | 20.9 | 1.2 | 6.3 |
| J.E. | 57 | E.I. | Right | 1.13 | 45.9 | 1.6 | 2.0 |
| A.F. | 61 | C.I. & E.I. | Left | 1.93 | 41.8 | 0.8 | |
| F.K. | 55 | C.I. | Right | 2.74 | 26.6 | 1.0 | 1.6 |
| J.K. | 44 | E.I. | Right | 2.25 | 16.1 | 1.0 | 1.0 |
| J.McG. | 55 | C.I. | Right | - | 28.2 | 1.3 | 3.7 |
| J.McL | 43 | E.I. | Left | 2.09 | 18.5 | 4.5 | 3.0 |

C.I. = Common Iliac Artery
E.I. = External Iliac Artery

Table 4B

| Name | Age | Site of Occluding Lesion | Leg | Resting Blood Flow (ml/100gm/min.) | Peak Blood Flow (ml/100gm/min.) | Time to Peak Blood Flow (mins.) | Duration of Peak Blood Flow (mins.) |
|---|---|---|---|---|---|---|---|
| J.M. | 56 | C.I.& E.I. | Right | 1.61 | 20.9 | 3.5 | 3.5 |
| F.N. | 53 | E.I. | Left | 1.13 | 35.0 | 1.7 | 2.3 |
| J.O'F. | 43 | C.I. | Left | 2.42 | 41.9 | 0.7 | 1.5 |
| L.P. | 49 | E.I. | Left | 1.13 | 48.3 | 0.7 | 1.3 |
| F.W. | 56 | C.I. | Right | 2.42 | 41.1 | 2.2 | 1.2 |
| A.S. | 44 | C.I. | Left | - | 37.8 | 0.7 | 1.7 |
| | | Mean | | 1.85 | 34.1 | 1.52 | 2.28 |
| | | | | ± | ± | ± | ± |
| | | one S.D. | | 0.75 | 12.1 | 1.10 | 1.35 |

C.I.= Common Iliac Artery

E.I.= External Iliac Artery

Peripheral Arterial Disease Group

Distal Occlusive Lesions

Table 4C

| Name | Age | Site of Occluding Lesion | Leg | Resting Blood Flow (ml/100gm/min.) | Peak Blood Flow (ml/100gm/min.) | Time to Peak Blood Flow (mins.) | Duration of Peak Blood Flow (mins.) |
|---|---|---|---|---|---|---|---|
| A.A. | 58 | S.F. | Right | 0.97 | 28.2 | 1.2 | 1.6 |
| | | | Left | 0.81 | 20.9 | 1.5 | 2.5 |
| S.A. | 59 | S.F. | Right | 0.81 | 40.3 | 1.2 | 2.1 |
| | | | Left | 1.29 | 31.0 | 1.0 | 2.3 |
| D.A. | 58 | P. | Left | 2.42 | 30.6 | 1.8 | 2.5 |
| W.B. | 47 | S.F. | Right | - | 37.0 | 1.3 | - |
| | | | Left | 0.81 | 22.5 | 1.0 | 0.9 |
| R.B. | 62 | S.F. | Right | 1.45 | 20.9 | 3.1 | 4.0 |
| J.B. | 61 | P. | Left | 0.97 | 11.3 | 1.0 | 1.3 |
| A.B. | 66 | P. | Right | 28.2 | 0.3 | 1.7 | |
| W.B. | 64 | P. | Left | 3.22 | 20.9 | 6.0 | 3.0 |
| G.B. | 39 | S.F. | Left | 1.77 | 21.7 | 0.3 | 0.9 |
| J.B. | 61 | S.F. | Right | 2.74 | 30.0 | 3.0 | 3.5 |
| | | | Left | 2.42 | 17.7 | 2.0 | 4.3 |
| T.C. | 53 | S.F. | Left | 0.81 | 23.3 | 1.5 | 2.1 |
| R.C. | 54 | S.F. | Right | 1.13 | 16.9 | 1.0 | 4.5 |
| | | | Left | 1.13 | 17.7 | 2.7 | 4.6 |
| B.C. | 65 | S.F. | Right | 2.42 | 16.9 | 3.0 | 5.0 |
| D.C. | 74 | S.F. | Right | 2.10 | 24.2 | 1.5 | 1.5 |

Table 4C

| Name | Age | Site of Occluding Lesion | Leg | Resting Blood Flow (ml/100gm/min.) | Peak Blood Flow (ml/100gm/min.) | Time to Peak Blood Flow (mins.) | Duration of Peak Blood Flow (mins.) |
|---|---|---|---|---|---|---|---|
| J.D. | 60 | F-P. | Right | 0.97 | 33.8 | 2.6 | 2.5 |
| J.D. | 59 | S.F. | Left | 1.61 | 20.1 | 5.0 | - |
| D.D. | 53 | S.F. | Right | 4.51 | 30.6 | 1.0 | 1.5 |
| 8 | | S.F.&P. | Left | 5.64 | 25.0 | 1.5 | 3.0 |
| R.D. | 61 | S.F. | Right | 1.93 | 17.7 | 1.5 | 2.0 |
| R.D. | 64 | S.F. | Right | 1.29 | 18.5 | 1.8 | 3.2 |
| M.D. | 52 | P. | Left | 5.64 | 39.4 | 2.0 | 1.5 |
| A.E. | 56 | S.F. | Right | 1.40 | 17.7 | 2.5 | 5.0 |
| T.E. | 59 | P. | Left | - | 46.6 | 0.6 | 1.4 |
| P.F. | 43 | S.F. | Right | 1.45 | 39.5 | 2.0 | - |
| J.F. | 56 | S.F. | Left | 2.42 | 16.9 | 2.3 | 5.0 |
| J.F. | 59 | S.F. | Left | 1.45 | 30.6 | 1.0 | 2.0 |
| J.D. | 50 | P. | Right | 1.29 | 11.6 | 2.1 | 5.4 |
| J.G. | 62 | P. | Left | 1.29 | 29.2 | 1.7 | 2.5 |
| J.G. | 66 | S.F. | Right | 0.97 | 15.3 | 1.3 | 2.4 |
| F.G. | 52 | P. | Left | 1.93 | 30.6 | 2.0 | - |
| C.H. | 61 | P. | Left | 1.29 | 25.8 | 0.5 | 0.5 |
| D.J. | 36 | S.F. | Right | 1.61 | 14.5 | 1.0 | 4.3 |

Table 4C

| Name | Age | Site of Occluding Lesion | Leg | Resting Blood Flow (ml/100gm/min.) | Peak Blood Flow (ml/100gm/min.) | Time to Peak Blood Flow (mins.) | Duration of Peak Blood Flow (mins.) |
|---|---|---|---|---|---|---|---|
| P.K. | 45 | S.F. | Right | 2.09 | 13.5 | 3.5 | 3.0 |
| R.K. | 66 | P. | Right | 1.77 | 15.3 | 2.3 | 3.0 |
| F.K. | 55 | S.F. | Left | - | 29.8 | 1.3 | 2.0 |
| C.K. | 46 | P. | Left | 1.77 | 22.5 | 2.5 | 3.5 |
| A.K. | 73 | S.F. | Right | 1.61 | 15.3 | 2.3 | 3.0 |
| | | P. | Left | 3.86 | 13.5 | 1.5 | 3.0 |
| F.L. | 53 | S.F.&.P. | Left | 1.61 | 37.8 | 1.2 | 3.0 |
| W.L. | 53 | P. | Left | 2.25 | 20.9 | 4.5 | 1.5 |
| J.McK. | 53 | S.F. | Right | 2.58 | 11.3 | 1.5 | - |
| C.McK. | 65 | S.F. | Left | - | 27.7 | 1.5 | 2.0 |
| C.McC. | 50 | S.F. | Left | 0.81 | 25.0 | 1.2 | 3.3 |
| J.McA. | 51 | S.F. | Right | 2.42 | 21.7 | 3.0 | 2.3 |
| M.McL. | 58 | P. | Left | 1.61 | 19.3 | 0.8 | 4.2 |
| P.McL. | 42 | P. | Right | 1.61 | 28.2 | 2.3 | 3.2 |
| A.McL. | 66 | S.F. | Right | 1.61 | 10.5 | 3.5 | 3.0 |
| T.McI. | 67 | P. | Right | 0.97 | 7.40 | 0.5 | 4.3 |
| W.McE. | 56 | P. | Right | 1.77 | 14.5 | 3.0 | 6.5 |
| I.McF. | 56 | S.F. | Right | 0.64 | 33.8 | 0.8 | 2.0 |
| | | | Left | 2.42 | 16.9 | 3.0 | 4.0 |

Table 4C

| Name | Age | Site of Occluding Lesion | Leg | Resting Blood Flow (ml/100gm/min.) | Peak Blood Flow (ml/100gm/min.) | Time to Peak Blood Flow (mins.) | Duration of Peak Blood Flow (mins.) |
|---|---|---|---|---|---|---|---|
| J.M. | 60 | S.F. | Right | 1.61 | 29.8 | 0.6 | 2.0 |
| | | | Left | 2.25 | 26.6 | 1.3 | 3.0 |
| W.M. | 56 | P. | Left | 1.61 | 12.1 | 3.0 | 1.0 |
| T.M. | 69 | P. | Left | 1.29 | 9.66 | 1.5 | 4.0 |
| W.N. | 53 | S.F. | Right | 0.97 | 42.7 | 2.5 | 3.0 |
| J.P. | 60 | P. | Right | 1.77 | 21.7 | 1.4 | 5.0 |
| W.P. | 62 | S.F. | Left | 0.97 | 6.44 | 1.7 | 3.3 |
| W.P. | 73 | S.F. | Right | 5.31 | 20.1 | 2.0 | 3.0 |
| | | | Left | 2.09 | 25.8 | 1.0 | 0.7 |
| J.L. | 59 | S.F. | Left | - | 35.4 | 2.0 | 2.3 |
| R.M. | 67 | S.F. | Left | - | 14.5 | 2.1 | 3.6 |
| A.Q. | 64 | P. | Right | 2.74 | 17.7 | 0.7 | 3.7 |
| J.Q. | 69 | S.F. | Right | 0.97 | 15.3 | 3.0 | 4.0 |
| N.R. | 49 | S.F. | Right | 0.97 | 28.2 | 1.6 | 3.0 |
| | | | Left | 1.29 | 12.9 | 3.5 | 3.6 |
| J.R. | 49 | S.F. | Right | 1.45 | 24.2 | 3.0 | 4.5 |
| J.R. | 75 | P. | Right | 1.61 | 11.3 | 2.0 | - |
| | | | Left | 4.35 | 11.3 | 3.0 | 3.5 |
| J.S. | 67 | S.F. | Right | - | 11.3 | 2.0 | 7.5 |
| W.S. | 50 | S.F. | Left | 1.77 | 33.0 | 1.7 | 1.7 |

## Table 4C

| Name | Age | Site of Occluding Lesion | Leg | Resting Blood Flow (ml/100gm/min.) | Peak Blood Flow (ml/100gm/min.) | Time to Peak Blood Flow (mins.) | Duration of Peak Blood Flow (mins.) |
|---|---|---|---|---|---|---|---|
| H.S. | 61 | S.F. | Left | 2.71 | 13.6 | 6.0 | 5.0 |
| S.S. | 56 | S.F. | Left | 1.29 | 25.8 | 2.0 | 2.6 |
| J.S. | 56 | S.F. | Right | 1.77 | 26.6 | 1.0 | 3.0 |
| J.S. | 59 | S.F. | Right | 1.61 | 17.7 | 1.6 | 3.0 |
| | | | Left | 2.42 | 13.7 | 2.5 | 4.7 |
| D.W. | 62 | S.F. | Left | - | 25.0 | 2.0 | 3.8 |
| Mean | | | | 1.88 | 22.5 | 1.97 | 3.05 |
| One S.D. | | | | ± 1.08 | ± 8.9 | ± 1.12 | ± 1.35 |

P. = Popliteal Artery

S.F. = Superficial Femoral Artery.

Peripheral Arterial Disease Group

Table 5A

Muscle Blood Flow Readings at Minute Intervals Following Release of the Occluding Cuff

Generalised Disease without Mean vessel occlusion.

| Time (mins.) | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 9.7 | 24.2 | 24.2 | 24.2 | 24.2 | 17.7 |
| 45.9 | 45.9 | 25.0 | 12.9 | - | - |
| 25.0 | 25.0 | 25.0 | 25.0 | 19.3 | 15.3 |
| 37.8 | 37.8 | 27.4 | 20.9 | 11.3 | 6.4 |
| 43.5 | 43.5 | 29.8 | 10.5 | - | - |
| 30.6 | 30.6 | 30.6 | 12.9 | - | - |
| 22.5 | 22.5 | 15.3 | 11.3 | 5.6 | - |
| 24.2 | 30.6 | 30.6 | 30.6 | 24.2 | 15.3 |
| 40.3 | 40.3 | 25.0 | - | - | - |
| 31.0 | 31.0 | 31.0 | 12.9 | - | - |
| 25.8 | 19.3 | 15.3 | 11.3 | 8.1 | 4.8 |
| 9.7 | 16.1 | 16.1 | 16.1 | 6.4 | 4.0 |
| 49.8 | 49.8 | 22.5 | - | - | - |
| 41.8 | 41.8 | 25.8 | 8.9 | - | - |
| 23.3 | 8.9 | 4.8 | - | - | - |
| 36.2 | 36.2 | 30.6 | - | - | - |
| 18.5 | 20.9 | 16.9 | 8.1 | - | - |
| 35.4 | 35.4 | 16.1 | - | - | - |

Muscle Blood Flow Readings at Minute Intervals

Generalised.

