# VOLUME II

# FIGURES, TABLES AND APPENDICES

FIGURES FOR CHAPTER 1

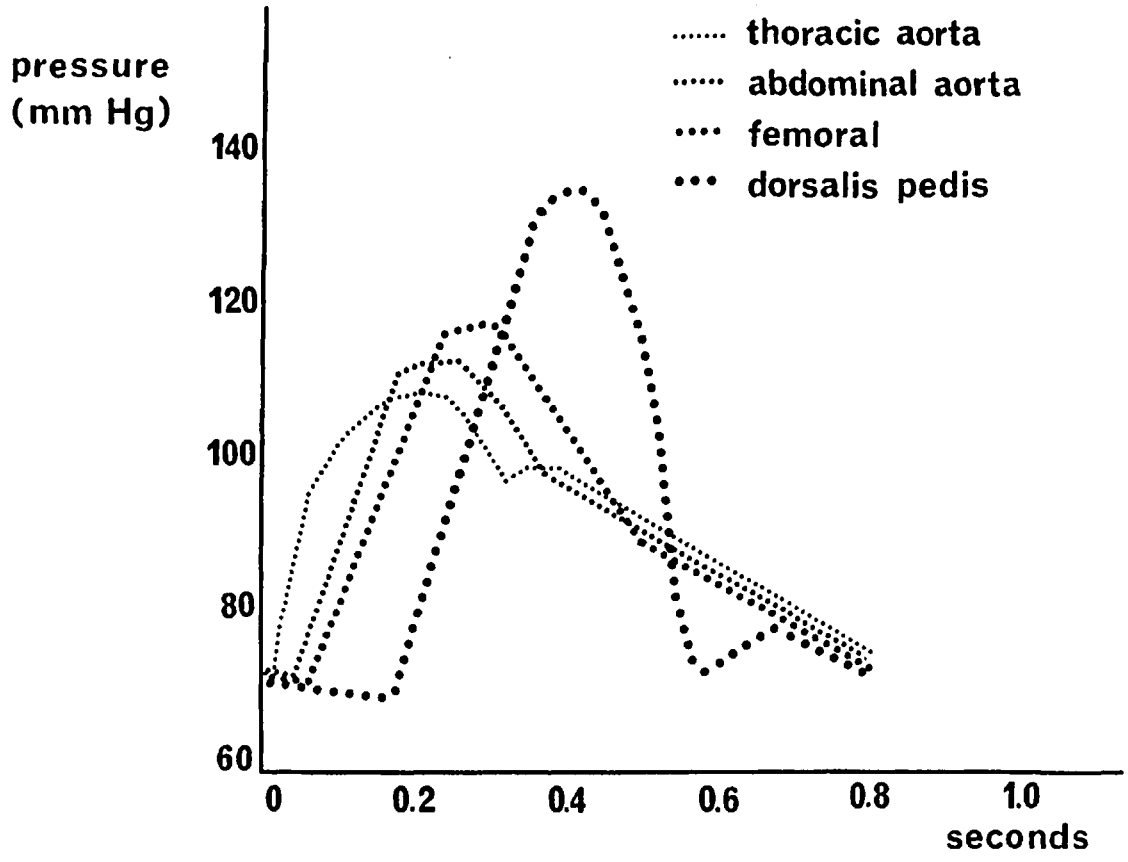



FIG. 1.1

Pressure waveform in thoracic aorta, abdominal aorta, femoral artery and dorsalis pedis. It shows that although the mean pressure in the arteries of the leg is lower than in the aorta, the systolic pressure is higher (Remington and Wood, 1956; McDonald, 1960).

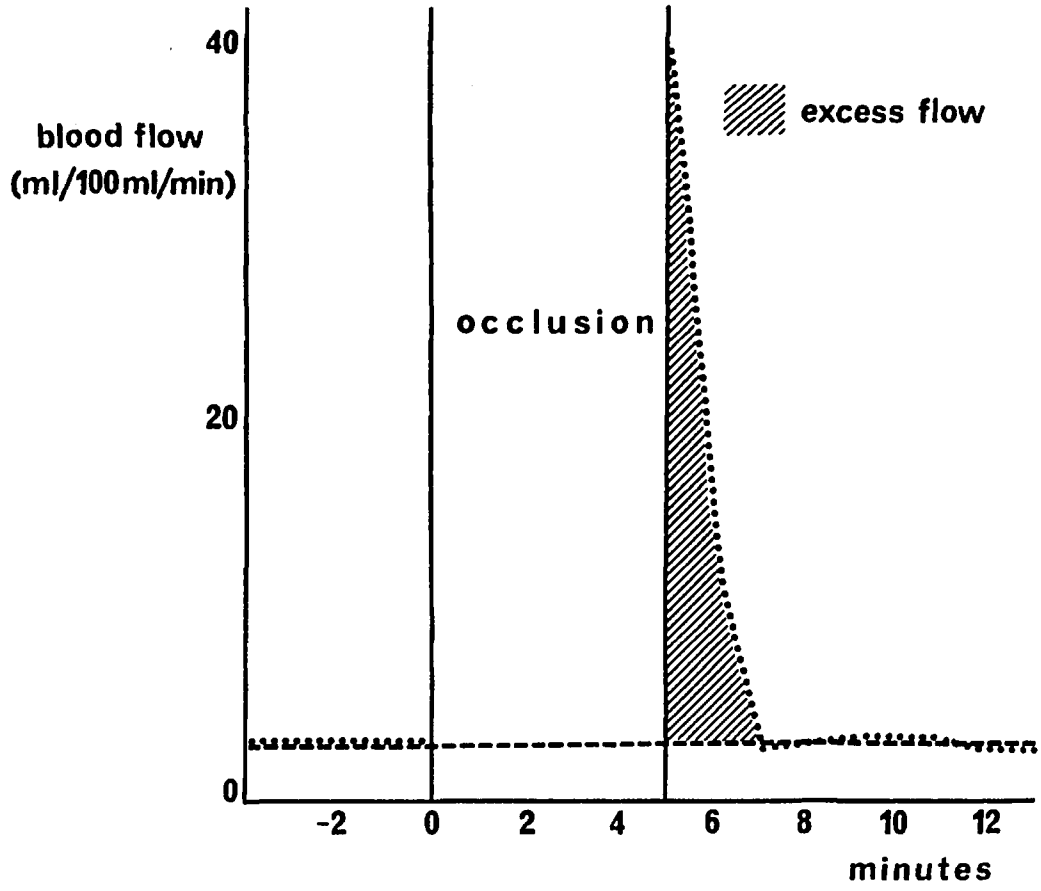



FIG. 1.2

Calculation of the total excess of flow during the period of reactive hyperaemia (area under the curve of flow plotted against time).

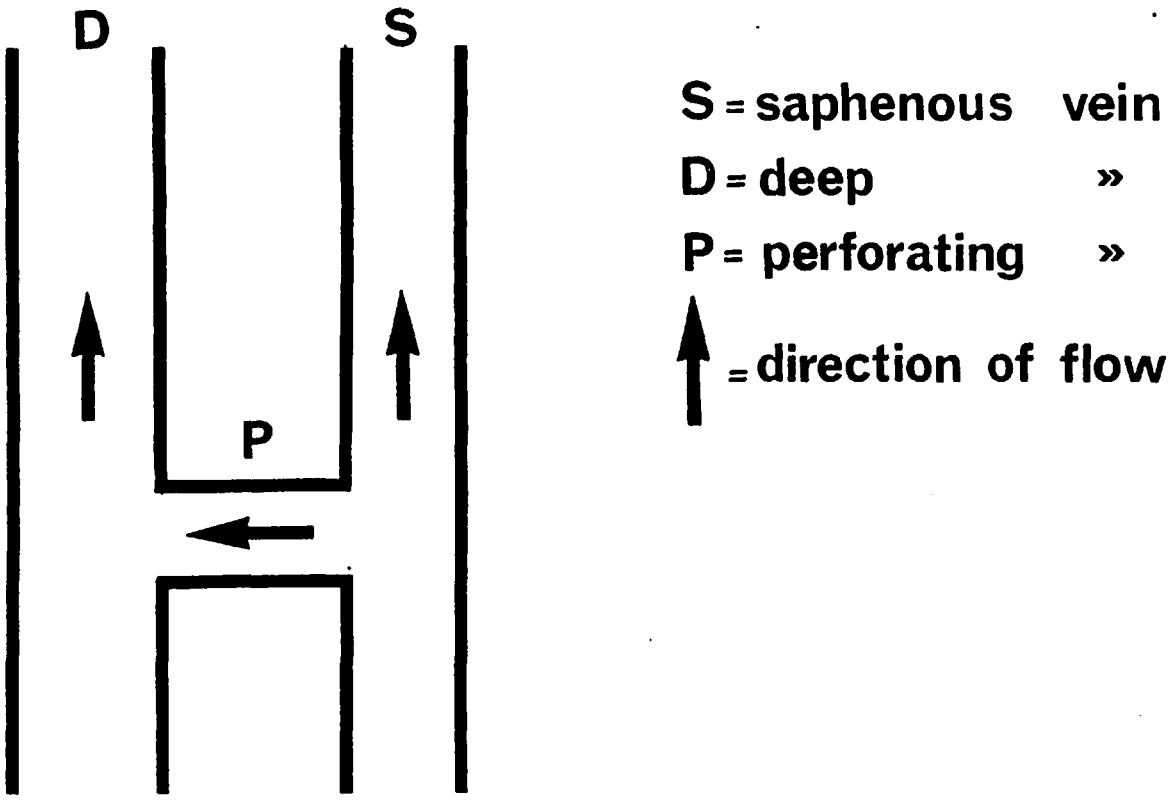



FIG. 1.3

Diagramatic representation of the direction of flow in the superficial, deep and perforating veins during the walking cycle in a normal limb.

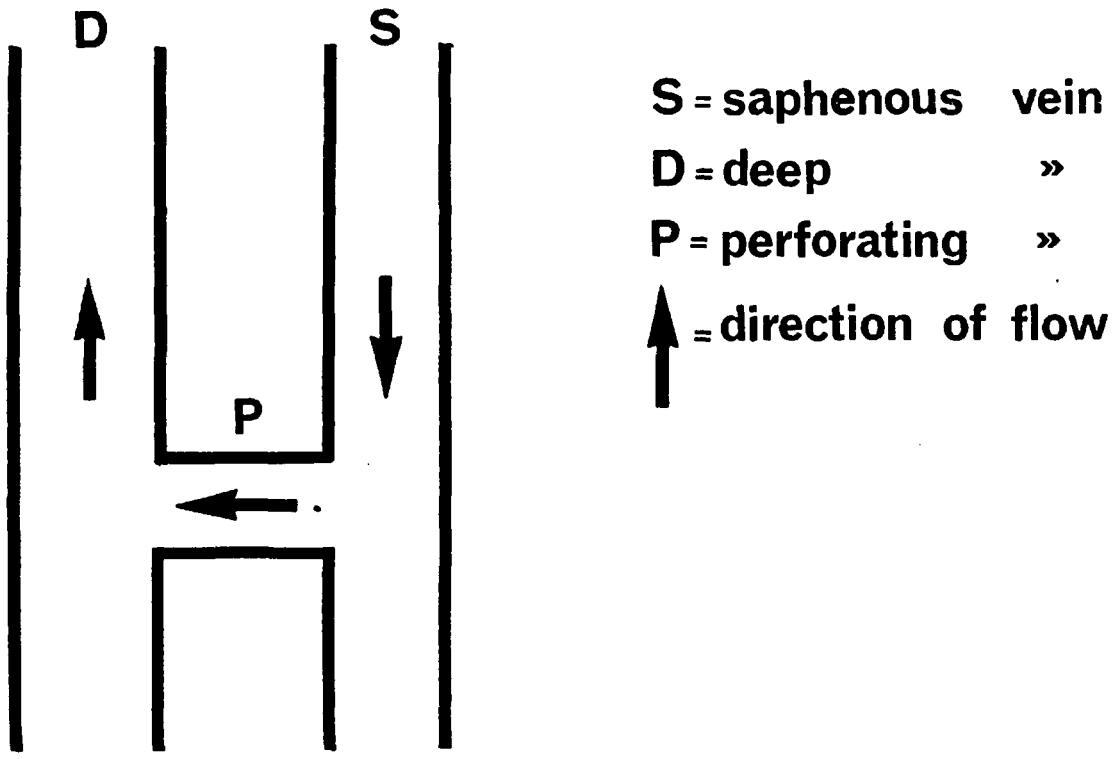



FIG. 1.4

Diagramatic representation of the direction of flow in the superficial, deep and perforating veins during the walking cycle in a limb with saphenofemoral incompetence only.

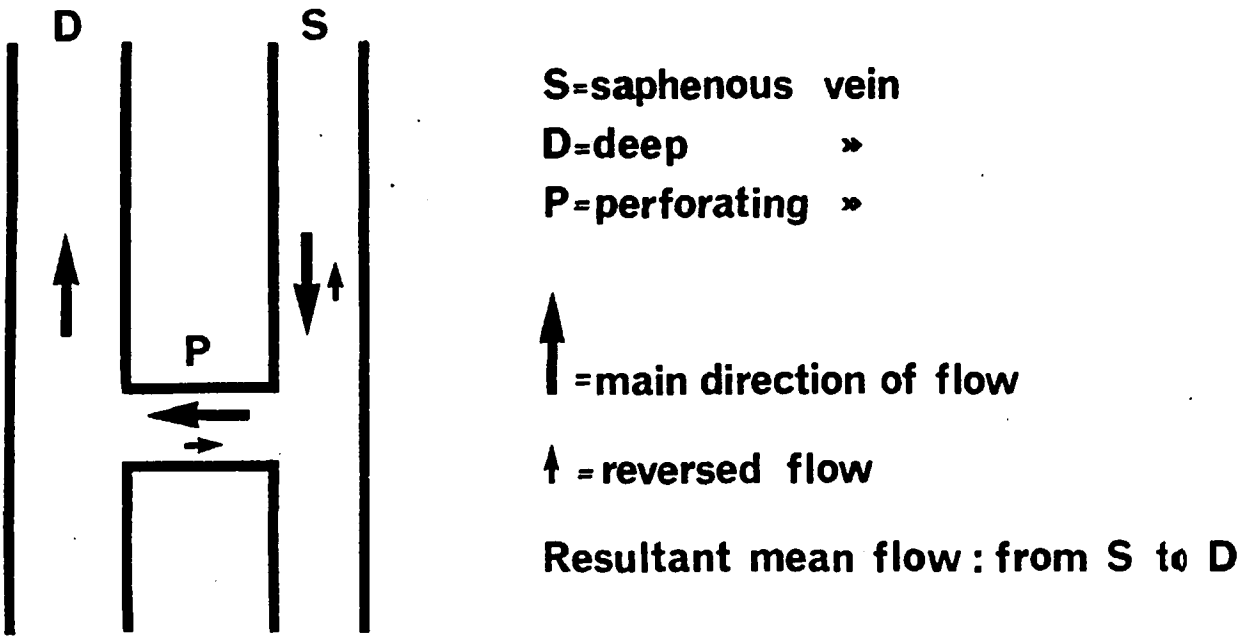



FIG. 1.5

Diagramatic representation of the direction of flow in the superficial, deep and perforating veins during the walking cycle in a limb with saphenofemoral incompetence and incompetent perforating veins.

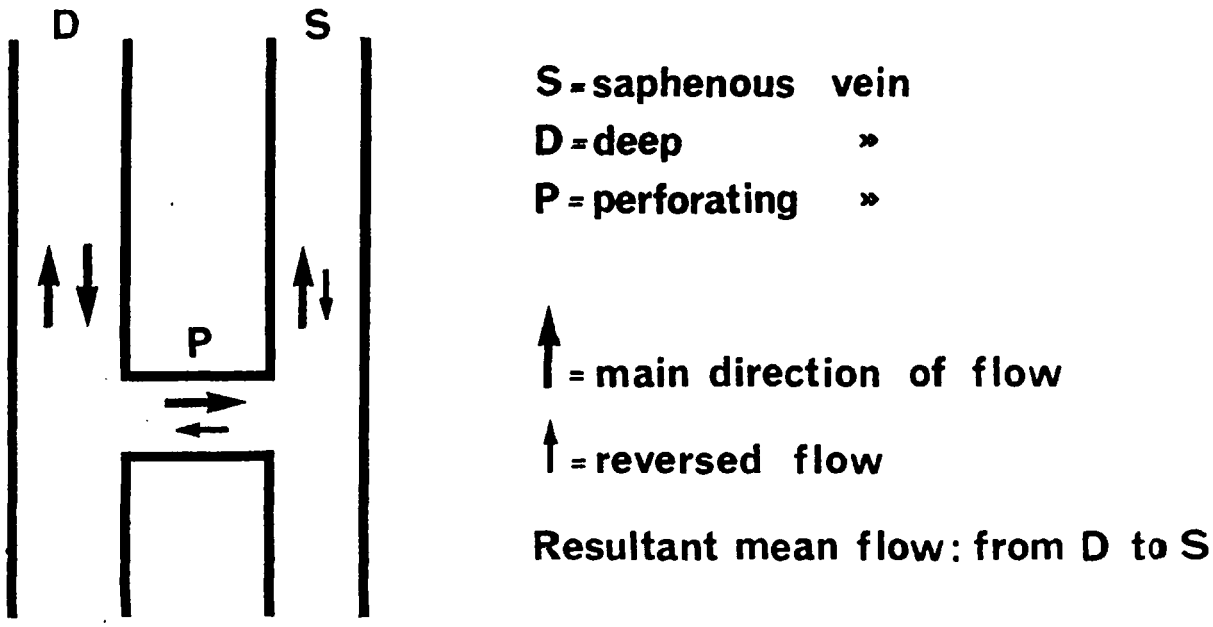



FIG. 1.6

Diagramatic representation of the direction of flow in the superficial, deep and perforating veins during the walking cycle in a limb with deep venous insufficiency.

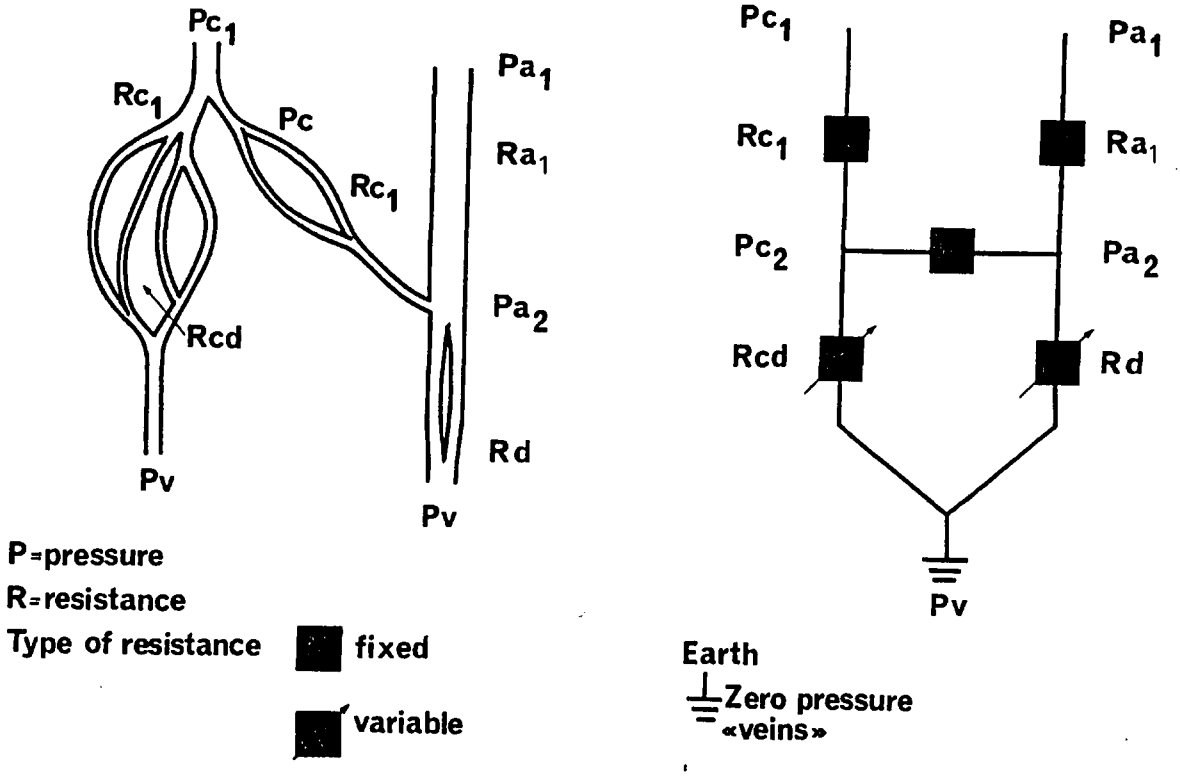



FIG. 1.7

An electrical model of the collateral circulation according to Strandness and Sumner (Strandness and Sumner, 1975).

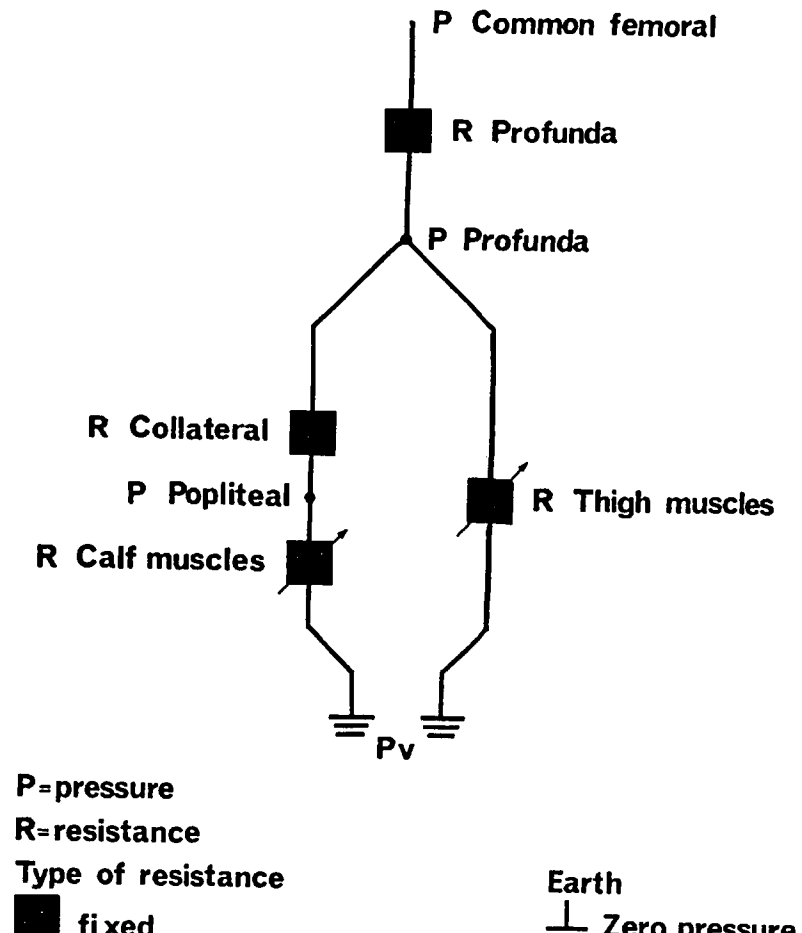



FIG. 1.8

Modification of the electrical model presented in Fig. 1.7 assuming that the main artery is occluded (Strandness and Sumner, 1975).

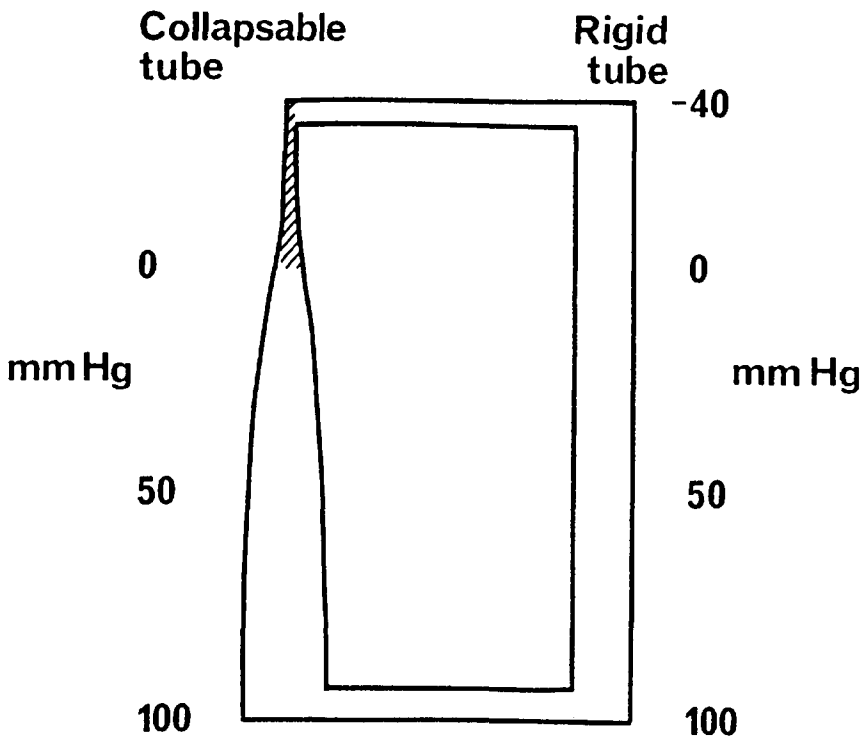



FIG. 1.9

Vertical tube model according to Gauer and Thorn (Gauer and Thorn, 1965).

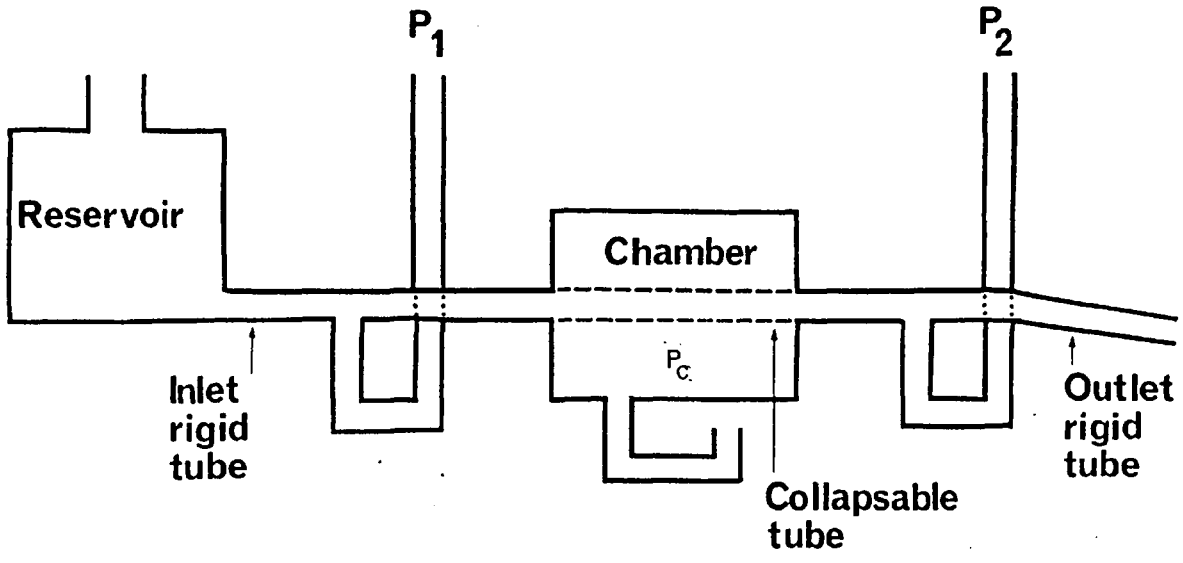



FIG. 1.10

Horizontal tube model according to Holt (Holt, 1969)

FIGURES FOR CHAPTER 2

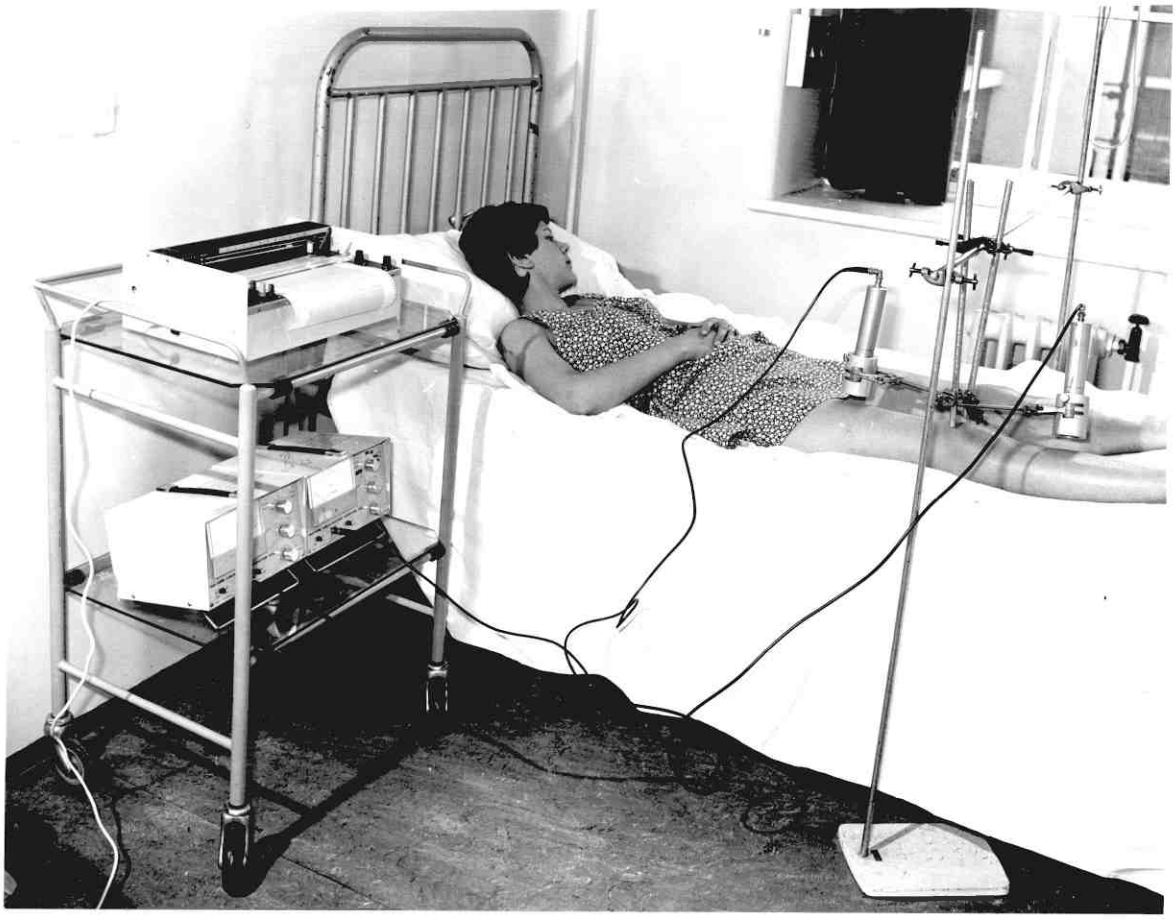


FIG. 2.1

Experimental set up for simultaneous 99m Tc - muscle clearance in the thigh and calf at rest and after exercise using heavy probes (Pitman - 235-isotope localisation monitors).

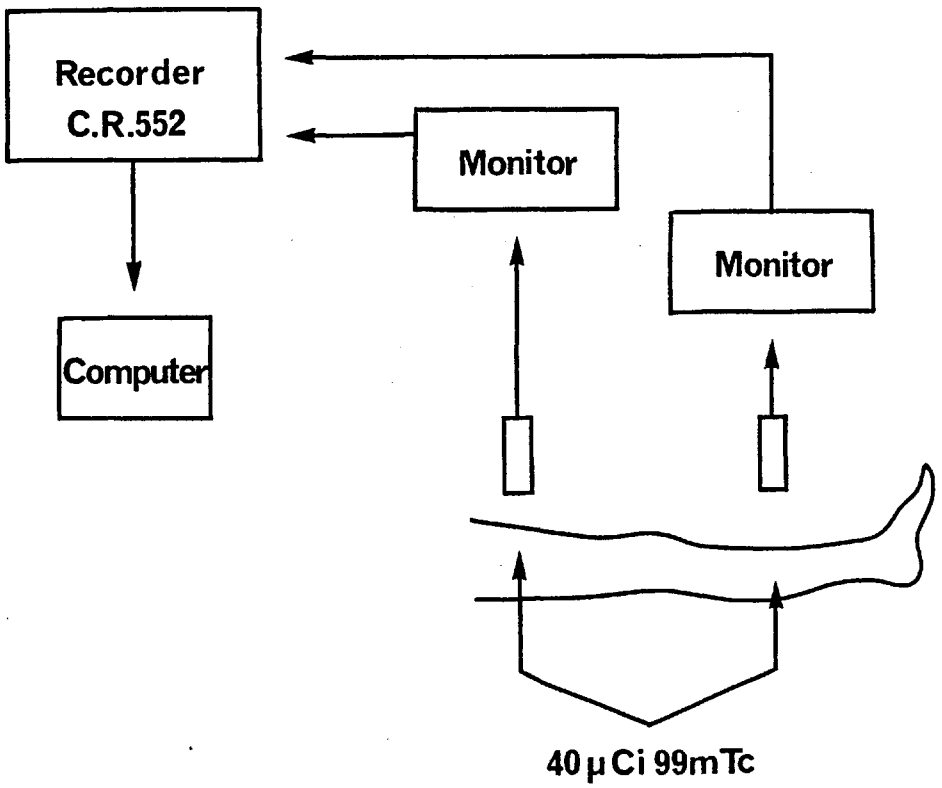



FIG. 2.2

Diagramatic representation of the experimental set-up for simultaneous 99m Tc muscle clearance in the thigh and calf at rest and after exercise.