Table 5A

| Time (mins.) | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 35.2 | 35.2 | 35.2 | 25.0 | 19.3 | 12.1 |
| 35.4 | 35.4 | 21.7 | 16.1 | 11.3 | 3.2 |
| 23.3 | 29.8 | 27.4 | - | - | - |
| 32.2 | 32.2 | 20.1 | - | - | - |
| 20.1 | 20.1 | 12.9 | 9.7 | 8.1 | 5.6 |
| 42.7 | 24.2 | 11.3 | 4.4 | - | - |
| 6.4 | 15.3 | 23.9 | 29.0 | 29.0 | 24.2 |
| 53.9 | 36.2 | 28.1 | 22.5 | 7.3 | 3.2 |
| 26.6 | 26.6 | 18.5 | 16.1 | 12.1 | 5.6 |
| 35.4 | 25.8 | 16.9 | - | - | - |
| 30.6 | 30.6 | 16.1 | 6.4 | - | - |
| 51.5 | 24.1 | 12.9 | 8.9 | 8.9 | 8.9 |
| 39.4 | 39.4 | 28.2 | 16.1 | 8.1 | 3.2 |
| 39.4 | 39.4 | 28.1 | 19.3 | - | - |
| 27.4 | 27.4 | 19.0 | - | - | - |
| 44.3 | 44.3 | 28.2 | 20.9 | - | - |
| 27.4 | 19.3 | 12.9 | 7.3 | - | - |
| 64.4 | 45.1 | 25.0 | - | - | - |
| 36.2 | 49.1 | 49.1 | 30.6 | - | - |

Muscle Blood Flow Readings at Minute Intervals

Generalised

Table 5A

| Time (mins.) | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 36.2 | 36.2 | 36.2 | 36.2 | 16.1 | 8.9 |
| 45.9 | 36.2 | 22.5 | 15.3 | 6.4 | - |
| 20.1 | 9.7 | 5.6 | 2.4 | - | - |
| 20.9 | 25.8 | 28.2 | 28.2 | 28.2 | 22.5 |
| 33.6 | 49.1 | 29.8 | 11.3 | - | - |
| 61.0 | 47.5 | 27.4 | 6.4 | - | - |
| 38.6 | 38.6 | 28.9 | 22.2 | - | - |
| 9.2 | 12.0 | 16.1 | 26.3 | 26.3 | 26.3 |
| 4.0 | 15.3 | 21.7 | 21.7 | 21.7 | 15.3 |
| 30.6 | 30.6 | 30.6 | 15.3 | 8.9 | 6.3 |
| 21.7 | 26.6 | 26.6 | 26.6 | 26.6 | 26.6 |
| 33.0 | 33.0 | 33.0 | 20.9 | 11.8 | 8.9 |
| 42.7 | 42.7 | 27.4 | 14.5 | 8.9 | - |
| 26.6 | 26.6 | 21.2 | 16.9 | 11.9 | 9.7 |
| 31.4 | 31.4 | 25.0 | 19.0 | 13.7 | 8.1 |
| 25.0 | 10.5 | 5.8 | - | - | - |
| 49.9 | 43.5 | 31.4 | - | - | - |
| 41.9 | 20.9 | 16.9 | 13.7 | 6.4 | - |

Muscle Blood Flow Readings at Minute Intervals

Generalised

Table 5A

| | Time (mins.) | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| | 30.6 | 30.6 | 30.6 | 22.5 | 15.3 | 11.3 |
| | 30.6 | 30.6 | 14.5 | - | - | - |
| | 15.3 | 24.2 | 29.8 | 29.8 | 17.7 | 11.3 |
| | 8.1 | 12.1 | 12.1 | 12.1 | 12.1 | 12.1 |
| | 46.7 | 46.7 | 35.4 | - | - | - |
| | 52.3 | 52.3 | 26.6 | - | - | - |
| | 32.2 | 32.2 | 24.2 | 24.2 | 16.1 | 11.3 |
| | 25.8 | 45.1 | 45.1 | 45.1 | 7.3 | - |
| | 55.6 | 34.6 | 24.2 | 12.9 | - | - |
| | 14.5 | 14.5 | 2.4 | - | - | - |
| | 20.1 | 28.2 | 28.2 | 18.5 | 10.9 | 7.1 |
| | 45.6 | 45.6 | 28.2 | - | - | - |
| | 48.3 | 48.3 | 39.5 | 29.8 | 15.3 | 10.1 |
| | 32.2 | 49.1 | 49.1 | 32.2 | 21.7 | 17.7 |
| | 15.3 | 28.9 | 28.9 | 19.3 | 12.1 | - |
| | 9.7 | 7.3 | 4.0 | 2.9 | - | - |
| Mean | 32.1 | 31.3 | 24.0 | 18.2 | 14.4 | 11.4 |
| one S.D. | ± 13.5 | ± 11.6 | ± 9.6 | ± 9.0 | ± 7.0 | ± 6.8 |

Table 5B

Muscle Blood Flow Readings at Minute Intervals

Proximal Occlusive Disease

| Time (mins.) | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| 6.8 | 9.7 | 18.5 | 18.5 | 18.5 |
| 11.3 | 17.7 | 41.1 | 34.6 | 34.6 |
| 42.7 | 32.2 | 32.2 | - | - |
| 27.4 | 27.4 | 10.5 | - | - |
| 29.8 | 29.8 | 29.8 | 29.2 | 16.1 |
| 16.6 | 45.9 | 45.9 | 36.2 | - |
| 41.8 | 41.8 | 26.5 | 16.1 | 9.7 |
| 23.3 | 31.4 | 41.1 | 20.9 | 11.3 |
| 25.0 | 25.0 | 17.7 | 6.4 | 3.7 |
| 61.2 | 61.2 | 39.4 | - | - |
| 25.8 | 46.7 | 46.7 | 25.0 | 12.1 |
| 16.1 | 16.1 | 11.3 | 3.2 | - |
| 26.6 | 26.6 | 19.3 | 12.1 | 4.8 |
| 7.3 | 16.1 | 17.7 | 20.9 | 20.9 |
| 4.8 | 9.7 | 11.8 | 14.5 | 18.5 |
| 16.9 | 28.2 | 28.2 | 28.2 | 28.2 |

Table 5B

Peripheral Arterial Disease Group

Muscle Blood Flow Readings at Minute Intervals

Following Release of the Occluding Cuff

Proximal Occlusive Disease

| | Time (mins.) | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| | 14.5 | 35.0 | 35.0 | 35.0 | 28.2 |
| | 41.9 | 41.9 | 24.2 | - | - |
| | 48.3 | 48.3 | 37.0 | - | - |
| | 37.8 | 37.8 | 17.5 | 10.0 | 5.7 |
| | 16.1 | 20.9 | 20.9 | 20.9 | 20.9 |
| Mean | 25.8 | 30.9 | 27.3 | 20.7 | 16.7 |
| & | ± | ± | ± | ± | ± |
| one S.D. | 15.1 | 13.6 | 11.6 | 10.1 | 9.4 |

Table 5C

Peripheral Arterial Disease Group

Muscle Blood Flow Readings at Minute Intervals

Following the Release of Occluding Cuff

Distal Occlusive Disease

| Time (mins.) | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 14.5 | 28.2 | 35.4 | 35.4 | 20.1 | 8.5 | - |
| 33.8 | 33.8 | 24.2 | 15.3 | 9.7 | - | - |
| 8.9 | 13.1 | 16.9 | 16.9 | 16.9 | 16.9 | 16.9 |
| 9.7 | 14.5 | 21.7 | 21.7 | 21.7 | 14.5 | 7.3 |
| 17.7 | 27.7 | 27.7 | 23.0 | 16.1 | - | - |
| 18.5 | 25.0 | 25.0 | 25.0 | 21.7 | 18.5 | 11.3 |
| 10.5 | 21.7 | 42.7 | 42.7 | 42.7 | 29.0 | 23.3 |
| 5.6 | 6.4 | 6.4 | 6.4 | 6.4 | 3.7 | 2.1 |
| 9.7 | 17.7 | 24.2 | 24.2 | 24.2 | 24.2 | 24.2 |
| 1.0 | 28.2 | 28.2 | 28.2 | 21.7 | 19.3 | - |
| 4.0 | 6.3 | 7.9 | 12.9 | 12.9 | 12.9 | 12.9 |
| 12.5 | 17.7 | 17.7 | 17.7 | 13.7 | 12.1 | 8.9 |
| 8.9 | 11.8 | 13.7 | 13.7 | 13.7 | 13.7 | 13.7 |
| 14.5 | 25.0 | 25.0 | 25.0 | 25.0 | 20.9 | 13.7 |
| 25.0 | 40.3 | 40.3 | 21.7 | 6.1 | - | - |
| 31.0 | 31.0 | 31.0 | 19.0 | 12.1 | - | - |
| 28.2 | 28.2 | 12.9 | - | - | - | - |

Table 5C

Muscle Blood Flow Readings at Minute Intervals

Distal Occlusive Disease

| Time (mins.) | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 16.9 | 16.9 | 16.9 | 16.9 | 16.9 | 13.7 | 9.7 |
| 9.1 | 13.7 | 17.7 | 17.7 | 17.7 | 17.7 | 17.7 |
| 4.0 | 8.1 | 11.3 | 14.5 | 20.1 | 20.1 | 20.1 |
| 30.6 | 30.6 | 14.5 | 12.1 | 8.9 | - | - |
| 12.9 | 25.0 | 25.0 | 25.0 | 19.3 | 12.1 | - |
| 12.9 | 21.7 | 33.8 | 33.8 | 33.8 | 26.6 | - |
| 3.2 | 8.9 | 11.6 | 11.6 | 11.6 | 11.6 | 11.6 |
| 12.1 | 15.3 | 15.3 | 8.9 | 6.4 | 4.5 | - |
| 36.2 | 47.5 | 47.5 | 32.2 | - | - | - |
| 14.5 | 18.5 | 22.5 | 22.5 | 22.5 | 22.5 | 12.1 |
| 10.7 | 12.9 | 15.3 | 15.3 | 15.3 | 9.7 | - |
| 10.7 | 13.8 | 13.8 | 13.8 | 11.3 | 10.1 | 6.9 |
| 2.3 | 4.8 | 9.7 | 10.5 | 10.5 | 10.5 | 7.3 |
| 19.3 | 19.3 | 19.3 | 19.3 | 19.3 | 8.5 | - |
| 7.4 | 7.4 | 7.4 | 7.4 | 7.4 | 4.8 | - |
| 13.7 | 21.7 | 21.7 | 21.7 | 21.7 | 21.7 | - |

Table 5C

Muscle Blood Flow Readings at Minute Intervals

Distal Occlusive Disease

| Time (mins.) | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 17.7 | 17.7 | 17.7 | 17.7 | 12.3 | 9.7 | 7.3 |
| 3.7 | 9.7 | 11.3 | 11.3 | 11.3 | 11.3 | 11.3 |
| 4.0 | 9.7 | 11.3 | 11.3 | 11.3 | 11.3 | 7.3 |
| 8.9 | 30.6 | 30.6 | 30.6 | 19.3 | 14.5 | 10.3 |
| 8.1 | 10.5 | 14.5 | 20.9 | 20.9 | 20.9 | 20.9 |
| 21.7 | 9.7 | 9.7 | 2.9 | - | - | - |
| 6.6 | 11.3 | 30.0 | 30.0 | 30.0 | 30.0 | 21.7 |
| 1.6 | 17.7 | 17.7 | 17.7 | 17.7 | 17.7 | 8.1 |
| 6.4 | 11.3 | 16.9 | 16.9 | 16.9 | 16.9 | 16.9 |
| 12.9 | 24.2 | 24.2 | 12.9 | 5.6 | - | - |
| 9.7 | 18.5 | 18.5 | 18.5 | 18.5 | 11.3 | 7.3 |
| 20.9 | 39.4 | 39.4 | 29.0 | - | - | - |
| 10.5 | 14.5 | 17.7 | 17.7 | 17.7 | 17.7 | 17.7 |
| 17.7 | 39.5 | 39.5 | - | - | - | - |
| 25.8 | 5.2 | 2.4 | - | - | - | - |
| 8.9 | 11.3 | 11.3 | 11.3 | 11.3 | - | - |
| 12.9 | 20.9 | 28.2 | 28.2 | 28.2 | 18.5 | 12.1 |

Table 5C

Muscle Blood Flow Readings at Minute Intervals

Distal Occlusive Disease

| Time (mins.) | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 29.8 | 29.8 | 24.2 | 18.5 | 12.9 | - | - |
| 20.9 | 26.6 | 26.6 | 26.6 | 24.2 | - | - |
| 4.03 | 7.3 | 12.9 | 12.9 | 3.2 | - | - |
| 5.3 | 9.7 | 9.7 | 9.7 | 9.7 | 8.1 | 8.1 |
| 8.9 | 12.1 | 14.5 | 14.5 | 14.5 | 10.5 | 8.1 |
| 5.3 | 20.1 | 20.1 | 20.1 | 20.1 | 12.9 | - |
| 25.8 | 20.9 | 11.3 | 5.6 | - | - | - |
| 7.3 | 9.7 | 15.3 | 15.3 | 15.3 | 15.3 | 15.3 |
| 5.6 | 11.3 | 11.3 | 11.3 | 11.3 | 11.3 | 11.3 |
| 16.1 | 33.0 | 33.0 | 16.1 | 8.9 | - | - |
| 8.1 | 10.5 | 11.6 | 12.9 | 13.2 | 13.6 | 13.6 |
| 11.3 | 25.8 | 25.8 | 25.8 | 19.3 | 16.9 | 16.9 |
| 20.9 | 26.6 | 26.6 | 26.1 | 20.9 | 13.7 | - |
| 19.3 | 28.2 | 19.3 | 13.7 | 8.9 | - | - |
| 10.9 | 20.9 | 20.9 | 20.9 | 8.5 | - | - |
| 11.3 | 11.3 | 4.2 | 2.4 | - | - | - |
| 28.9 | 37.0 | 37.0 | - | - | - | - |

Table 5C

Muscle Blood Flow Readings at Minute Intervals

Distal Occlusive Disease

| | Time (mins.) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | 22.5 | 14.5 | 5.6 | - | - | - | - |
| | 4.8 | 10.5 | 15.3 | 20.9 | 20.9 | 20.9 | 20.9 |
| | 14.5 | 23.3 | 23.3 | 18.5 | 15.3 | 15.3 | 9.7 |
| | 10.5 | 17.7 | 17.7 | 12.1 | 8.9 | 4.0 | - |
| | 46.6 | 46.6 | 26.6 | - | - | - | - |
| | 10.5 | 12.1 | 16.9 | 16.9 | 16.9 | 16.9 | 16.9 |
| | 30.6 | 30.6 | 30.6 | 16.9 | 12.1 | - | - |
| | 12.1 | 29.2 | 29.2 | 29.2 | 17.7 | - | - |
| | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 | 11.3 | - |
| | 20.1 | 29.8 | 29.8 | 16.1 | 10.1 | - | - |
| | 0.6 | 4.8 | 8.9 | 13.5 | 13.5 | 13.5 | 6.4 |
| | 8.1 | 12.1 | 15.3 | 15.3 | 15.3 | 7.3 | 4.0 |
| | 8.1 | 10.5 | 14.5 | 15.3 | 15.3 | 15.3 | 15.3 |
| | 18.5 | 37.8 | 37.8 | 37.8 | 15.3 | - | - |
| Mean & one S.D. | 14.0 ± 9.1 | 19.7 ± 10.3 | 20.4 ± 9.7 | 18.5 ± 7.9 | 15.9 ± 6.8 | 14.6 ± 5.9 | 12.7 ± 5.5 |

Table 6A

Aorto Iliac Thromboendarterectomy Group

Muscle Blood Flow Before and after Surgery

| Name | Age | Pre-operative | | | Post-operative | | |
|---|---|---|---|---|---|---|---|
| | | P.B.F. ml/100gm/min. | Time to P.B.F. mins. | Duration of P.B.F. mins. | P.B.F. ml/100gm/min. | Time to P.B.F. mins. | Duration of P.B.F. mins. |
| J.B. | 61 | 11.3 | 1.0 | 1.3 | 19.3 | 1.0 | 1.5 |
| P.B. | 59 | 10.5 | 0.7 | 3.0 | 53.1 | 0.7 | 2.0 |
| T.B. | 63 | 25.0 | 0.8 | 1.5 | 38.6 | 0.1 | 0.9 |
| R.C. | 51 | 61.2 | 1.0 | 1.5 | 43.5 | 0.3 | 0.9 |
| G.C. | 27 | 46.7 | 1.2 | 2.5 | 88.5 | 0.6 | 0.9 |
| T.E. | 59 | 46.6 | 0.6 | 1.4 | 53.9 | 1.3 | 1.5 |
| J.G. | 56 | 49.1 | 1.2 | 1.8 | 51.5 | 0.7 | 2.3 |
| W.H. | 53 | 36.2 | 1.0 | 3.0 | 64.4 | 0.2 | 1.3 |
| F.K. | 55 | 26.6 | 1.0 | 1.6 | 55.5 | 0.8 | 0.9 |
| | | 29.8 | 1.3 | 2.0 | 51.5 | 1.0 | 1.3 |
| R.K. | 61 | 20.1 | 0.6 | 3.0 | 28.2 | 0.7 | 2.0 |
| W.L. | 57 | 24.2 | 3.0 | 2.5 | 20.9 | 4.0 | 3.0 |
| J.M. | 56 | 16.9 | 2.0 | 4.5 | 44.3 | 0.7 | 1.5 |
| | | 10.5 | 6.0 | 4.5 | 16.9 | 5.0 | 2.5 |
| W.M. | 56 | 21.7 | 2.3 | 2.9 | 26.6 | 2.0 | 2.3 |
| | | 30.6 | 1.0 | 2.6 | 28.2 | 1.0 | 2.7 |
| D.M. | 39 | 26.6 | 2.0 | | 27.3 | 0.5 | 2.5 |
| J.McL. | 43 | 35.4 | 1.0 | 1.5 | 53.1 | 0.8 | 1.2 |
| | | 18.5 | 3.0 | 4.5 | 58.0 | 0.5 | 1.3 |
| J.McG. | 55 | 28.2 | 1.3 | 3.7 | 52.3 | 0.5 | 0.6 |

Table 6A

| Name | Age | Pre-operative | | | Post-operative | | |
|---|---|---|---|---|---|---|---|
| | | P.B.F. ml/100gm/min. | Time to P.B.F. mins. | Duration of P.B.F. mins. | P.B.F. ml/100gm/min. | Time to P.B.F. mins. | Duration of P.B.F. mins. |
| L.P. | 49 | 48.3 | 0.7 | 1.3 | 37.8 | 1.3 | 1.3 |
| S.P. | 50 | 11.2 | 5.0 | 2.7 | 22.5 | 2.3 | 2.6 |
| A.S. | 44 | 37.8 | 0.7 | 1.7 | 15.4 | 1.0 | 1.0 |
| J.T. | 54 | 20.9 | 1.2 | 6.3 | 49.1 | 0.5 | 1.4 |
| T.P. | 39 | 45.7 | 1.3 | 1.3 | 61.2 | 1.2 | 2.0 |
| | | 43.0 | 1.3 | 1.3 | 56.0 | 0.4 | 1.2 |
| M.T. | 49 | 29.2 | 0.7 | 1.7 | 59.6 | 0.3 | 1.3 |
| Mean | | 30.1 | 1.59 | 2.52 | 43.6 | 1.09 | 1.63 |
| one S.D. | | ± 13.7 | ± 1.37 | ± 1.29 | ± 17.7 | ± 1.11 | ± 0.66 |

Table 6B

Aorto Iliac Thromboendarterectomy Group

Patients with Improvement in intermittent claudication: muscle blood flow at minute intervals following release of the occluding cuff.

| | | Pre-operative | | | | | | Post-operative | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | Age | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 |
| P.B. | 61 | 10.5 | 10.5 | 10.5 | 8.9 | 7.3 | | 53.1 | 53.1 | 27.4 | - |
| T.B. | 59 | 25.0 | 25.0 | 17.7 | 6.4 | 3.7 | | 38.6 | 8.9 | - | - |
| R.C. | 51 | 61.2 | 61.2 | 39.4 | - | - | | 43.5 | 14.5 | 8.1 | 4.0 |
| G.C. | 27 | 25.8 | 46.7 | 46.7 | 25.0 | - | | 88.6 | 28.9 | 10.1 | - |
| J.G. | 56 | 36.2 | 49.1 | 49.1 | 30.6 | - | | 51.5 | 51.5 | 51.5 | 12.6 |
| W.H. | 53 | 36.2 | 36.2 | 36.2 | 36.2 | 16.1 | | 64.4 | 20.9 | 8.1 | - |
| F.K. | 55 | 26.6 | 26.6 | 19.3 | 13.1 | 4.8 | | 55.5 | 31.4 | 9.7 | 5.6 |
| F.K. | 55 | 20.1 | 29.8 | 29.8 | 16.1 | 10.1 | | 51.5 | 51.5 | 19.3 | 6.0 |
| R.K. | 61 | 20.1 | 20.1 | 20.1 | 14.5 | 10.5 | | 28.2 | 28.2 | 20.1 | 8.1 |
| W.M. | 56 | 30.6 | 30.6 | 30.6 | 15.3 | 8.9 | | 28.2 | 28.2 | 28.2 | 17.7 |
| J.M. | 56 | 9.7 | 16.9 | 16.9 | 16.9 | 16.9 | | 44.3 | 44.3 | 20.1 | 8.1 |
| J.McL. | 43 | 35.4 | 35.4 | 27.4 | 14.5 | 7.3 | | 53.1 | 53.1 | 33.8 | 20.1 |
| J.McL. | 43 | 6.4 | 9.7 | 18.5 | 18.5 | 18.5 | | 58.0 | 46.7 | 20.1 | 12.1 |
| J.McG. | 55 | 16.9 | 28.2 | 28.2 | 28.2 | 28.2 | | 52.3 | 22.5 | 8.1 | - |
| D.M. | 39 | 21.7 | 26.6 | 26.6 | 26.6 | 26.6 | | 27.3 | 27.3 | 27.3 | 18.0 |
| T.P. | 39 | 25.6 | 45.7 | 20.8 | 6.5 | 2.9 | | 29.0 | 61.2 | 21.4 | 8.7 |
| T.P. | 39 | 30.5 | 43.0 | 43.0 | 20.8 | 7.7 | | 56.0 | 24.2 | 11.3 | 5.3 |
| S.P. | 50 | 2.7 | 5.7 | 6.5 | 8.6 | 11.2 | | 7.7 | 17.7 | 22.5 | 22.5 |
| J.T. | 54 | 16.1 | 20.9 | 20.9 | 20.9 | 20.9 | | 49.1 | 37.8 | 31.4 | 18.5 |
| M.T. | 49 | 29.2 | 29.2 | 13.1 | 5.6 | 3.5 | | 59.6 | 37.8 | 26.2 | 15.1 |
| Mean | | 24.3 | 29.9 | 26.7 | 17.5 | 12.1 | | 47.0 | 34.5 | 21.3 | 12.2 |
| one | | ± | ± | ± | ± | ± | | ± | ± | ± | ± |
| S.D. | | 13.0 | 14.3 | 11.9 | 8.8 | 7.9 | | 17.3 | 14.9 | 11.9 | 6.1 |

Table 7

Aorto Iliac Thromboendarterectomy Group
Peak Muscle Blood Flow
Over 1st Post-Operative Year

| Name | Age | Pre-operative P.B.F. ml/100gm/min. | 3 Months P.B.F. ml/100gm/min. | 6 Months P.B.F. ml/100gm/min. | 1 Year P.B.F. ml/100gm/min. |
|---|---|---|---|---|---|
| P.B. | 59 | 10.5 | 53.1 | 49.1 | 50.7 |
| R.C. | 51 | 61.2 | 43.5 | 33.0 | 35.4 |
| J.G. | 56 | 49.1 | 51.5 | 62.5 | 53.1 |
| W.H. | 52 | 36.2 | 64.4 | 50.7 | 59.6 |
| F.K. | 55 | 26.6 | 55.5 | 29.2 | 66.0 |
| | | 29.8 | 51.5 | 23.3 | 46.7 |
| R.K. | 61 | 20.1 | 28.2 | 25.0 | 12.9 |
| J.M. | 56 | 16.9 | 44.3 | - | 41.9 |
| D.M. | 39 | 26.6 | 27.3 | 35.4 | 25.0 |
| S.P. | 50 | 11.2 | 22.5 | 29.0 | 25.8 |
| | | 16.9 | 26.6 | 33.8 | 27.4 |
| J.T. | 54 | 20.9 | 49.1 | 58.8 | 53.5 |
| | | 41.9 | 35.4 | 61.2 | 70.5 |
| Mean & oneS.D. | | 28.3 ± 15.2 | 42.5 ± 13.3 | 40.9 ± 14.6 | 43.7 ± 17.5 |