FIG. 2.3

Walking on the treadmill

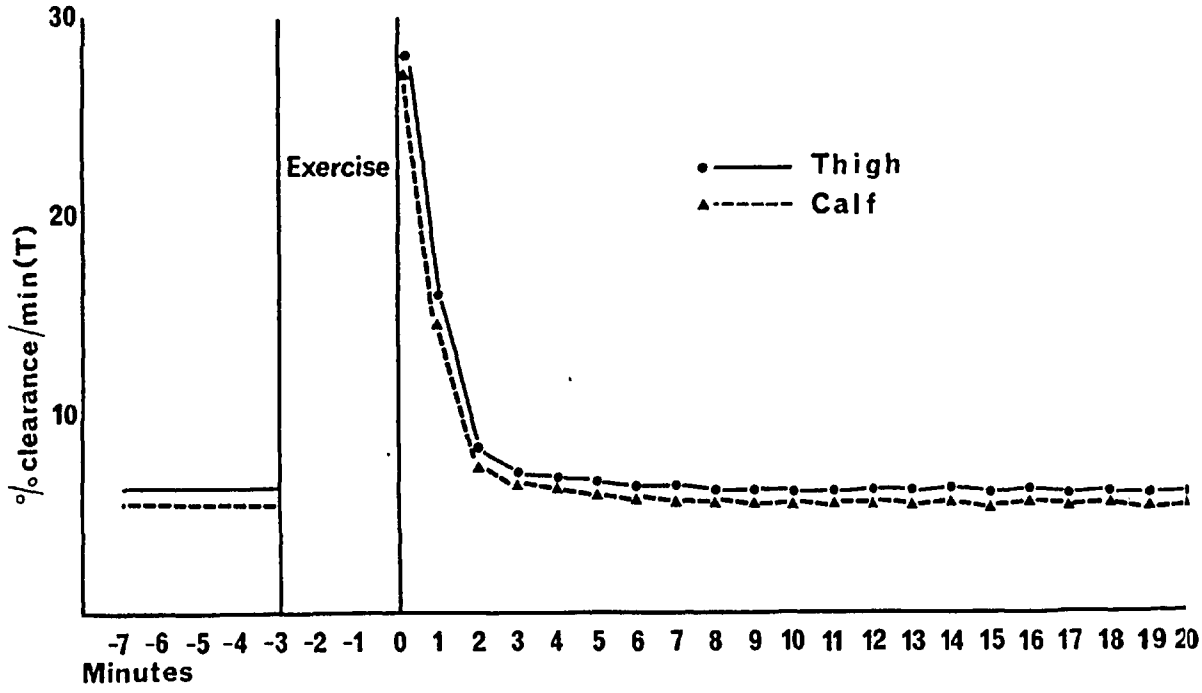



FIG. 2.4

Graph of the percentage clearance per minute (T) against time for the calculation of Total excess of T, Maximum value of post-exercise T, Hyperaemic Index, Time of onset of maximum value of post-exercise T and Total period of increased post-exercise T.

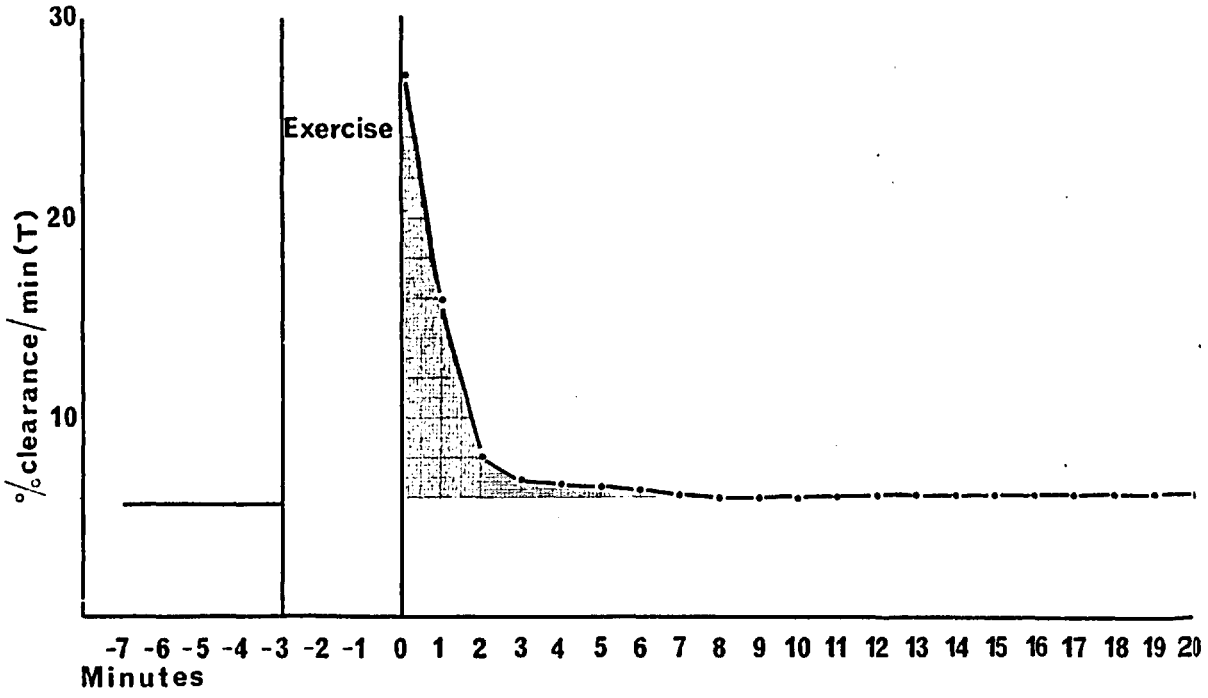



FIG. 2.5

Calculation of the Total excess of post-exercise T(A) (shaded area).

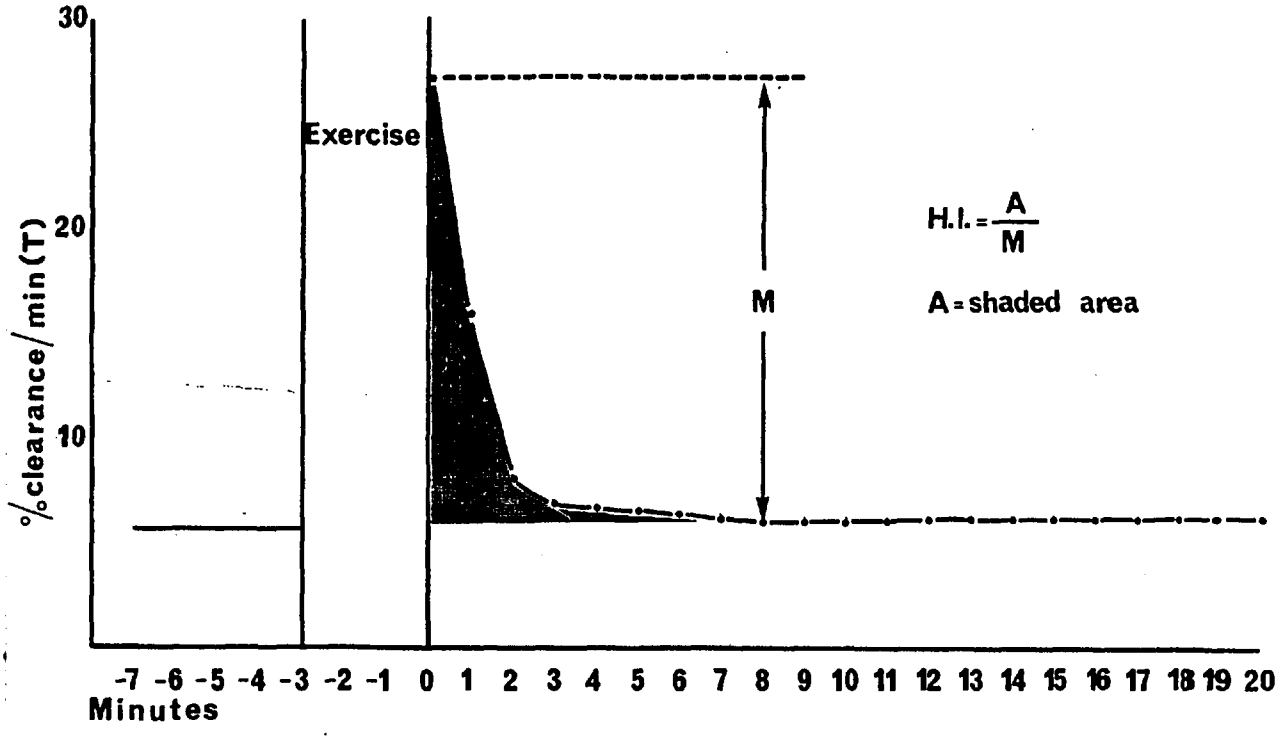



FIG. 2.6

Calculation of the Hyperaemic Index (H.I.).

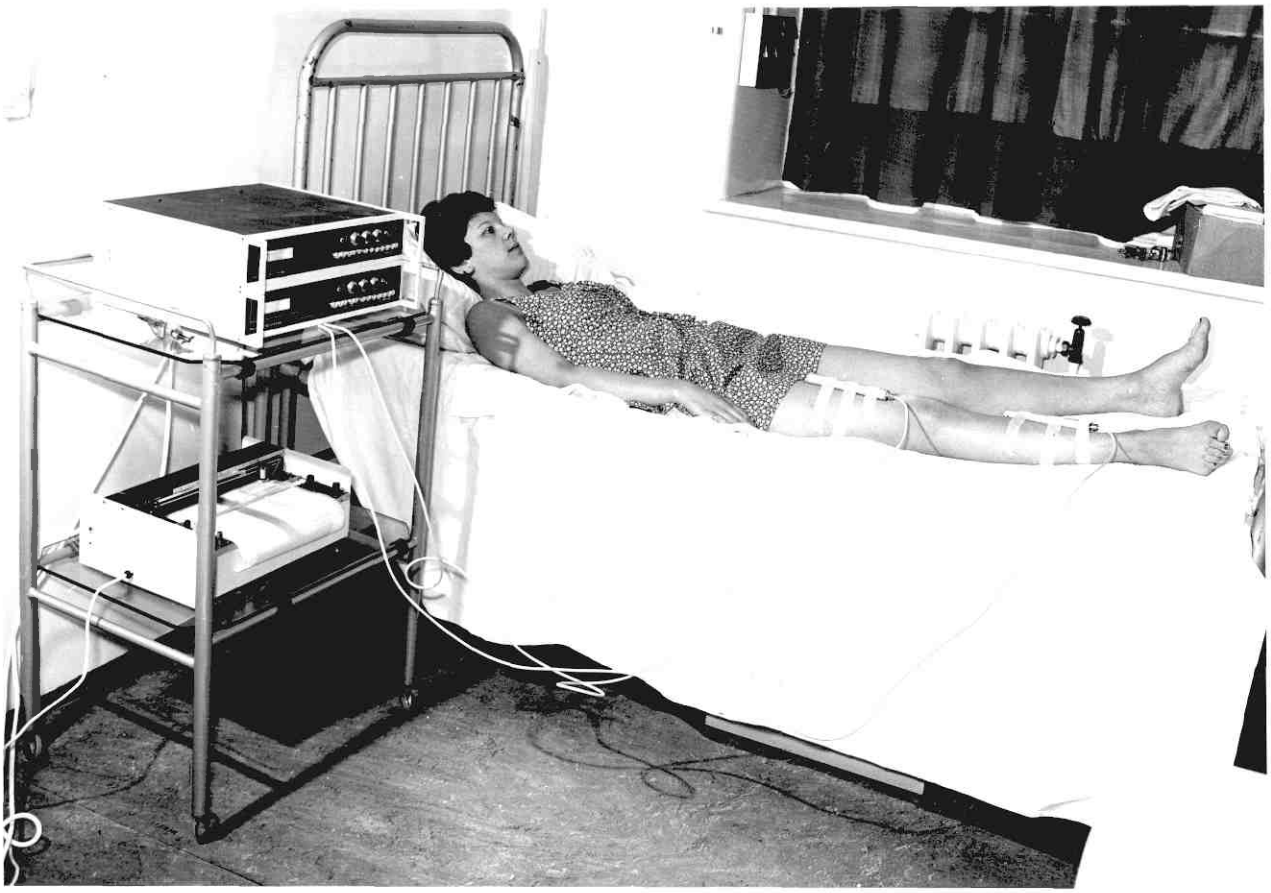


FIG. 2.7

Experimental set-up for simultaneous 99m Tc muscle clearance in the thigh and calf at rest, during and after exercise using light probes (Dual Channel Analysers - Model 45-24).

FIGURES AND TABLES FOR CHAPTER 3

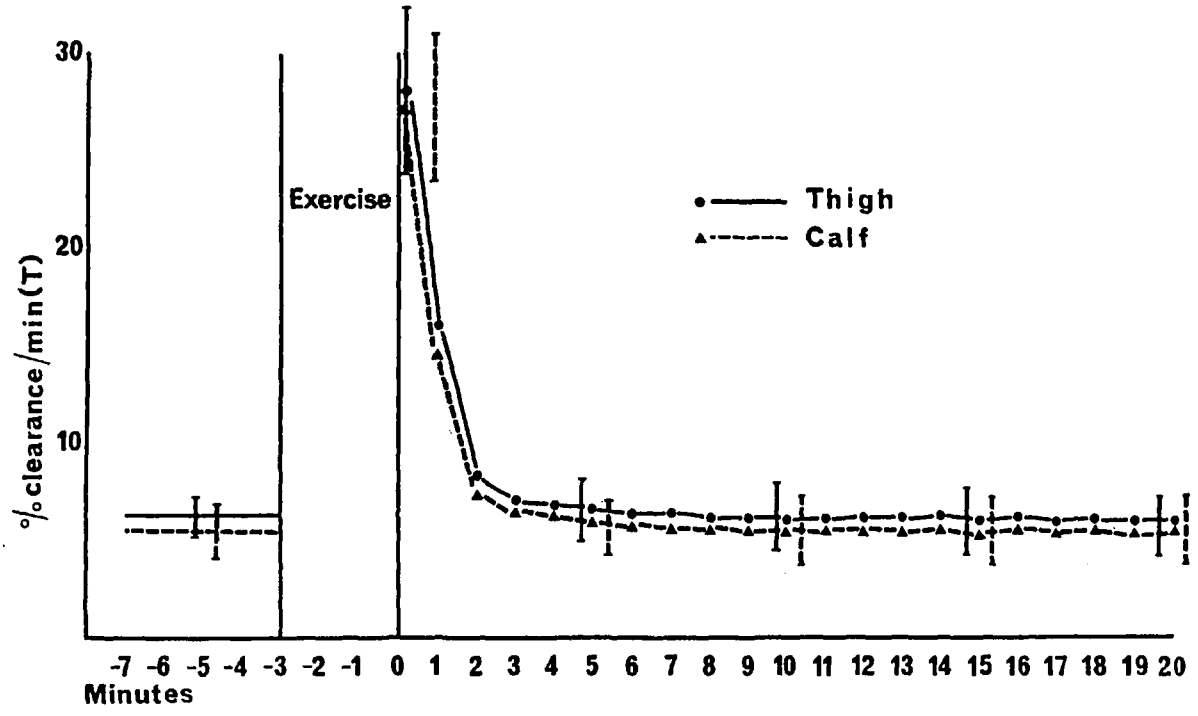



FIG. 3.1

The mean values of T and standard deviation in Group A (normal limbs) before and after exercise (Clinical Study I).

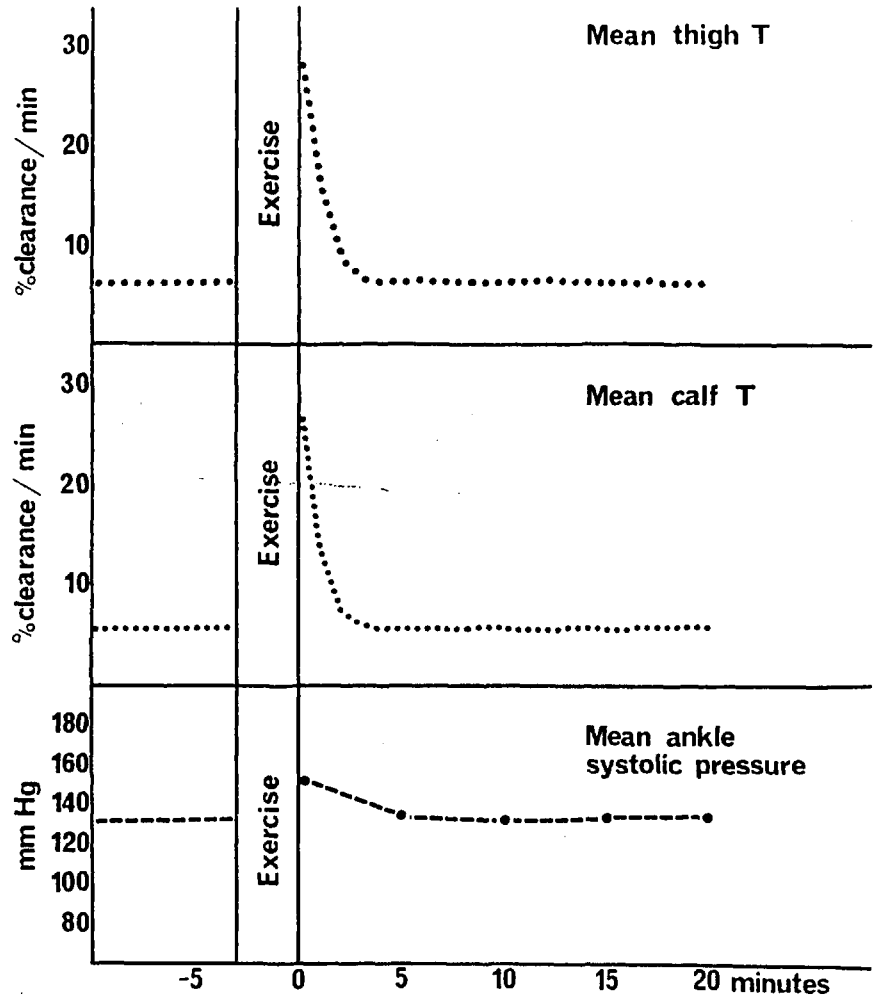



FIG. 3.2

The mean changes of thigh T, calf T and ankle systolic pressure in Group A (normal limbs) before and after exercise (Clinical Study I).

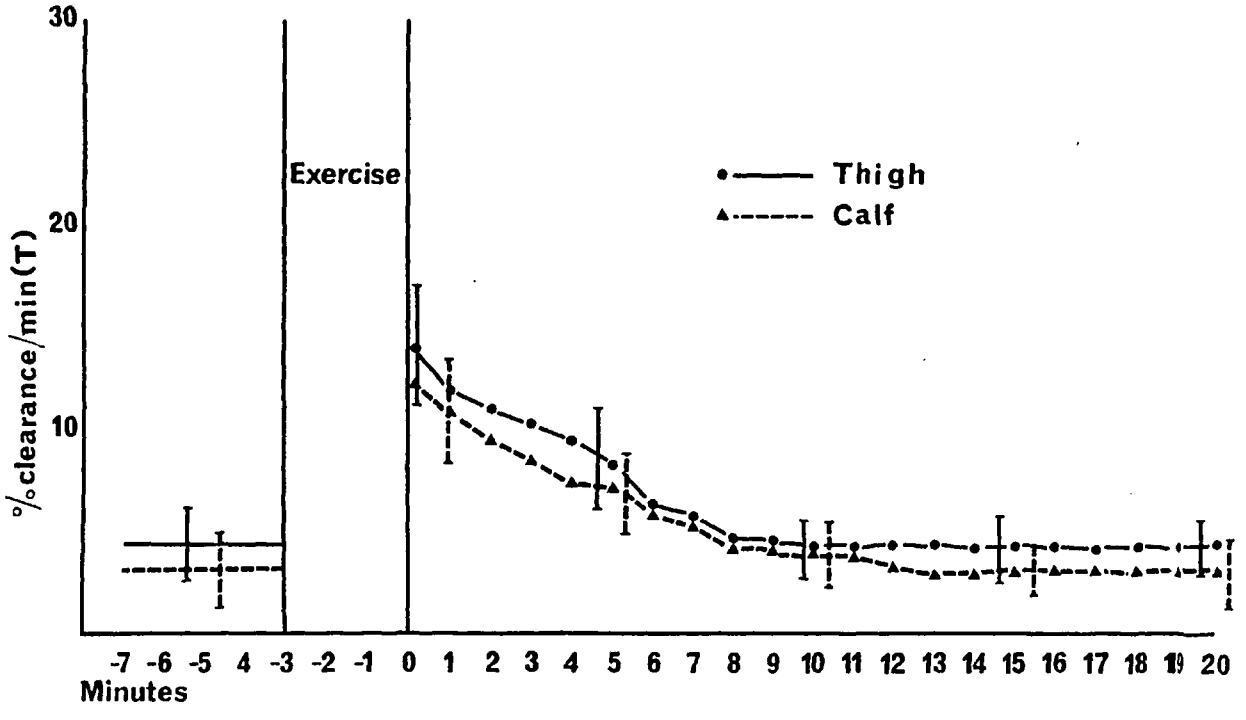



FIG. 3.3

The mean values of T and standard deviation in Group B (limbs with iliac occlusion only) before and after exercise (Clinical Study I).

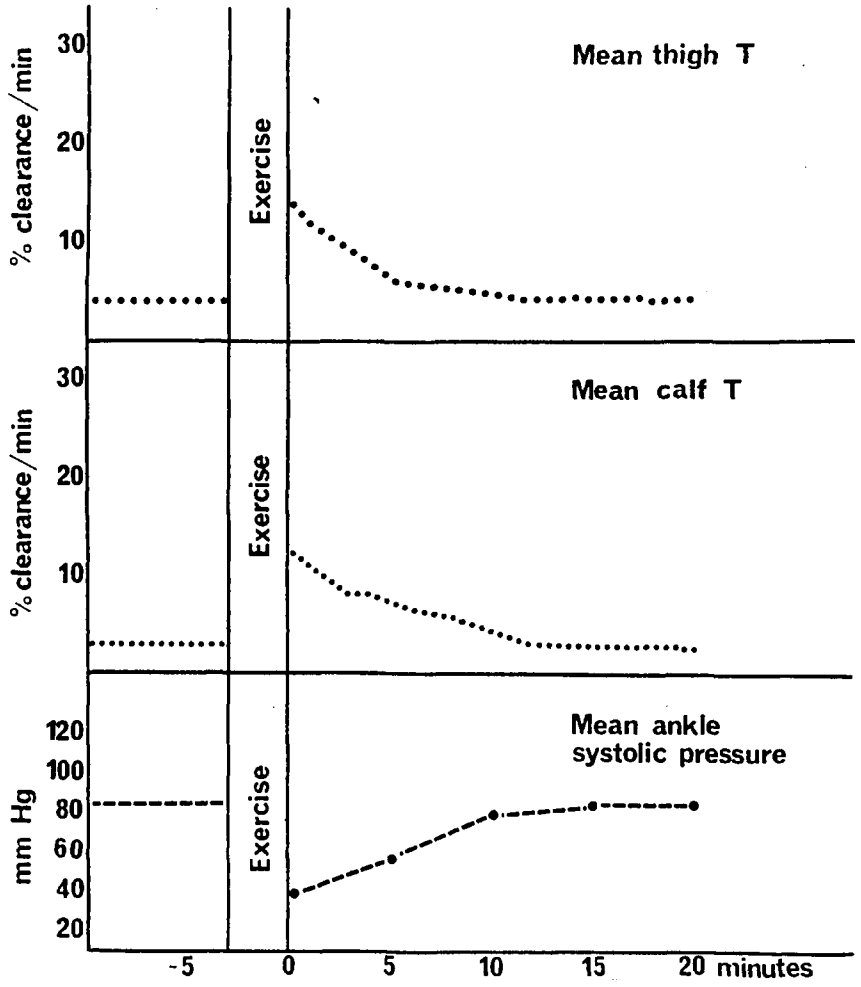



FIG. 3.4

The mean changes of thigh T, calf T and ankle systolic pressure in Group B (limbs with iliac occlusion only) before and after exercise (Clinical Study I).

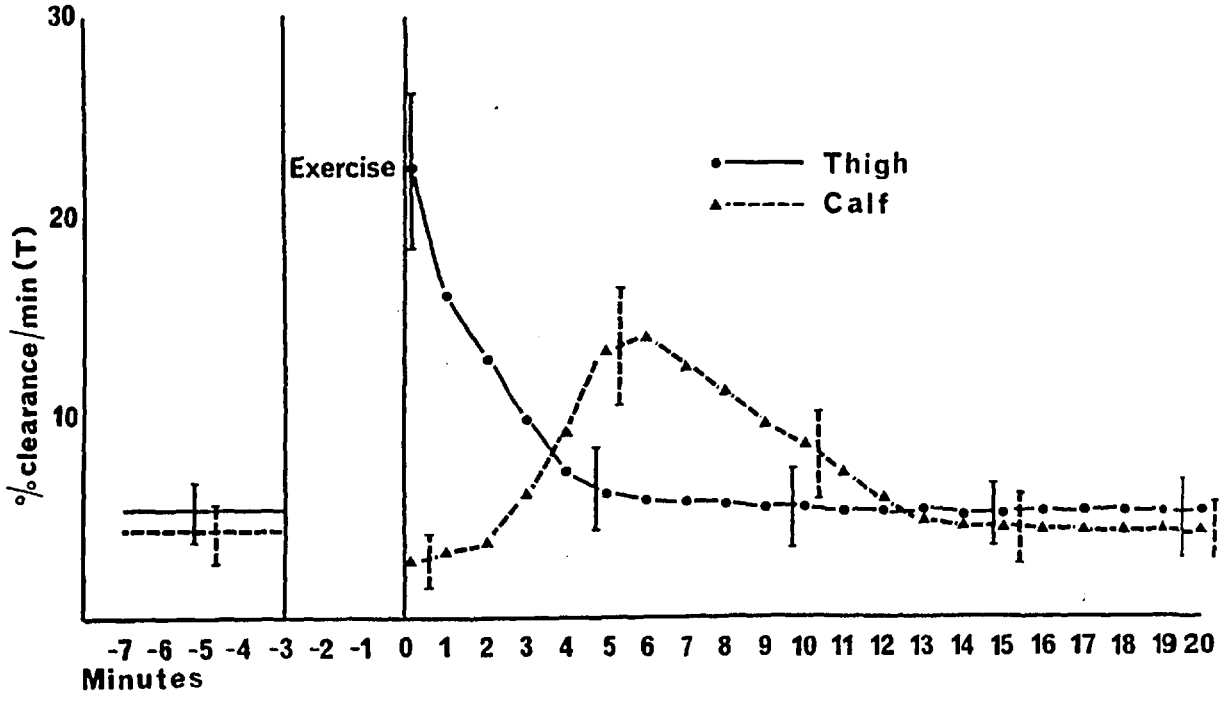



FIG. 3.5

The mean values of T and standard deviation in Group C (limbs with superficial femoral artery occlusion only) before and after exercise (Clinical Study I).

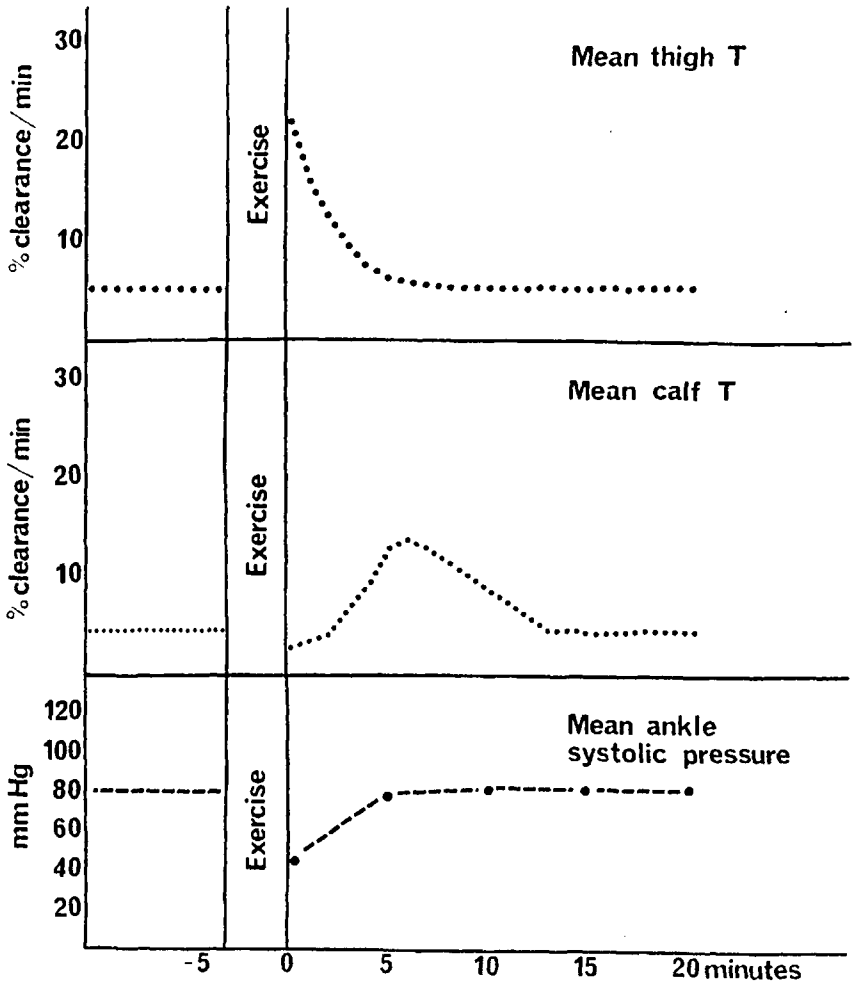



FIG. 3.6

The mean changes of thigh T, calf T and ankle systolic pressure in Group C (limbs with superficial femoral artery occlusion) before and after exercise (Clinical Study I).

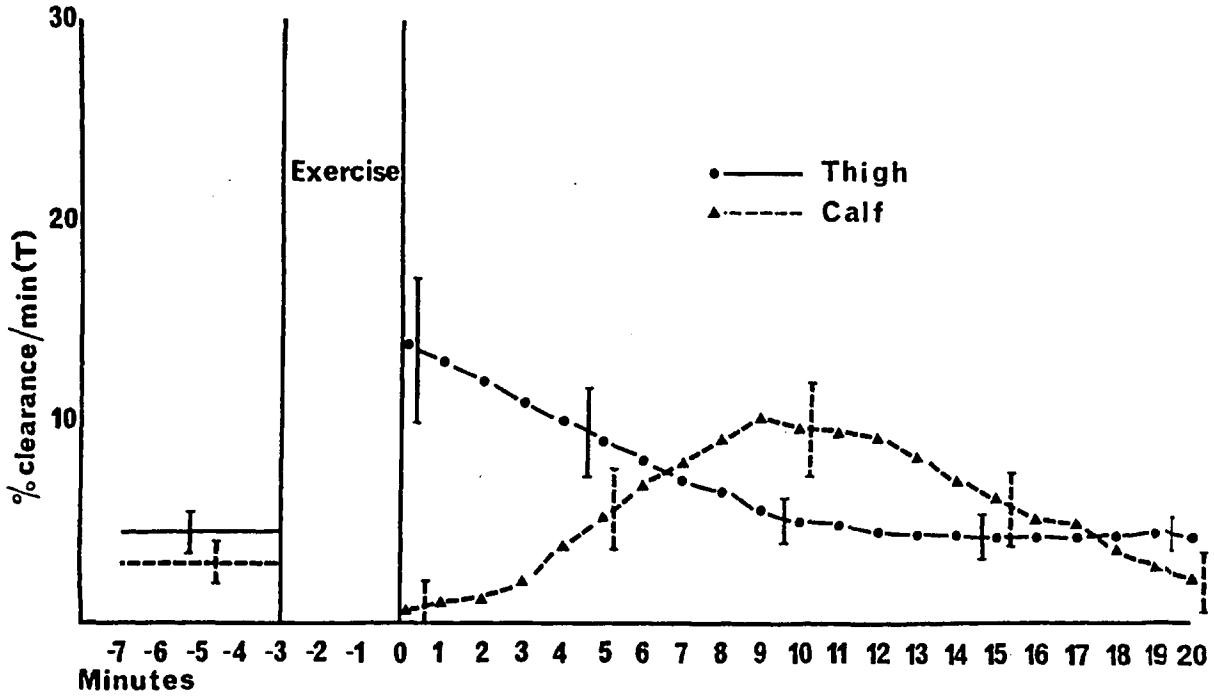



FIG. 3.7

The mean values of T and standard deviation in Group D (limbs with combined aortoiliac and femoropopliteal lesions) before and after exercise (Clinical Study I).

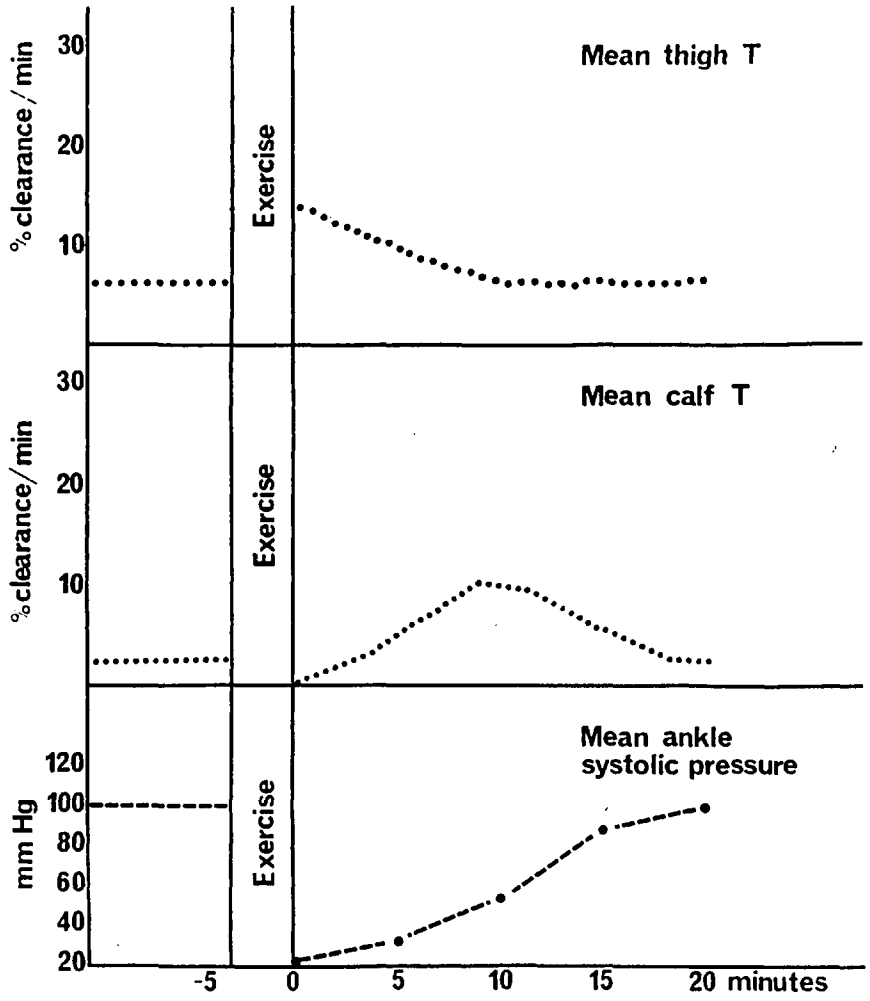



FIG. 3.8

The mean changes of thigh T, calf T and ankle systolic pressure in Group D (limbs with combined aortoiliac and femoropopliteal lesions) before and after exercise (Clinical Study I).