## Table 8A

### Aorto Iliac Graft Group

Patients with an improvement in intermittent claudication following operation

| Name | Age | Pre-operative | | | Post-operative | | |
|---|---|---|---|---|---|---|---|
| | | P.B.F. | Time to P.B.F. | Duration of P.B.F. | P.B.F. | Time to P.B.F. | Duration of P.B.F. |
| R.K. | | 15.3 | 2.3 | 3.0 | 13.7 | 1.5 | 3.5 |
| | | 20.1 | 0.4 | 1.0 | 26.6 | 0.7 | 1.2 |
| J.K. | | 17.7 | 2.7 | 3.6 | 31.4 | 1.3 | 2.3 |
| | | 11.3 | 3.0 | 4.5 | 37.0 | 0.7 | 1.5 |
| J.McA. | | 30.6 | 0.8 | 3.0 | 70.0 | 0.4 | 3.6 |
| | | 39.4 | 0.4 | 1.5 | 49.1 | 0.3 | 1.3 |
| G.K. | | 37.0 | 0.5 | 1.3 | 26.6 | 0.7 | 1.3 |
| | | 50.4 | 0.3 | 1.0 | 40.1 | 0.3 | 1.0 |
| J.S. | | 19.3 | 3.5 | 5.0 | 40.3 | 1.2 | 2.0 |
| | | 25.7 | 1.5 | 2.5 | 76.5 | 0.5 | 1.2 |
| Mean | | 26.7 | 1.54 | 2.64 | 41.1 | 0.77 | 1.89 |
| one S.D. | | ± 12.4 | ± 1.23 | ± 1.44 | ± 19.5 | ± 0.45 | ± 0.96 |

Table 8B

Aorto Iliac Graft Group

Patients without an improvement in intermittent claudication following operation

| Name | Age | Pre-operative | | | Post-operative | | |
|---|---|---|---|---|---|---|---|
| | | P.B.F. | Time to P.B.F. | Duration Of P.B.F. | P.B.F. | Time to P.B.F. | Duration of P.B.F. |
| A.A. | | 28.2 | 1.2 | 1.6 | 25.3 | 0.8 | 1.8 |
| | | 20.9 | 1.5 | 2.5 | 20.1 | 1.1 | 2.3 |
| W.W. | | 58.0 | 0.3 | 0.7 | 61.2 | 0.5 | 1.4 |
| | | 29.5 | 2.0 | 1.3 | 24.5 | 1.6 | 1.9 |
| J.C. | | 9.7 | 6.0 | 4.0 | 10.3 | 5.1 | 3.2 |
| | | 19.2 | 1.7 | 2.3 | 10.9 | 1.5 | 4.3 |
| Mean | | 27.6 | 2.12 | 2.07 | 25.4 | 1.77 | 2.48 |
| one S.D | | ± | ± | ± | ± | ± | ± |
| | | 16.5 | 1.99 | 1.16 | 18.7 | 1.69 | 1.08 |

Table 9A

Femoral and Popliteal Thromboendarterectomy Group

The Effect of Thromboendarterectomy on Muscle Blood Flow

Before and After Surgery

| Name | Age | Pre-operative | | | Post-operative | | |
|---|---|---|---|---|---|---|---|
| | | P.B.F. ml/100gm/min. | Time to P.B.F. mins | Duration of P.B.F. mins. | P.B.F. ml/100gm/min. | Time to P.B.F. mins. | Duration of P.B.F. mins. |
| W.B. | 47 | 37.0 | 1.3 | - | 67.6 | 0.5 | 1.3 |
| J.C. | 47 | 38.0 | 2.0 | 3.3 | 56.4 | 0.7 | 2.3 |
| A.C. | 47 | 22.5 | 0.7 | 3.7 | 36.2 | 0.5 | 1.2 |
| | | 28.2 | 0.7 | 1.5 | 41.9 | 0.7 | 1.0 |
| A.D. | 48 | 45.6 | 0.6 | 1.2 | 86.9 | 0.3 | 0.7 |
| T.E. | 60 | 53.9 | 1.3 | 1.5 | 64.4 | 0.3 | 1.2 |
| J.F. | 56 | 16.9 | 2.3 | 5.0 | 80.5 | 0.3 | 1.3 |
| J.F. | 59 | 30.6 | 1.0 | 2.0 | 40.9 | 0.2 | 1.0 |
| F.G. | 57 | 16.1 | 2.0 | 6.5 | 33.0 | 0.3 | 1.3 |
| F.L. | 53 | 37.8 | 1.2 | 3.0 | 62.0 | 0.3 | 2.0 |
| T.M. | 29 | 28.2 | 2.5 | 1.7 | 64.4 | 0.5 | 1.4 |
| | | 32.2 | 2.0 | 2.3 | 60.4 | 0.3 | 1.3 |
| J.M. | 56 | 16.9 | 1.6 | 2.4 | 51.1 | 0.5 | 1.0 |
| C.McK. | 65 | 27.7 | 1.5 | 2.0 | 58.0 | 0.3 | 1.3 |
| A.M. | 54 | 12.9 | 2.3 | 5.4 | 30.5 | 0.3 | 1.0 |
| W.P. | 62 | 6.4 | 1.7 | 3.3 | 61.2 | 0.3 | 0.9 |
| J.R. | 49 | 24.2 | 3.0 | 4.5 | 50.7 | 0.5 | 1.5 |
| J.S. | 49 | 44.3 | 0.8 | 1.8 | 54.7 | 0.5 | 1.5 |
| W.M. | 57 | 28.0 | 2.0 | 3.7 | 35.5 | 0.3 | 2.3 |
| L.D. | 40 | 29.7 | 1.5 | 1.8 | 63.6 | 0.4 | 1.0 |

Table 9A

| Name | Age | Pre-operative | | | Post-operative | | |
|---|---|---|---|---|---|---|---|
| | | P.B.F. ml/100gm/min. | Time to P.B.F. mins. | Duration of P.B.F. mins. | P.B.F. ml/100gm/min. | Time to P.B.F. mins. | Duration of P.B.F. mins. |
| T.H. | 47 | 34.0 | 1.7 | 1.3 | 38.6 | 0.3 | 0.4 |
| C.K. | 63 | 45.0 | 1.3 | 1.3 | 88.6 | 0.2 | 1.5 |
| R.B. | 62 | 20.9 | 3.1 | 4.0 | 20.9 | 2.3 | 4.5 |
| J.L. | 51 | 26.3 | 3.5 | 3.5 | 29.8 | 1.0 | 2.0 |
| J.McA. | 51 | 21.7 | 3.0 | 2.3 | 14.9 | 1.7 | 3.5 |
| J.S. | 59 | 13.7 | 2.5 | 4.7 | 20.1 | 1.0 | 3.8 |
| M.D. | 48 | 26.5 | 1.6 | 3.3 | 33.0 | 0.8 | 1.9 |
| Mean | | 28.3 | 1.80 | 2.96 | 49.8 | 0.57 | 1.65 |
| one | | ± | ± | ± | ± | ± | ± |
| S.D. | | 11.3 | 0.79 | 1.43 | 19.8 | 0.47 | 0.96 |

Table 9B

Femoral and Popliteal Thromboendarterectomy Group

Successful Limbs

Muscle Blood Flow at Minute Intervals Following Release of the Occluding Cuff

| | | Pre-operative | | | | | | | Post-operative | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 1 | 2 | 3 | 4 | 5 |
| L.D. | 40 | 12.9 | 29.7 | 29.7 | 15.1 | 10.1 | 8.7 | 3.7 | 63.6 | 30.6 | 14.5 | 7.7 | |
| W.M. | 57 | 11.4 | 28.0 | 28.0 | 28.0 | 28.0 | 18.0 | 13.8 | 35.5 | 35.5 | 35.5 | 20.8 | 5.7 |
| J.S. | 49 | 44.3 | 44.3 | 32.2 | 25.8 | - | - | - | 54.7 | 54.7 | 26.6 | - | - |
| J.R. | 49 | 9.7 | 17.7 | 24.2 | 24.2 | 24.2 | 24.2 | 24.2 | 50.7 | 50.7 | 29.8 | - | - |
| W.P. | 62 | 5.6 | 6.4 | 6.4 | 6.4 | 6.4 | 3.7 | 2.1 | 61.2 | 21.7 | 19.3 | 11.3 | - |
| A.M. | 54 | 7.3 | 10.1 | 12.9 | 12.9 | 12.9 | 12.9 | 12.9 | 30.5 | 17.6 | 6.8 | 4.4 | 3.2 |
| C.McK | 65 | 17.7 | 27.7 | 27.7 | 23.0 | 16.1 | - | - | 58.0 | 33.8 | 23.3 | - | - |
| J.M. | 56 | 14.5 | 16.9 | 16.9 | 16.9 | 10.6 | - | - | 51.0 | 33.0 | 28.2 | 19.9 | - |
| T.M. | 29 | 9.7 | 16.9 | 28.2 | 28.2 | 17.7 | 11.3 | - | 64.4 | 44.3 | 20.1 | - | - |
| | | 12.9 | 32.2 | 32.2 | 32.1 | 16.1 | 10.5 | - | 60.4 | 40.3 | 20.9 | 7.3 | - |
| F.L. | 53 | 18.5 | 37.8 | 37.8 | 37.8 | 15.3 | - | - | 62.0 | 62.0 | 21.7 | - | - |
| F.G. | 57 | 7.3 | 16.1 | 16.1 | 16.1 | 16.1 | 16.1 | 16.1 | 33.0 | 21.7 | 12.9 | 9.2 | 7.3 |
| J.F. | 56 | 30.6 | 30.6 | 30.6 | 16.9 | 12.1 | - | - | 40.9 | 28.9 | 8.5 | 2.4 | - |
| J.F. | 59 | 10.5 | 12.1 | 16.9 | 16.9 | 16.9 | 16.9 | 16.9 | 80.5 | 35.4 | - | - | - |
| T.E. | 60 | 33.8 | 53.9 | 35.4 | 20.4 | - | - | - | 64.4 | 32.2 | 13.7 | - | - |
| A.D. | 48 | 45.6 | 27.4 | 38.9 | 4.8 | 3.2 | - | - | 86.9 | 21.7 | 8.1 | - | - |
| A.C. | 47 | 22.5 | 22.5 | 22.5 | 22.5 | 13.7 | 7.3 | 4.8 | 36.2 | 20.9 | 7.3 | 4.4 | 1.9 |
| | | 28.2 | 28.2 | 19.3 | 12.1 | 8.1 | 5.6 | - | 41.9 | 27.4 | 10.0 | 5.8 | 3.2 |

## Table 9B

| | | Pre-operative | | | | | | | Post-operative | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 1 | 2 | 3 | 4 | 5 |
| J.C. | 47 | 16.0 | 38.0 | 38.0 | 38.0 | 38.0 | - | - | 56.4 | 56.4 | 56.4 | - | - |
| W.B. | 47 | 28.9 | 37.0 | 37.0 | 37.0 | - | - | - | 67.6 | 41.1 | 19.3 | - | - |
| T.H. | 47 | 17.6 | 34.0 | 34.0 | 22.4 | 19.2 | 16.1 | - | 18.7 | 6.4 | 2.4 | - | - |
| C.K. | 63 | 30.5 | 45.0 | 45.0 | 20.8 | 12.9 | 5.4 | - | 88.6 | 25.8 | 8.5 | - | - |
| Mean & one S.D. | | 19.8 ± 11.7 | 27.8 ± 12.2 | 26.4 ± 10.3 | 21.7 ± 9.3 | 15.7 ± 7.9 | 12.1 ± 6.0 | 11.8 ± 7.7 | 54.9 ± 18.1 | 33.7 ± 13.8 | 18.8 ± 12.3 | 9.3 ± 6.4 | 4.3 ± 2.2 |

Table 10A

Femoral and Popliteal Thromboendarterectomy Group

Non-Operated Limbs

| Name | Age | Pre-operative | | | Post-operative | | |
|---|---|---|---|---|---|---|---|
| W.B. | 47 | 42.5 | 1.0 | 0.9 | 52.3 | 1.0 | 1.7 |
| J.C. | 47 | 50.0 | 0.7 | 1.3 | 53.1 | 0.7 | 1.2 |
| A.D. | 48 | 51.5 | 0.2 | 1.0 | 66.0 | 0.5 | 0.9 |
| J.F. | 56 | 44.3 | 0.7 | 1.5 | 49.9 | 0.5 | 1.5 |
| J.F. | 59 | 28.2 | 0.3 | 1.7 | 16.6 | 0.2 | 0.8 |
| F.G. | 57 | 33.7 | 1.3 | 3.7 | 31.4 | 0.3 | 1.6 |
| T.H. | 47 | 51.5 | 0.1 | 1.7 | 31.4 | 0.4 | 2.9 |
| C.K. | 63 | 60.5 | 0.3 | 1.7 | 66.0 | 0.2 | 1.6 |
| C.McK. | 65 | 35.4 | 1.0 | 1.8 | 31.9 | 0.4 | 0.8 |
| W.M. | 57 | 31.5 | 1.3 | 3.0 | 31.0 | 1.7 | 1.7 |
| A.M. | 54 | 29.8 | 0.2 | 1.7 | 27.3 | 0.7 | 1.0 |
| W.P. | 62 | 25.0 | 0.2 | 0.8 | 27.4 | 0.7 | 2.3 |
| J.R. | 49 | 49.9 | 0.4 | 1.0 | 54.7 | 1.0 | 1.5 |
| J.S. | 49 | 40.5 | 0.5 | 1.2 | 45.9 | 0.2 | 2.5 |
| Mean | 41 | 41.0 | 0.59 | 1.64 | 41.8 | 0.61 | 1.57 |
| one S.D. | | ± 10.7 | ± 0.42 | ± 0.81 | ± 15.5 | ± 0.41 | ± 0.64 |

Table 10B

Femoral and Popliteal Thromboendarterectomy Group
Non-Operated Limbs

Muscle Blood Flow at Minute Intervals Following Release of the Occluding Cuff

| | | Pre-Operative | | | | | Post-Operative | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | Age | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| W.B. | 47 | 42.5 | 14.5 | 5.6 | - | - | 52.3 | 42.3 | 33.0 | 8.9 | - |
| J.C. | 47 | 50.0 | 50.0 | 23.5 | 16.1 | 13.0 | 53.1 | 45.9 | 27.4 | 16.6 | 3.7 |
| A.D. | 48 | 51.5 | 10.5 | 4.6 | - | - | 66.0 | 28.2 | 13.4 | 6.3 | - |
| J.F. | 56 | 44.3 | 44.3 | 28.2 | 20.9 | - | 49.9 | 49.9 | 16.1 | 8.5 | - |
| J.F. | 59 | 28.2 | 28.2 | 19.3 | 16.1 | 8.9 | 16.6 | 7.3 | 5.3 | 1.6 | - |
| F.G. | 57 | 9.7 | 33.7 | 33.7 | 33.7 | 33.7 | 31.4 | 31.4 | 16.9 | 12.9 | 8.9 |
| T.H. | 47 | 51.5 | 32.1 | 22.4 | 16.1 | 9.6 | 66.0 | 45.9 | 20.1 | - | - |
| C.K. | 63 | 60.5 | 25.6 | 14.5 | 7.9 | - | 31.9 | 10.0 | 5.6 | 2.3 | - |
| C.McK. | 65 | 35.4 | 35.4 | 24.2 | 16.1 | 11.3 | 22.4 | 31.0 | 31.0 | 31.0 | 20.0 |
| W.M. | 57 | 22.4 | 31.5 | 31.5 | 31.5 | 16.9 | 27.3 | 18.2 | 6.5 | 3.8 | 3.6 |
| A.M. | 54 | 29.8 | 22.5 | 12.1 | 7.3 | - | 27.4 | 27.4 | 27.4 | 16.1 | - |
| W.P. | 62 | 25.0 | 10.5 | 5.8 | - | - | 54.7 | 37.3 | - | - | - |
| J.R. | 49 | 49.9 | 43.5 | 31.4 | - | - | 45.9 | 36.2 | 32.2 | - | - |
| J.S. | 49 | 40.5 | 26.6 | 19.3 | - | - | 31.4 | 31.4 | 31.4 | 22.5 | 18.8 |
| Mean | | 38.7 | 29.2 | 19.7 | 18.4 | 15.6 | 41.2 | 32.3 | 20.5 | 11.9 | 11.0 |
| | | ± | ± | ± | ± | ± | ± | ± | ± | ± | ± |
| one S.D. | | 14.2 | 12.2 | 10.0 | 9.3 | 9.3 | 16.2 | 13.8 | 10.6 | 9.1 | 8.0 |

Table 11A

Femoral and Popliteal Thromboendarterectomy Group

M.B.F. During 1st Post-Operative Year

| Name | Age | Pre-operative P.B.F. ml/100gm/Min. | 3 Months P.B.F. ml/100gm/min. | 6 Months P.B.F. ml/100gm/min. | 1 Year P.B.F. ml/100gm/min. |
|---|---|---|---|---|---|
| W.B. | 47 | 37.0 | 67.6 | 53.9 | 42.7 |
| A.C. | 47 | 22.5 | 36.2 | - | 42.0 |
| | | 28.2 | 41.9 | - | 43.5 |
| A.D. | 48 | 45.6 | 86.9 | 64.5 | 62.8 |
| T.E. | 60 | 53.1 | 64.4 | 56.4 | 61.4 |
| J.F. | 56 | 16.9 | 80.5 | 45.1 | 41.1 |
| J.F. | 59 | 30.6 | 40.9 | 53.9 | 47.7 |
| F.G. | 57 | 16.1 | 33.0 | 25.8 | 25.0 |
| F.L. | 53 | 37.8 | 62.0 | 25.0 | 80.5 |
| J.M. | 56 | 16.9 | 51.1 | 58.8 | 43.5 |
| C.McK. | 65 | 27.7 | - | 58.0 | 65.2 |
| W.P. | 62 | 6.4 | 61.2 | 46.7 | 39.4 |
| J.R. | 49 | 24.2 | 50.7 | 35.4 | 26.6 |
| J.S. | 49 | 44.3 | 54.7 | 66.8 | 41.9 |
| W.M. | 56 | 28.0 | 35.5 | 45.9 | 36.2 |
| L.D. | 41 | 29.7 | 63.6 | 41.1 | 35.4 |
| | Mean | 29.1 | 51.9 | 48.4 | 45.9 |
| | one S.D. | ± 12.2 | ± 20.9 | ± 13.1 | ± 14.7 |

Table 11B

Femoral and Popliteal Thromboendarterectomy Group

Pattern A

| Name | Age | Pre-operative P.B.F. ml/100gm/min. | 3 months P.B.F. ml/100gm/min. | 6 months P.B.F. ml/100gm/min. | 1 Year P.BF. ml/100gm/min. |
|---|---|---|---|---|---|
| J.S. | 49 | 44.3 | 54.7 | 66.8 | 41.9 |
| W.B. | 47 | 37.0 | 67.6 | 53.9 | 42.7 |
| A.D. | 48 | 45.6 | 86.9 | 64.5 | 62.8 |
| J.F. | 56 | 16.9 | 80.5 | 45.1 | 41.1 |
| F.G. | 57 | 16.1 | 33.0 | 25.8 | 25.0 |
| W.P. | 62 | 6.4 | 61.2 | 46.7 | 39.4 |
| J.R. | 49 | 24.2 | 50.7 | 35.4 | 26.6 |
| L.D. | 40 | 29.7 | 63.6 | 41.1 | 35.4 |
| Mean one S.D. | | 27.5 ± 14.2 | 62.3 ± 17.0 | 47.4 ± 12.9 | 39.4 ± 11.7 |

Table 11C

Femoral and Popliteal Thromboendarterectomy Group

Pattern B

| Name | Age | Pre-operative P.B.F. ml/100gm/min. | 3 Months P.B.F. ml/100gm/min. | 6 Months P.B.F. ml/100gm/min. | 1 Year P.B.F. ml/100gm/min. |
|---|---|---|---|---|---|
| A.C. | 47 | 22.5 | 36.2 | - | 42.0 |
| | | 28.2 | 41.9 | - | 43.5 |
| T.E. | 60 | 53.1 | 64.4 | 56.4 | 61.4 |
| J.F. | 59 | 30.6 | 40.9 | 53.9 | 47.7 |
| J.M. | 56 | 16.9 | 51.1 | 58.8 | 43.5 |
| C.McK | 65 | 27.7 | - | 58.0 | 65.2 |
| W.M. | 57 | 28.0 | 35.5 | 45.9 | 36.2 |
| F.L. | 53 | 37.8 | 62.0 | 25.0 | 80.5 |
| Mean | | 30.6 | 47.5 | 49.7 | 52.5 |
| | | ± | ± | ± | ± |
| one S.D. | 10.9 | 11.4 | 13.0 | 15.1 | |

Table 12

Vein Bypass Graft Group

Muscle Blood Flow Before and After Surgery

| Name | Pre-operative | | | | Post-operative | | |
|---|---|---|---|---|---|---|---|
| | Age | P.B.F. ml/100gm/min. | Time to P.B.F. mins. | Duration of P.B.F. mins. | P.B.F. ml/100gm/min. | Time to P.B.F. mins. | Duration of P.B.F. mins. |
| M.B. | 55 | 17.7 | 1.2 | 1.8 | 29.0 | 0.3 | 1.5 |
| K.B. | 66 | 27.4 | 3.3 | 1.7 | 29.0 | 0.5 | 0.8 |
| L.D. | 40 | 18.5 | 2.8 | 5.0 | 49.9 | 0.3 | 1.3 |
| J.E. | 56 | 28.2 | 2.3 | 2.5 | 50.7 | 0.7 | 2.0 |
| W.F. | 60 | 18.5 | 1.5 | 5.2 | 51.5 | 0.3 | 1.4 |
| D.J. | 36 | 14.5 | 1.0 | 4.3 | 41.1 | 0.5 | 1.7 |
| P.K. | 45 | 13.5 | 3.5 | 3.0 | 41.0 | 0.7 | 1.0 |
| I.McF. | 58 | 35.4 | 0.7 | 2.5 | 64.5 | 0.1 | 1.7 |
| C.McK | 66 | 40.3 | 1.3 | 3.0 | 66.0 | 0.2 | 1.1 |
| C.McC. | 50 | 29.2 | 1.8 | 2.4 | 44.3 | 0.3 | 1.9 |
| D.W. | 62 | 25.0 | 2.0 | 3.8 | 54.7 | 0.6 | 1.7 |
| J.L. | 59 | 35.4 | 2.0 | 2.3 | 83.7 | 0.3 | 1.1 |
| T.McE. | 59 | 13.7 | 1.0 | 3.7 | 72.5 | 0.5 | 1.4 |
| D.M. | 58 | 23.0 | 1.0 | 3.0 | 51.5 | 0.3 | 0.3 |
| M.McK. | 48 | 12.9 | 1.2 | 2.0 | 42.7 | 0.2 | 2.1 |
| J.McK. | 55 | 22.9 | 1.3 | 5.2 | 56.4 | 0.3 | 2.4 |
| P.D. | 54 | 32.5 | 1.0 | 3.3 | 46.7 | 0.3 | 0.7 |
| Mean | | 24.0 | 1.70 | 3.22 | 51.5 | 0.38 | 1.42 |
| | | ± | ± | ± | ± | ± | ± |
| one S.D. | | 8.6 | 0.84 | 1.15 | 14.3 | 0.17 | 0.60 |

Table 13

Vein Bypass Graft Group

M.B.F. at Minute Intervals Following Release of the Occluding Cuff

| | | Pre-operative | | | | | | | Post-operative | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 1 | 2 | 3 | 4 |
| K.B. | 66 | 10.9 | 13.2 | 21.5 | 27.4 | 27.4 | 16.1 | | 29.0 | 13.7 | 6.8 | 4.0 |
| M.B. | 55 | 12.1 | 17.7 | 17.7 | 9.7 | 4.8 | - | | 29.0 | 20.9 | 12.1 | 8.1 |
| P.D. | 54 | 32.5 | 32.5 | 32.5 | 32.5 | 23.3 | 12.9 | | 46.7 | 10.5 | 2.4 | - |
| J.E. | 56 | 12.1 | 18.9 | 28.2 | 28.2 | 22.5 | 16.9 | | 50.7 | 50.7 | 29.8 | 17.7 |
| W.F. | 60 | 12.1 | 18.5 | 18.5 | 18.5 | 18.5 | 18.5 | | 51.5 | 38.6 | 25.0 | 12.8 |
| D.J. | 36 | 14.5 | 14.5 | 14.5 | 14.5 | 14.5 | 8.9 | | 41.1 | 41.1 | 28.2 | 23.3 |
| P.K. | 45 | 0.6 | 4.8 | 8.9 | 13.5 | 13.5 | 13.5 | | 41.0 | 30.6 | 20.1 | 11.3 |
| J.L. | 59 | 14.5 | 28.2 | 35.4 | 35.4 | 20.1 | 8.5 | | 83.7 | 43.5 | 20.1 | 6.4 |
| J.McK. | 55 | 15.0 | 22.9 | 22.9 | 22.9 | 22.9 | 22.9 | | 56.4 | 56.4 | 22.5 | - |
| M.McM. | 48 | 9.7 | 12.9 | 12.9 | 7.7 | 4.4 | 1.6 | | 42.7 | 42.7 | 31.4 | 14.5 |
| I.McF. | 58 | 35.4 | 35.4 | 35.4 | 25.0 | 14.8 | 2.9 | | 64.5 | 43.5 | 12.9 | 9.7 |
| C.McK. | 66 | 24.2 | 40.3 | 40.3 | 40.3 | 32.2 | 17.7 | | 70.5 | 36.2 | 16.9 | 8.9 |
| C.McC. | 50 | 13.1 | 29.2 | 29.2 | 29.2 | 17.7 | 13.7 | | 44.3 | 44.3 | 26.6 | 16.9 |
| T.McE. | 59 | 13.7 | 13.7 | 13.7 | 13.7 | 8.5 | 2.7 | | 72.5 | 49.9 | 14.5 | - |
| D.M. | 58 | 23.0 | 23.0 | 23.0 | 23.0 | 12.2 | 9.2 | | 29.8 | 12.1 | 5.3 | - |
| D.W. | 62 | 14.5 | 25.0 | 25.0 | 25.0 | 25.0 | 20.9 | | 54.7 | 54.7 | 29.2 | 12.1 |
| L.D. | 40 | 3.2 | 11.3 | 18.5 | 18.5 | 18.5 | 18.5 | | 49.9 | 29.8 | 12.9 | 8.4 |
| Mean one S.D. | | 15.4 ± 9.0 | 21.3 ± 9.5 | 23.4 ± 9.0 | 22.6 ± 9.1 | 17.7 ± 7.7 | 12.8 ± 6.6 | | 50.5 ± 15.6 | 36.4 ± 14.7 | 18.6 ± 9.1 | 11.9 ± 5.2 |