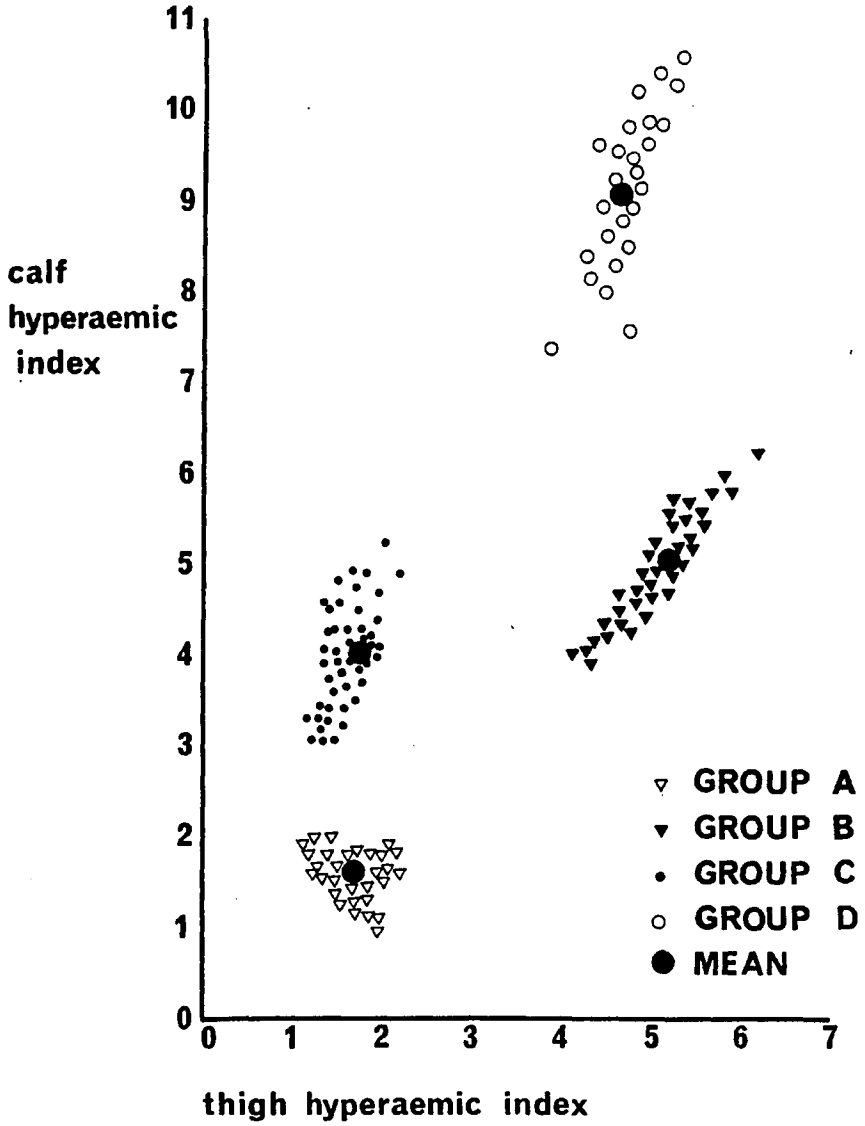



FIG. 3.9

Analysis of the Hyperaemic Indices in the thigh and in the calf for every limb studied. The means from Table 3.1 are shown as large black dots (Clinical Study I).

T A B L E 3.1

Mean and standard deviation of thigh and calf Hyperaemic Indices in Groups A to D. (Clinical Study I)

| | Group A | Group B | Group C | Group D |
|---|---|---|---|---|
| Thigh Hyperaemic Index (H.I) | 1.53 ± 0.19 | 4.89 ± 0.48 | 1.50 ± 0.16 | 4.55 ± 0.37 |
| Calf Hyperaemic Index (H.I) | 1.54 ± 0.20 | 5.02 ± 0.60 | 4.30 ± 0.52 | 9.10 ± 1.14 |

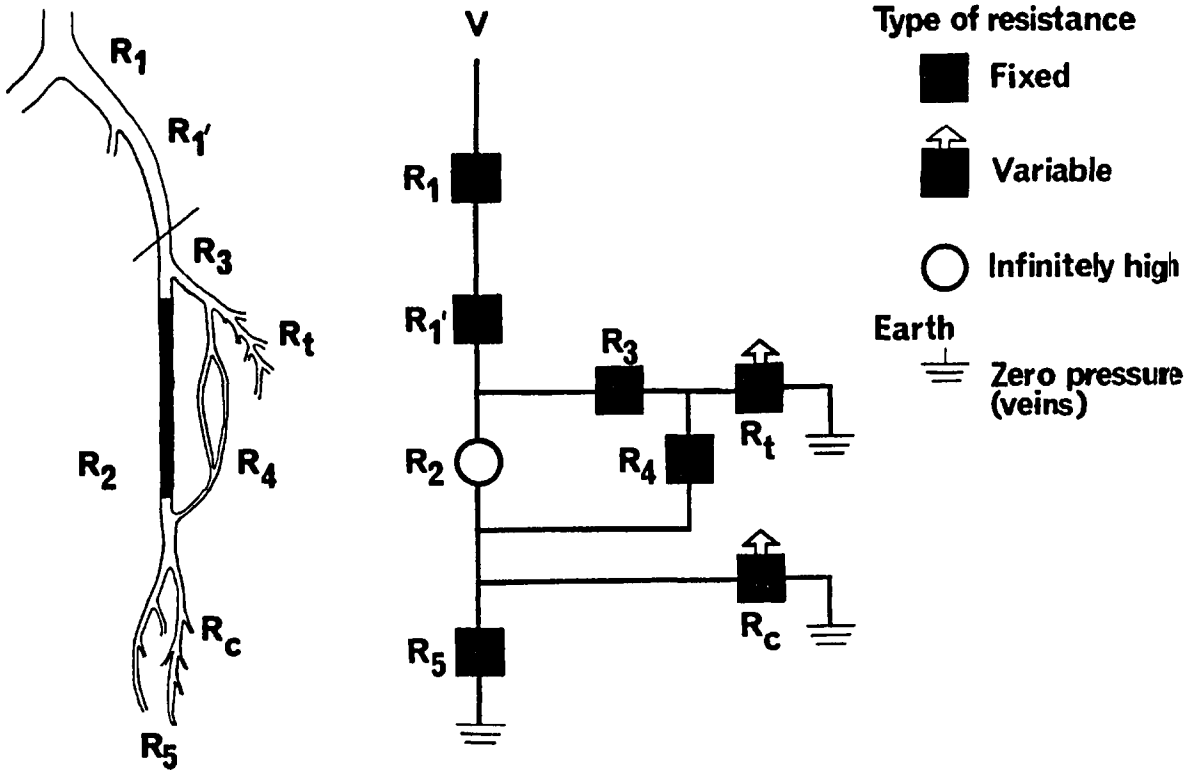



FIG. 3.10

Diagramatic representation of the arterial tree and its electrical analogue in a limb with superficial femoral artery occlusion only (Clinical Study I).

$R_1$ = Resistance of common iliac artery (fixed)

$R_i'$ = Resistance of external iliac artery (fixed)

$R_2$ = Resistance of superficial femoral artery ($\infty$)

$R_3$ = Resistance of profunda femoris artery (fixed)

$R_4$ = Resistance of collateral artery (fixed)

$R_5$ = Resistance of main calf artery (fixed)

$R_t$ = Resistance of thigh muscle bed (variable)

$R_c$ = Resistance of calf muscle bed (variable)

V = Assumed constant pressure (voltage) in aorta.

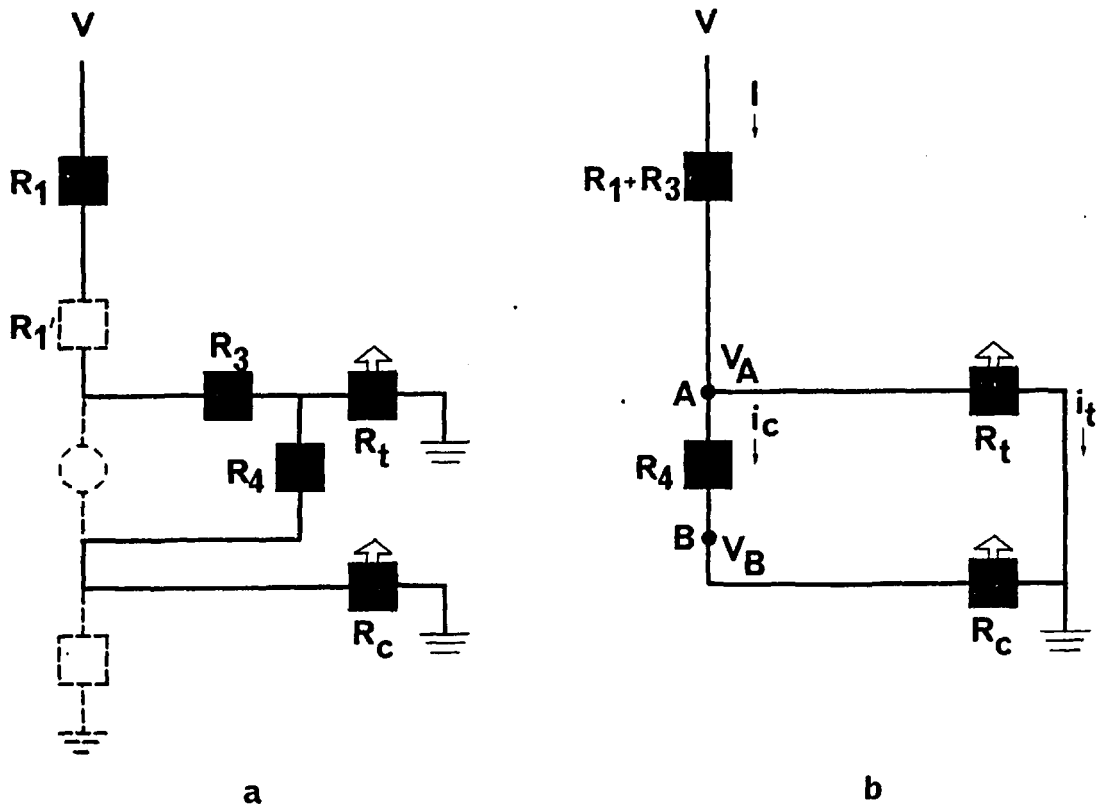



FIG. 3.11, a and b

Simplification of the electrical model in Figure 3.10 by omitting the resistance of the occluded superficial femoral artery ($R_2$) and the fixed resistances of the external iliac ($R_1'$) and of the main arteries distal to the occlusion ($R_5$).

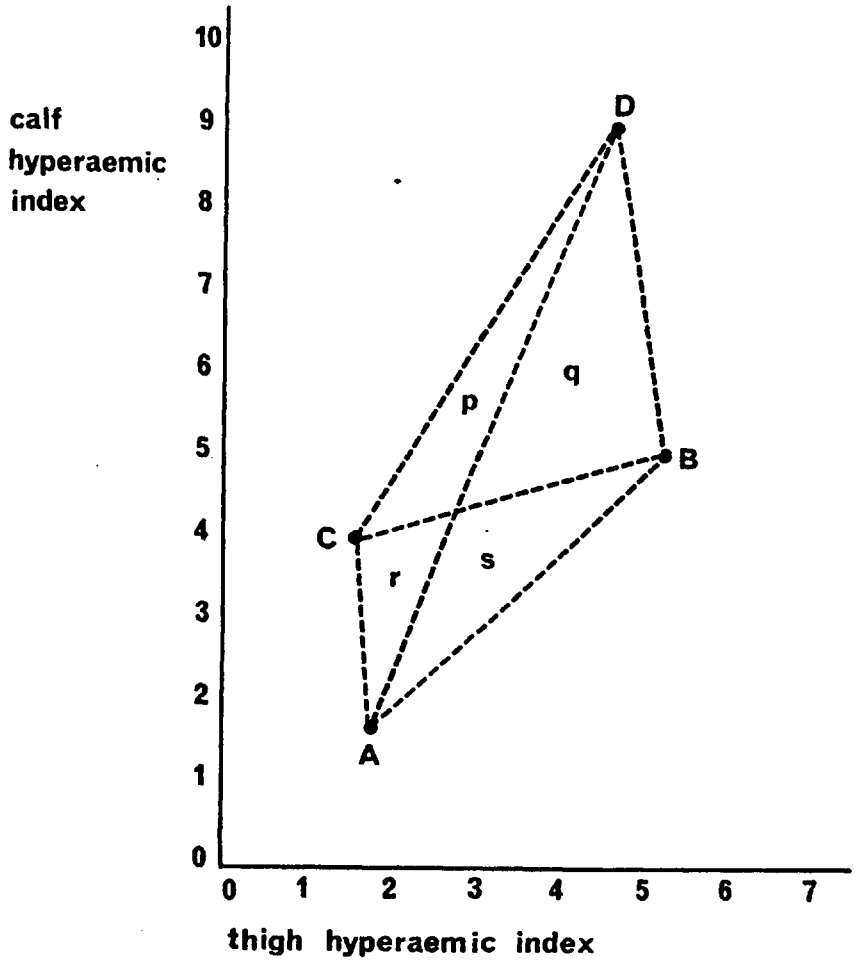



FIG. 3.12

Analysis of the mean thigh and calf Hyperaemic Indices of the four groups (A to D) studied (Clinical Study I).

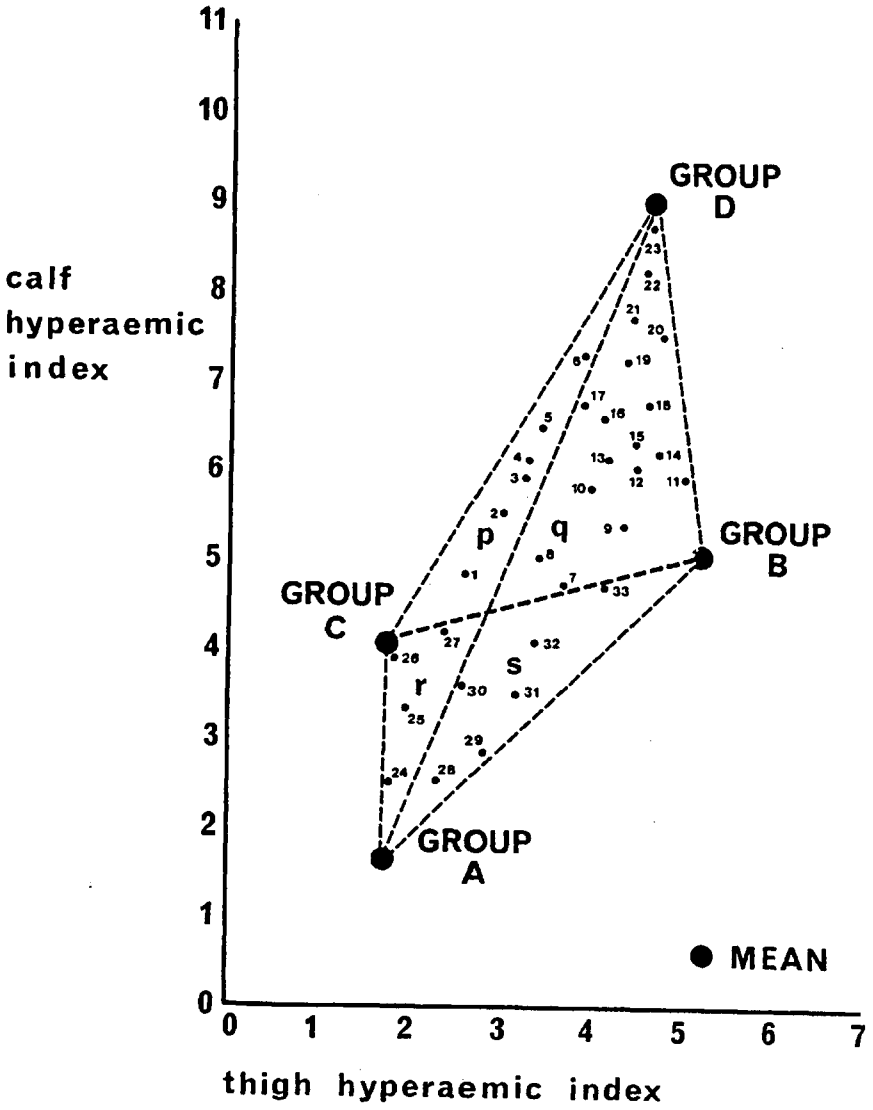



FIG. 3.13

Analysis of the thigh and calf Hyperaemic Indices for every limb with combined aortoiliac and femoropopliteal stenoses studied (Clinical Study II).

# TABLE 3.2

Degree of stenosis of the aortoiliac and femoropopliteal Segments and relative stenosis according to the aortographic findings in relation to triangles p , q , r , s . (Clinical Study II)

| Position of Limbs (Fig. 3.13) | Limb No. | Degree of Stenosis According to the Aortogram | | Relative Stenosis |
|---|---|---|---|---|
| | | Femoropopliteal Segment (FP) | Aortoiliac Segment (AI) | |
| | 1 | > 70 | < 10 | FP>AL |
| | 2 | > 70 | 10-40 | FP>AI |
| Triangle | 3 | > 70 | 10-40 | FP>AI |
| p | 4 | > 70 | 10-40 | FP>AI |
| | 5 | > 70 | 40-70 | FP>AI |
| | 6 | > 70 | 40-70 | FP>AI |
| | 7 | 10-40 | > 70 | FP<AI |
| | 8 | 10-40 | > 70 | FP<AI |
| | 9 | 10-40 | > 70 | FP<AI |
| | 10 | 10-40 | > 70 | FP<AI |
| | 11 | 10-40 | > 70 | FP<AI |
| Triangle | 12 | 10-40 | > 70 | FP<AI |
| q | 13 | 10-40 | > 70 | FP<AI |
| | 14 | 10-40 | > 70 | FP<AI |
| | 15 | 10-40 | > 70 | FP<AI |
| | 16 | 40-70 | > 70 | FP<AI |
| | 17 | 40-70 | > 70 | FP<AI |
| | 18 | 40-70 | > 70 | FP<AI |
| | 19 | 40-70 | > 70 | FP<AI |
| | 20 | > 70 | 100 | FP<AI |
| | 21 | > 70 | 100 | FP<AI |
| | 22 | > 70 | 100 | FP<AI |
| | 23 | > 70 | 100 | FP<AI |

Continuation from previous page:.. TABLE 3.2

| Position of Limbs (Fig3.13) | Limb No. | Degree of Stenosis According to the Aortogram | | Relative Stenosis |
|---|---|---|---|---|
| | | Femoropopliteal Segment (FP) | Aortoiliac Segment (AI) | |
| triangle r | 24 | 10-40 | < 10 | FP>AI |
| | 25 | 40-70 | < 10 | FP>AI |
| | 26 | 40-70 | < 10 | FP>AI |
| | 27 | 100 | < 10 | FP>AI |
| triangle s | 28 | < 10 | 10-40 | FP<AI |
| | 29 | < 10 | 10-40 | FP<AI |
| | 30 | 10-40 | 10-40 | FP<AI |
| | 31 | 10-40 | 40-70 | FP<AI |
| | 32 | 10-40 | 40-70 | FP<AI |
| | 33 | 10-40 | 40-70 | FP<AI |

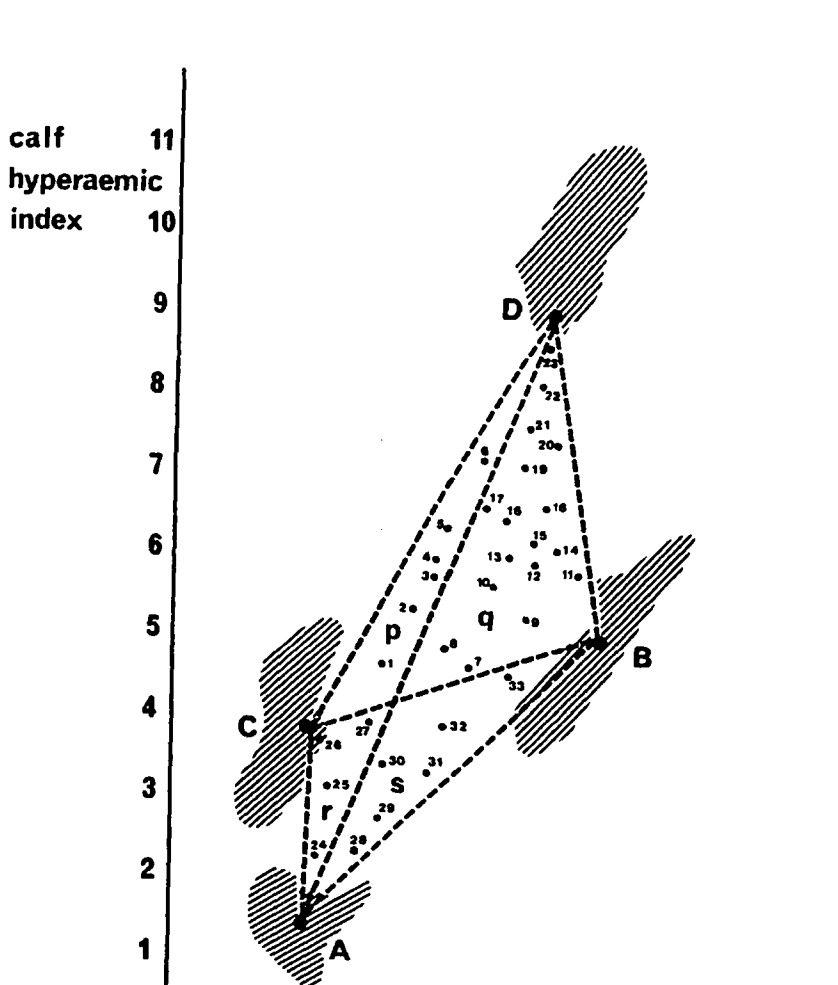



FIG. 3.14

Graphical representation of the results of Clinical Study I and Clinical Study II (by superimposing Figs. 3.9 and 3.13).

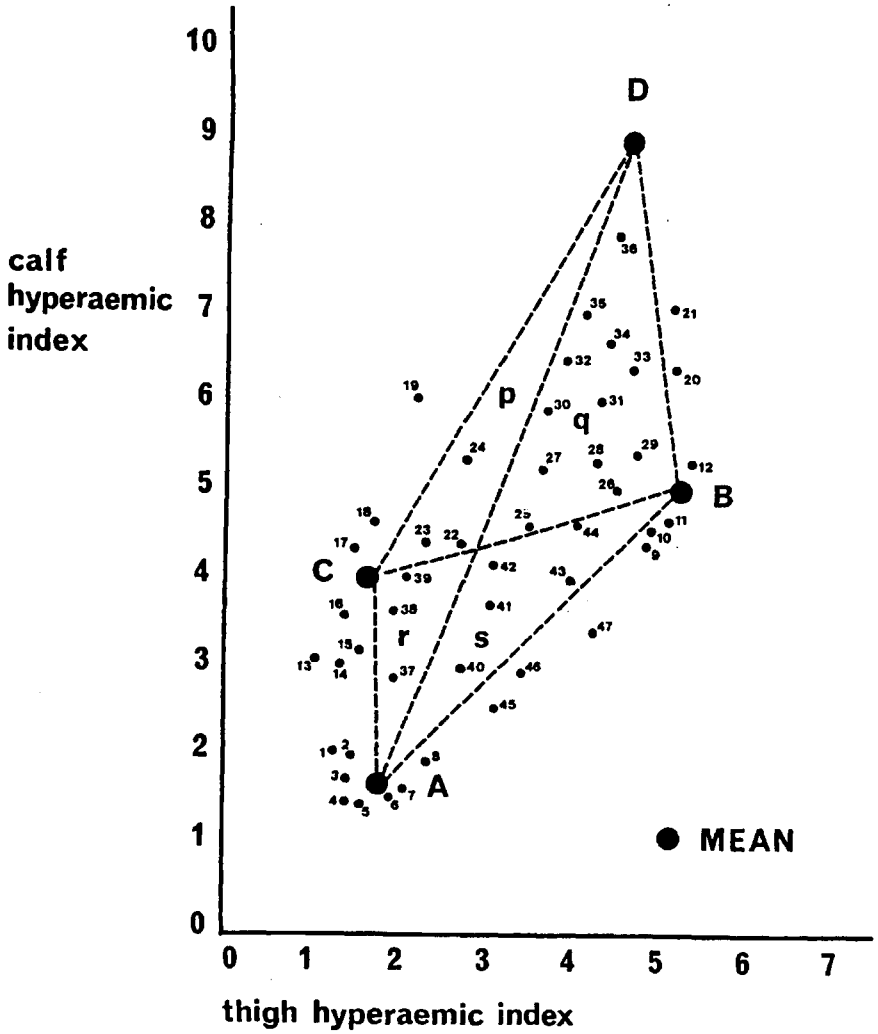



FIG. 3.15

Analysis of the thigh and calf Hyperaemic Indices prospectively (Clinical Study III).

TABLE 3.3

Degree of stenosis in the aortoiliac and femoropopliteal segments and relative stenosis according to the Hyperaemic Index in relation to triangles p, q, r, s. (Clinical Study II)
(Key: mild = 10%-40%; moderate = 40%-70%; severe: >70% stenosis)

| Position of Limbs (Fig.3.15) | Limb No | Degree of Stenosis According to H.I. | | Relative Stenosis According to H.I |
|---|---|---|---|---|
| | | Fem-Pop | Aortoiliac | |
| near A outside quatrangle | 1 | normal | normal | |
| | 2 | normal | normal | |
| | 3 | normal | normal | |
| | 4 | normal | normal | |
| | 5 | normal | normal | |
| | 6 | normal | normal | |
| | 7 | normal | normal | |
| | 8 | normal | normal | |
| near B outside quatrangle | 9 | normal | occlusion | |
| | 10 | normal | occlusion | |
| | 11 | normal | occlusion | |
| | 12 | normal | occlusion | |

Continuation from previous page

TABLE 3.3

| Position of Limbs (Fig. 3.15) | Limb No | Degree of Stenosis Accodring to H.I | | Relative Stenosis According to H.I |
|---|---|---|---|---|
| | | Fem-POP | Aortoiliac | |
| near C outside quatrangle | 13 | occlusion | normal | |
| | 14 | occlusion | normal | |
| | 15 | occlusion | normal | |
| | 16 | occlusion | normal | |
| | 17 | occlusion | normal | |
| | 18 | occlusion | normal | |
| Between C&D outside quatrangle | 19 | occlusion | mild to moderate stenosis | |
| Between B&D outside quatrangle | 20 | mild to moderate stenosis | occlusion | |
| | 21 | mild to moderate stenosis | occlusion | |
| Triangle p | 22 | severe stenosis | mild to moderate | FP>AI |
| | 23 | severe stenosis | mild to moderate stenosis | FP>AI |
| | 24 | severe stenosis | mild to moderate stenosis | FP>AI |

Continuation from previous page

TABLE 3.3

| Position of (Limbs (Fig. 3.15) | Limb No | Degree of Stenosis According to H.I | | Relative Stenosis According to H.I |
|---|---|---|---|---|
| | | Femo-POP | Aortoiliac | |
| | 25 | mild to moderate stenosis | severe stenosis | FP<AI |
| triangle p | 26 | mild to moderate stenosis | severe stenosis | FP<AI |
| | 27 | mild to moderate stenosis | severe stenosis | FP<AI |
| | 28 | mild to moderate stenosis | severe stenosis | FP<AI |
| | 29 | mild to moderate stenosis | severe stenosis | FP<AI |
| | 30 | mild to moderate stenosis | severe stenosis | FP<AI |
| | 31 | mild to moderate stenosis | severe stenois | FP<AI |
| | 32 | mild to moderate stenosis | severe stenosis | FP<AI |
| | 33 | mild to moderate stenosis | severe stenosis | FP<AI |
| | 34 | mild to moderate stenosis | severe stenosis | FP<AI |
| | 35 | mild to moderate stenosis | severe stenosis | FP<AI |
| | 36 | severe stenosis | severe stenosis | FP<AI |

Continuation from previous page

TABLE 3.3

| Position of Limbs (Fig.3.15) | Limb No | Degree of Stenosis According to H.I | | Relative Stenosis According to H.I |
|---|---|---|---|---|
| | | Fem-Pop | Aortoiliac | |
| triangle r | 37 | moderate stenosis | mild stenosis | FP>AI |
| | 38 | moderate stenosis | mild stenosis | FP>AI |
| | 39 | moderate stenosis | mild stenosis | FP>AI |
| triangle s | 40 | mild stenosis | moderate stenosis | FP<AI |
| | 41 | mild stenosis | moderate stenosis | FP<AI |
| | 42 | mild stenosis | moderate stenosis | FP<AI |
| | 43 | mild stenosis | moderate stenosis | FP<AI |
| | 44 | mild stenosis | moderate stenosis | FP<AI |
| Between A & B outside quatrangle | 45 | normal | mild to moderate stenosis | |
| | 46 | normal | mild to moderate stenosis | |
| | 47 | normal | mild to moderate stenosis | |

TABLE 3.4

Degree of stenosis in the aortoiliac and femoropopliteal segments and relative stenosis according to the aortographic findings in relation to triangles p, q, r, s. (Clinical Study II).

| Position of Limbs (Fig.3.15) | Limb No | Degree of Stenosis According to Aortogram | | Relative Stenosis According to aortogram |
|---|---|---|---|---|
| | | Femoropopliteal | Aortoiliac | |
| near A outside quatrangle | 1 | 0 | 0 | |
| | 2 | 0 | 0 | |
| | 3 | 0 | 0 | |
| | 4 | 0 | 0 | |
| | 5 | 0 | 0 | |
| | 6 | 0 | 0 | |
| | 7 | 0 | 0 | |
| | 8 | 0 | 0 | |
| near B outside quatrangle | 9 | 0 | 100 | |
| | 10 | 0 | 100 | |
| | 11 | 0 | 100 | |
| | 12 | 0 | 100 | |

Continuation from previous page

TABLE 3.4

| Position of Limbs (Fig.3.15) | Limb No | Degree of Stenosis According to Aortogram | | Relative Stenosis According to Aortogram |
|---|---|---|---|---|
| | | Femoropopliteal | Aortoiliac | |
| near C outside quatrangle | 13 | 100 | 0 | |
| | 14 | 100 | 0 | |
| | 15 | 100 | 0 | |
| | 16 | 100 | 0 | |
| | 17 | 100 | 0 | |
| | 18 | 100 | 0 | |
| Between C and D outside quatrangle | 19 | <10 | 40-70 | |
| Between B and D outside quatrangle | 20 | 10-40 | 100 | FP<AI |
| | 21 | 40-70 | 100 | FP<AI |
| triangle P | 22 | >70 | 10-40 | FP>AI |
| | 23 | >70 | <10 | FP>AI |
| | 24 | >70 | 10-40 | FP>AI |

Continuation from previous page

TABLE 3.4

| Position of Limbs (Fig. 3.15) | Limb No | Degree of Stenosis According to Aortogram | | Relative Stenosis According to Aortogram |
|---|---|---|---|---|
| | | Femoropopliteal | Aortoiliac | |
| triangle q | 25 | 10-40 | >70 | FP<AI |
| | 26 | < 10 | >70 | FP<AI |
| | 27 | 10-40 | >70 | FP<AI |
| | 28 | 10-40 | >70 | FP<AI |
| | 29 | 10-40 | >70 | FP<AI |
| | 30 | 40-70 | >70 | FP<AI |
| | 31 | 40-70 | >70 | FP<AI |
| | 32 | 40-70 | >70 | FP<AI |
| | 33 | 40-70 | >70 | FP<AI |
| | 34 | 40-70 | >70 | FP<AI |
| | 35 | 40-70 | >70 | FP<AI |
| | 36 | 40-70 | >70 | FP<AI |
| triangle r | 37 | 10-40 | <10 | FP>AI |
| | 38 | 40-70 | <10 | FP>AI |
| | 39 | 40-70 | <10 | FP>AI |

Continuation from previous page... TABLE 3.4

| Position Limbs (Fig 3.15) | Limb No. | Degree of Stenosis According to Aortogram | | Relative Stenosis According to Aortogram |
|---|---|---|---|---|
| | | Femoropopliteal | Aortoiliac | |
| triangles | 40 | <10 | 10-40 | FP< AI |
| | 41 | 10-40 | 40-70 | FP< AI |
| | 42 | 10-40 | 40-70 | FP< AI |
| | 43 | <10 | 40-70 | FP< AI |
| | 44 | 10-40 | 40-70 | FP< AI |
| Between A & B outside quatrangle | 45 | 0 | 40-70 | FP<AI |
| | 46 | 0 | 40-70 | FP<AI |
| | 47 | 0 | 40-70 | FP<AI |

TABLES (3.3 and 3.4) 3.5

Degree of stenosis in the aortoiliac and femoropopliteal segments and relative stenosis according to the aortographic findings and the Hyperaemic Index in relation to triangles p, q, r, s. (Clinical Study II). (Key: mild = 10%-40%; moderate = 40%-70%; severe = >70% stenosis).

| Position of Limbs (Fig 3.15) | Limb No | Degree of Stenosis According to the Hyperaemic Index (H.I) | | Relative Stenosis According to H.I | Degree of Stenosis According to the Aortogram (A) | | Relative Stenosis According to (A) |
|---|---|---|---|---|---|---|---|
| | | Femoropopliteal Segment (FP) | Aortoiliac Segment (AI) | | FP | AI | |
| near A outside quatrangle | 1 | normal | normal | | 0 | 0 | |
| | 2 | normal | normal | | 0 | 0 | |
| | 3 | normal | normal | | 0 | 0 | |
| | 4 | normal | normal | | 0 | 0 | |
| | 5 | normal | normal | | 0 | 0 | |
| | 6 | normal | normal | | 0 | 0 | |
| | 7 | normal | normal | | 0 | 0 | |
| | 8 | normal | normal | | 0 | 0 | |
| near B outside quatrangle | 9 | normal | occlusion | | 0 | 100 | |
| | 10 | normal | occlusion | | 0 | 100 | |
| | 11 | normal | occlusion | | 0 | 100 | |
| | 12 | normal | occlusion | | 0 | 100 | |

Continuation from previous page

TABLES (3.3 and 3.4) 3.5

| Position of Limbs (Fig 3.15) | Limb No | Degree of Stenosis According to the Hyperaemic Index (H.I) | | Relative Stenosis According to H.I. | Degree of Stenosis According to the Aortogram (A) | | Relative Stenosis According to A |
|---|---|---|---|---|---|---|---|
| | | Femoropopliteal Segment (FP) | Aortoiliac Segment (AI) | | FP | AI | |
| near C outside quatrangle | 13 | occlusion | normal | | 100 | 0 | |
| | 14 | occlusion | normal | | 100 | 0 | |
| | 15 | occlusion | normal | | 100 | 0 | |
| | 16 | occlusion | normal | | 100 | 0 | |
| | 17 | occlusion | normal | | 100 | 0 | |
| | 18 | occlusion | normal | | 100 | 0 | |
| between C & D outside quatrangle | 19 | occlusion | mild to moderate stenosis | | 100 | 40-70 | |
| between B & D outside quatrangle | 20 | mild to moderate | occlusion | | 10-40 | 100 | FP<AI |
| | 21 | mild to moderate | occlusion | | 40-70 | 100 | FP<AI |
| triangle p | 22 | severe stenosis | mild to moderate stenosis | FP>AI | >70 | 10-40 | FP>AI |
| | 23 | severe stenosis | mild to moderate | FP>AI | >70 | <10 | FP>AI |
| | 24 | severe stenosis | mild to moderate | FP>AI | >70 | 10-40 | FP>AI |