Table 14

Vein Bypass Graft Group

Muscle Blood Flow from Non-Operative Limb

| Name | Age | Pre-operative | | | Post-operative | | |
|---|---|---|---|---|---|---|---|
| | | P.F.B. ml/100gm/min. | Time to P.B.F. mins. | Duration of P.B.F. mins. | P.B.F. ml/100gm/min. | Time to P.B.F. mins. | Duration of P.B.F. mins. |
| K.B. | | 51.5 | 0.3 | 1.0 | 37.8 | 0.3 | 0.9 |
| M.B. | 55 | 20.9 | 1.3 | 1.5 | 32.2 | 1.3 | 2.0 |
| P.D. | 54 | 30.6 | 0.1 | 0.6 | 35.4 | 0.3 | 0.4 |
| J.E. | 56 | 67.6 | 0.3 | 0.9 | 73.3 | 0.7 | 1.5 |
| W.F. | 60 | 35.4 | 0.3 | 3.1 | 37.0 | 0.2 | 2.7 |
| J.L. | 59 | 61.0 | 0.4 | 1.3 | 66.0 | 0.2 | 1.1 |
| J.McK. | 55 | 48.3 | 0.1 | 1.6 | 53.9 | 0.3 | 2.4 |
| I.McF. | 58 | 50.7 | 0.5 | 1.1 | 46.5 | 0.7 | 1.0 |
| C.McK. | 66 | 66.4 | 0.2 | 1.1 | 70.5 | 0.1 | 1.2 |
| C.McC. | 50 | 35.4 | 1.0 | 1.8 | 31.9 | 0.4 | 0.8 |
| T.McE. | 59 | 52.3 | 0.1 | 0.8 | 45.9 | 0.3 | 0.4 |
| D.M. | 58 | 52.5 | 0.1 | 1.0 | 74.9 | 0.1 | 1.2 |
| D.W. | 62 | 30.6 | 0.3 | 3.6 | 34.6 | 0.3 | 1.5 |
| Mean | | 46.4 | 0.38 | 1.49 | 49.2 | 0.40 | 1.32 |
| one | | ± | ± | ± | ± | ± | ± |
| S.D. | | 14.6 | 0.37 | 0.89 | 16.6 | 0.34 | 0.70 |

Table 15

Vein Bypass Graft Group

M.B.F. at Minute Intervals Following Release of the Occluding Cuff

| | | Pre-operative | | | | Post-operative | | | |
|---|---|---|---|---|---|---|---|---|---|
| Name | Age | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| K.B. | 66 | 51.5 | 24.1 | 12.9 | 8.9 | 37.8 | 17.7 | 6.1 | 2.4 |
| M.B. | 55 | 16.1 | 20.9 | 20.9 | 10.5 | 25.0 | 32.2 | 32.2 | 23.3 |
| P.D. | 54 | 12.9 | 7.2 | 2.1 | - | 16.1 | 8.5 | 2.3 | - |
| J.E. | 56 | 67.6 | 41.1 | 22.5 | 8.9 | 73.3 | 73.3 | 51.5 | 23.3 |
| W.F. | 60 | 35.4 | 35.4 | 35.4 | 20.3 | 37.0 | 37.0 | 30.6 | 21.7 |
| J.L. | 59 | 61.0 | 47.5 | 27.4 | 6.4 | 66.0 | 38.6 | 21.7 | 7.2 |
| J.McK. | 55 | 48.3 | 41.9 | 32.2 | 20.1 | 53.9 | 53.9 | 23.3 | 12.1 |
| I.McF. | 58 | 50.7 | 31.4 | 10.5 | 6.4 | 46.5 | 24.7 | 12.9 | 6.5 |
| C.McK. | 66 | 66.4 | 32.2 | 11.3 | - | 70.5 | 36.2 | 16.9 | 8.9 |
| C.McC. | 50 | 35.4 | 35.4 | 24.2 | 16.1 | 31.9 | 10.0 | 5.6 | 2.3 |
| T.McE. | 59 | 28.2 | 8.9 | 2.7 | - | 19.3 | 5.6 | - | - |
| D.M. | 58 | 52.5 | 29.0 | 8.7 | 4.4 | 74.9 | 33.0 | 15.8 | 4.8 |
| D.W. | 62 | 30.6 | 30.6 | 30.6 | 22.5 | 34.6 | 27.4 | 23.3 | 16.9 |
| Mean | | 42.8 | 29.7 | 18.6 | 12.5 | 45.1 | 30.6 | 20.2 | 11.8 |
| one S.D. | | ± 17.9 | ± 12.0 | ± 11.2 | ± 6.7 | ± 20.7 | ± 18.8 | ± 13.7 | ± 8.2 |

Table 16

Vein Bypass Graft Group

M.B.F. During First Post-Operative Year.

| Name | Age | Pre-operative P.B.F. ml/100gm/min. | 3 Months P.B.F. ml/100gm/min. | 6 Months P.B.F. ml/100gm/min. | 1 Year P.B.F. ml/100gm/min. |
|---|---|---|---|---|---|
| M.B. | 55 | 17.7 | 29.0 | 26.6 | 38.5 |
| J.E. | 56 | 28.2 | 50.7 | 55.5 | 72.5 |
| W.F. | 60 | 18.5 | 51.5 | 42.0 | 34.6 |
| D.J. | 36 | 14.5 | 41.1 | 32.7 | 37.8 |
| I.McF. | 58 | 35.4 | 64.5 | 74.9 | 61.2 |
| C.McK. | 66 | 40.3 | 66.0 | 66.0 | 64.5 |
| C.McC. | 50 | 29.2 | 44.3 | 42.5 | 39.4 |
| D.W. | 62 | 25.0 | 54.7 | - | 63.6 |
| Mean | | 26.1 | 50.2 | 48.6 | 51.5 |
| | | ± | ± | ± | ± |
| one S.D. | | 9.0 | 12.2 | 17.6 | 15.3 |

Table 17

Lumbar Sympathectomy Group

The Effect of Sympathectomy on Resting Muscle Blood Flow

Before and After Surgery

| Name | Age | Pre-operative R.B.F. ml/100gm/min. | Post-operative R.B.F. ml/100gm/min |
|---|---|---|---|
| S.A. | 59 | 1.29 | 1.77 |
| C.A. | 64 | 1.61 | 0.65 |
| | | 2.55 | 2.89 |
| A.B. | 66 | 0.48 | 0.81 |
| J.B. | 61 | 1.93 | 0.97 |
| J.B. | 67 | 0.97 | 1.13 |
| J.B. | 28 | 1.29 | 2.42 |
| R.B. | 62 | 1.45 | 0.81 |
| R.C. | 54 | 1.13 | 0.97 |
| M.C. | 63 | 2.82 | 2.09 |
| T.C. | 57 | 0.48 | 0.81 |
| H.C. | 62 | 1.61 | 1.93 |
| R.D. | 60 | 1.93 | 0.97 |
| J.D. | 59 | 1.61 | 2.42 |
| D.D. | 53 | 5.64 | 3.22 |
| J.D. | 60 | 0.97 | 0.81 |
| J.D. | 61 | 1.29 | 1.29 |
| G.D. | 75 | 0.97 | 1.29 |
| J.G. | 65 | 0.97 | 1.29 |
| G.H. | 56 | 4.19 | 1.45 |

Table 17

The Effect of Sympathectomy on Resting Muscle Blood Flow

| Name | Age | Pre-operative R.B.F. ml/100gm/min. | Post-operative R.B.F. ml/100gm/min. |
|---|---|---|---|
| W.H. | 39 | 3.06 | 1.13 |
| R.J. | 69 | 1.45 | 1.13 |
| R.J. | 72 | 1.29 | 1.77 |
| I.K. | 54 | 1.29 | 1.61 |
| C.K. | 46 | 1.77 | 1.45 |
| A.K. | 73 | 3.86 | 1.13 |
| W.L. | 57 | 1.45 | 1.13 |
| J.M.(2) | 60 | 1.29 | 0.80 |
| D.M. | 40 | 2.58 | 1.45 |
| M.McL. | 58 | 1.13 | 1.61 |
| H.McH | 45 | 1.61 | 2.09 |
| T.McM. | 66 | 1.29 | 1.29 |
| J.McA. | 51 | 1.13 | 1.29 |
| W.P. | 64 | 0.97 | 0.97 |
| J.P. | 60 | 1.77 | 0.81 |
| W.P. | 63 | 1.29 | 0.81 |
| A.Q. | 65 | 2.74 | 0.48 |
| P.S. | 30 | 1.61 | 2.09 |
| A.S. | 46 | 1.61 | 1.29 |

Table 17

The Effect of Sympathectomy on Resting Muscle Blood Flow

| Name | Age | Pre-operative R.B.F. ml/100gm/min | Post-operative R.B.F. ml/100gm/min |
|---|---|---|---|
| T.S. | 50 | 2.25 | 1.29 |
| J.Y. | 59 | 1.61 | 1.45 |
| J.M. | 56 | 0.97 | 0.97 |
| H.C. | 42 | 0.81 | 1.77 |
| S.McK. | 41 | 1.29 | 1.45 |
| W.S. | 60 | 0.97 | 1.93 |
| T.McI. | 67 | 0.97 | 0.97 |
| J.McD. | 65 | 2.09 | 2.25 |
| J.W. | 47 | 0.81 | 0.97 |
| Mean | | 1.67 | 1.40 |
| | | ± | ± |
| one S.D. | | 0.97 | 0.59 |

# Table 18A

## Lumbar Sympathectomy Group

## Peak Muscle Blood Flow Before and After Surgery

| Name | Age | Pre-operative | | | Post-operative | | |
|---|---|---|---|---|---|---|---|
| | | P.B.F. ml/100gm/min. | Time to P.B.F. mins. | Duration of P.B.F. mins. | P.B.F. ml/100gm./min | Time to P.B.F. mins. | Duration of P.B.F. mins. |
| H.A. | 46 | 37.8 | 0.5 | 0.5 | 38.6 | 0.3 | 2.3 |
| S.A. | 59 | 31.0 | 1.0 | 2.3 | 27.4 | 1.0 | 2.7 |
| C.A. | 64 | 13.7 | 0.9 | 2.9 | 16.1 | 0.1 | 1.3 |
| | | 12.9 | 2.7 | 4.0 | 13.8 | 2.0 | 3.0 |
| A.B. | 66 | 21.7 | 1.0 | 2.5 | 25.0 | 0.3 | 1.3 |
| J.B. | 61 | 19.3 | 1.0 | 1.5 | 27.4 | 1.0 | 1.5 |
| J.B. | 67 | 16.9 | 5.0 | 4.5 | 12.1 | 6.0 | 5.5 |
| J.B. | 28 | 36.2 | 0.4 | 1.6 | 42.7 | 0.3 | 1.6 |
| R.B. | 62 | 13.1 | 2.1 | 4.6 | 12.1 | 0.5 | 3.5 |
| R.C. | 54 | 17.7 | 2.7 | 4.6 | 25.8 | 0.6 | 3.5 |
| M.C. | 63 | 1 .7 | 4.5 | 3.0 | 8.9 | 5.0 | 5.5 |
| T.C. | 57 | 16.1 | 5.1 | 5.1 | 17.4 | 3.1 | 4.5 |
| H.C. | 62 | 45.6 | 0.7 | 1.5 | 32.2 | 0.7 | 1.7 |
| R.D. | 60 | 17.7 | 1.5 | 2.0 | 11.3 | 1.1 | 2.6 |
| J.D. | 59 | 20.1 | 5.0 | | 16.1 | 3.0 | |
| D.D. | 53 | 25.0 | 1.5 | 3.0 | 22.5 | 2.0 | 2.5 |
| J.D. | 59 | 33.8 | 1.6 | 2.5 | 38.6 | 1.6 | 2.6 |
| J.D. | 61 | 11.6 | 2.1 | 5.4 | 12.9 | 1.8 | 3.0 |
| G.D. | 75 | 12.1 | 2.1 | 2.4 | 11.3 | 2.1 | 2.6 |
| J.G. | 65 | 15.3 | 1.3 | 2.4 | 19.3 | 1.0 | 2.3 |
| G.H. | 56 | 22.9 | 2.5 | 3.0 | 26.6 | 2.2 | 2.7 |

Table 18A

| Name | Age | Pre-operative | | | Post-operative | | |
|---|---|---|---|---|---|---|---|
| | | P.B.F. ml/100gm/min. | Time to P.B.F. mins. | Duration of P.B.F. mins. | P.B.F. ml/100gm/min. | Time to P.B.F. mins. | Duration of P.B.F. mins. |
| A.H. | 64 | 37.0 | 0.7 | 2.1 | 25.8 | 1.3 | 5.2 |
| A.H. | 39 | 32.2 | 0.5 | 2.1 | 20.9 | 0.5 | 2.5 |
| W.J. | 68 | 14.2 | 3.3 | 4.1 | 13.4 | 2.3 | 3.7 |
| R.J. | 72 | 18.5 | 2.5 | 4.7 | 25.0 | 1.2 | 2.3 |
| I.K. | 54 | 45.1 | 1.7 | 2.4 | 25.8 | 1.7 | 1.7 |
| C.K. | 46 | 22.5 | 2.5 | 3.5 | 28.2 | 2.0 | 2.0 |
| A.K. | 73 | 13.8 | 1.5 | 3.0 | 14.5 | 4.5 | 3.0 |
| W.L. | 57 | 28.2 | 1.0 | 3.3 | 45.6 | 0.3 | 2.2 |
| J.M.(2) | 60 | 24.1 | 3.0 | 3.7 | 25.0 | 2.0 | 2.33 |
| D.M. | 40 | 30.6 | 0.5 | 2.5 | 26.6 | 0.7 | 1.6 |
| M.McL. | 58 | 19.3 | 1.2 | 4.0 | 30.1 | 1.0 | 2.0 |
| H.McH. | 45 | 45.6 | 0.8 | 1.5 | 68.4 | 0.7 | 1.6 |
| T.McM. | 66 | 15.3 | 0.8 | 4.4 | 18.0 | 1.0 | 5.0 |
| J.McA. | 51 | 14.9 | 1.7 | 3.5 | 17.7 | 1.2 | 1.1 |
| W.P. | 64 | 13.7 | 3.3 | 4.3 | 12.1 | 4.0 | 9.0 |
| J.P. | 60 | 21.7 | 1.4 | 5.0 | 10.5 | 1.5 | 2.0 |
| W.P. | 63 | 23.3 | 2.0 | 5.5 | 25.8 | 1.5 | 3.4 |
| A.Q. | 65 | 17.7 | 0.7 | 3.7 | 29.7 | 1.0 | 1.7 |
| P.S. | 30 | 51.5 | 0.3 | 1.8 | 55.6 | 0.4 | 1.9 |
| A.S. | 46 | 12.2 | 0.5 | 6.2 | 14.5 | 1.7 | 4.5 |
| T.S. | 50 | 22.5 | 4.0 | 1.5 | 24.2 | 2.3 | 1.3 |

## Table 18A

| Name | Age | Pre-operative | | | Post-operative | | |
|---|---|---|---|---|---|---|---|
| | | P.B.F. ml/100gm./min. | Time to P.B.F. mins | Duration of P.B.F. mins | P.B.F. ml/100gm/min. | Time to P.B.F. mins. | Duration of P.B.F. mins. |
| J.Y. | 59 | 22.5 | 0.7 | 1.9 | 21.7 | 1.1 | 3.1 |
| J.M. | 56 | 18.5 | 2.0 | 3.5 | 16.1 | 2.0 | 1.6 |
| H.C. | 42 | 31.9 | 1.3 | 2.2 | 37.8 | 0.7 | 2.0 |
| S.McK. | 41 | 15.3 | 1.5 | 2.5 | 23.3 | 2.5 | 2.0 |
| J.S. | 60 | 52.3 | 0.5 | 1.6 | 53.1 | 0.3 | 1.7 |
| T.McI. | 67 | 7.4 | 0.5 | 4.3 | 7.57 | 0.5 | 2.6 |
| W.McA. | 44 | 7.3 | 3.5 | 6.0 | 6.52 | 2.0 | 3.3 |
| J.McD. | 65 | 15.8 | 1.3 | 3.2 | 26.6 | 1.0 | 3.5 |
| J.W. | 47 | 15.3 | 3.5 | 4.0 | 12.1 | 1.3 | 3.5 |
| Mean | | 22.8 | 1.84 | 3.23 | 23.9 | 1.57 | 2.79 |
| | | ± | ± | ± | ± | ± | ± |
| one S.D. | | 11.2 | 1.23 | 1.33 | 12.8 | 1.23 | 1.37 |

Table 18B

Lumbar Sympathectomy Group

Patients with Improvement in Intermittent Claudication

| | | | Pre-operative | | | Post-operative | |
|---|---|---|---|---|---|---|---|
| Name | Age | P.B.F. ml/100gm/min. | Time to P.B.F. ml/100gm/min. | Duration of P.B.F. ml/100gm/min. | P.B.F. ml/100gm/min. | Time to P.B.F. ml/100gm/min. | Duration of P.B.F. ml/100gm./min. |
| S.A. | 59 | 31.0 | 1.0 | 2.3 | 27.4 | 1.0 | 2.3 |
| M.C. | 63 | 11.7 | 4.5 | 3.0 | 8.9 | 5.0 | 5.5 |
| J.B. | 59 | 33.8 | 1.6 | 2.5 | 38.6 | 1.6 | 2.6 |
| J.D. | 61 | 11.6 | 2.1 | 5.4 | 12.9 | 1.8 | 2.6 |
| G.D. | 75 | 12.1 | 2.1 | 2.4 | 11.3 | 2.1 | 2.6 |
| A.H. | 64 | 37.0 | 0.7 | 2.1 | 25.8 | 1.3 | 1.0 |
| W.L. | 57 | 28.2 | 1.0 | 3.3 | 45.6 | 0.3 | 2.2 |
| A.S. | 46 | 12.2 | 0.5 | 6.2 | 14.5 | 1.7 | 4.5 |
| Mean & one S.D. | | 22.1 ± 11.4 | 1.69 ± 1.29 | 3.45 ± 1.66 | 23.1 ± 13.6 | 1.96 ± 1.39 | 2.83 ± 1.03 |

Table 18C

Lumbar Sympathectomy Group

Patients Without Improvement in Intermittent Claudication

| Name | Age | Pre-operative P.B.F. ml/100gm/min. | Pre-operative Time to P.B.F. ml/100gm/min. | Pre-operative Duration of P.B.F. ml/100gm/min. | Post-operative P.B.F. ml/100gm./min. | Post-operative Time to P.B.F. ml/100gm/min. | Post-operative Duration of P.B.F. ml/100gm/min. |
|---|---|---|---|---|---|---|---|
| C.A. | 64 | 13.7 | 0.9 | 2.9 | 16.1 | 0.1 | 1.3 |
| | | 12.9 | 2.7 | 4.0 | 13.8 | 2.0 | 3.0 |
| A.B. | 66 | 21.7 | 1.0 | 2.5 | 25.0 | 0.3 | 0.9 |
| J.B. | 61 | 19;3 | 1.0 | 1.5 | 27.4 | 1.0 | 1.0 |
| J.B. | 67 | 16.9 | 5.0 | 4.5 | 12.1 | 6.0 | 5.0 |
| R.B. | 62 | 13.1 | 2.1 | 4.6 | 12.1 | 0.5 | 3.2 |
| T.C. | 57 | 16.1 | 5.1 | 5.1 | 17.4 | 3.1 | 4.1 |
| H.C. | 62 | 45.6 | 0.7 | 1.5 | 32.2 | 0.7 | 1.3 |
| R.D. | 60 | 17.7 | 1.5 | 2.0 | 11.3 | 1.1 | 2.6 |
| J.D. | 59 | 20.1 | 5.0 | - | 16.1 | 3.0 | - |
| D.D. | 53 | 25.0 | 1.5 | 3.0 | 22.5 | 2.0 | 2.0 |
| J.G. | 65 | 15.3 | 1.3 | 2.4 | 19.3 | 1.0 | 2.0 |
| G.H. | 56 | 22.9 | 2.5 | 3.0 | 26.6 | 2.2 | 2.7 |
| W.J. | 68 | 14.2 | 2.3 | 4.1 | 13.4 | 2.3 | 3.7 |
| R.J. | 72 | 18.5 | 2.5 | 4.7 | 25.0 | 1.2 | 2.3 |
| I.K. | 54 | 45.1 | 1.7 | 2.4 | 25.8 | 1.7 | 1.7 |
| J.M. | 60 | 24.1 | 3.0 | 3.7 | 25.0 | 2.0 | 2.3 |
| H.McH. | 45 | 45.6 | 0.8 | 1.5 | 68.4 | 0.7 | 1.6 |

Table 18C

Lumbar Sympathectomy Group

| Name | Age | Pre-operative | | | Post-operative | | |
|---|---|---|---|---|---|---|---|
| | | P.B.F. ml/100gm/min. | Time to P.B.F. ml/100gm/min. | Duration of P.B.F. ml/100gm/min. | P.B.F. ml/100gm/min. | Time to P.B.F. ml/100gm/min. | Duration of P.B.F. ml/100gm/min |
| J.McA | 51 | 14.9 | 1.7 | 3.5 | 17.7 | 1.2 | 1.1 |
| W.P. | 63 | 23.3 | 2.0 | 5.5 | 25.8 | 1.5 | 3.4 |
| A.Q. | 65 | 17.7 | 0.7 | 3.7 | 29.7 | 1.0 | 1.7 |
| J.M. | 56 | 18.5 | 2.0 | 3.5 | 16.1 | 2.0 | 1.6 |
| S.McK. | 41 | 15.3 | 1.5 | 2.5 | 23.3 | 2.5 | 2.0 |
| J.S. | 60 | 52.3 | 0.5 | 1.6 | 53.1 | 0.3 | 1.7 |
| W.McA. | 44 | 7.3 | 3.5 | 6.0 | 6.5 | 2.0 | 3.3 |
| J.W. | 47 | 15.3 | 3.5 | 4.0 | 12.1 | 1.3 | 3.5 |
| W.P. | 64 | 13.7 | 3.3 | 4.3 | 12.1 | 4.0 | 9.0 |
| Mean | | 21.0 | 2.20 | 3.38 | 22.0 | 1.73 | 2.62 |
| & one S.D. | | ± 11.5 | ± 1.78 | ± 1.28 | ± 13.6 | ± 1.27 | ± 1.67 |

Table 18D

Lumbar Sympathectomy Group

Patients with Deterioration in Intermittent Claudication

| Name | Age | Pre-operative | | | Post-operative | | |
|---|---|---|---|---|---|---|---|
| | | P.B.F. ml/100gm/min. | Time to P.B.F. ml/100gm/min. | Duration of P.B.F. ml/100gm/min. | P.B.F. ml/100gm/min. | Time to P.B.F. ml/100gm/min | Duration of P.B.F. ml/100gm/min. |
| J.P. | 60 | 21.7 | 1.4 | 5.0 | 10.5 | 1.5 | 2.0 |
| T.S. | 50 | 22.5 | 4.0 | 1.5 | 24.2 | 2.3 | 1.3 |
| J.McD. | 65 | 15.8 | 1.3 | 3.2 | 26.6 | 1.0 | 3.5 |
| Mean | | 20.0 | 2.23 | 3.23 | 20.4 | 1.60 | 2.27 |

<u>Table 19</u>

<u>Lumbar Sympathectomy Group</u>

<u>M.B.F. from Non-Operated Limbs</u>

| Name | Age | P.B.F. ml/100gm/min. | Pre-operative Time to P.B.F. ml/100gm/min. | Pre-operative Duration of P.B.F. ml/100gm/min. | Post-operative P.B.F. ml/100gm/min. | Post-operative Time to P.B.F. ml/100gm/min. | Post-operative Duration of P.B.F. ml/100gm/min |
|---|---|---|---|---|---|---|---|
| S.A. | 59 | 40.3 | 1.2 | 2.1 | 42.7 | 1.2 | 1.8 |
| H.A. | 46 | 60.4 | 0.3 | 1.2 | 51.5 | 0.5 | 1.2 |
| R.B. | 62 | 23.0 | 0.7 | 1.6 | 24.2 | 0.3 | 1.0 |
| J.B. | 28 | 30.6 | 0.5 | 2.7 | 59.6 | 0.3 | 0.8 |
| J.B. | 67 | 15.3 | 4.0 | 4.5 | 10.5 | 6.0 | - |
| A.B. | 66 | 30.6 | 0.3 | 1.8 | 37.0 | 0.3 | 1.0 |
| H.C. | 62 | 40.3 | 0.7 | 1.3 | 27.4 | 1.1 | 1.7 |
| T.C. | 57 | 21.7 | 1.5 | 3.3 | 27.4 | 1.9 | 2.9 |
| R.C. | 54 | 16.9 | 1.0 | 4.5 | 17.7 | 0.5 | 1.5 |
| H.C. | 42 | 45.9 | 0.5 | 1.3 | 51.8 | 0.3 | 1.1 |
| J.D. | 61 | 27.4 | 0.7 | 2.8 | 36.7 | 0.7 | 1.4 |
| D.D. | 53 | 30.6 | 1.0 | 1.5 | 27.4 | 0.8 | 1.2 |
| J.G. | 65 | 23.3 | 0.8 | 1.6 | 25.8 | 0.8 | 1.5 |
| A.H. | 64 | 52.3 | 0.3 | 2.3 | 56.4 | 0.5 | 1.2 |
| G.H. | 56 | 41.9 | 0.9 | 1.4 | 29.0 | 0.3 | 2.0 |
| W.J. | 68 | 28.2 | 3.0 | 2.3 | 24.9 | 3.0 | 3.0 |
| A.K. | 73 | 15.3 | 2.3 | 3.0 | 16.1 | 5.0 | 4.0 |
| C.K. | 46 | 55.6 | 0.5 | 0.5 | 51.5 | 1.0 | 0.6 |
| W.L. | 57 | 33.0 | 0.6 | 2.0 | 32.2 | 0.5 | 2.1 |
| J.McA. | 51 | 31.4 | 0.6 | 2.0 | 32.2 | 0.4 | 2.0 |