Continuation from previous page

TABLE 3.5

| Position of Limbs (Fig 3.15) | Limb No | Degree of Stenosis According to the Hyperaemic Index (H.I) | | Relative Stenosis According to H.I. | Degree of Stenosis According to the Aortogram (A) | | Relative Stenosis According to A |
|---|---|---|---|---|---|---|---|
| | | Femoropopliteal Segment (FP) | Aortoiliac Segment (AI) | | FP | AI | |
| | 25 | mild to moderate stenosis | severe stenosis | FP<AI | 10-40 | >70 | FP<AI |
| | 26 | mild to moderate stenosis | severe stenosis | FP<AI | <10 | >70 | FP<AI |
| | 27 | mild to moderate stenosis | severe stenosis | FP<AI | 10-40 | >70 | FP<AI |
| | 28 | mild to moderate stenosis | severe stenosis | FP<AI | 10-40 | >70 | FP<AI |
| triangle q | 29 - | mild to moderate stenosis | severe stenosis | FP<AI | 10-40 | >70 | FP<AI |
| | 30 | mild to moderate stenosis | severe stenosis | FP<AI | 10-40 | >70 | FP<AI |
| | 31 | mild to moderate stenosis | severe stenosis | FP<AI | 40-70 | >70 | FP<AI |
| | 32 | mild to moderate stenosis | severe stenosis | FP<AI | 40-70 | >70 | FP<AI |
| | 33 | mild to moderate stenosis | severe stenosis | FP<AI | 40-70 | >70 | FP<AI |
| | 34 | mild to moderate stenosis | severe stenosis | FP<AI | 40-70 | >70 | FP<AI |
| | 35 | mild to moderate stenosis | severe stenosis | FP<AI | 40-70 | >70 | FP<AI |
| | 36 | severe stenosis | severe stenosis | FP<AI | 40-70 | >70 | FP<AI |

Continuation from previous page

Table 3.5

| Position of Limbs (Fig 3.15) | Limb No | Degree of Stenosis According to the Hyperaemic Index (H.I) | | Relative Stenosis According to H.I | Degree of Stenosis According to the Aortgoram (A) | | Relative Stenosis According to A |
|---|---|---|---|---|---|---|---|
| | | Femoropopliteal Segment (FP) | Aortoiliac Segment (AI) | | FP | AI | |
| triangle r | 37 | moderate stenosis | mild stenosis | FP>AI | 10-40 | < 10 | FP>AI |
| | 38 | moderate stenosis | mild stenosis | FP>AI | 40-70 | < 10 | FP>AI |
| | 39 | moderate stenosis | mild stenosis | FP>AI | 40-70 | < 10 | FP>AI |
| triangle s | 40 | mild stenosis | moderate stenosis | FP<AI | >10 | 10-40 | FP<AI |
| | 41 | mild stenosis | moderate stenosis | FP<AI | 10-40 | 40-70 | FP<AI |
| | 42 | mild stenosis | moderate stenosis | FP<AI | 10-40 | 40-70 | FP<AI |
| | 43 | mild stenosis | moderate stenosis | FP<AI | <10 | 40-70 | FP<AI |
| | 44 | mild stenosis | moderate stenosis | FP<AI | 10-40 | 40-70 | FP<AI |
| between A & B out-side quatrangle | 45 | normal | mild to moderate stenosis | | 0 | 40-70 | FP<AI |
| | 46 | normal | mild to moderate stenosis | | 0 | 40-70 | FP<AI |
| | 47 | normal | mild to moderate stenosis | | 0 | 40-70 | FP<AI |

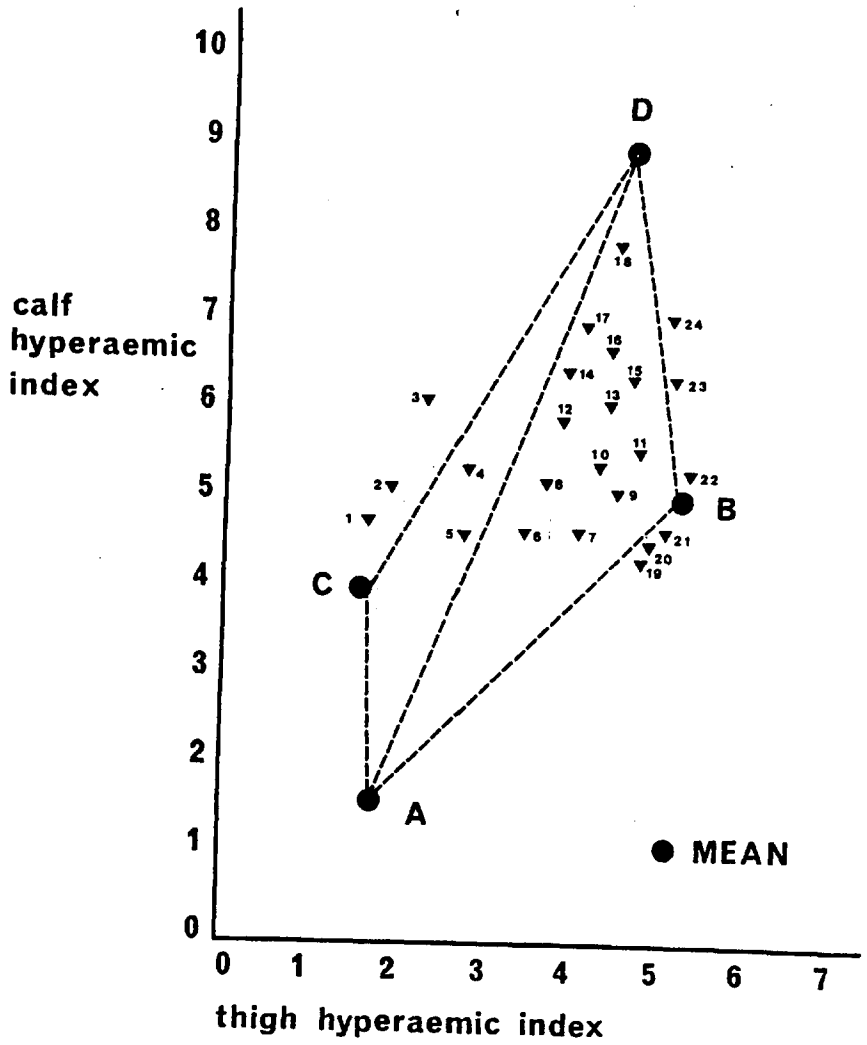



FIG. 3.16

Analysis of the thigh and calf Hyperaemic Indices preoperatively (Clinical Study III).

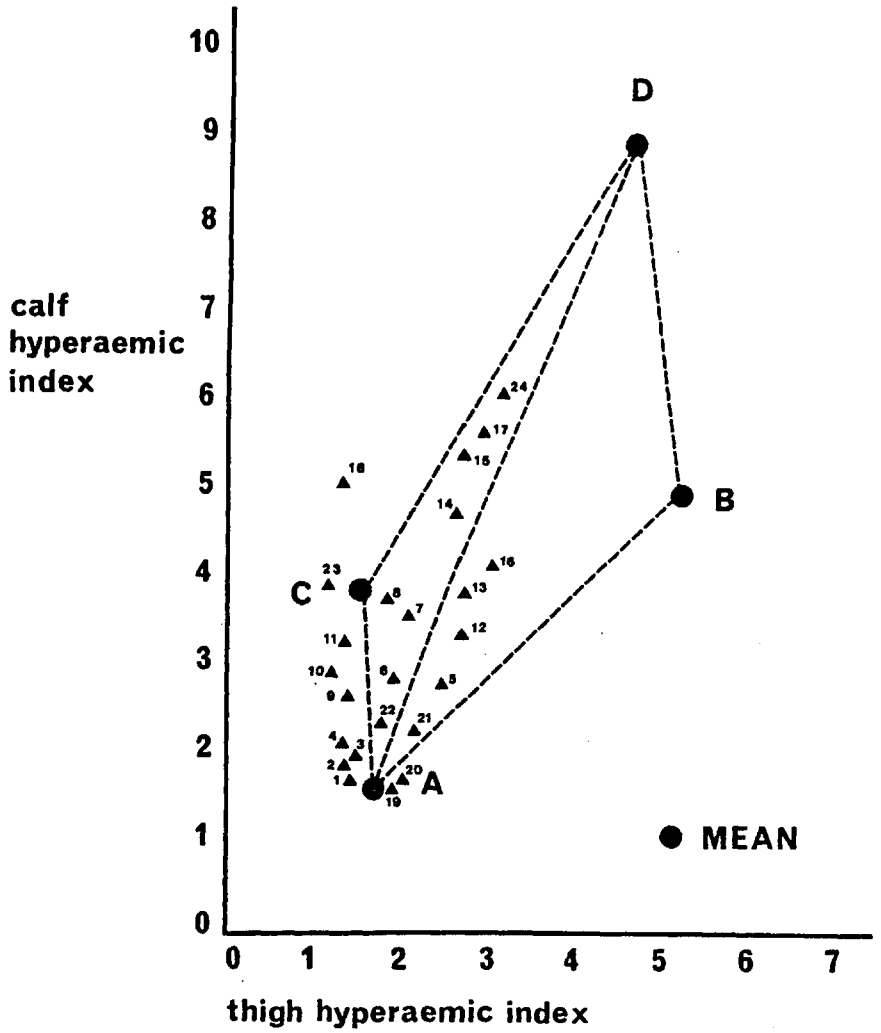



FIG. 3.17

Analysis of the thigh and calf Hyperaemic Indices post-operatively (Clinical Study III).

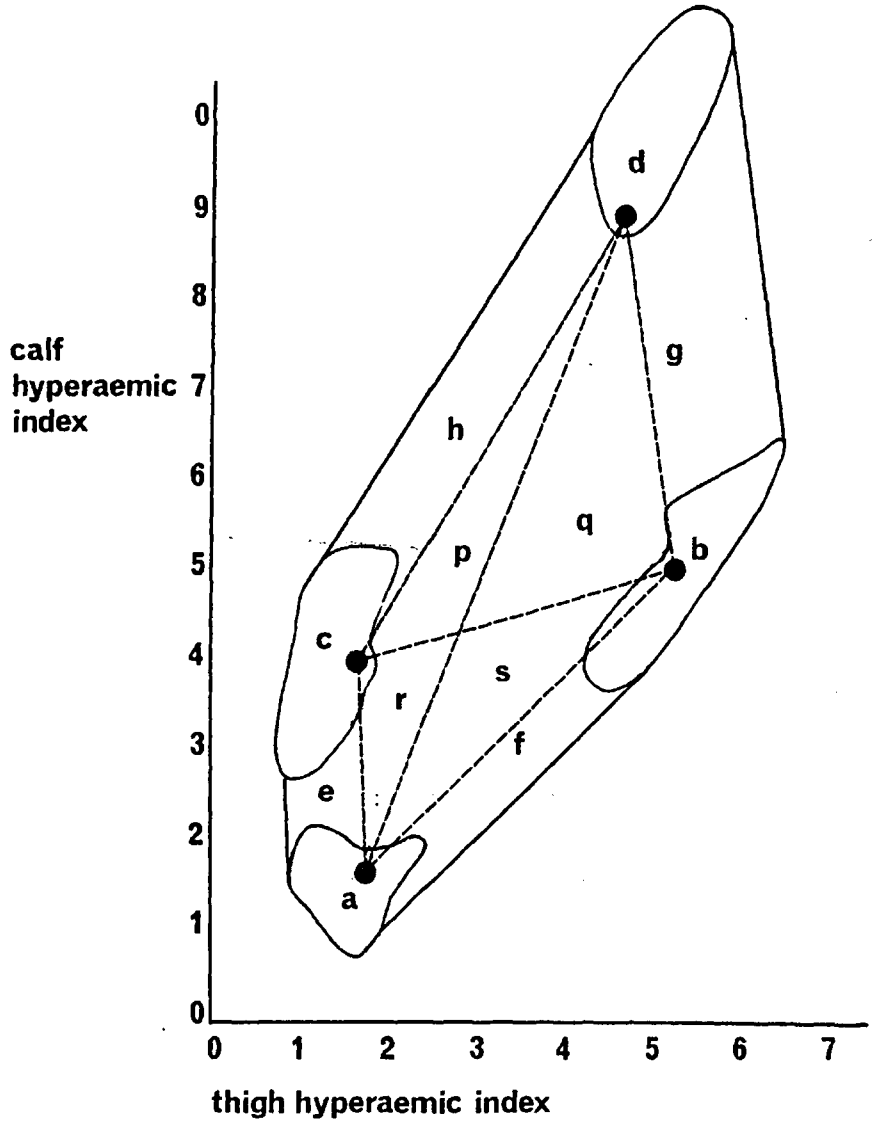



FIG. 3.18

Diagnostic chart based on calf and thigh Hyperaemic Indices. a, normal arterial tree; b, aortoiliac occlusion only; c, femoropopliteal occlusion only; d, aortoiliac and femoropopliteal occlusion; e, superficial femoral or popliteal stenosis only; f, aortoiliac stenosis only; g, aortoiliac occlusion and superficial femoral stenosis; h, superficial femoral occlusion and aortoiliac stenosis; p, aortoiliac and superficial femoral stenosis (SF stenosis > 70 per cent: SF stenosis > AI stenosis); q, aortoiliac and superficial femoral stenosis (AI stenosis > 70 per cent: AI stenosis > SF stenosis); r, aortoiliac and superficial femoral stenosis (both stenoses < 70 per cent: SF stenosis > AI stenosis); s, aortoiliac and superficial femoral stenosis (both stenoses < 70 per cent: AI stenosis > SF stenosis).

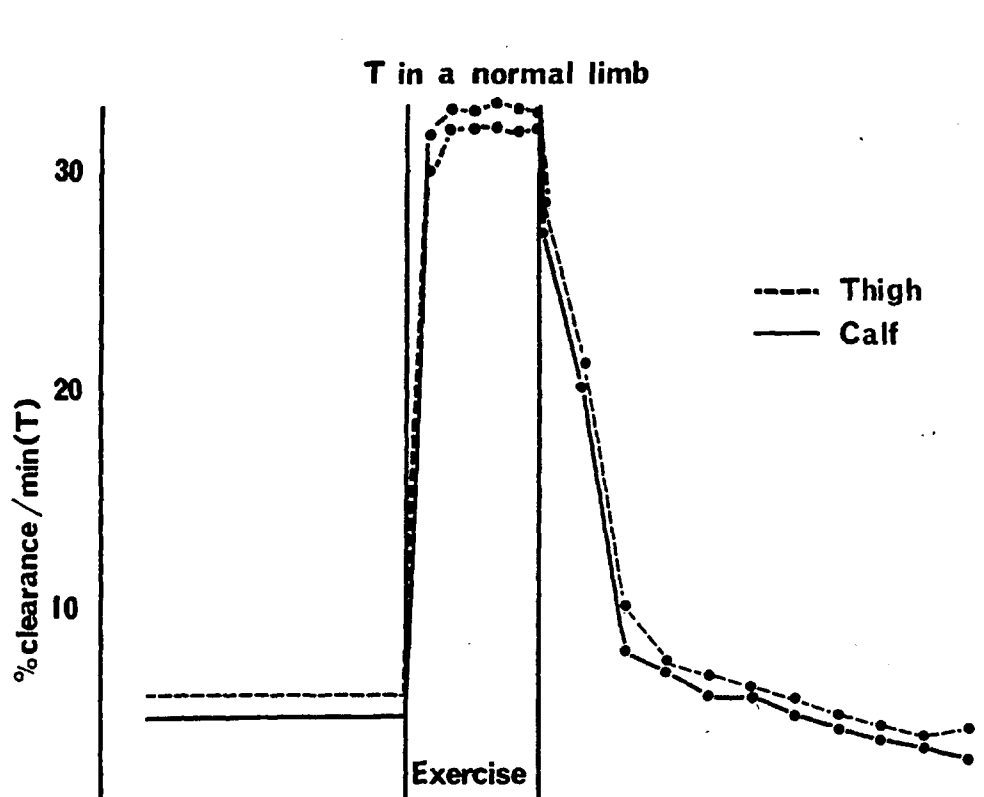



FIG. 3.19

Changes of T in the thigh and calf of a normal limb before, during and after exercise (Clinical Study IV).

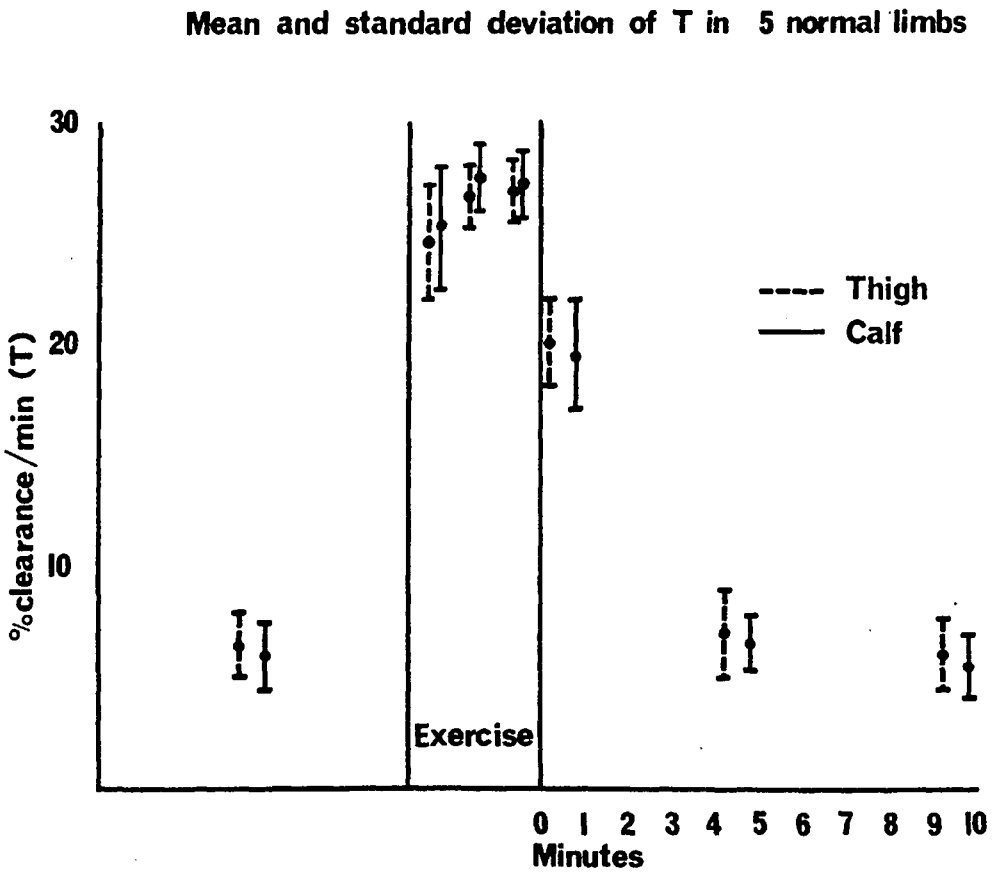



FIG. 3.28

Mean values of thigh T and calf T in Group 0 (normal limbs)(Clinical Study IV).

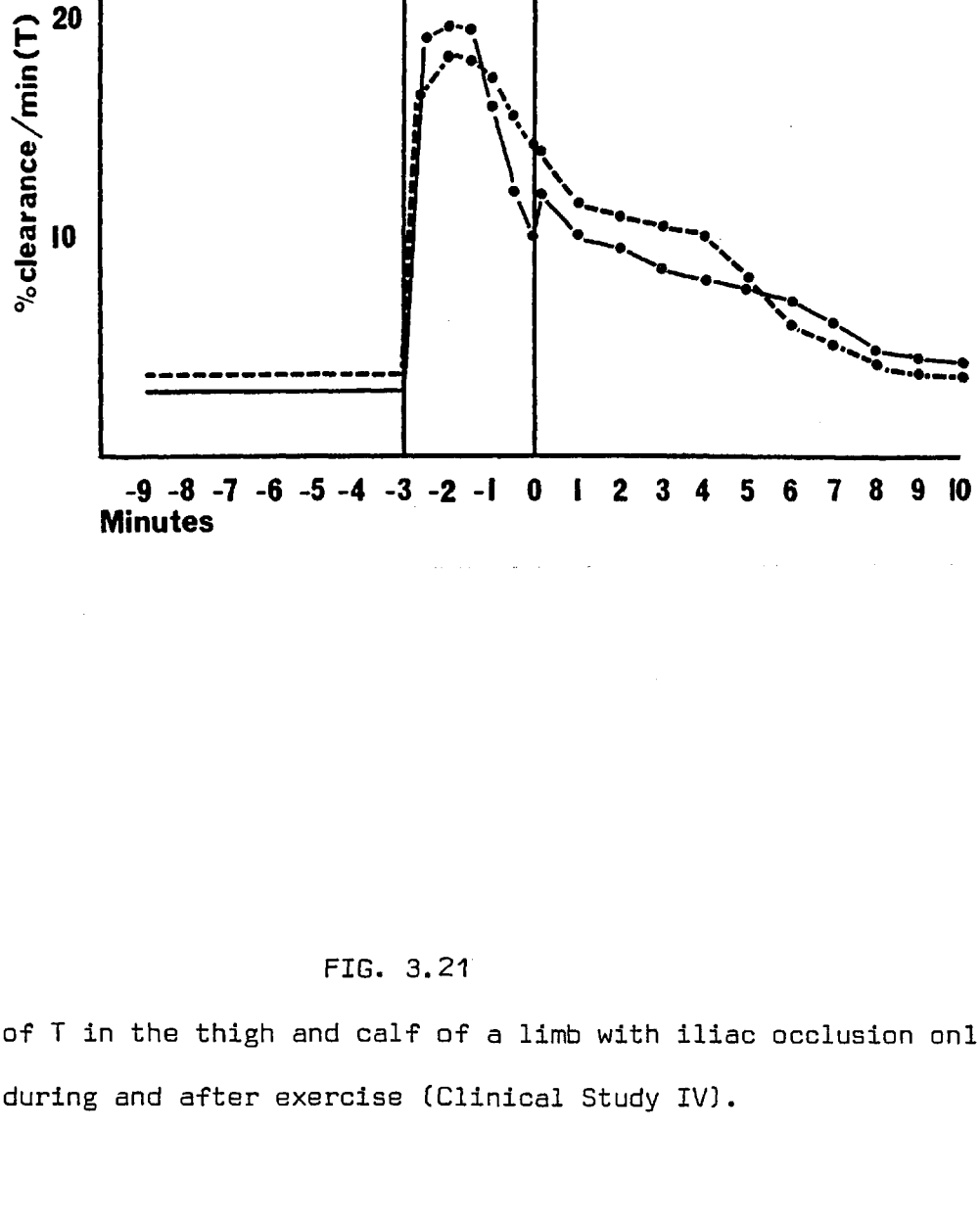



FIG. 3.21

Changes of T in the thigh and calf of a limb with iliac occlusion only, before, during and after exercise (Clinical Study IV).

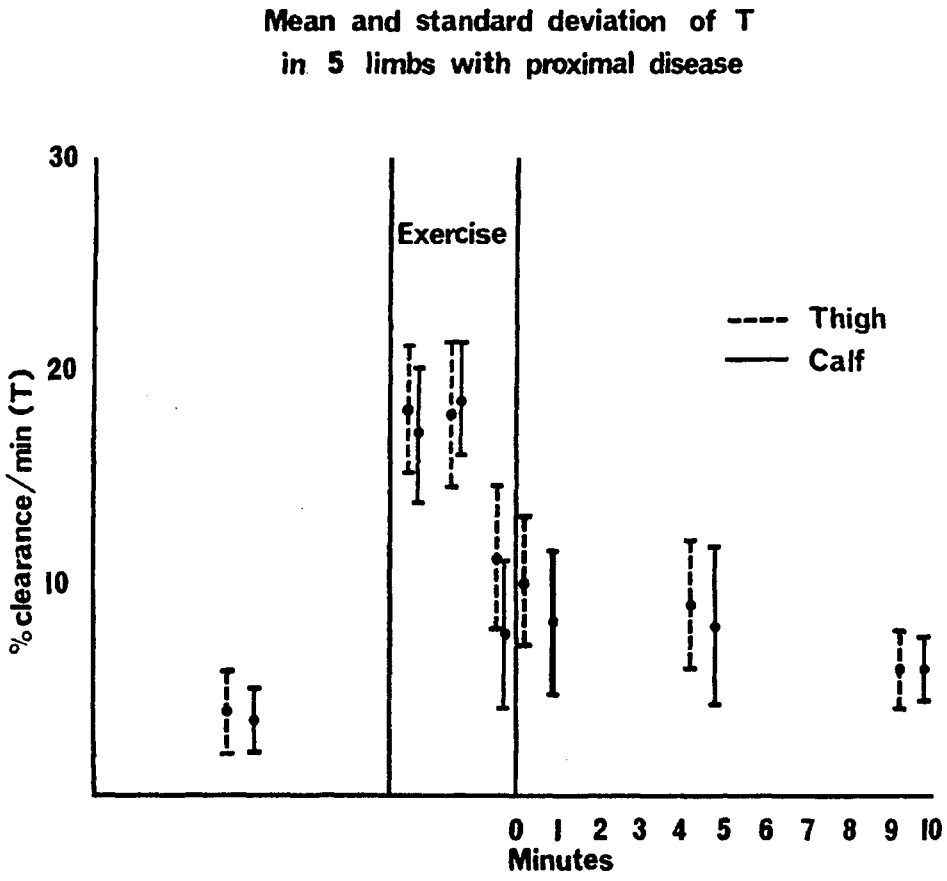



FIG. 3.22

Mean values of thigh T and calf T in Group 1 (limbs with iliac occlusion only)(Clinical Study IV).

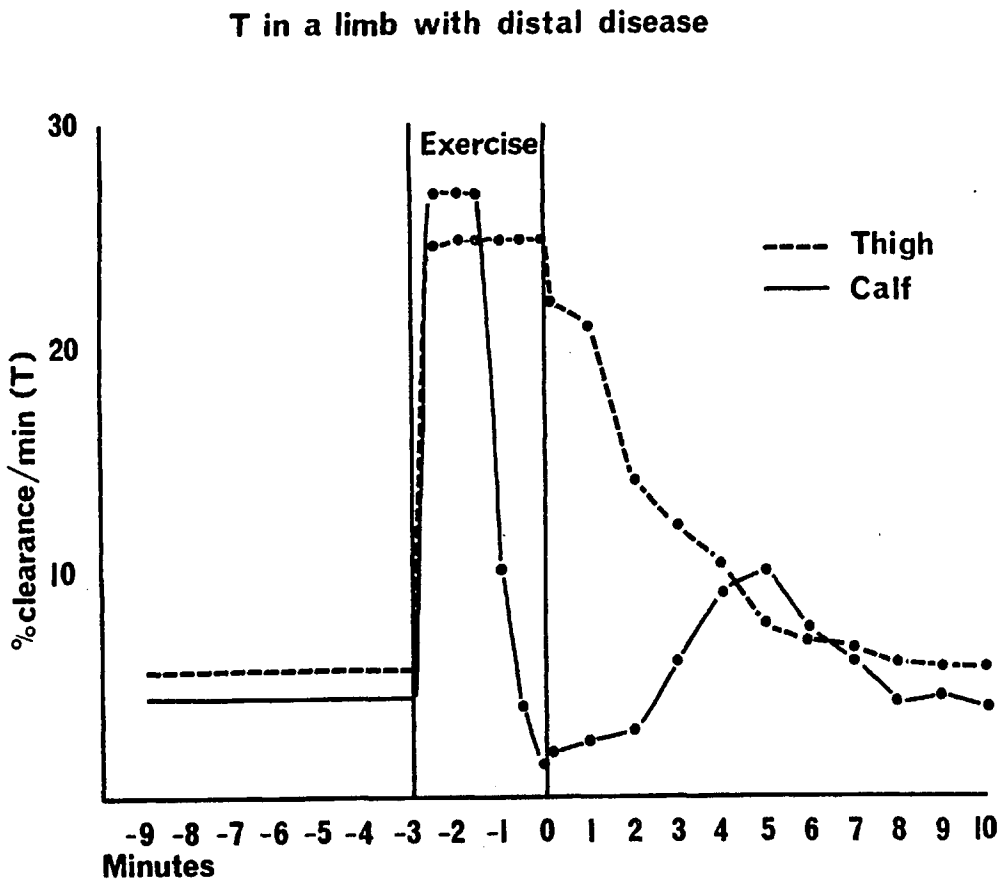



FIG. 3.23

Changes of T in the thigh and calf of a limb with superficial femoral artery occlusion only, before, during and after exercise (Clinical Study IV).

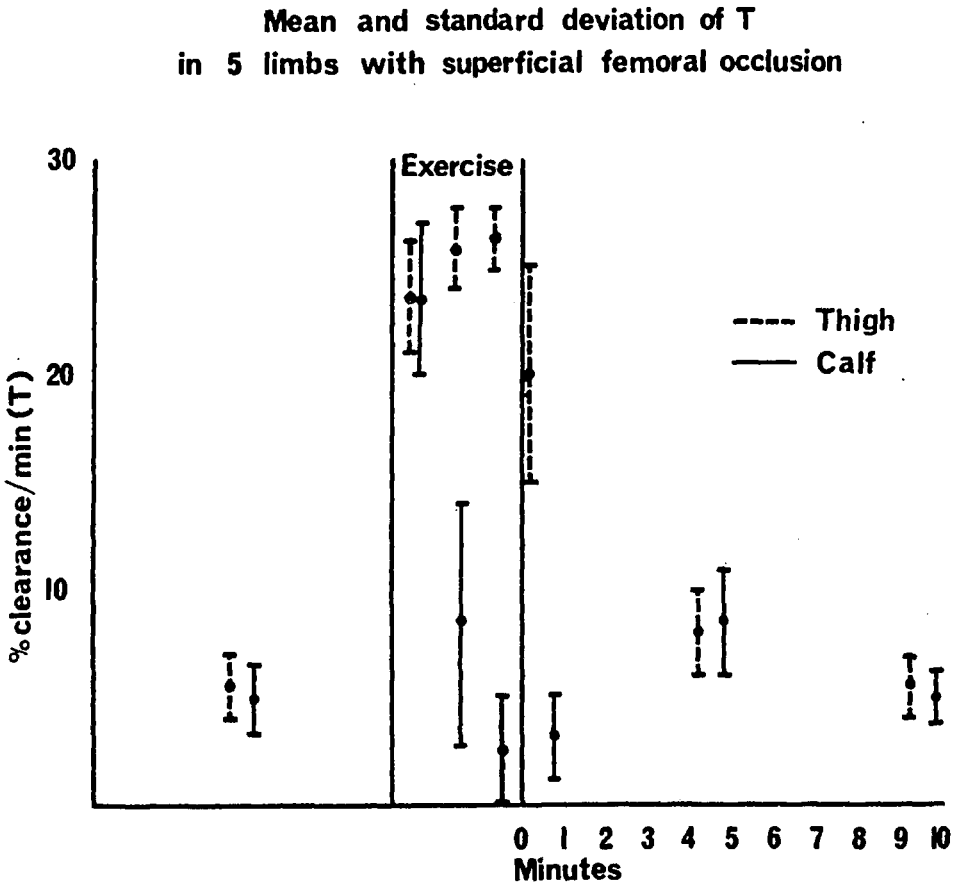



FIG. 3.24

Mean values of thigh T and calf T in Group 2 (limbs with superficial femoral artery occlusion only)(Clinical Study IV).

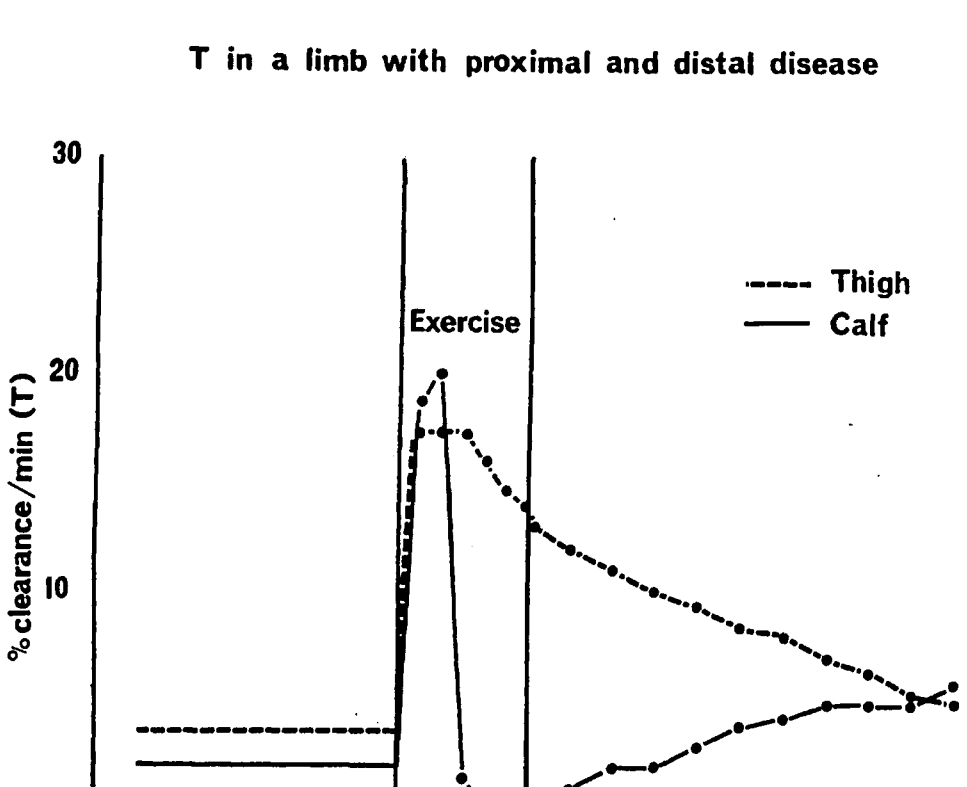



FIG. 3.25

Changes of T in the thigh and calf of a limb with combined severe aortoiliac and femoropopliteal lesions, before, during and after exercise (Clinical Study IV).