Table 19

| Name | Age | Pre-operative | | | Post-operative | | |
|---|---|---|---|---|---|---|---|
| | | P.B.F. ml/100gm/min. | Time to P.B.F. ml/100gm./min. | Duration of P.B.F. ml/100gm/min. | P.B.F. ml/100gm/min. | Time to P.B.F. ml/100gm/min. | Duration of P.B.F. ml/100gm/min |
| T.McM. | 66 | 6.6 | 2.8 | 5.0 | 6.9 | 2.3 | 3.9 |
| M.McL | 58 | 28.2 | 1.3 | 2.0 | 20.9 | 1.2 | 1.9 |
| D.M. | 40 | 51.5 | 0.5 | 1.5 | 45.9 | 0.7 | 1.0 |
| J.M. | 60 | 34.7 | 1.0 | 1.7 | 37.5 | 0.7 | 2.3 |
| S.McK. | 41 | 25.8 | 2.5 | 1.5 | 22.5 | 3.0 | 1.5 |
| J.M. | 56 | 37.8 | 1.0 | 1.5 | 35.0 | 1.0 | 1.0 |
| J.McB. | 65 | 40.3 | 0.5 | 2.0 | 61.2 | 0.2 | 1.2 |
| W.McA. | 44 | 6.4 | 2.0 | 2.0 | 6.3 | 1.8 | 3.7 |
| W.P. | 63 | 48.3 | 0.1 | 1.6 | 41.1 | 0.5 | 2.7 |
| W.P. | 64 | 46.7 | 0.3 | 1.0 | 37.0 | 0.3 | 1.6 |
| A.Q. | 65 | 48.3 | 0.7 | 1.3 | 48.3 | 0.7 | 1.7 |
| T.S. | 50 | 25.8 | 1.3 | 1.3 | 33.8 | 2.7 | 1.7 |
| A.S. | 46 | 49.9 | 0.3 | 1.4 | 38.6 | 0.3 | 1.4 |
| P.S. | 30 | 51.5 | 0.3 | 1.8 | 69.2 | 0.4 | 2.2 |
| J.Y. | 59 | 30.6 | 0.5 | 1.7 | 23.3 | 1.1 | 2.8 |
| Mean | | 34.2 | 1.04 | 2.03 | 34.6 | 1.21 | 1.84 |
| one S.D. | | ± 13.8 | ± 0.90 | ± 1.00 | ± 15.4 | ± 1.33 | ± 0.88 |

Table 20A

Lumbar Sympathectomy Group.

Muscle Blood Flow During 1st Post-Operative Year

In Patients Without an Improvement in Intermittent Claudication

| Name | Age | Pre-Op. P.B.F. | 7 day P.B.F. | 1 Month P.B.F. | 3 Month P.B.F. | 6 Month P.B.F. | 1 Year P.B.F. |
|---|---|---|---|---|---|---|---|
| A.B. | 66 | 21.7 | 12.9 | 25.0 | 19.3 | 20.9 | 27.4 |
| J.B. | 61 | 19.3 | - | - | 27.4 | 12.9 | 19.3 |
| R.B. | 62 | 13.1 | 15.3 | 12.1 | 13.5 | 20.3 | 17.6 |
| H.C. | 62 | 45.6 | 26.9 | - | 32.2 | - | 45.0 |
| J.G. | 65 | 15.3 | 20.1 | 19.3 | 13.7 | 29.0 | 34.0 |
| R.J. | 72 | 18.5 | 15.8 | - | 25.0 | - | 8.9 |
| J.McA. | 51 | 14.9 | 12.1 | 17.7 | 23.3 | 16.9 | 15.3 |
| A.Q. | 65 | 17.7 | 29.7 | - | 31.4 | 25.0 | 27.4 |
| J.M. | 56 | 18.5 | 14.5 | - | 16.1 | 25.8 | 16.9 |
| J.S. | 60 | 52.3 | 53.1 | - | - | 53.9 | 54.7 |
| J.W. | 47 | 15.3 | 12.1 | - | 8.1 | 22.5 | 34.0 |
| G.H. | 56 | 22.9 | 26.6 | - | 33.8 | 22.4 | 35.4 |
| J.M. | 60 | 24.1 | 19.2 | 25.0 | 17.4 | 36.2 | 29.8 |
| C.A. | 64 | 13.7 | - | 16.1 | 17.6 | 22.1 | 30.6 |
| | | 12.9 | - | 13.8 | 9.7 | 28.2 | 34.6 |
| I.K. | 54 | 45.1 | - | 25.8 | 26.2 | 31.4 | 55.0 |
| Mean | | 23.2 | 21.5 | 19.4 | 21.0 | 26.3 | 30.4 |
| | | ± | ± | ± | ± | ± | ± |
| One S.D. | | 12.7 | 11.7 | 14.4 | 8.2 | 9.9 | 13.3 |

Table 20B

Lumbar Sympathectomy Group

M.B.F. During 1st Post-Operative Year

In Patients with an Improvement in Intermittent Claudication

| Name | Age | Pre Op. P.B.F. | 7 Days P.B.F. | 1 Month P.B.F. | 3 Month P.B.F. | 6 Month P.B.F. | 1 Year P.B.F. |
|---|---|---|---|---|---|---|---|
| S.A. | 59 | 31.0 | 27.4 | - | 30.6 | 27.4 | 40.1 |
| J.B. | 61 | 11.6 | 17.4 | 12.9 | 19.2 | 30.5 | 24.2 |
| J.D. | 59 | 33.8 | 38.6 | - | - | - | 41.1 |
| G.D. | 75 | 12.1 | 11.3 | 25.0 | 26.6 | 25.0 | 22.5 |
| M.C. | 63 | 11.7 | 8.9 | 16.1 | - | 25.0 | 23.4 |
| A.H. | 64 | 37.0 | 16.9 | 25.8 | 32.5 | 48.3 | 25.0 |
| W.L. | 57 | 28.2 | 19.3 | 45.6 | 38.5 | 31.4 | 37.0 |
| A.S. | 46 | 12.2 | 8.9 | 14.5 | 24.2 | 22.5 | 34.8 |
| Mean & one S.D. | | 22.2 ± 11.3 | 18.6 ± 10.2 | 23.3 ± 12.2 | 28.6 ± 6.8 | 30.0 ± 8.6 | 31.0 ± 8.6 |

Table 21

Lumbar Sympathectomy Group

M.B.F. during 1st Post Operative Year
in the non-operated limbs

| Name | Age | Pre-operative P.B.F. ml/100gm/min. | 3 Months P.B.F. ml/100gm/min. | 6 Months P.B.F. ml/100gm/min. | 1 Year P.B.F. ml/100gm/min. |
|---|---|---|---|---|---|
| S.A. | 59 | 40.3 | 37.4 | 12.9 | 44.3 |
| A.B. | 66 | 30.6 | 34.6 | 31.4 | 33.8 |
| R.B. | 62 | 23.0 | 35.4 | 17.4 | 24.2 |
| H.C. | 62 | 40.3 | 31.4 | - | 45.0 |
| J.D. | 59 | 22.5 | 19.3 | 10.5 | 20.9 |
| J.G. | 65 | 23.3 | 35.6 | 58.0 | 42.0 |
| I.K. | 54 | 52.3 | 45.9 | 61.2 | 58.0 |
| D.M. | 40 | 51.5 | 45.9 | 44.0 | 43.5 |
| H.McH. | 45 | 59.6 | - | 49.1 | 70.0 |
| J.McA. | 51 | 31.4 | 37.8 | 23.3 | 18.5 |
| A.Q. | 65 | 48.3 | 38.6 | 45.1 | 44.3 |
| A.S. | 46 | 49.9 | 53.9 | 58.0 | 49.9 |
| J.M. | 56 | 37.8 | 35.0 | 42.7 | 41.9 |
| J.S. | 60 | 28.2 | - | 33.0 | 38.6 |
| A.H. | 64 | 52.3 | 64.5 | 51.5 | 53.9 |
| G.H. | 56 | 41.9 | 57.3 | 34.7 | 49.9 |
| W.L. | 59 | 33.0 | 37.5 | 49.1 | 34.6 |
| M.McL. | 58 | 28.2 | 21.5 | 31.7 | 19.3 |
| J.D. | 61 | 27.4 | 37.5 | 35.5 | 29.0 |
| J.M. | 60 | 34.7 | 39.4 | 27.4 | 37.0 |
| Mean | | 37.8 | 39.4 | 37.7 | 39.9 |
| One S.D. | | ± 11.4 | ± 11.2 | ± 15.2 | ± 13.4 |

THE MEASUREMENT OF THE BLOOD FLOW THROUGH SKELETAL MUSCLE FROM THE LOCAL CLEARANCE OF $^{133}$XENON ... ... ... ... ... GRAHAM BELL


## SUMMARY

A technique for the measurement of the blood flow through skeletal muscle, from the local clearance of the radio-active inert gas $^{133}$xenon, has been described. The muscle blood flow estimations had a mean coefficient of variation of 10 per cent over time intervals up to 3 months and from this it was concluded that the technique would be of value for long-term studies.

In a group of 58 normal subjects, the mean resting blood flow was 2.28 ml./100 gm./min. (S.D. $\pm$ 0.92). Muscle blood flow was studied following ischaemic exercise and the mean peak blood flow was 62.0 ml./100 gm./min. (S.D. $\pm$ 17.7), mean time to peak blood flow was 0.46 min. (S.D. $\pm$ 0.37), and mean duration of peak blood flow was 1.08 min. (S.D. $\pm$ 0.21). In this normal group, it was found that the peak muscle blood flow was

significantly reduced in the over 40-60 and over 60 age groups.

A group of 109 patients (177 limbs) suffering from atherosclerotic peripheral arterial disease have been studied. There was no difference between resting blood flow in this group and that in the normal group. Following ischaemic exercise, the mean peak blood flow was 29.3 ml./100 gm./min. (S.D. $\pm$ 12.0), time taken to achieve peak blood flow was 1.67 min. (S.D. $\pm$ 1.0) and duration of peak blood flow 2.41 (S.D. $\pm$ 1.27). These changes were statistically significant ($p < 0.001$ in all cases). Thus, the typical finding in patients suffering from peripheral arterial disease is a reduction in the level of peak blood flow, a delay in reaching the level of peak blood flow and a prolongation of the peak blood flow. These changes were found to be greatest in patients with occlusive lesions distal to the inguinal ligament and least in patients with generalised disease without main vessel occlusion: those patients who had occlusive lesions proximal to the inguinal ligament lay somewhere in between.

The technique has been used in the study of patients who had direct arterial surgery for atherosclerosis of the peripheral vessels. Seventy-six patients have been studied before and after surgery. These were subdivided into patients having surgery to the aorto-iliac region (either thrombo-endarterectomy or replacement graft) and surgery to the femoro-popliteal region (either thrombo-endarterectomy or bypass vein graft). In all these groups, there was good correlation between the muscle blood flow results and the success or failure of the surgical procedure and the blood flow results provided objective evidence of the result. It was also found that, following successful surgery, the muscle blood flow may revert to a normal pattern. In the aorto-iliac thrombo-endarterectomy group, the results were seriously impaired if there was a distal occlusive lesion present in addition to the proximal lesion. In the group studied, only 31 per cent of the patients with an additional distal occlusion showed an improvement in peak muscle blood flow and relief in claudication compared to 61 per cent in the group as a whole.

In the different groups studied, there were cases where the patient claimed relief of claudication yet the patient showed no improvement in peak muscle blood flow. The time taken to reach peak blood flow following release of the occluding cuff was reduced in some instances, however, Thus, this reduction in time to achieve peak blood flow appeared to be sufficient to improve the symptom of intermittent claudication.

In other cases, arteriography was carried out and this confirmed that the operated segment had undergone occlusion; the muscle blood flow measurements therefore may be of value in selecting those patients who should have post-operative arteriography.

In the first post-operative year, peak muscle blood flow studies were carried out at 3 months, 6 months and 1 year in all groups. In most cases the improvement in peak muscle blood flow was well maintained during this period. However, in 50 per cent of the patients having thrombo-endarterectomy to the femoral and popliteal arteries, there was a gradual return towards the pre-operative level following an initial improvement. This suggests that these patients should have continued long-term follow-up as they appear to be at risk of late failure.

In 50 patients (51 limbs), a study has been made of muscle blood flow before and after lumbar sympathectomy. There was no change in resting blood flow, peak blood flow, time to achieve peak blood flow or duration of peak blood flow following operation. 21.1 per cent of patients claimed improvement in the symptom of intermittent claudication when followed up over the first post-operative year. Peak muscle blood flow in the non-operated limb showed a gradual increase in 20 per cent of cases over a similar period of time. It has been concluded that the improvement in intermittent claudication occasionally found following lumbar sympathectomy is due to the opening up of the collateral circulation rather than to the operation itself.