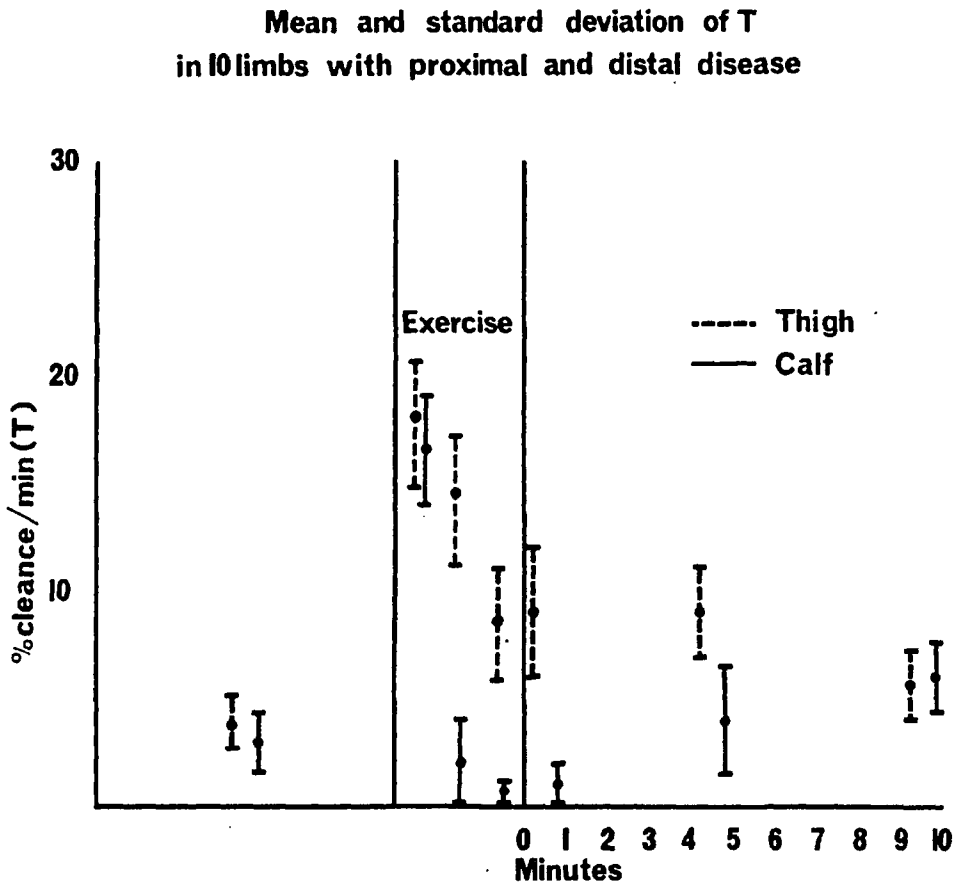



FIG. 3.26

Mean values of thigh T and calf T in Group 3 (limbs with combined severe aortoiliac and femoropopliteal lesions)(Clinical Study IV).

FIGURES FOR CHAPTER 4

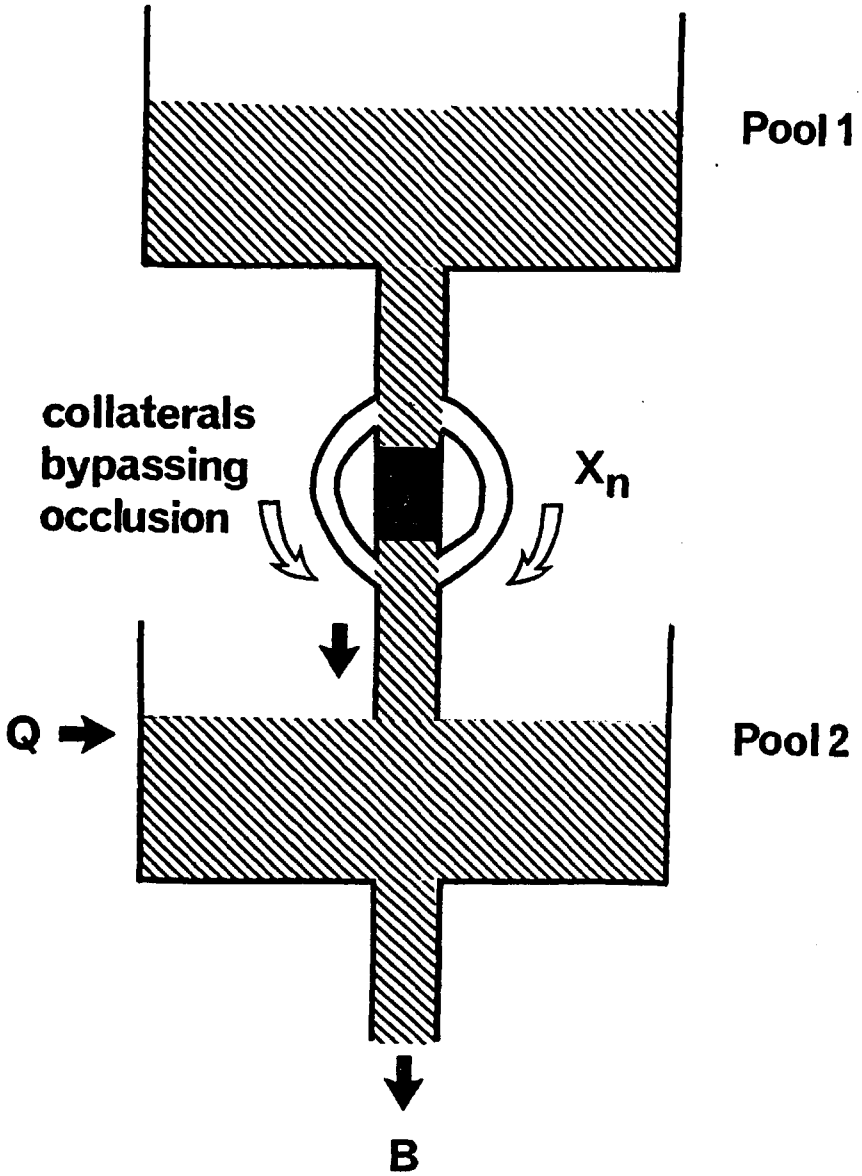



Fig. 4.1

Two - pool haemodynamic model

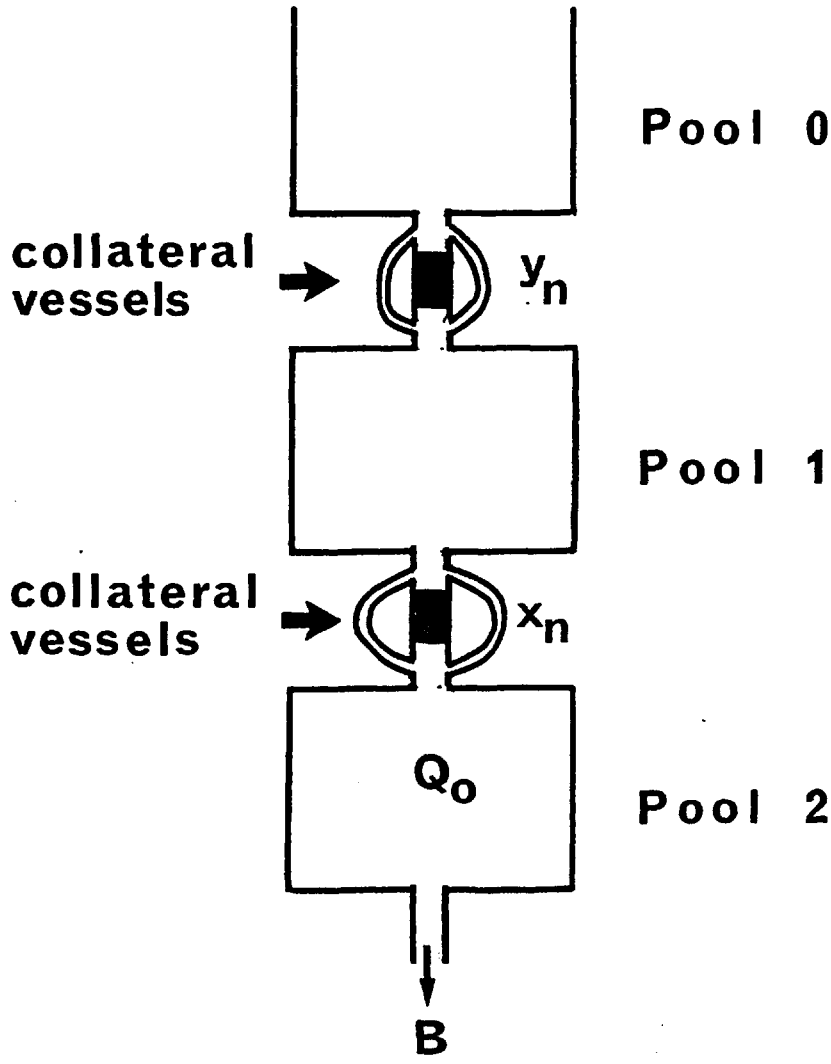



Fig. 4.2

Three - pool haemodynamic model

FIGURES FOR CHAPTER 5

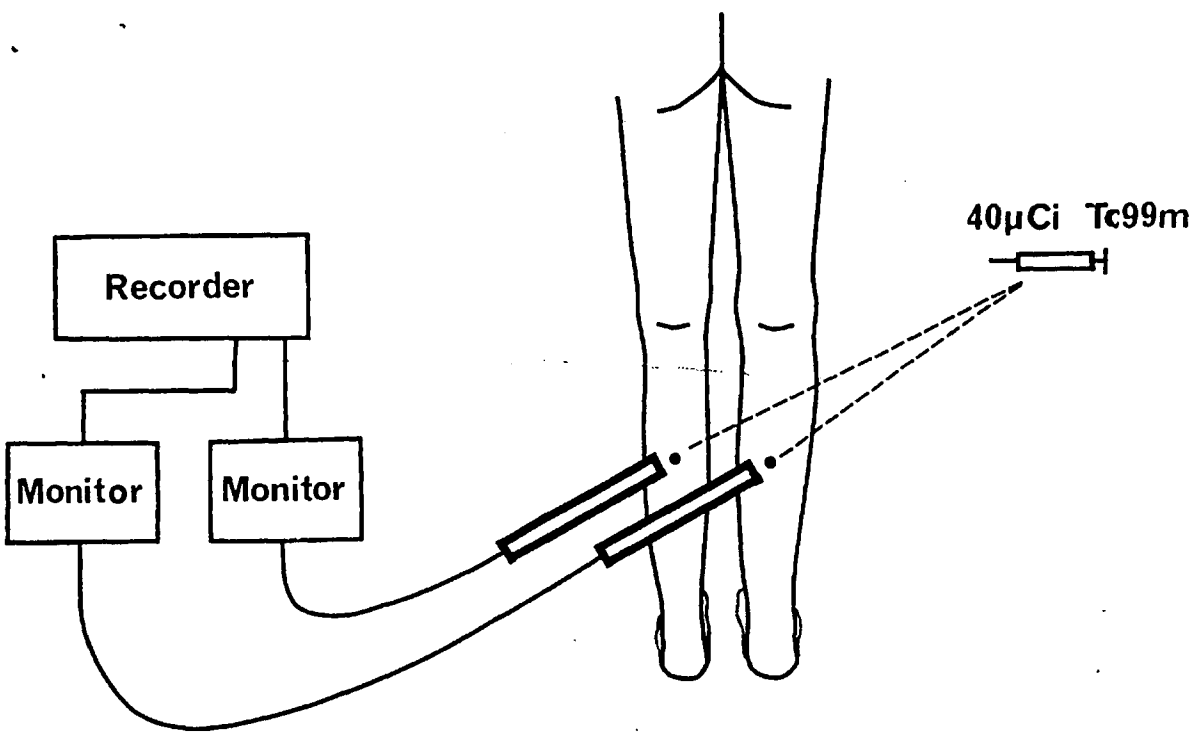



Fig.5.1

Diagramatic representation of the experimental set-up for simultaneous $^{99m}$Tc muscle clearance in both calves during tiptoeing.

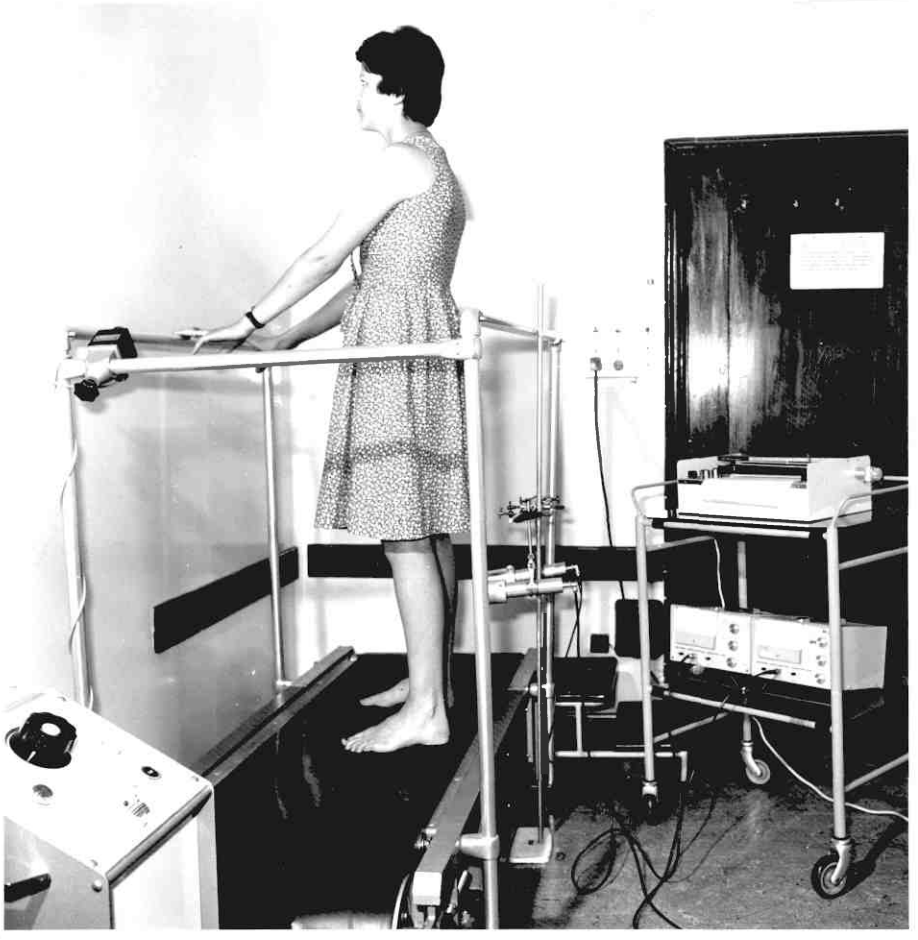


FIG. 5.2

Experimental set-up for simultaneous $^{99m}Tc$ muscle clearance in both calves during tiptoeing, using heavy probes. (Initial phase - the heel on the ground).

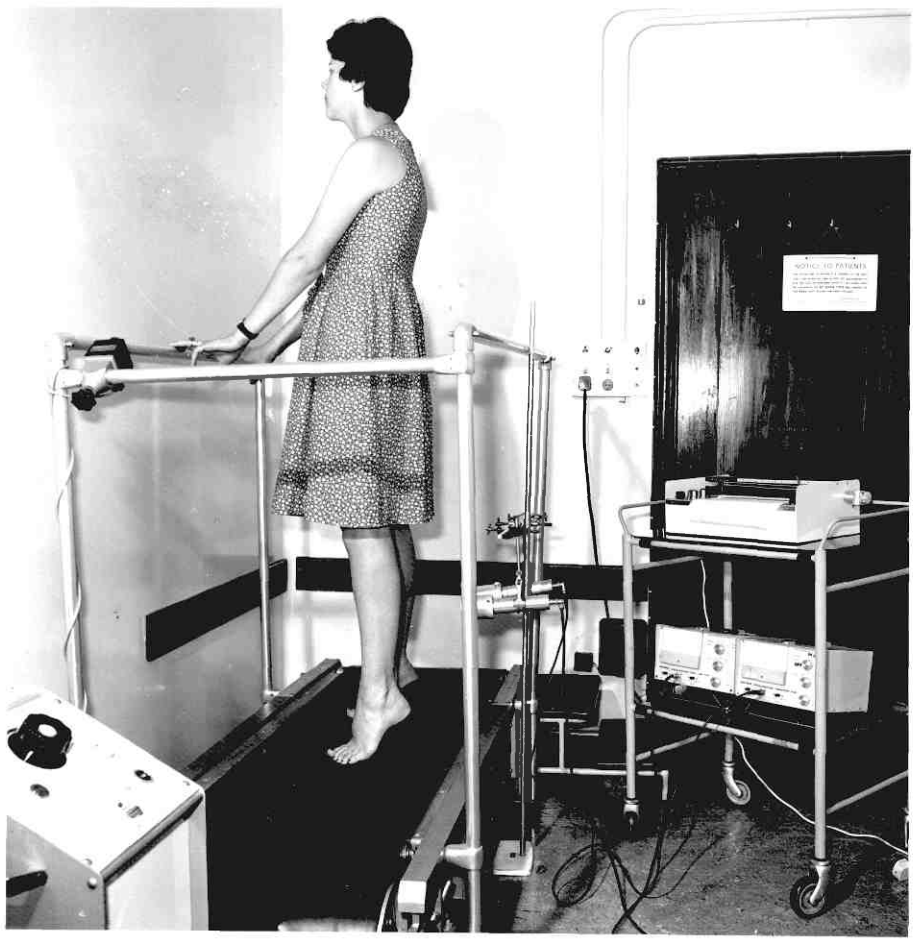


FIG. 5.3

Experimental set-up for simultaneous $^{99m}Tc$ muscle clearance in both calves during tip-toeing, using heavy probes (second phase - on tiptoe).

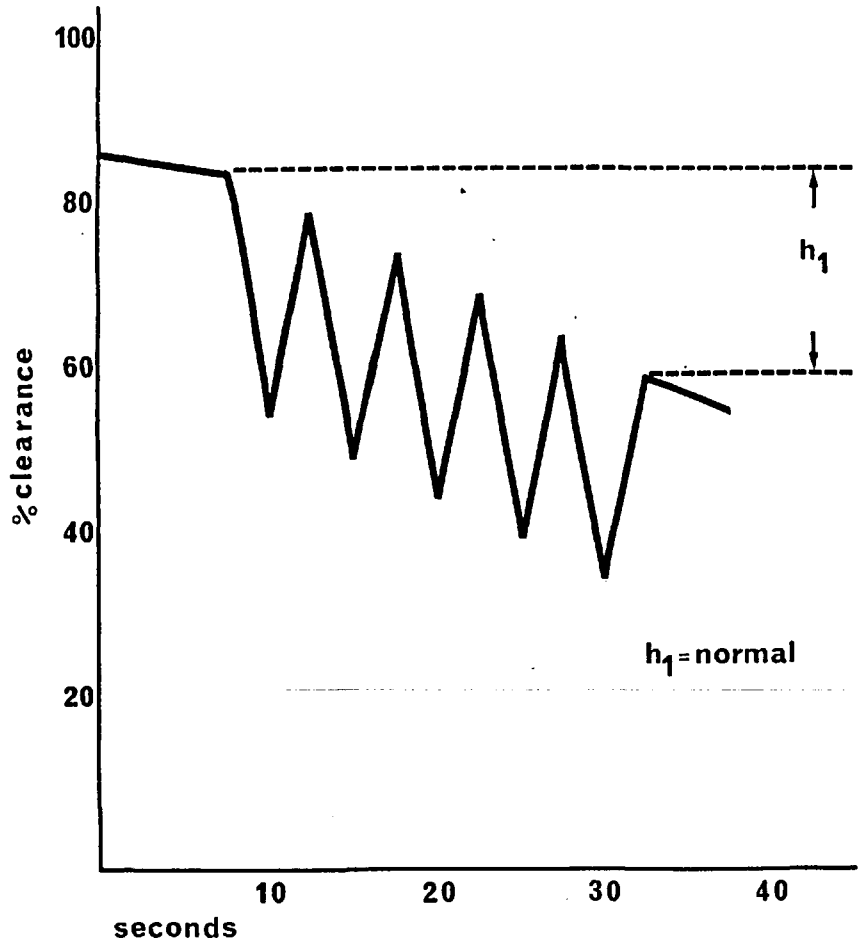



Fig.5.4a

Schematic representation of the clearance curve obtained during five movements on tiptoe, using heavy probes. The upward and downward component of each movement was due to the variable distance of the radiation sources from the probes during tiptoeing. The height $h_i$ is representing the cleared amount of radioactivity.

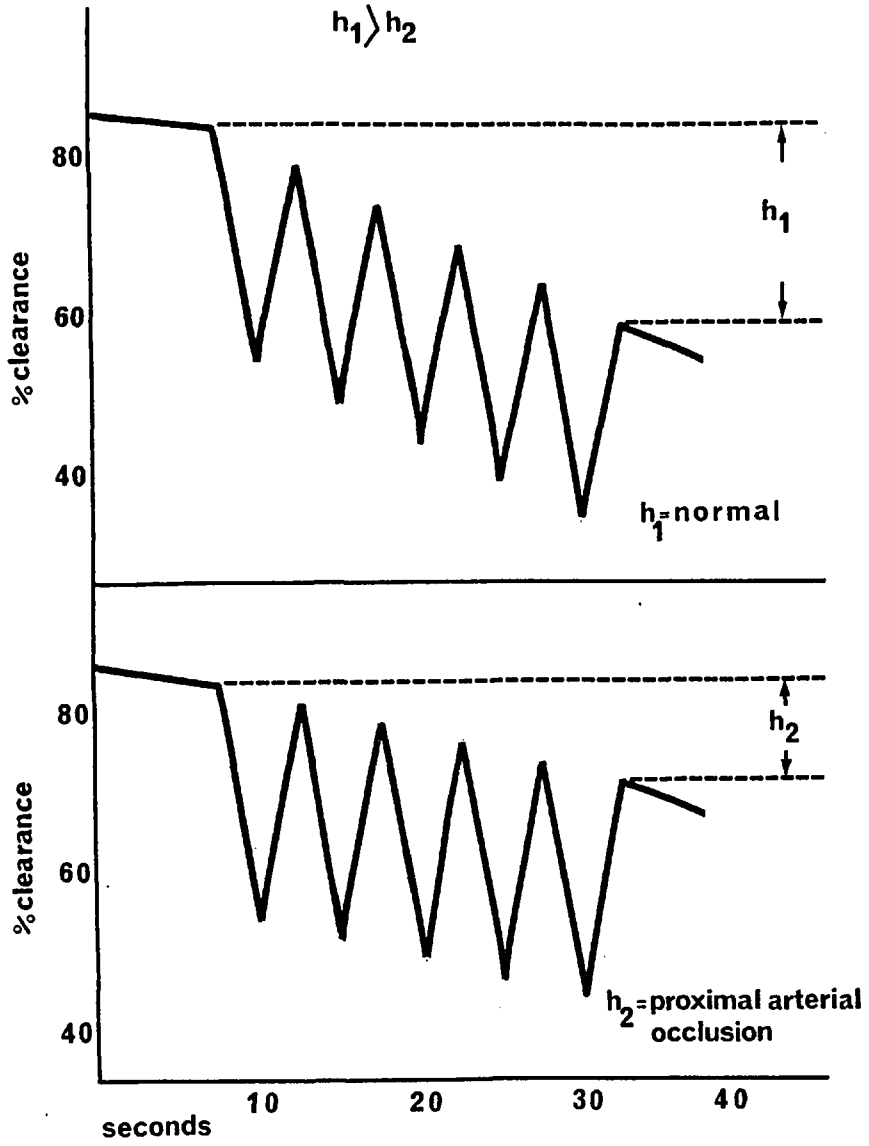



Fig. 5.4b

Schematic representation of the clearance curve obtained from a normal limb and from a limb with proximal arterial disease during a five-movement session using heavy probes. The cleared amount of radioactivity is greater in a normal limb (height $h_1$) than in a limb with proximal arterial disease (height $h_2$).

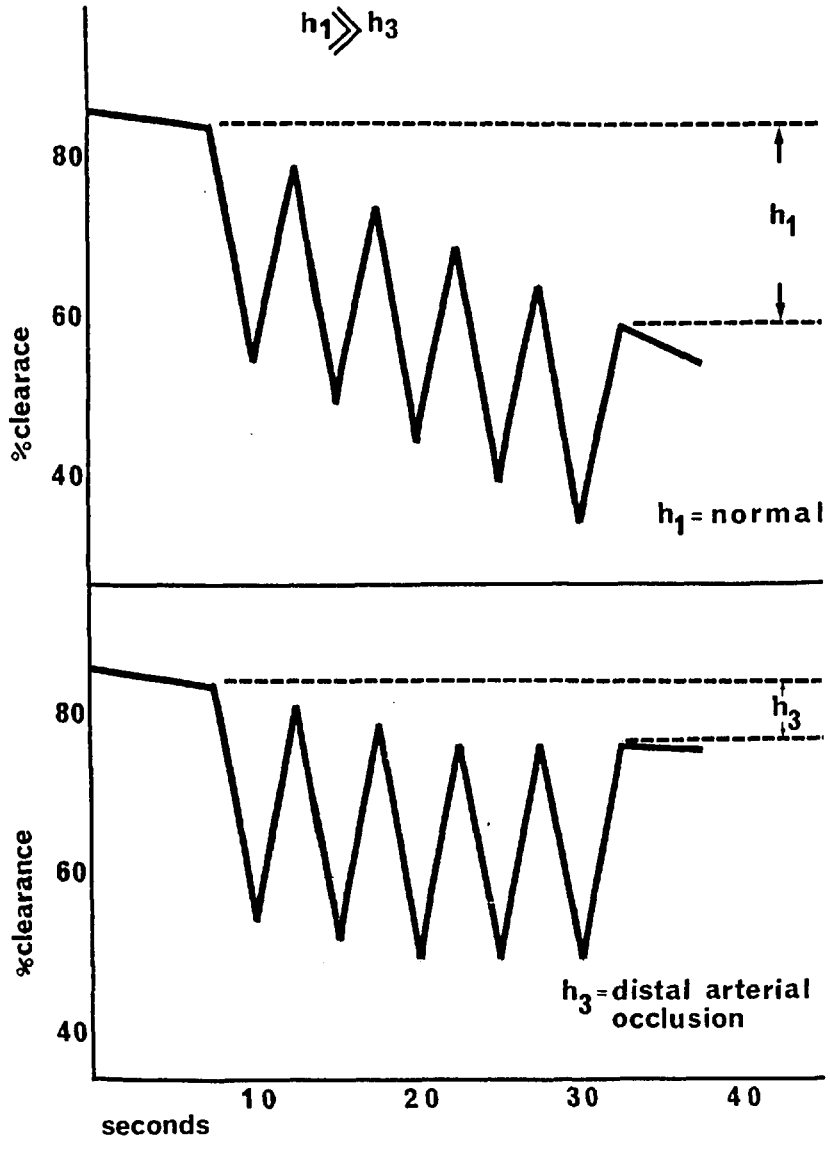



Fig. 5.4c

Schematic representation of the clearance curve obtained from a normal limb and from a limb with distal arterial disease during a five - movement session using heavy probes. The cleared amount of radioactivity is significantly greater in a normal limb (height $h_1$) than in a limb with distal arterial disease. (height $h_3$).

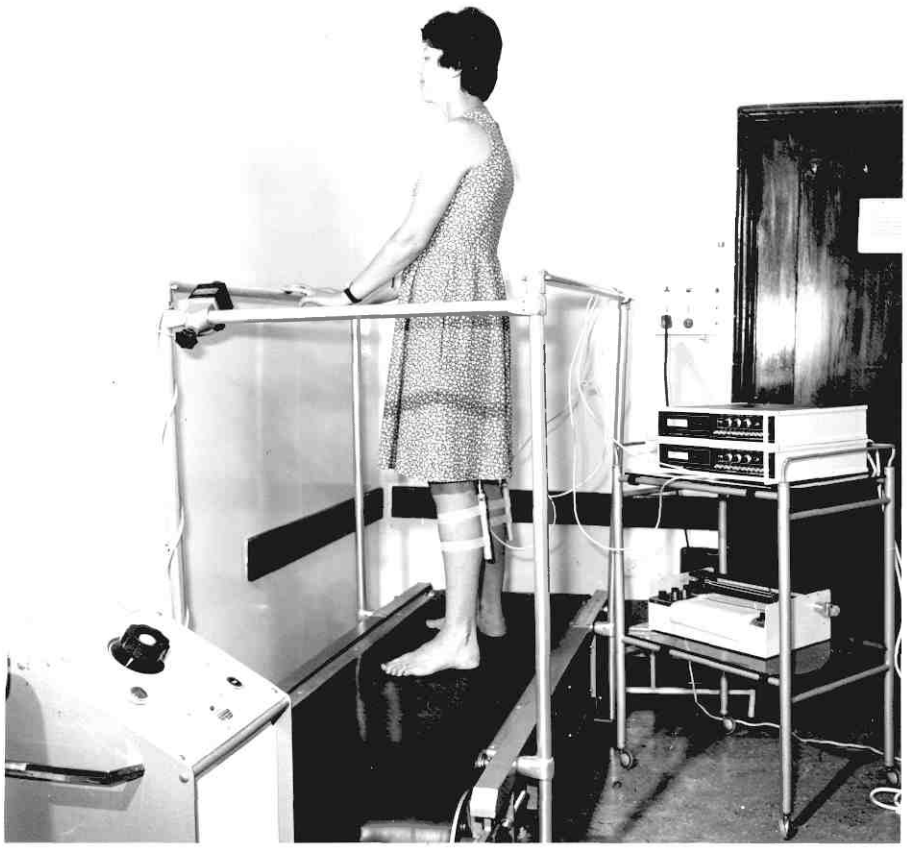


FIG. 5.5

Experimental set-up for simultaneous $^{99m}Tc$ muscle clearance in both calves during tiptoeing, using light probes. (Initial phase - the heel on the ground).

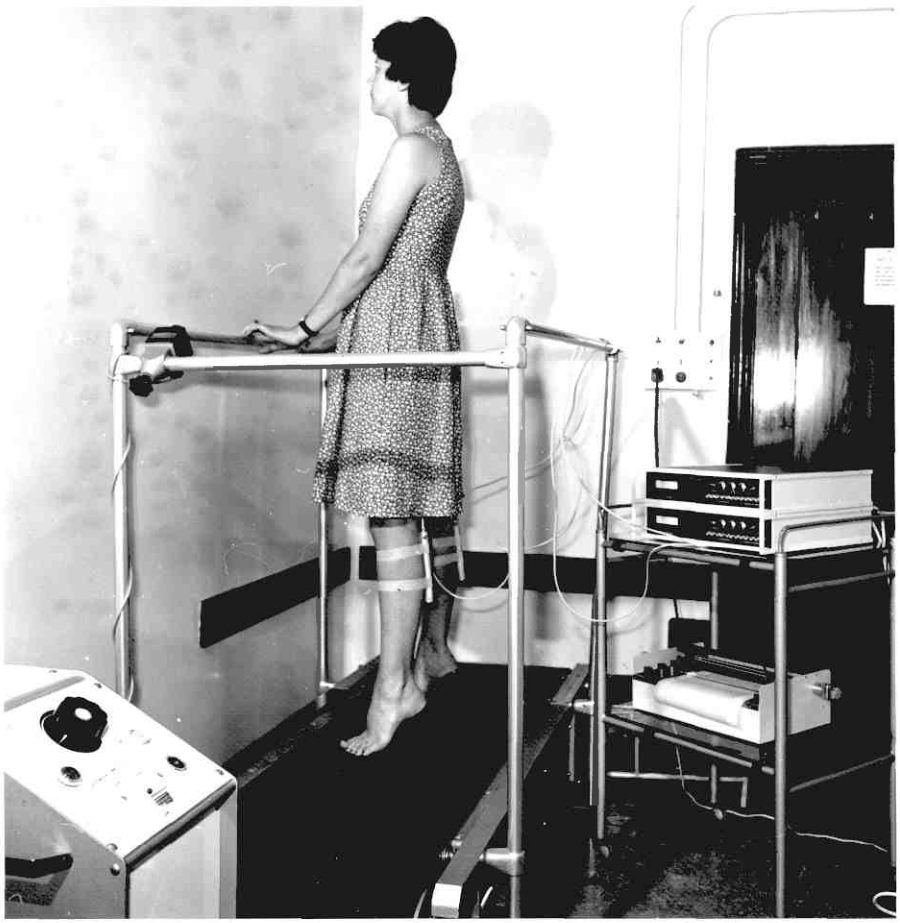


FIG. 5.6

Experimental set-up for simultaneous $^{99m}Tc$ muscle clearance in both calves during tiptoeing, using light probes (second phase - on tiptoe).

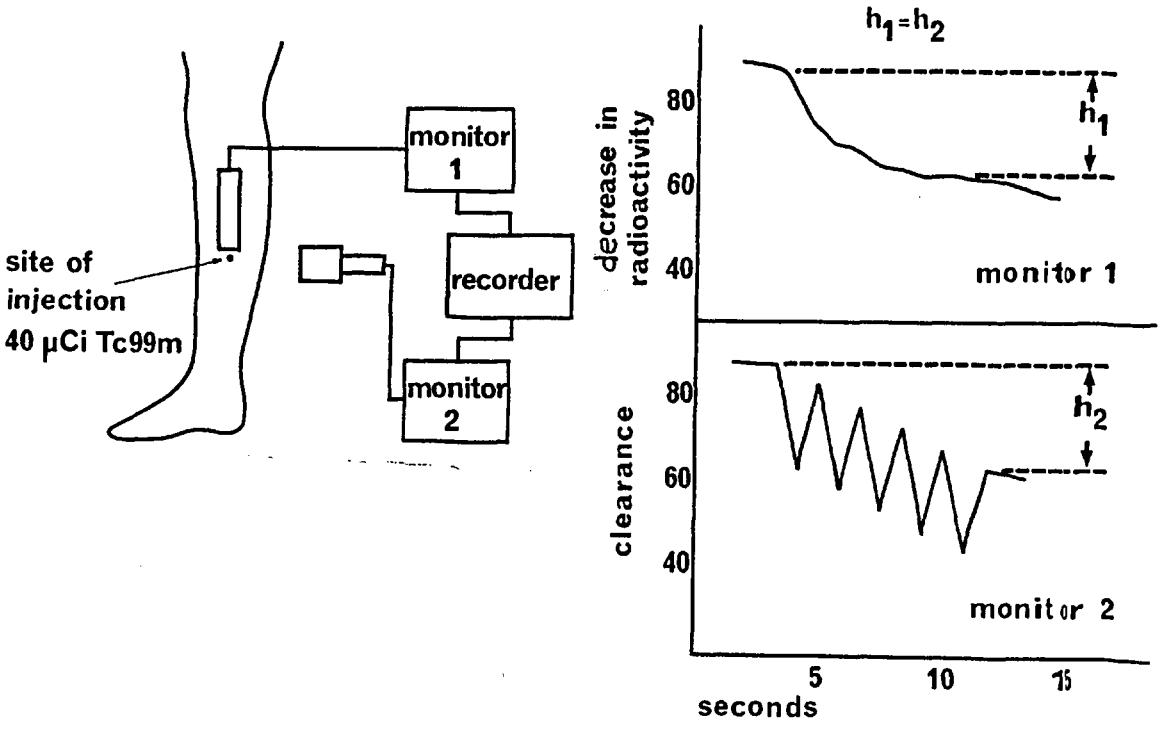



Fig. 5.7

Schematic representation of the clearance curves obtained simultaneously from a normal calf using a light and a heavy probe. During a five-movement session on tiptoe, the cleared amount of radioactivity was equal (heights $h_1$ and $h_2$ respectively). However, the light probe gave a much smoother clearance curve.

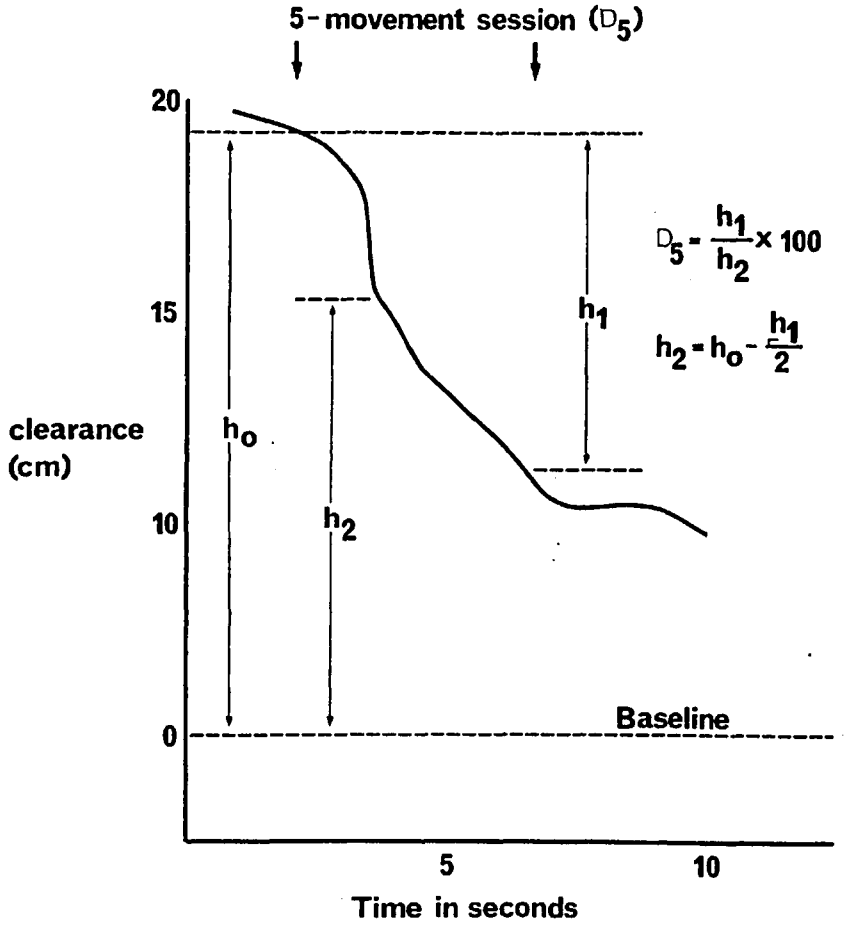



Fig 5.8

Calculation of the total percentage clearance $D_5$ during five tiptoe movements.

FIGURES AND TABLES FOR CHAPTER 6

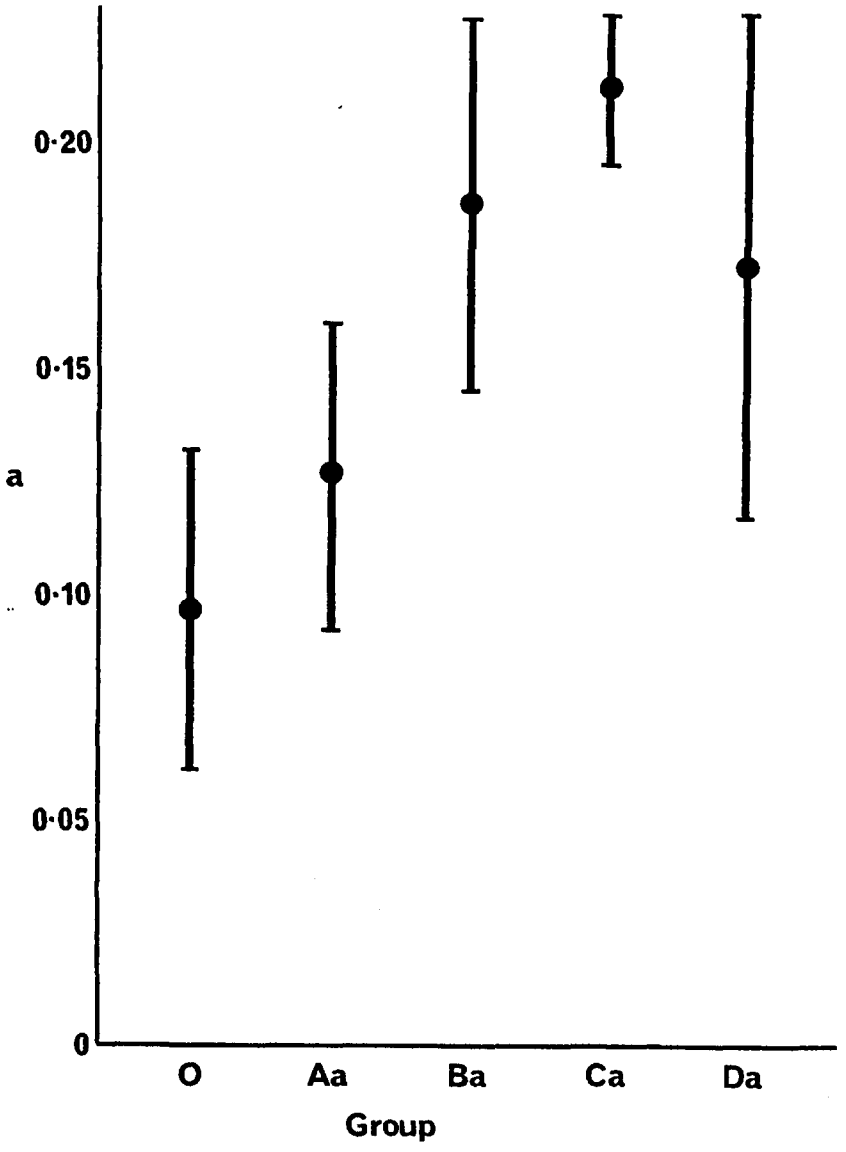



Fig.6.1

The mean values of a and standard deviation in the five groups studied (O to Da) (Clinical Study V)

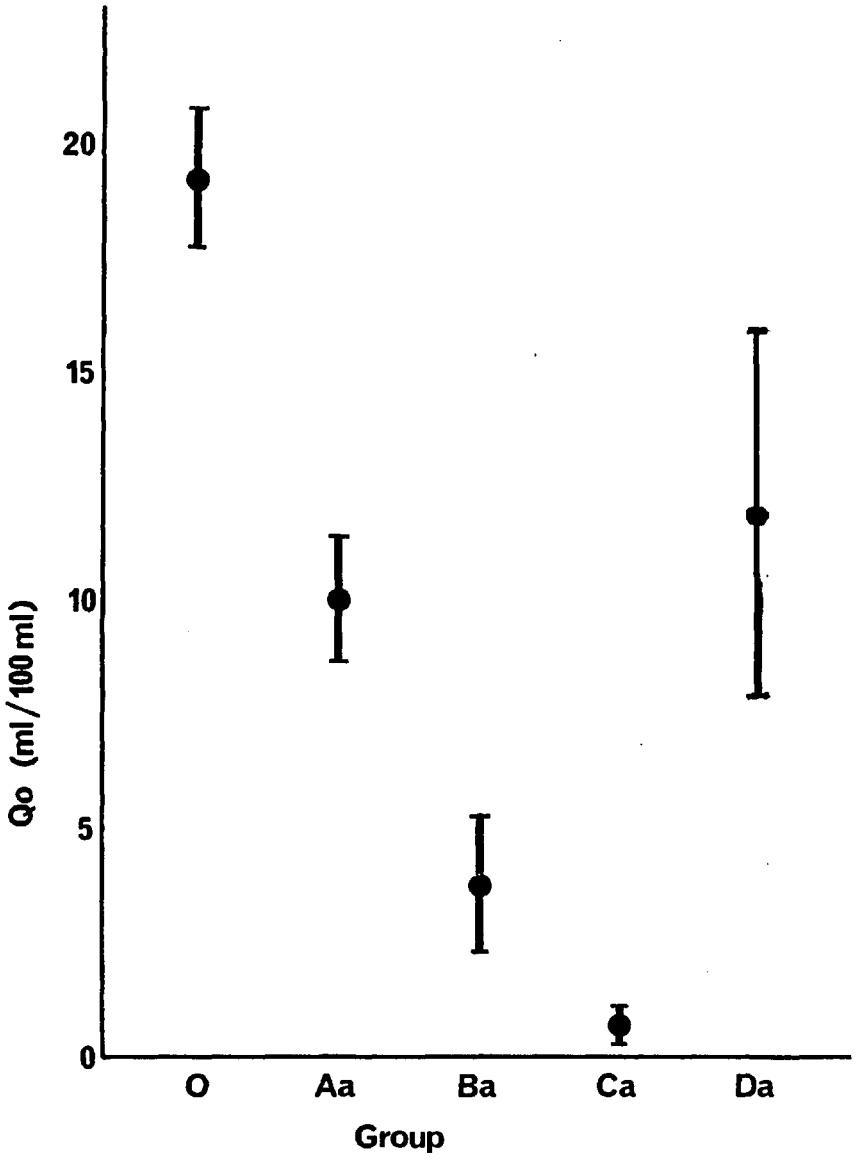



Fig.6.2

The mean values of $Q_o$ and standard deviation in the five groups studied. (O to Da) (Clinical Study V)

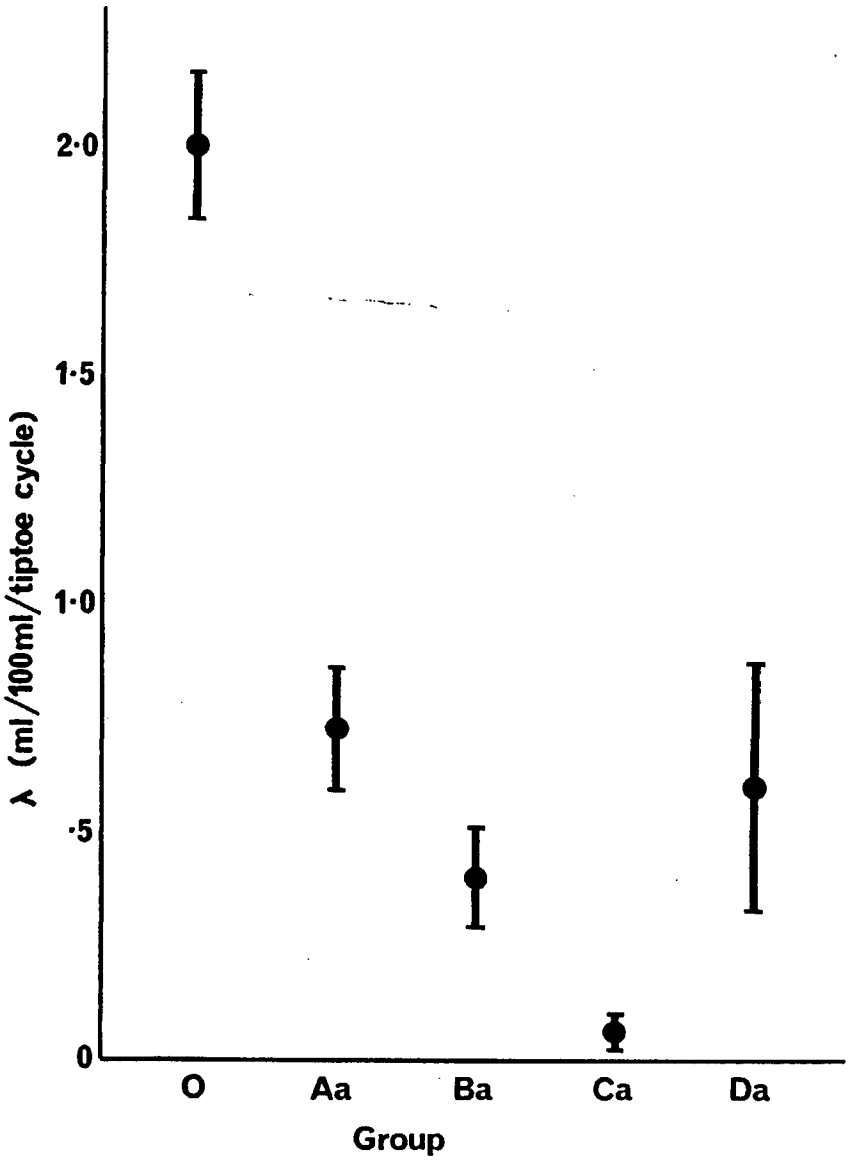



Fig.6.3

The mean values of λ and standard deviation in the five groups studied (O to Da) (Clinical Study V)

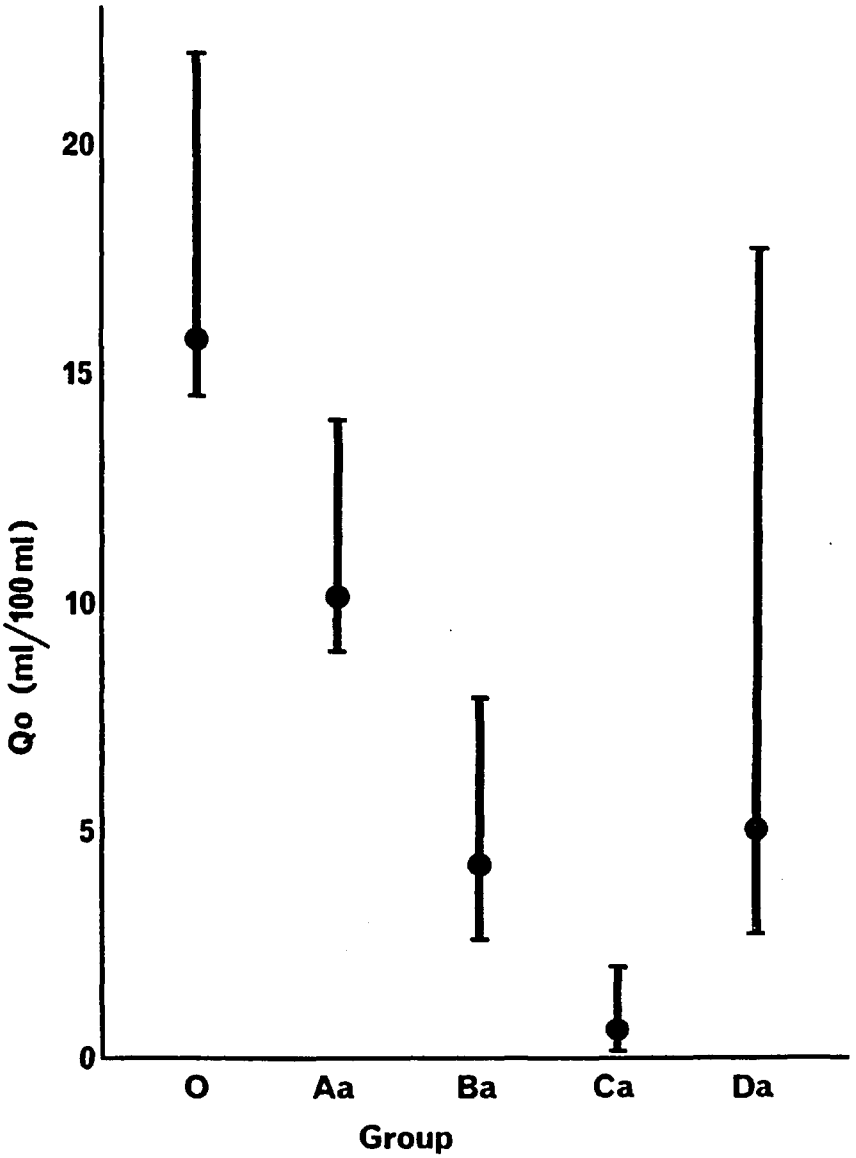



Fig.6.4

The median and 95 per cent tolerance levels of $Q_o$ in the five groups studied. (O to Da) (Clinical Study V)

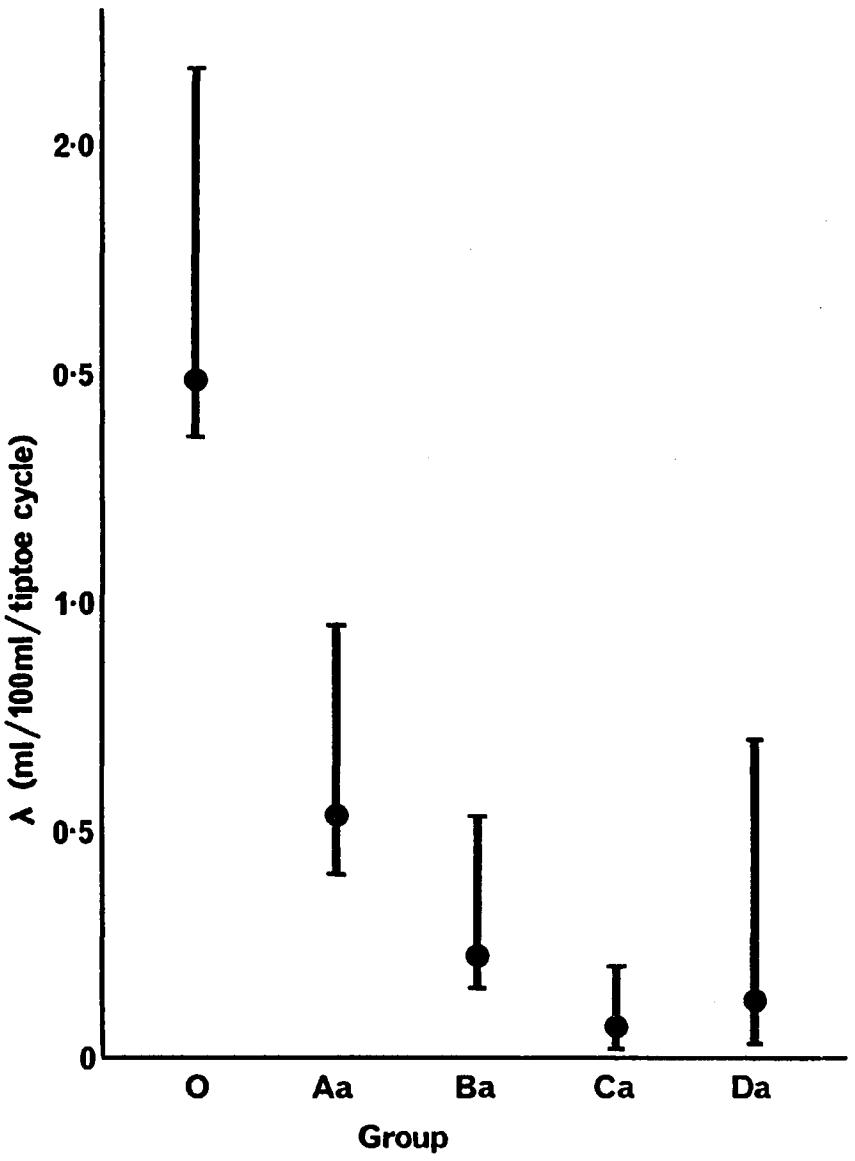



Fig.6.5

The median and 95 per cent tolerance levels of λ in the five groups studied (O to Da) (Clinical Study V)

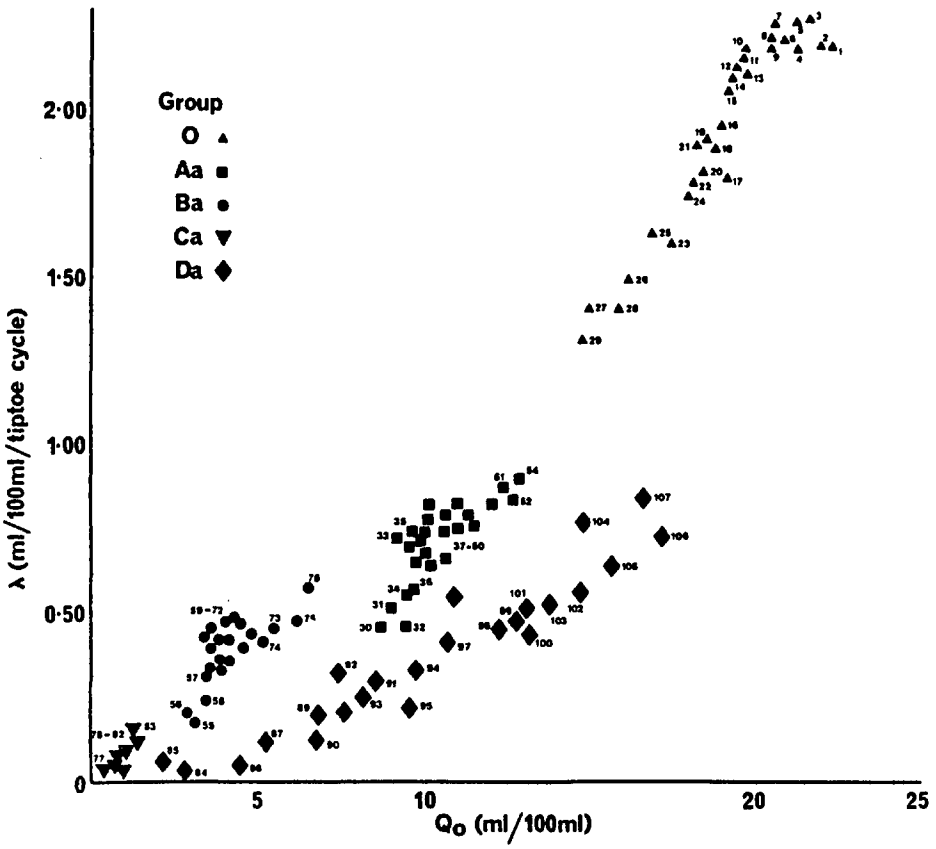



Fig.6.6

Analysis of $Q_o$ and λ in the five groups studied (O to Da) (Clinical Study V)

TABLE 6.1

The Values of a, Qo and λ for Every Normal Limb Studied (Group 0) (Clinical Study V)

| Group | Limb No | a (%) | Qo (ml/100 ml) | λ (ml/100 ml/ tiptoe cycle |
|---|---|---|---|---|
| | 1 | 5.3 | 22.45 | 2.18 |
| | 2 | 6.2 | 22.38 | 2.19 |
| | 3 | 5.9 | 21.74 | 2.28 |
| | 4 | 6.8 | 21.43 | 2.17 |
| | 5 | 7.4 | 21.28 | 2.26 |
| | 6 | 7.1 | 20.96 | 2.20 |
| | 7 | 7.7 | 20.90 | 2.24 |
| | 8 | 8.2 | 20.81 | 2.21 |
| | 9 | 8.8 | 20.79 | 2.18 |
| | 10 | 7.- | 19.98 | 2.18 |
| 0 | 11 | 8.5 | 19.91 | 2.16 |
| normal limbs | 12 | 8.8 | 19.84 | 2.14 |
| | 14 | 9.2 | 19.65 | 2.10 |
| | 15 | 9.9 | 19.36 | 2.05 |
| | 16 | 10.4 | 19.39 | 4.93 |
| | 17 | 9.8 | 19.12 | 1.78 |
| | 18 | 10.6 | 18.90 | 1.86 |
| | 19 | 11.2 | 19.04 | 1.94 |
| | 20 | 10.9 | 18.46 | 1.81 |
| | 21 | 11.8 | 18.64 | 1.90 |
| | 22 | 12.4 | 18.24 | 1.78 |
| | 23 | 11.9 | 17.60 | 1.59 |
| | 24 | 12.8 | 18.08 | 1.74 |
| | 25 | 13.4 | 16.96 | 1.62 |
| | 26 | 12.6 | 16.28 | 1.49 |
| | 27 | 13.8 | 14.90 | 1.41 |
| | 28 | 12.6 | 15.97 | 1.39 |
| | 29 | 14.2 | 14.08 | 1.31 |

## LEGEND TO TABLE 6.2

Degree of stenosis of the aortoiliac and femoropopliteal segment according to the aortographic findings in relation to the values of a, Qo and λ in groups Aa (limbs with iliac occlusion only), Ba (limbs with superficial femoral artery occlusion only), Ca (limbs with aortoiliac and femoropopliteal stenosis) (Clinical Study V).

(Key: ↑ = long occlusion or stenosis longer than 5 cm;

↓ = short occlusion or stenosis shorter than 5 cm).

T A B L E 6.2

| Group | Limb No | a (%) | Qo (ml/ 100 ml) | λ ml / (100 ml tiptoe cycle) | AORTOGRAPHIC FINDINGS | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | DEGREE OF LESION % | | SITE OF ART LESION | |
| | | | | | A.I. Segment | F.P. Segment | A.I. Segment | F.P Sgment |
| | 30 | 15.8 | 8.65 | 0.46 | 100 | - | Ext Iliac ↑ | - |
| | 31 | 13.6 | 9.08 | 0.52 | 100 | - | Ext Iliac ↑ | - |
| | 32 | 15.2 | 9.37 | 0.45 | 100 | - | Ext Iliac ↑ | - |
| | 33 | 15.4 | 9.34 | 0.72 | 100 | - | Ext Iliac ↑ | - |
| | 34 | 14.8 | 9.48 | 0.56 | 100 | - | Com + Ext Iliacs | - |
| | 35 | 14.6 | 9.59 | 0.74 | 100 | - | Ext Iliac ↑ | - |
| | 36 | 14.0 | 9.61 | 0.58 | 100 | - | Com + Ext Iliacs | - |
| | 37 | 14.3 | 9.60 | 0.71 | 100 | - | Ext Iliac ↑ | - |
| Aa | 38 | 14.8 | 9.86 | 0.66 | 100 | - | Ext Iliac ↑ | - |
| limbs with | 39 | 13.6 | 9.75 | 0.69 | 100 | - | Ext Iliac ↑ | - |
| Iliac | 40 | 13.9 | 9.84 | 0.72 | 100 | - | Com + Ext Iliacs | - |
| Occlusion only | 41 | 13.5 | 9.97 | 0.72 | 100 | - | Com Iliac ↓ | - |
| | 42 | 12.8 | 9.95 | 0.77 | 100 | - | Com + Ext Iliacs | - |
| | 43 | 13.8 | 10.02 | 0.66 | 100 | - | Ext Iliac ↑ | - |
| | 44 | 12.4 | 10.10 | 0.83 | 100 | - | Ext Iliac ↑ | - |
| | 45 | 12.8 | 10.56 | 0.59 | 100 | - | Ext Iliac ↓ | - |
| | 46 | 13.4 | 10.55 | 0.76 | 100 | - | Com Iliac ↕ | - |
| | 47 | 12.2 | 10.67 | 0.79 | 100 | - | Ext Iliac ↑ | - |

Continuation from previous page

TABLE 6.2

| Group | Limb No | a (%) | Qo (ml/100 ml) | $\left(\frac{\lambda \text{ ml}}{(100 \text{ ml tiptoe}) \text{ cycle}}\right)$ | AORTOGRAPHIC FINDINGS | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | DEGREE OF ART LESION % | | SITE OF ART LESION | |
| | | | | | A.I.Segment | F.P. Segment | A.I. Segment | F.P. Segment |
| | 48 | 11.9 | 10.81 | 0.81 | 100 | - | Ext Iliac ↑ | - |
| | 49 | 11.1 | 10.86 | 0.80 | 100 | - | Com Iliac ↑ | - |
| | 50 | 10.0 | 11.48 | 0.75 | 100 | - | Com Iliac ↕ | - |
| | 51 | 10.6 | 11.24 | 0.77 | 100 | - | Ext Iliac ↕ | - |
| | 52 | 9.2 | 12.36 | 0.88 | 100 | - | Com Iliac ↕ | - |
| | 53 | 8.2 | 12.57 | 0.84 | 100 | - | Com Iliac ↕ | - |
| | 54 | 18.9 | 12.52 | 0.89 | 100 | - | Ext Iliac ↕ | - |

| Group | Limb No | a (%) | Qo (ml/100ml) | λ (100ml tiptqel cycle) | AORTOGRAPHIC FINDINGS | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | DEGREE OF ART LESION % | | SITE ART LESION | |
| | | | | | A.I. Segment | F.P. Segment | A.I. Segment | F.P. Segment |
| | 55 | 23.2 | 3.04 | 0.18 | - | 100 | - | Sup Fem + Pop |
| | 56 | 22.8 | 2.95 | 0.19 | - | 100 | - | Sup Fem + Pop |
| | 57 | 21.2 | 3.42 | 0.31 | - | 100 | - | Sup Fem + Pop |
| | 58 | 20.6 | 3.54 | 0.24 | - | 100 | - | Sup Fem + Pop |
| | 59 | 21.9 | 3.58 | 0.34 | - | 100 | - | Sup Fem ↑ |
| | 60 | 20.5 | 3.56 | 0.39 | - | 100 | - | Sup Fem ↑ |
| | 61 | 19.6 | 3.90 | 0.33 | - | 100 | - | Sup Fem ↑ |
| Ba | 62 | 19.9 | 3.65 | 0.39 | - | 100 | - | Sup Fem ↑ |
| Limbs | 63 | 18.2 | 4.10 | 0.36 | - | 100 | - | Sup Fem ↑ |
| with | 64 | 18.6 | 3.48 | 0.45 | - | 100 | - | Sup Fem ↑ |
| super- | 65 | 17.1 | 3.56 | 0.44 | - | 100 | - | Sup Fem ↑ |
| ficial femoral artery occlusion only | 66 | 17.8 | 4.10 | 0.49 | - | 100 | - | Sup Fem ↑ |

Continuation from previous page

TABLE 6.2

| Group | Limb No | a (%) | Qo (ml/100 ml) | $\frac{\lambda \text{ ml}}{(100 \text{ ml tiptoe}) \text{ cycle}}$ | AORTOGRAPHIC FINFINGS | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | DEGREE OF ART LESION % | | SITE OF ART LESION | |
| | | | | | A.I Segment | F.P. Segment | A.I. Segment | F.P. Segment |
| | 67 | 17.4 | 3.80 | 0.42 | - | 100 | - | Sup Fem ↑ |
| | 68 | 16.2 | 4.08 | 0.45 | - | 100 | - | Sup Fem ↑ |
| | 69 | 15.0 | 4.12 | 0.49 | - | 100 | - | Sup Fem ↑ |
| | 70 | 15.6 | 4.60 | 0.41 | - | 100 | - | Sup Fem ↑ |
| | 71 | 14.4 | 4.48 | 0.44 | - | 100 | - | Sup Fem ↓ |
| | 72 | 14.8 | 4.62 | 0.47 | - | 100 | - | Sup Fem ↓ |
| | 73 | 13.6 | 5.60 | 0.46 | - | 100 | - | Sup Fem ↓ |
| | 74 | 13.7 | 5.12 | 0.51 | - | 100 | - | Sup Fem ↓ |
| | 75 | 12.5 | 6.22 | 0.49 | - | 100 | - | Sup Fem ↓ |
| | 76 | 13.2 | 6.54 | 0.60 | - | 100 | - | Sup Fem ↓ |
| | 77 | 22.3 | 0.42 | 0.02 | 100 | 100 | Com Iliac ↑ | Sup Fem + Pop |
| Ca Limbs with aortoiliac & femor-opopliteal occlusion | 78 | 24.5 | 0.83 | 0.02 | 100 | 100 | Ext Iliac ↑ | Sup Fem ↑ |
| | 79 | 20.8 | 0.67 | 0.03 | 100 | 100 | Com Iliac ↓ | Sup Fem ↑ |
| | 80 | 23.6 | 1.02 | 0.09 | 100 | 100 | Com Iliac ↓ | Sup Fem ↑ |
| | 81 | 19.2 | 0.94 | 0.06 | 100 | 100 | Ext Iliac ↑ | Sup Fem ↓ |
| | 82 | 21.4 | 1.28 | 0.11 | 100 | 100 | Ext Iliac ↑ | Sup Fem ↓ |
| | 83 | 17.4 | 1.43 | 0.12 | 100 | 100 | Ext Iliac ↓ | Sup Fem ↓ |

Continuation from previous page

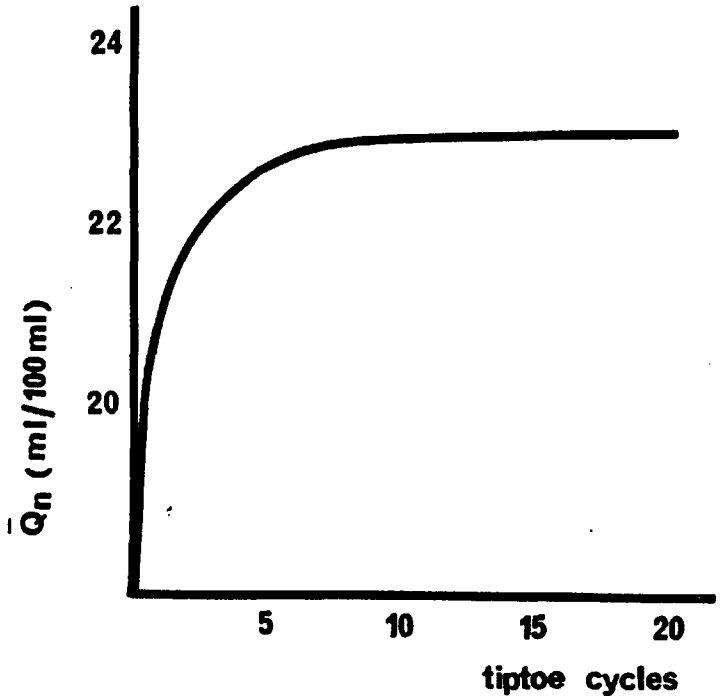
TABLE 6.2

| Group | Limb No | a (%) | Qo (ml/100 ml) | $\left(\frac{\lambda \text{ ml}}{(100 \text{ ml tiptoe}) \text{ cycle}}\right)$ | AORTOGRAPHIC FINDINGS | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | DEGREE OF ART LESION % | | SITE OF ART LESION | |
| | | | | | A.I. Segment | F.P. Segment | A.I. Segment | F.P. Segment |
| | 84 | 23.7 | 2.85 | 0.02 | >70 | >70 | Com Iliac ↓ | Sup Fem ↓ |
| | 85 | 21.8 | 2.12 | 0.06 | 40>70 | >70 | Ext Iliac ↓ | Sup Fem ↑ |
| | 86 | 22.0 | 4.54 | 0.05 | 40>70 | >70 | Ext Iliac ↓ | Sup Fem ↓ |
| | 87 | 22.6 | 5.26 | 0.12 | >70 | >70 | Ext Iliac ↑ | Sup Fem ↑ |
| | 88 | 20.1 | 7.72 | 0.21 | >70 | >70 | Ext Iliac ↓ | Sup Fem + Pop |
| | 89 | 19.2 | 6.94 | 0.18 | 40-70 | 40-70 | Com + Ext Iliac | Sup Fem ↑ |
| | 90 | 21.4 | 6.90 | 0.16 | 40-70 | 40-70 | Com Iliac ↓ | Sup Fem + Pop |
| | 91 | 18.4 | 8.52 | 0.31 | 40-70 | 40-70 | Com Iliac ↑ | Sup Fem ↓ |
| | 92 | 19.9 | 7.46 | 0.33 | 10-40 | 10-40 | Com Iliac ↓ | Sup Fem + Pop |
| | 93 | 17.9 | 8.04 | 0.26 | 40-70 | 10-40 | Ext Iliac ↑ | Sup Fem ↓ |
| Da | 94 | 17.3 | 9.98 | 0.34 | >70 | 10-40 | Ext Iliac ↓ | Sup Fem ↑ |
| | 95 | 15.2 | 9.62 | 0.21 | >70 | 10-40 | Ext Iliac ↓ | Sup Fem ↑ |
| limbs with aortoiliac & femor-opopliteal stenosis | 96 | 16.9 | 12.32 | 0.47 | >70 | <10 | Ext Iliac ↓ | Sup Fem + Pop |
| | 97 | 16.6 | 10.82 | 0.42 | 40-70 | 10-40 | Ext Iliac ↓ | Sup Fem ↓ |
| | 98 | 13.9 | 10.56 | 0.56 | >70 | 10-40 | Com Iliac ↓ | Sup Fem ↓ |
| | 99 | 15.8 | 12.97 | 0.49 | 40-70 | <10 | Comp + Ext Iliacs | Sup Fem ↑ |
| | 100 | 14.1 | 13.24 | 0.45 | 40-70 | <10 | Ext Iliac ↑ | Sup Fem ↑ |

Continuation from previous page...

TABLE 6.2

| Group | Limb No | a (%) | Qo (ml/100 ml) | ( λ / ml ) (100 ml tiptoe) cycle | AORTOGRAPHIC FINDINGS | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | DEGREE OF ART LESION % | | SITE OF ART LESION | |
| | | | | | A.I. Segment | F.P.Segment | A.I. Segment | F.P.Segment |
| | 101 | 14.3 | 13.12 | 0.51 | 40-70 | 10-40 | Ext Iliac ↓ | Sup Fem ↓ |
| | 102 | 13.1 | 14.90 | 0.56 | 40-70 | <10 | Com Ext Iliac | Sup Fem ↓ |
| | 103 | 12.0 | 13.78 | 0.53 | 10-40 | <10 | Ext Iliac ↑ | Sup Fem ↓ |
| | 104 | 12.6 | 14.99 | 0.76 | 10-40 | 10-40 | Ext Iliac ↑ | Sup Fem + Pop |
| | 105 | 11.2 | 15.84 | 0.64 | 10-40 | <10 | Ext Iliac ↓ | Sup Fem + Pop |
| | 106 | 11.9 | 17.30 | 0.73 | 10-40 | <10 | Com Iliac ↓ | Sup Fem ↑ |
| | 107 | 8.2 | 16.92 | 0.84 | 10-40 | <10 | Com + Ext Iliacs | Sup Fem ↓ |




**GROUP O**

$\bar{a} = 0.09$

$\bar{Q}_o = 19.0$ ml/100ml

$\bar{\lambda} = 2.1$ ml/100ml/tiptoe cycle

$\bar{n} = 7$ tiptoe cycles

$\bar{Q}_f = \frac{\bar{\lambda}}{\bar{a}} = 23$ ml/100ml

Fig.6.7

Mean values of $Q_n$ ($\bar{Q}n$) in Group O (normal limbs) in relation to the number of tiptoe cycles (Clinical Study V)

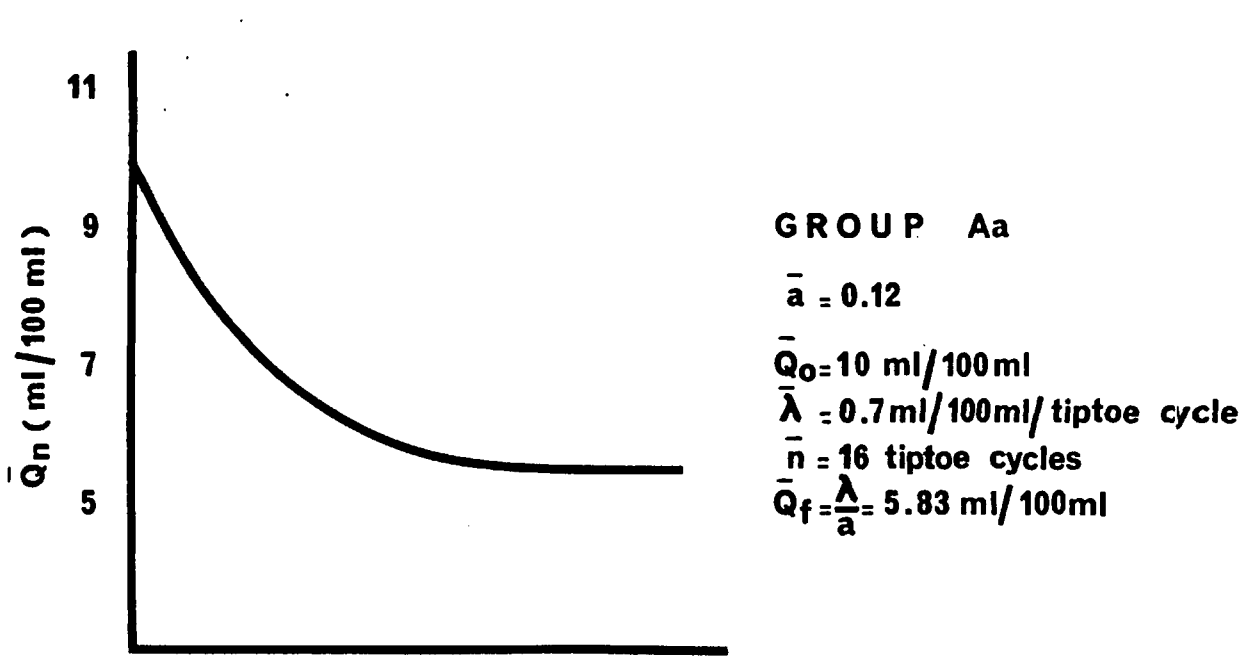



Fig.6.8

Mean values of Qn ($\bar{Q}n$) in group Aa (limbs with iliac occlusion only) in relation to the number of tiptoe cycles (Clinical Study V)

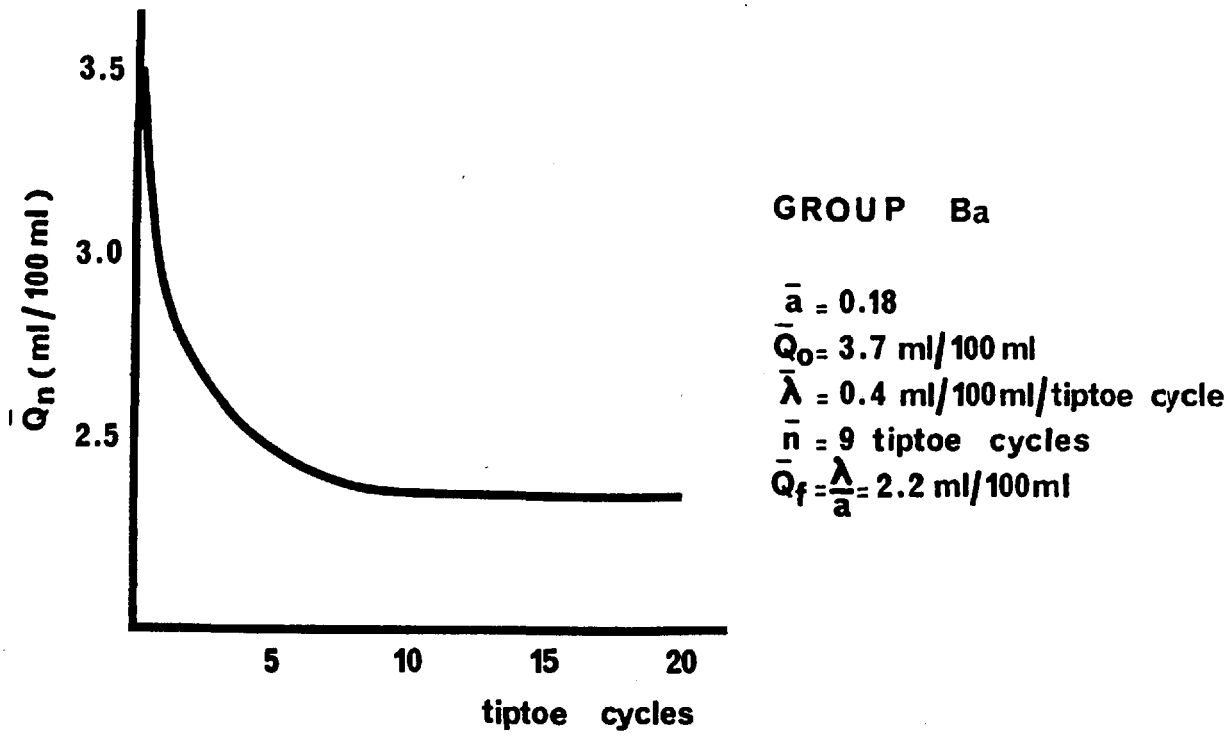
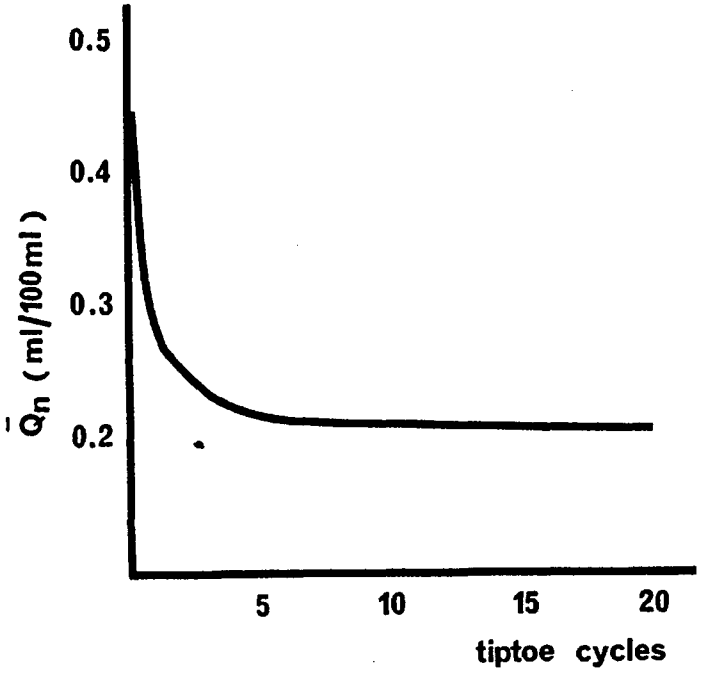



Fig. 6.9

Mean values of Qn ($\bar{Q}n$) in group Ba (limbs with superficial femoral artery occlusion only) in relation to the number of tiptoe cycles (Clinical Study V).




**GROUP Ca**

$\bar{a}$ = 0.22
$\bar{Q}_o$ = 0.45 ml/100ml
$\bar{\lambda}$ = 0.07 ml/100ml/tiptoe cycle
$\bar{n}$ = 7 tiptoe cycles
$\bar{Q}_f = \frac{\bar{\lambda}}{\bar{a}}$ = 0.22 ml/100ml

Fig. 6.10

Mean values of Qn ($\bar{Q}n$) in group Ca (Limbs with combined aortoiliac and femoropopliteal occlusions) in relation to the number of tiptoe cycles (Clinical Study V)

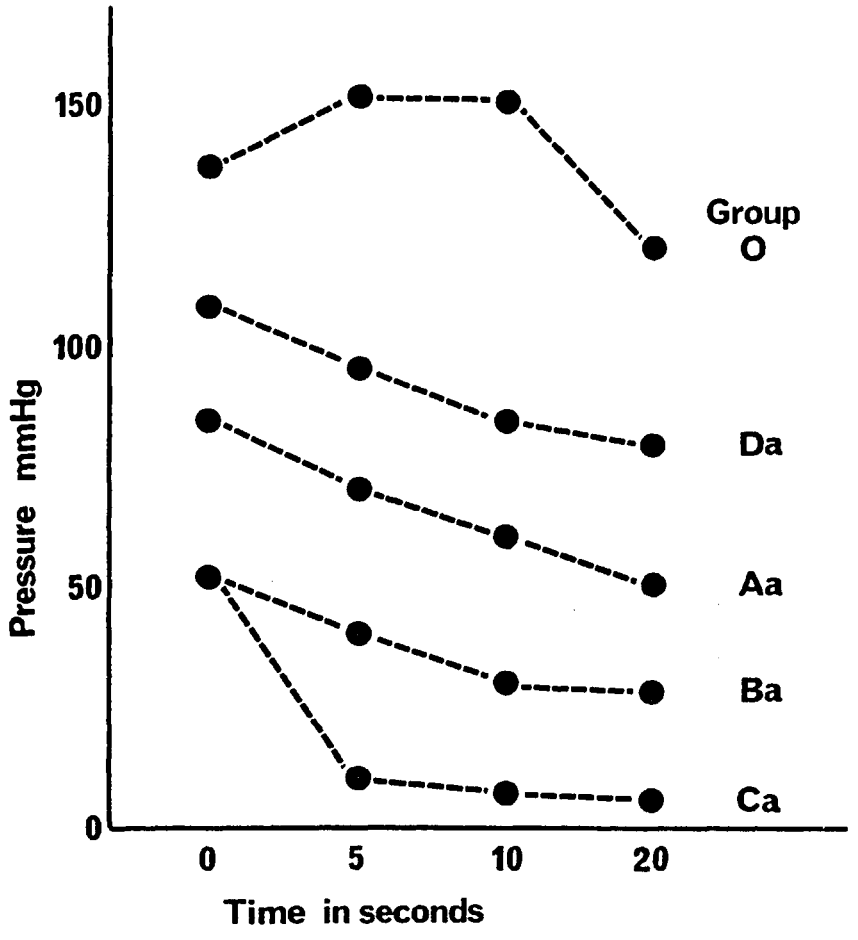



Fig. 6.11

Mean values of the ankle systolic pressures at rest and after 5, 10 and 20 tiptoe cycles in the five groups studied (O to Da) (Clinical Study V).

TABLE 6.3

The Values of $P_r$, $P_5$, $P_{10}$ and $P_{20}$ for every limb studied in relation to the values of a, Qo and $\lambda$ (Clinical Study V). (Key: * = Decrease in $P_{20}$; und = Pressure unrecordable)

| Group | Limb | a (%) | $Q_o$ (ml/100 ml) | $\lambda$ (ml/100 ml / tiptoe cycle) | $P_r$(mmHg) | $P_5$(mmHg) | $P_{10}$(mmHg) | $P_{20}$(mmHg) |
|---|---|---|---|---|---|---|---|---|
| | 1 | 5.3 | 22.45 | 2.18 | 130 | 138 | 140 | 140 |
| | 2 | 6.2 | 22.38 | 2.19 | 125 | 135 | 135 | 115* |
| | 3 | 5.9 | 21.74 | 2.28 | 140 | 150 | 150 | 150 |
| | 4 | 6.8 | 21.43 | 2.17 | 135 | 135 | 145 | 145 |
| | 5 | 7.4 | 21.28 | 2.26 | 150 | 150 | 165 | 165 |
| | 6 | 7.1 | 20.96 | 2.20 | 140 | 150 | 150 | 120* |
| | 7 | 7.7 | 20.90 | 2.24 | 120 | 120 | 130 | 130 |
| | 8 | 8.2 | 20.81 | 2.21 | 110 | 125 | 120 | 135 |
| | 9 | 8.8 | 20.79 | 2.18 | 110 | 125 | 125 | 85* |
| | 10 | 7.9 | 19.98 | 2.18 | 145 | 145 | 160 | 160 |
| O | 11 | 8.5 | 19.91 | 2.16 | 125 | 130 | 135 | 135 |
| | 12 | 8.8 | 19.84 | 2.14 | 120 | 120 | 120 | 140 |
| (normal limbs) | 13 | 9.4 | 19.42 | 2.09 | 115 | 120 | 125 | 125 |
| | 14 | 9.2 | 19.65 | 2.10 | 120 | 120 | 120 | 100* |
| | 15 | 9.9 | 19.36 | 2.05 | 120 | 120 | 140 | 140 |
| | 16 | 10.4 | 19.39 | 1.93 | 150 | 150 | 160 | 110* |
| | 17 | 9.8 | 19.12 | 1.78 | 135 | 135 | 150 | 150 |
| | 18 | 10.6 | 18.90 | 1.86 | 140 | 140 | 155 | 160 |

Continuation from previous page

TABLE 6.3

| Group | Limb No | a (%) | Qo (ml/100 ml) | λ (ml/100 ml / tiptoe cycle) | $P_{r(mmHg)}$ | $P_{5(mmHg)}$ | $P_{10(mmHg)}$ | $P_{20(mmHg)}$ |
|---|---|---|---|---|---|---|---|---|
| | 19 | 11.2 | 19.04 | 1.94 | 120 | 130 | 130 | 80* |
| | 20 | 10.9 | 18.46 | 1.81 | 135 | 135 | 140 | 100* |
| | 21 | 11.8 | 18.64 | 1.90 | 140 | 150 | 150 | 155 |
| | 22 | 12.4 | 18.24 | 1.78 | 130 | 150 | 150 | 150 |
| | 23 | 11.9 | 17.60 | 1.59 | 100 | 130 | 120 | 120 |
| | 24 | 12.8 | 18.08 | 1.74 | 120 | 135 | 135 | 95* |
| | 25 | 13.4 | 16.96 | 1.62 | 130 | 130 | 145 | 150 |
| | 26 | 12.6 | 16.28 | 1.49 | 130 | 130 | 145 | 145 |
| | 27 | 13.8 | 14.90 | 1.41 | 115 | 130 | 125 | 100* |
| | 28 | 12.6 | 15.97 | 1.39 | 115 | 115 | 125 | 125 |
| | 29 | 14.2 | 14.68 | 1.31 | 145 | 145 | 160 | 160 |
| | 30 | 16.8 | 8.65 | 0.46 | 100 | 75 | 60 | 45 |
| | 31 | 13.6 | 9.08 | 0.52 | 105 | 90 | 75 | 35 |
| | 32 | 15.2 | 9.37 | 0.45 | 90 | 80 | 50 | 45 |
| | 33 | 15.4 | 9.34 | 0.72 | 90 | 80 | 65 | 50 |
| | 34 | 14.8 | 9.48 | 0.56 | 105 | 70 | 40 | und |
| Aa | 35 | 14.6 | 9.59 | 0.74 | 100 | 60 | 35 | und |
| (limbs with iliac occlusion) | 36 | 14.0 | 9.61 | 0.58 | 105 | 75 | 60 | 35 |

Continuation from previous page

TABLE 6.3

| Group | Limb No | a (%) | Qo (ml/100 ml) | $\lambda$ (ml/100 ml / tiptoe cycle) | $P_r$(mmHg) | $P_5$(mmHg) | $P_{10}$(mmHg) | $P_{20}$(mmHg) |
|---|---|---|---|---|---|---|---|---|
| | 37 | 14.3 | 9.60 | 0.71 | 80 | 40 | 25 | und |
| | 38 | 14.8 | 9.86 | 0.66 | 85 | 60 | 40 | 20 |
| | 39 | 13.6 | 9.75 | 0.69 | 90 | 75 | 45 | 35 |
| | 40 | 13.9 | 9.84 | 0.72 | 85 | 75 | 75 | 45 |
| | 41 | 13.5 | 9.97 | 0.72 | 80 | 60 | 60 | 30 |
| | 42 | 12.8 | 9.95 | 0.77 | 90 | 60 | 40 | und |
| | 43 | 13.8 | 10.02 | 0.66 | 100 | 70 | 45 | 45 |
| | 44 | 12.4 | 10.10 | 0.83 | 100 | 60 | 60 | und |
| | 45 | 12.8 | 10.56 | 0.59 | 85 | 60 | 45 | 30 |
| | 46 | 13.4 | 10.55 | 0.76 | 85 | 55 | 55 | 30 |
| | 47 | 12.2 | 10.67 | 0.79 | 80 | 60 | 45 | 45 |
| | 48 | 11.9 | 10.81 | 0.81 | 85 | 70 | 45 | 25 |
| | 49 | 11.1 | 10.86 | 0.80 | 90 | 75 | 35 | 30 |
| | 50 | 10.0 | 11.48 | 0.75 | 105 | 85 | 70 | 55 |
| | 51 | 10.6 | 11.24 | 0.77 | 90 | 75 | 45 | und |
| | 52 | 9.2 | 12.36 | 0.88 | 80 | 65 | 55 | 40 |
| | 53 | 8.2 | 12.57 | 0.84 | 125 | 90 | 85 | 70 |
| | 54 | 8.9 | 12.52 | 0.89 | 100 | 65 | 50 | 35 |

continuation from previous page

TABLE 6.3

| Group | Limb No | a (%) | Qo (ml/100 ml) | λ (ml/100 ml)/(tiptoe cycle) | $P_r$(mmHg) | $P_5$ (mmHg) | $P_{10}$(mmHg) | $P_{20}$(mmHg) |
|---|---|---|---|---|---|---|---|---|
| Ba (limbs with superficial femoral artery occlusion only) | 55 | 23.2 | 3.04 | 0.18 | 90 | 45 | und | und |
| | 56 | 22.8 | 2.95 | 0.18 | 85 | 60 | 25 | 25 |
| | 57 | 21.2 | 3.42 | 0.31 | 110 | 70 | und | und |
| | 58 | 20.6 | 3.54 | 0.24 | 75 | 45 | 30 | 30 |
| | 59 | 21.9 | 3.58 | -.34 | 80 | 45 | und | und |
| | 60 | 20.5 | 3.56 | 0.39 | 100 | 65 | 40 | 35 |
| | 61 | 19.6 | 3.90 | 0.33 | 125 | 80 | 45 | 40 |
| | 62 | 19.9 | 3.65 | 0.39 | 100 | 65 | 30 | und |
| | 63 | 18.2 | 4.10 | 0.36 | 85 | 60 | 25 | 25 |
| | 64 | 18.6 | 3.48 | 0.45 | 70 | 60 | 25 | 25 |
| | 65 | 17.1 | 3.56 | 6.44 | 75 | 35 | und | und |
| | 66 | 17.8 | 4.10 | 0.49 | 95 | 45 | 35 | und |
| | 67 | 17.4 | 3.80 | 0.42 | 100 | 80 | 30 | 25 |
| | 68 | 16.2 | 4.08 | 0.45 | 120 | 75 | 35 | 30 |
| | 69 | 15.0 | 4.12 | 0.49 | 80 | 60 | 35 | 35 |
| | 70 | 15.6 | 4.60 | 0.41 | 70 | 45 | 30 | 30 |
| | 71 | 14.4 | 4.48 | 0.44 | 70 | 50 | 30 | 30 |
| | 72 | 14.8 | 4.62 | 0.47 | 85 | 70 | 35 | 25 |

Continuation from previous page.....

TABLE 6.3

| Group | Limb No | a (%) | Qo (ml/100 ml) | $\lambda$ (ml/100 ml / tiptoe cycle) | $P_r$(mmHg) | $P_5$(mmHg) | $P_{10}$(mmHg) | $P_{20}$(mmHg) |
|---|---|---|---|---|---|---|---|---|
| | 72 | 14.8 | 4.62 | 0.47 | 85 | 70 | 35 | 25 |
| | 73 | 13.6 | 5.60 | 0.46 | 90 | 55 | 30 | und |
| | 74 | 13.7 | 5.12 | 0.51 | 80 | 45 | und | und |
| | 75 | 12.5 | 6.22 | 0.49 | 100 | 50 | 25 | 20? |
| | 76 | 13.2 | 6.54 | 0.60 | 70 | 65 | 30 | 30 |
| Ca (limbs with aortoiliac & femoropop-liteal occlusion) | 77 | 22.3 | 0.42 | 0.02 | 100 | 35 | und | und |
| | 78 | 24.5 | 0.83 | 0.02 | 120 | 20 | und | und |
| | 79 | 20.8 | 0.67 | 0.03 | 80 | und | und | und |
| | 80 | 23.6 | 1.02 | 0.09 | 60 | und | und | und |
| | 81 | 19.2 | 0.94 | 0.06 | 75 | 30 | 20? | und |
| | 82 | 21.4 | 1.28 | 0.11 | 75 | und | und | und |
| | 83 | 17.4 | 1.43 | 0.12 | 85 | 35 | 25 | und |
| | 84 | 23.7 | 2.95 | 0.02 | 85 | 45 | 25 | und |
| | 85 | 21.8 | 2.12 | 0.06 | 100 | 55 | 45 | 25 |
| | 86 | 22.0 | 4.54 | 0.05 | 70 | 30 | und | und |
| | 87 | 22.6 | 5.26 | 0.12 | 70 | 50 | 30 | und |
| | 88 | 20.1 | 7.72 | 0.21 | 95 | 60 | 45 | 30 |
| | 89 | 19.2 | 6.94 | 0.18 | 110 | 75 | 50 | 35 |

Continuation from previous page

TABLE 6.3

| Group | Limb No | a (%) | Qo (ml/100 ml) | $\lambda$ $\frac{(ml/100\ ml)}{(tiptoe\ cycle)}$ | $P_{r(mmHg)}$ | $P_{5(mmHg)}$ | $P_{10(mmHg)}$ | $P_{20(mmHg)}$ |
|---|---|---|---|---|---|---|---|---|
| Da (limbs with aortoiliac and femoropop-liteal stenoses) | 90 | 21.4 | 6.90 | 0.16 | 65 | 45 | 20 | und |
| | 91 | 18.4 | 8.52 | 0.31 | 120 | 75 | 60 | 40 |
| | 92 | 19.9 | 7.46 | 0.33 | 105 | 60 | 55 | 30 |
| | 93 | 17.9 | 8.04 | 0.26 | 95 | 65 | 40 | 25 |
| | 94 | 17.3 | 9.98 | 0.34 | 95 | 40 | 25 | und |
| | 95 | 17.3 | 9.98 | 0.34 | 95 | 40 | 35 | 25 |
| | 96 | 15.2 | 9.62 | 0.21 | 80 | 60 | 35 | 25 |
| | 97 | 16.6 | 10.82 | 0.42 | 105 | 75 | 70 | 40 |
| | 98 | 13.9 | 10.56 | 0.56 | 85 | 60 | 45 | 30 |
| | 99 | 15.8 | 12.97 | 0.49 | 85 | 85 | 45 | 30 |
| | 100 | 14.1 | 13.24 | 0.45 | 90 | 80 | 65 | 40 |
| | 101 | 14.3 | 13.12 | 0.51 | 75 | 60 | 60 | 45 |
| | 102 | 13.1 | 14.90 | 0.56 | 100 | 100 | 85 | 70 |
| | 103 | 12.0 | 13.78 | 0.53 | 95 | 80 | 65 | 50 |
| | 104 | 12.6 | 14.99 | 0.76 | 85 | 85 | 80 | 65 |
| | 105 | 11.2 | 15.84 | 0.64 | 110 | 85 | 80 | 60 |
| | 106 | 11.9 | 17.30 | 0.73 | 115 | 100 | 100 | 70 |
| | 107 | 8.2 | 16.92 | 0.84 | 115 | 115 | 115 | 90 |

TABLE 6.4

Values of $\overline{\lambda}$ , $\overline{a}$ , $\overline{Q}_o$ , $\overline{W}_1$ , $\overline{Q}$ final and $W_f$ in groups 0 to $C_a$ (Clinical Study V)

| | $\overline{\lambda}$ Amount of blood entering pool 2 per tiptoe cycle (ml/100 ml of tissue) /tiptoe cycle) | $\overline{a}$ Amount of blood leaving pool 2 in any cycle expressed as fraction of Qn | $\overline{Q}_o$ Amount of blood in pool 2 at rest (ml/100 ml tissue) | $\overline{W}_1$ Amount of blood leaving pool 2 in 1st cycle (a x Qo) | $\overline{Q}$ final Amount in Pool 2 when its volume reaches a steady value i.e. amount entering = amount leaving (ml/100 ml tissue) | W f. Amount leaving pool 2 when steady state is reached (a x Q final) (ml/100 ml tissue) |
|---|---|---|---|---|---|---|
| 0 | 2.1 | 0.09 | 19 | 1.7 | 23.0 | 2.1 |
| Aa | 0.7 | 0.12 | 10 | 1.2 | 5.83 | 0.7 |
| Ba | 0.4 | 0.18 | 3.7 | 0.67 | 2.20 | 0.4 |
| Ca | 0.07 | 0.22 | 0.45 | 0.10 | 0.22 | 0.07 |

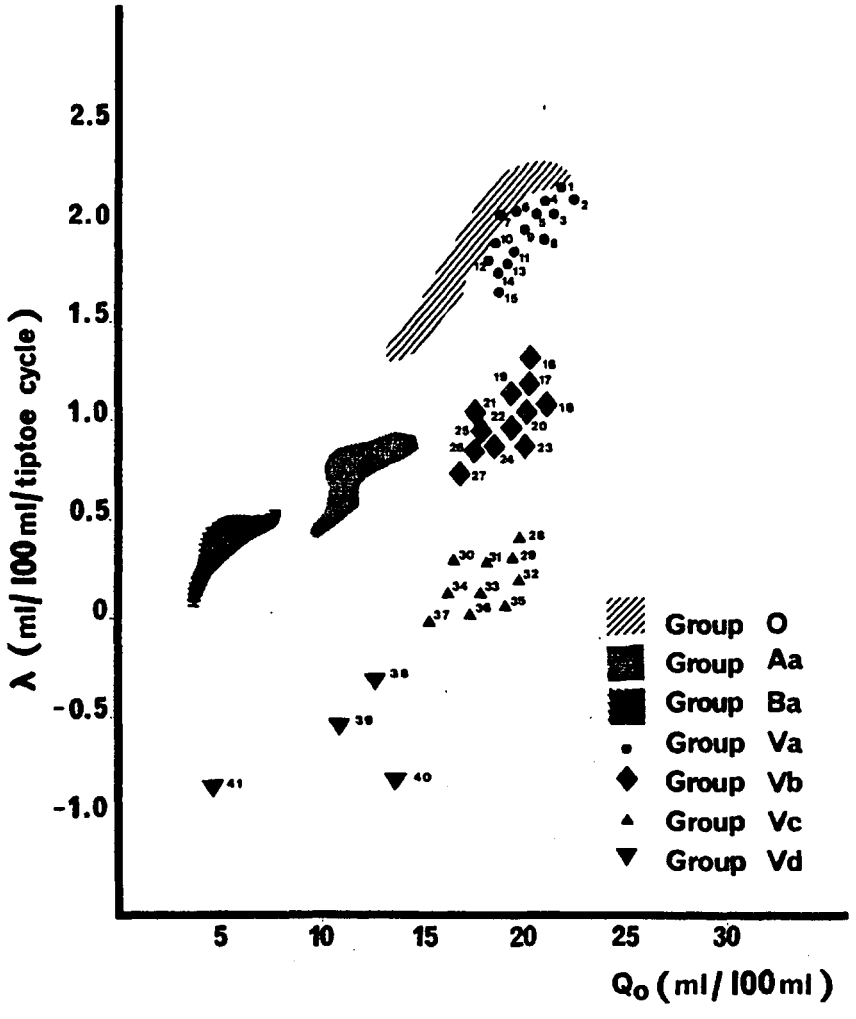



Fig 6.12

Analysis of Qo and λ in the four groups (Va to Vd) studied (Clinical Study VI). Groups O, Aa and Ba (see Fig. 5.6) are included for comparison as shaded areas.

## TABLE 6.5

Values of, $Q_o$ and $\lambda$, before and after the application of the external compression in the 8 limbs studied. (Clinical Study VII)

| | BEFORE EXTERNAL COMPRESSION | | AFTER EXTERNAL COMPRESSION | |
|---|---|---|---|---|
| No of limb | $Q_o$ (ml/100 ml) | $\lambda$ (ml/100 ml/) (tiptoeing ) | $Q_o$ (ml/100 ml) | $\lambda$ (ml/100 ml/ ) (tiptoeing ) |
| 1 | 20.02 | 1.52 | 20.50 | 2.21 |
| 2 | 21.53 | 1.31 | 21.30 | 1.85 |
| 3 | 18.40 | 1.21 | 18.87 | 1.90 |
| 4 | 17'42 | 0.92 | 17.90 | 1.60 |
| 5 | 20.92 | 0.58 | 20.09 | 1.25 |
| 6 | 20.92 | 0.58 | 20.09 | 1.25 |
| 7 | 18.08 | 0.30 | 18.90 | 1.23 |
| 8 | 15.90 | 0.25 | 15.83 | 1.08 |

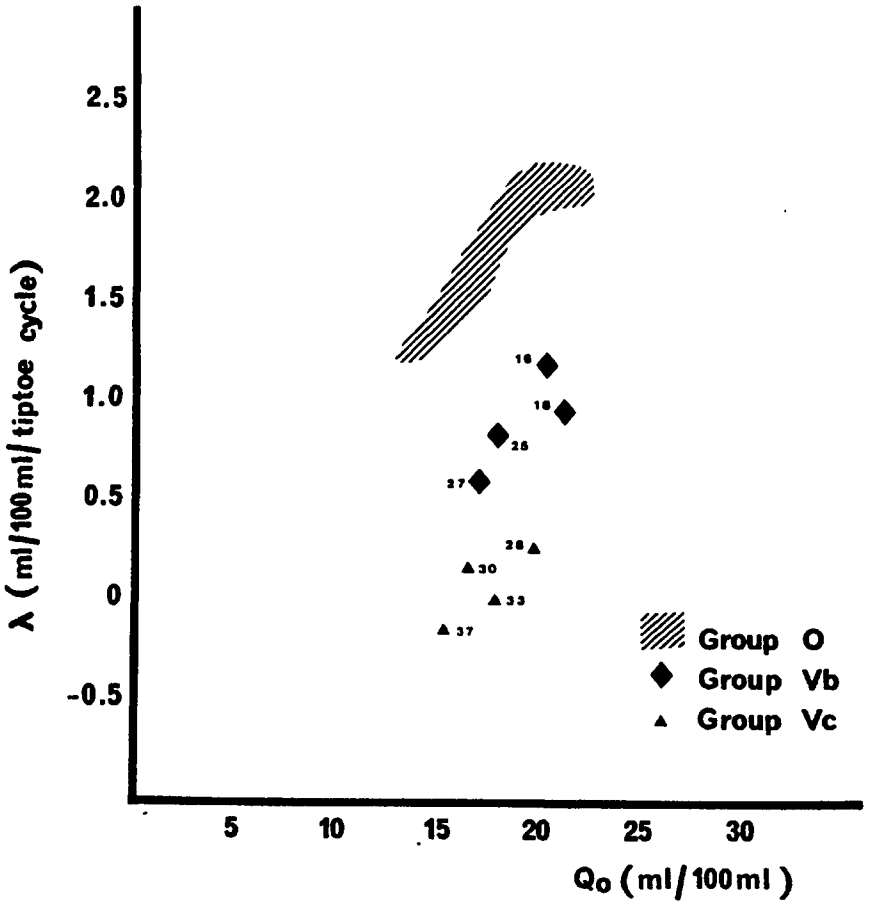

2.5
2.0
1.5
1.0
0.5
0
-0.5
λ (ml/100ml/tiptoe cycle)
5
10
15
20
25
30
Qo (ml/100ml)
Group O
Group Vb
Group Vc

Fig. 6.13a

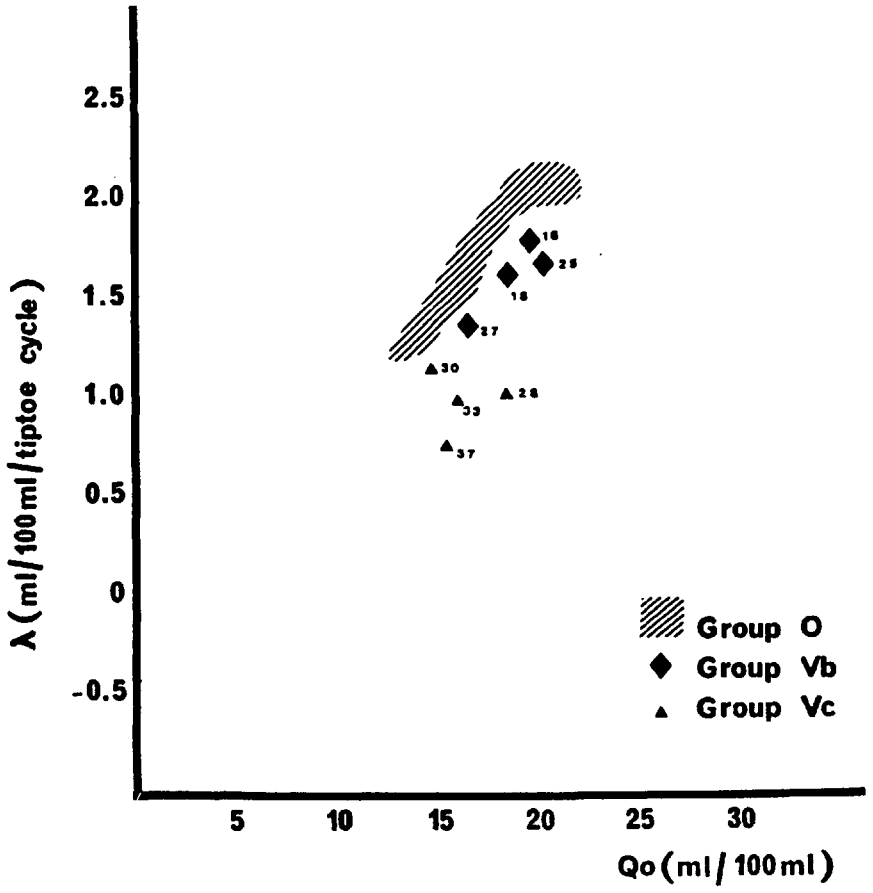



Fig.6.13b

Analysis of the values of Qo and λ for the 8 limbs studied before the application of the external support (Fig 6.13a) and after the application of the external support (Fig 6.13b) (Clinical Study VII).

# APPENDICES

# A P P E N D I X A1

## KETY'S MATHEMATICAL ANALYSIS OF THE CLEARANCE OF A LOCALLY INJECTED RADIOACTIVE TRACER ($^{24}$Na)

According to Kety (Kety, 1949)

Let

A = small unit mass of tissue into which $^{24}Na$ has been injected.

S = sodium space (extracellular volume)

$F_A$ = arterial blood flow

$F_V$ = venous blood flow

$F_L$ = lymphatic flow

$C_S$ = concentration of $^{24}Na$ in S

$C_A$ = concentration of $^{24}Na$ in $F_A$

$C_V$ = concentration of $^{24}Na$ in $F_V$

$C_L$ = concentration of $^{24}Na$ in $F_L$

$Q_0$ = initial amount of $^{24}Na$

Q = concentration of $^{24}Na$ per A

$C_S = \frac{Q}{S}$

m and n = constants with values between 0 and 1 expressing the extent to which capillary blood and lymph come to equilibrium with the tissue concentration of $^{24}Na$ respectively. They depend on the diffusion rate of $^{24}Na$, the diffusion distances, the capillary - tissue interface, the proportion of the arteriovenous shunts and the filtration - absorption of the extracellular fluid at the capillary.

Over a short period of time (dt) an amount of venous blood ($F_V dt$) and of lymphatic fluid ($F_L dt$) flows out of the tissue whereas an amount of arterial blood ($F_A dt$) flows into the tissue. The changes of Q (dQ) during dt would be equal to the amount of blood brought into the

tissues ($F_A dt$) minus the amount of blood ($F_V dt$) and lymph ($F_L dt$) carried out of the tissues. Thus,

$$dQ = F_A C_A dt - F_V C_V dt - F_L C_L dt \qquad (A1.1)$$

Assuming that the arterial concentration of the radioactive isotope can be considered negligible, equation A1.1 can be rewritten as

$$dQ = - F_V C_V dt - F_L C_L dt \qquad (A1.2)$$

Or

$$\frac{dQ}{dt} = - F_V C_V - F_L C_L$$

As

$$C_V = m C_S \text{ and } C_L = n C_S$$

$$\frac{dQ}{dt} = - F_V m C_S - F_L n C_S \qquad (A1.3)$$

Or

$$\frac{dQ}{dt} = -C_S (mF_V + nF_L) \qquad (A1.4)$$

But

$$C_S = \frac{Q}{S}$$

Therefore

$$\frac{dQ}{dt} = - \frac{Q}{S} (mF_V + nF_L) \qquad (A1.5)$$

Or

$$\frac{dQ}{dt} = - Q \left( \frac{mF_V}{S} + \frac{nF_L}{S} \right) \qquad (A1.6)$$

Let

$$\frac{mF_V}{S} + \frac{nF_L}{S} = K \qquad (A1.7)$$

$$\frac{dQ}{dt} = - Q.K \qquad (A1.8)$$

Equation A1.8 can be solved for Q as

$$Q = Q_o \, e^{-Kt} \qquad \text{(A1.9)}$$

Since $F_V$ is a constant fraction, r, of $F_A$ and similarly $F_L$ is a constant fraction 1 - r of $F_A$ under amy one set of physiologic circumstances then equation A1.7 can be rewritten as

$$K = \frac{mr\ F_A + n\ (1 - r)\ F_A}{S} \qquad \text{(A1.10)}$$

Let $$\frac{mr + n\ (1-r)}{S} = Q$$

$$K = FA.Q \qquad \text{A1.11)}$$

Equations A1.9 and A1.11 imply that the tissue deposit $^{24}Na$ would decrease along a single exponential curve which, if plotted semilogarithmically, clearance constant K, can provide a quantitative measure of the ability of the local circulation to remove freely diffusible substances.

# A P P E N D I X A2

## LASSEN'S MATHEMATICAL ANALYSIS OF THE CLEARANCE OF A LOCALLY INJECTED RATIO-ACTIVE TRACER ($^{133}X_e$)

Fundamental to the calculations is the assumption of the maintenance of a complete diffusion equilibrium, thus

$$C_{muscle} = \lambda C_{blood} \qquad (A2.1)$$

where $C_{muscle}$ = amount of $^{133}Xe$ per gramme of muscle

$C_{blood}$ = amount of $^{133}Xe$ per ml of blood

$\lambda$ = muscle to blood partition coefficient taken to be 0.70 for blood with a heamatocrit of about 40%(Conn,1961).

According to Lassen (Lassen et al, 1964)

Let $Q$ = amount of $^{133}Xe$ in the tissue at any given time.

$Q'$ = the first derivative of Q with respect to time.

$C_a$ = concentration of $^{133}Xe$ in arterial blood which can be considered negligible since $^{133}Xe$ is effectively eliminated by the lungs.

$C_v$ = concentration of $^{133}Xe$ in venous blood

$C_L$ = concentration of $^{133}Xe$ in lymph which can be considered negligible since lymphatic flow is quite small in comparison to venous blood flow.

Application of the Fick principle leads to the well known relation

$$Q' = F\,(C_a - C_v) \qquad (A2.2)$$

where

$$F = \frac{1}{100}\ M.B.F.\ .\ W \qquad (A2.3)$$

M.B.F. = muscle blood flow per 100g of tissue

W = the tissue weight in grammes

Since $C_a \approx 0$ equation A2.2 can be rewritten as

$$Q' = - FC_v \qquad (A2.4)$$

Inserting equation A2.3 into equation A2.4

$$Q' = - \frac{1}{100} \cdot M.B.F \cdot W. C_v \qquad (A2.5)$$

or

$$M.B.F. = - 100 \cdot \frac{Q'}{C_v.W} \text{ (ml per 100g per min)} \qquad (A2.6)$$

Equation A2.1 can be rewritten as

$$C_v.W = \frac{1}{0.70} C_{muscle} .W \qquad (2.7)$$

or

$$C_v.W = \frac{1}{0.70} \cdot Q \qquad (A2.8)$$

By inserting equation A2.8 into equation A2.5 it can be shown that

$$M.B.F. = - 70 \cdot \frac{Q'}{Q} \text{ (ml per 100g per min)} \qquad (A2.9)$$

By using a logarithmic potentiometer (Lassen et al., 1974) the clearance rate can be obtained from the tangent of the curve whose slope is $[(\log_{10} \frac{Q}{dt})]$

Since,

$$\log_e (10) \cdot d \log_{10} \frac{Q}{dt} = d \log_e \frac{Q}{dt} = \frac{Q'}{Q} \qquad (A2.10)$$

then

$$M.B.F = - 70 \cdot \log_e (10).d \log_{10} \frac{Q}{dt} \qquad (2.11)$$

or

$$M.B.F = - 161.D \quad (ml \text{ per } 100g \text{ per min}) \qquad (A2.12)$$

D being the slope of the logarithmic disappearance curve of the radioactivity,

Although Q cannot be observed directly, as the counting rate is only proportional to Q, however, since the desired ratio is $\frac{Q'}{Q}$ or $d(\log_{10} \frac{Q}{dt})$ the factor of proportionality cancels out.

# A P P E N D I X A3

## MATHEMATICAL ANALYSIS OF THE PERCENTAGE CLEARANCE PER MINUTE (T)

It has been mentioned (see section 2.22) that the percentage clearance per minute (T) can be obtained from equation 2.1.

$$T = \frac{f(t) - f(t+1)}{f(t) + f(t+1)} \times 200 \qquad (2.1)$$

By using the above equation the rate of clearance for any muscle clearance curve can be determined without making any assumptions about the nature of the curve, i.e. without assuming that the final shape of curve is exponential (Kety, 1948; Lassen et al., 1964) (See Appendices A1 and A2).

Assuming exponential decay the percentage clearance per minute (T) can be obtained from the following equation.

$$T = -\log_e 10 \cdot 100 \cdot D$$

D being the slope of the logarithmic disappearance curve of the radioactivity (see Appendix A2).

The mathematical analysis of the exponential decay of any muscle clearance curve follows:

Let

$Q_o$ = initial amount of a locally injected radioactive isotope measured in some convenient units, since $(\frac{dQ}{dt}) / Q$ appears as a ratio

A = the logarithm to the base 10 of $Q_o$ ($A = \log_{10} Q_o$)

D = the slope of the logarithm to the base 10 of Q against time in minutes.

Since a quantity of radioactivity Q will remain in the tissues after t minutes, whose logarithm is

$$\log_{10} Q = A - Dt \text{ , it implies that}$$

$$Q = 10^{(A - Dt)} \qquad \text{(A3.1)}$$

or

$$Q = 10^{A} \cdot 10^{-Dt} \qquad \text{(A3.2)}$$

But, $10^{A} = 10^{\log_{10} Q_o} = Q_o$

Therefore,

$$Q = Q_o \cdot 10^{-Dt} \qquad \text{(A3.3)}$$

Let $10^{-D} = e^{-a}$ (A3.4)

On taking natural logarithms, equation A3.4 can be rewritten as

$$- D \log_e 10 = - a \qquad \text{(A3.5)}$$

Inserting equation A3.5 into equation A3.3

$$Q = Q_o \cdot e^{-D \log_e 10.t} \qquad \text{(A3.6)}$$

On taking natural logarithms, equation A3.6 can be rewritten as

$$\text{Log}_e Q = \log_e Q_o - D. \log_e 10.t \qquad \text{(A3.7)}$$

Bearing in mind that

$$\frac{d.\log_e y}{dx} = \frac{1}{y} \cdot \frac{dy}{dx}$$

On differentiating

$$\frac{1}{Q} \cdot \frac{dQ}{dt} = -D \cdot \log_e 10 \qquad \text{(A3.8)}$$

Therefore,

$$\text{Unit clearance per minute} = -D \log_e 10 \qquad \text{(A3.10)}$$

and

$$\text{Percentage clearance per minute (T)} = -D \log_e 10.100 \qquad \text{(A3.11)}$$

Let, $\lambda$ be the muscle to blood partition coefficient. Then muscle blood flow (M.B.F.) can be calculated from:

$$M.B.F = -D\log_e 10 \cdot 100\ \lambda \qquad \text{(A3.12)}$$

or

$$M.B.F = T \cdot \lambda$$

Although the above mathematical analysis has been used in general by all previous workers who have dealt with quantitative muscle clearance techniques, it can be shown mathematically that the percentage clearance per minute corresponds to the exponential decay only under the assumption of slow single exponential decay, when the percentage clearance per minute remains constant. Under any other condition, i.e. during the post-exercise hyperaemia, the percentage clearance per minute will not be constant but it will vary with time. This can be expressed as follows:

Let $f(t) = A.e^{-at}$ so that

$f(t + 1) = A.e^{-a(t + 1)}$

where $f(t)$ is the radioactivity measured at time t and $f(t+1)$

the radioactivity measured one minute later.

But

$$T = \frac{f(t) - f(t+1)}{f(t) + f(t+1)} \times 200$$

On differentiating with respect to time the previous equation can be rewritten as

$$\frac{T^{(t)}}{200} = \frac{Ae^{-at} - Ae^{-a(t+1)}}{Ae^{-at} + Ae^{-a(t+1)}} \qquad (A3.13)$$

or

$$\frac{T^{(t)}}{200} = \frac{Ae^{-at} \cdot - 1 - e^{-a}}{Ae^{-at} \quad 1 + e^{-a}} \qquad (A3.14)$$

or

$$e^{-a} = \frac{1 - \frac{T^{(t)}}{200}}{1 + \frac{T^{(t)}}{200}} \qquad (A3.15)$$

where, $T^{(t)}$ is the differential of T with respect to time. This implies that for small a and small T

$$1 - a + \text{negligible terms} = 1 - \frac{T}{200} \times 2 + \text{negligible terms}$$

or

$$\boxed{T \approx 100\ a} \qquad (A3.16)$$

- For any a and T and still with single exponential decay

$$T = 100 \tanh \left(\frac{a}{2}\right) \qquad \text{(A3.17)}$$

From these two equations (A3.12 and A3.13) it is apparent that an error exists in the calculations of the percentage clearance per minute when the assumption of the logarithmic decay of the clearance curve is taken into consideration (equation $T = -\log_e 10.\ 100.0$)

# A P P E N D I X A4

## ISOTOPE LOCALISATION MONITOR - MODEL 235

Description of Instrument

The model 235 is a portable battery operated ratemeter with scintilation detector probe designed to have a wide variety of applications.

Six selective channels are provided, tuned to $^{125}I$, $^{133}Xe$, $^{99m}Tc$, $^{51}Cr$ and $^{113m}In$, but other isotopes might be selected at the expense of one of them.

Five ranges are provided up to 3,000 counts per second to cover a wide range of doses with different isotopes. The counts are displayed on a 5 inch linear scale matter.

The selective channels ensure that the background level is kept at a minimum. A "zero trim" control on the rear panel is used to back off a high background count when looking for a small change. Two twim constants are incorporated which are selected by a switch on the front panel.

The hand-hold probe used with the model 235 has a 1 x 1 inches scintillation detector combined with a 1 inch photo-multiplier tube, which is connected to the instrument with a 5 foot lead. The variable depth collimator can be varied between 1 inch and zero in three steps. When not in use the probe and lead are housed in the back of the instrument.

Specification

Ratemeter

| | |
|---|---|
| Ranges: | 0-30, 0-100, 0-300, 0-1000, 0-3000 counts per second. |
| Scale: | 0-3, 0-10 and special scale of 0-120%. |
| Channels: | Six selective channels tuned to specific isotopes such as $^{125}I$, $^{99m}Tc$, $^{133}Xe$, $^{51}Cr$ and $^{113m}In$. |
| Controls: | Range selection with battery check<br>isotope selection.<br>Set percentage variable control.<br>Time constant switch - fast and slow.<br>CPS/set present switch.<br>Gain Trim.<br>Zero Trim. |
| Electronics | Fully transistorised. |
| Time constants: | Approximately 2 and 12 seconds. |
| Recorded output: | 0-1 mA into 1,500 ohms. |
| Audio output: | Jack plus output to earphone (100 ohms). |
| Power: | 2 x $^{PP}9$ batteries. |
| Dimensions: | 10" x 6" x 8" |
| Weights | Ratemeter and battery: 9.5 lbs. |

Remote probe

| | |
|---|---|
| Detector: | 1" x 1" NaI scintillation detector with 1" photomultiplier tube. |
| Lead length: | 5ft. coaxial, detachable. |
| Collimator: | Variable depth collimator between 0-1". Outside diameter : 2.5". Length: 2.5". |
| Probe dimensions: | Length: 8.5" |
| Weights: | Probe and collimator: 3 lbs. |

Controls

Range selection: There are five ranges available : 0-3,000 0-1000, 0-300, 0-100 and 0-30 counts per second. These are read in conjunction with the 0-3 and 0-10 scales on the meter. As two batteries are used there are two battery check positions. For proper operation the meter pointer must be within the square marked "BAT" in both battery positions.

Isotope selection: There are five isotope selection positions which are used for six isotopes:

(a) Iodine 125 has an energy level of 35 Kev - the channel width is set to $\pm$ 15 KeV.

(b) Xenon 133 has an energy level of 80 KeV - the channel width is set to $\pm$ 20 KeV.

(c) Technetium $^{99m}$ has an energy level of 140 KeV - channel width is set to $\pm$ 20 KeV.

(d) Crhomium 51 and Iodine 131. Because these two isotopes have similar energy levels (320 KeV and 364 KeV respectively)

they have been included as a single isotope. The channel width is set at ± 80 keV, at about 347 keV.

(e) Indium 113m has an energy level of 390 KeV - the channel width is set to ± 60 KeV.

Each channel has a fixed channel width which cannot be adjusted. Isotopes other than those described above may be selected at the expense of one of them up to an energy level of 500 KeV.

CPS/percent switch: When in the "CPS" position the reading on the meter is showing counts per second, regardless of the position of the "set percent" control. When in the "Percent" position the "set percent" control is brought into effect and the reading can be adjusted to read 100 per cent on the top scale using a reference source.

Time constant: This varies the time taken for the reading on the meter to reach a steady reading. The two times are 2 secs. and 12 secs.

Gain trim (rear panel): This is a fine gain control to peak any of the channels on its respective isotope. By tuning one channel, all other are automatically correct, except $^{125}I$ which has a preset gain control within the case.

Zero trim (rear panel): Allows accurate adjustment of the 0 c.p.s. position.

Recorder output (rear panel): 0-1 mA into 1500 ohms.

Any reader either galvanometric or potentionmetric, may be used providing the input resistance is greater than 1,500 ohms.

Audio output (rear panel): This output is fed to earphones having a resistance of 100 ohms or greater.

# A P P E N D I X A5

## DUAL CHANNEL ANALYSER - MODEL 45-24

## DESCRIPTION OF INSTRUMENT

The model 45-24 is a combined instrument including high voltage supply for scintillation or Geiger detectors, pulse shaping amplifier, two pulse height analysers and ratemeter with linear as well as logarithmic output.

Twelve ranges are provided up to 20,000 counts per second. The counts are displayed on a percentage ratemeter with a logarithmic and a linear output. The negative input pulses are amplified and shaped through a three-stage linear amplifier with current input and low impedance. The amplifier has a superior overloading characteristic due to the fact that all transistors go into conduction and not into cut-off when a pulse appears. If positive input pulses are connected to the amplifier then only two of the three amplifier stages are used. For this purpose, a front panel switch activated a 10 to 1 attenuator.

The lower and upper pulse height discriminator Channel II is intended for use with $^{125}I$ and is adjusted only by the high voltage to a maximum count-rate. Setting for other isotope energies is possible by adjusting the lower and upper pulse height discriminator Channel I downwards for lower energies. The upper level discriminator in both channels (I and II) has a longer time constant enabling the upper level discriminator to veto the output from the lower level discriminator. Setting for other isotope energies is also possible by adjusting the "set gain" for higher energies up to 10 times; increase of the high voltage setting corresponds to a decrease in energy.

SPECIFICATIONS

1) High Voltage Supply:

| | |
|---|---|
| Voltage Range: | 300-1300 V positive. |
| Current Range: | 0-1 mA at 1000 V, 0-0.7 mA at 1300 V. |
| Indication: | 10 turn counting dial. |
| Stability: | Better than 0.001 % per % mains change; |
| | Better than 0.003% per $^{o}$C temperature change. |
| Connector: | MHV marked HV. |

2) Pulse Amplifier:

| | |
|---|---|
| Input GM: | AC - parallel to input SC; |
| | DC - parallel to HV; |
| | Connector MHV |
| Input SG: | Negative pulse; |
| | Impedance 1000 Ω; |
| | Connector BNC |
| Gain: | Switch at X10 : 500; |
| | Switch at X1 : 50. |
| Pulse Shaping: | 1 µs integration and 1 µs differentiation. |
| Overload: | Less than 5 µs recovery time for 100 times overload. |
| Gain Stability: | Better than 0.03% per $^{o}$C temperature change. |

3) Pulse Height Discriminator Channel I:

| | |
|---|---|
| Discrimination Range: | 0.2-4 V or 50-1000 scale divisions on 10 turn counting dial. |
| Channel Width: | 0.04-4 V or 10-1000 scale divisions on 10 turn counting dial. |

Analysing Time: 3 µs

Mode Switch (Differential): Output for pulses in channel.

Integral: Output for pulses higher than discrimination level.

Stability: Better than 0.003% FS per $^{o}$C temperature change.

Output: 6X positive pulse 1 µs;
BNS connector marked OUT I.

4) Pulse Height Discriminator Channel II:

Discrimination Level: Fixed at 0.08 V 20 scale divisions except when applying an external voltage to the SCAN input (BNC connector); external 0-15 V negative will scan the 20-1000 scale divisons.

Channel Width: Fixed at 0.18 V 45 scale divisions.

Output: 6 V positive pulse 1 µs;
BNC connector marked OUT II.

5) Ratemeter:

Range: 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 5000, 10000 and 20000 counts per second FSD.

Time Constant: 0.3, 1, 3, 10 and 30 seconds.

Indication: 80 mm scale moving coil instrument.

Accuracy: Better than 2% FSD.

Input PB: The input is through a high impedance signal pad internally connected to the OUT I, and the ratemeter is responds to Channel I.
By connecting a normal impedance (approximately 1 KΩ) source to input PB by a coaxial cable

the signal pad will be charted and the ratemeter will respond to the PB input signal (BNC connector).

Output LIN: 100 mV positive FSD for recorder.

Accuracy: Better than 2%;
BNC connector.

Output LOG: 0-100 mV positive for 2 decades for recorder.

Accuracy: Better than 5% on upper 90% of scale;
50-100 mV;
Positive for 1 decade.

6) General:

Power Requirements: 220 V ± 10%;
50 cps;
15 w.

Operating Temperature Range: 0-50 $^{o}$C.

Dimensions: 420 mm wide, 90 mm high, 40 mm deep.

Weight: 6 Kg.

CONTROLS AND CONNECTORS

1) Front Panel:

High Voltage: 10 turn potentiometer for adjusting detector voltage.

Range: 300-1300 V. The counting dial is equipped with a brake.

Discriminator Level: 10 turn potentiometer for adjusting Channel I lower level.

Range: 0.5 to 10.0. The counting dial is equipped with a brake.

Channel Width: 10 turn potentiometer for adjusting Channel I difference between upper and lower level.

Range: 0.1 to 10.0. The counting dial is equipped with a brake.

Gain: X1 or X10 switch for main amplifier gain.

Mode: "Integral"/"Differential" switch. "Integral" means that Channel I only is discriminated downwards. "Differential" means that Channel I is in the "window" mode.

Note: Channel II has fixed lower and upper level.

Ratemeter Range Switch: 4 + 3 push button switch selects ratemeter range.

Range: 10 x 0.5 = 5; 10 x 1 = 10; 10 x 2 = 20; 100 x 0.5 = 50; 100 x 1 = 100; 100 x 2 = 200; 1000 x 0.5 = 500; 1000 x 1 = 1000; 1000 x 2 = 2000; 10000 x 0.5 = 5000; 10000 x 1 = 10000; 10000 x 2 = 20000 counts per second full scale.

Ratemeter Time Constant Switch: 5 push-button switch for selection of ratemeter integrating time.

Range: 0.3, 1, 3, 10 and 30 seconds.

2) Rear Panel:

Mains Receptacle: 220 or 110 V 10% 50-60 cps.

GND Binding Post: Frame (ground).

+15 V BNC Connector: +15 V max 20 mA for preamplifier etc.

-15 V BNC Connector: -15 V max 20 mA for preamplifier etc.

HV MHV
Connector: High Voltage for scintillation detectors etc.

GM MHV
Connector: High voltage parallel to signal input. For Geiger dectectors and for scintillation detectors carrying high voltage bias and signal in the same cable.

SC BNC
Connector: Signal input from scintillation detector etc.

AMP BNC
Connector: Signal input from preamplifier etc. Positive pulses.

SCAN BNC: By applying an external voltage between 0 and -15 V, Channel II is scanned through the full spectrum.

PB BNG
Connector: Ratemeter input is internally connected to the OUT I (Channel I output) through a high impedance signal pad. By connecting a low impedance (less than 2 KΩ) source to PB connector by a coaxial cable the signal pad will be shorted and the ratemeter will respond to the PB signal.

OUT I
BNC Connector: Output from Channel I.

OUT II
BNC Connector: Output from Channel II.

LOG BNC
Connector: Logarithmic ratemeter output over 2 decades 100 mV full scale.

LIN BNC
Connector: Linear output from ratemeter; 100 mV full scale.

# A P P E N D I X A6

## DIRECTIONAL DOPPLER - MODEL 806

## DESCRIPTION OF INSTRUMENT

The Model-806 directional Doppler includes two meters on the front panel indicating the direction of flow and the relative flow velocity. This device introduces a phase-shift prior to detection making possible the identification and separation of positive and negative Doppler shifts depending on the direction of blood flow.

To obtain the directional characteristics, probes of operating frequency in the vicinity of 10 MH are used. The output from the receiving crystal is fed to a pair of phase detectors which compare the receiver output quadrature carriers from the transmitter. The Doppler difference is in the audible range; its frequency is proportional to the velocity of the particles in the blood. The two audible outputs from the two directions, away and towards the probe, are fed to stereo-headphones. The forward flow is heard in one ear and the reverse flow in the other.

For flow velocity recordings the two audio outputs are passed to a pair of zero-crossing detectors and integrators. A cross-coupled clamp between the two circuits is used so that the first arriving signal from a particular reflection inhibits the others and preserves the directional characteristics.

The instrument operates from ordinary torch batteries (1.5V).

## PANEL DESCRIPTION

Oscillator Frequency, controls the frequency of the electrical energy used to activate the transmitting crystal in the probe. It is the nature of the crystal to vibrate more at some frequencies than at others.

The frequency at which it vibrates best is the mechanical resonant frequency, which is marked on one of the plugs of each probe.

Demodulator, is the tuning control for the receiving part of the Doppler (the part that receives the reflected ultrasound).

Earphone Volume, controls the audio signal fed to the stereo output jacks.

Meter, shows condition of the batteries only. As battery voltage falls, performance will be degraded and the meter calibration will also fall off.

Power-High-Low: The transcutaneous probes are normally used in the high jack which utilises all the power the instrument is capable of delivering. For flow studies with peri-arterial probes the low jack is used to minimise the possibility of overloading the receiver with stray energy from the twisted wires.

Common: This is the receiver (demodulator) input jack.

Output Filter, controls the amount of smoothing applied to the output voltages which are recorded.

Calibration Input A and B: These jacks are meant for insertion of known frequencies from an external source to either verify the calibration of the meters or to mark frequency levels on a recorder.

Signal Output A and B: These jacks are used only when two channels are recorded simultaneously. Both outputs are positive, thus flow away from the probe still gives a positive deflection.

Selected: This jack is used when a single channel is reached. The signal fed to this jack is controlled by the switch above it.

Output Level, is a two-channel attenuator used to reduce the signal level for these recorders not capable of handling the full output of this instrument.

Zero-Cross Input, makes the sound waves uniform.

Meter Multiplier: This switch controls the sensitivity of both flow indicating meters.

# A P P E N D I X A7

## RECIRCULATION OF $^{99m}Tc$

AIM

Recirculation of 99m Tc was tested by giving a single injection of 40 µCi of $^{99m}$Tc in the gastrocnemius muscle and by measuring the amount of radioactivity at rest and after exercise for 20 minutes over the point of injection and over the precorduim.

MATERIAL AND METHOD

5 healthy volunteers without any evidence of arterial disease were studied. Their ages ranged between 18 and 25 years.

All the volunteers rested for 20 minutes before starting the test. Forty µCi of $^{99m}$Tc as sodium pertechnate diluted in 0.2 ml of saline were injected into the thickest part of the right gastrocnemius. The probes of two 235-isotope localisation monitors (see Appendix A4) were placed over the site of the injection and over the precordium, at the level of the 4th intercostal space and the position was marked to enable accurate replacement of the probes. The output from the detector was recorded continuously on a CR 552 recorder. Clearance curves were recorded for 5 minutes at rest and for 20 minutes after a 3-minute walk on the treadmill at 4.5 Km per hour.

RESULTS

The amount of radioactivity over the precordium at rest and after exercise indicated the radioactivity as a result of recirculation. This could be expressed as a percentage of the remaining radioactivity at the site of the injection at any time.

Calculations were carried out according to the following

equation:

$$R_{recirc.} = \frac{R_{prec.}}{R_{gastr.}} \times 100$$

where $R_{recirc.}$ was taken to be the radioactivity as a result of recirculation at the $n^{th}$ minute, $R_{prec.}$ the amount of radioactivity over the praccordium at the $n^{th}$ minute and $R_{gastr.}$ the amount of radioactivity at the point of injection at the $n^{th}$ minute.

The mean radioactivity as a result of recirculation was 0.23% at rest; it was 0.65% immediately after exercise; 0.45% at the fifth post-exercise minute; 0.32% at the tenth post-exercise minute; 0.39% at the fifteenth post-exercise minute; finally, it was 0.29% at the twentieth post-exercise minute.

## DISCUSSION

The results suggested that the amount of radioactivity over the precordium as a result of recirculation was, at any time, less than 1 per cent in comparison to the remaining radioactivity at the point of the injection. According to these results and for the purpose of the measurements made in this thesis recirculation of $^{99m}Tc$ can be considered as negligible (see also Appendix A11).

# A P P E N D I X  A8

## Reproducibility of $^{99m}$Tc muscle clearance at rest and after exercise in normal limbs.

Aim

Measurements of the percentage clearance per minute (T) at rest and after exercise by means of $^{99m}Tc$ muscle clearance were carried out on the same normal volunteers repeatedly in order to demonstrate the reproducibility of this method.

Material and Methods

5 normal volunteers (5 limbs) were studied. Their mean age was 32.4 years.

5 tests were carried out on every normal volunteer on 5 consecutive days. All the normal volunteers rested for 20 minutes before starting each test. Forty µCi of $^{99m}Tc$ as sodium pertechnate diluted in 0.2 ml of saline were injected into the thickest part of the calf. The probe of a Pitman 235 - isotope localisation monitor (see Appendix A4) was placed at the site of the injection and the position was marked to enable accurate replacement of the probe after exercise as well as repetition of the injection during the consecutive tests. The output from the detector was recorded continuously on a CR - 552 pen recorder for 10 minutes at rest. Then, the normal volunteers walked on the treadmill for 3 minutes at 4.5 km per hour. Clearance curves were recorded for 20 minutes after the end of the exercise. From the clearance curves obtained, the percentage clearance per minute (T) was calculated using equation 2.1 (see section 2.22).

Results

The results are listed in tables A8.1 to A8.5.

Discussion

The percentage clearance per minute (T) at rest was stable, with an overall coefficient of variation 3 percent. In contrast, immediately after exercise, T was markedly increased in comparison to the resting level. It showed a five to sevenfold increase during the first post-exercise minute and then returned to the resting level and remained unchanged during the post-exercise rest period. The coefficient of variation of T during the first post-exercise minute was 12 percent.

These results suggested that the reproducibility of the percentage clearance per minute T at rest and after exercise measured by means of $^{99m}Tc$ muscle clearance is acceptable.

TABLE A8.1

T at rest (1-10 min) and after exercise (1-20 min) in the calf of a normal limb.

| | PERCENTAGE CLEARANCE PER MINUTE (T) | | | | |
|---|---|---|---|---|---|
| Time (Min) | Test 1 | Test 2 | Test 3 | Test 4 | Test 5 |
| 1 | 3.60 | 3.90 | 4.00 | 3.55 | 4.15 |
| 2 | 3.75 | 4.00 | 3.90 | 3.45 | 4.10 |
| 3 | 3.55 | 3.85 | 4.05 | 3.50 | 4.10 |
| 4 | 3.55 | 3.85 | 3.80 | 3.50 | 4.20 |
| 5 | 3.70 | 3.90 | 3.85 | 3.62 | 4.15 |
| 6 | 3.65 | 3.95 | 3.85 | 3.60 | 4.20 |
| 7 | 3.80 | 3.85 | 4.00 | 3.55 | 4.15 |
| 8 | 3.75 | 4.00 | 4.05 | 3.66 | 4.18 |
| 9 | 3.60 | 3.75 | 4.05 | 3.50 | 4.23 |
| 10 | 3.50 | 3.80 | 4.05 | 3.58 | 4.18 |
| 1 | 25.20 | 2645 | 24.35 | 23.90 | 24.90 |
| 2 | 10.40 | 10.52 | 10.30 | 11.00 | 10.40 |
| 3 | 3.75 | 3.80 | 4.05 | 4.00 | 4.25 |
| 4 | 3.75 | 3.75 | 4.00 | 3.80 | 4.20 |
| 5 | 3.60 | 3.75 | 3.93 | 3.60 | 4.10 |
| 6 | 3.55 | 4.00 | 3.97 | 3.65 | 4.15 |
| 7 | 3.70 | 4.05 | 3.97 | 3.50 | 4.18 |
| 8 | 3.80 | 3.90 | 3.70 | 3.50 | 4.15 |
| 9 | 3.75 | 3.93 | 3.85 | 3.45 | 4.23 |
| 10 | 3.60 | 3.86 | 3.80 | 3.40 | 4.28 |
| 11 | 3.70 | 3.80 | 3.80 | 3.60 | 4.30 |
| 12 | 3.70 | 3.82 | 4.00 | 3.60 | 4.30 |

TABLE A8.1 Continued..../

| | PERCENTAGE CLEARANCE PER MINUTE (T) | | | | |
|---|---|---|---|---|---|
| Time (Min) | Test 1 | Test 2 | Test 3 | Test 4 | Test 5 |
| 13 | 3.58 | 3.80 | 4.00 | 3.66 | 4.36 |
| 14 | 3.50 | 3.80 | 3.93 | 3.52 | 4.26 |
| 15 | 3.63 | 3.90 | 4.05 | 3.50 | 4.30 |
| 16 | 3.60 | 3.95 | 4.10 | 3.55 | 4.20 |
| 17 | 3.75 | 3.90 | 4.10 | 3.45 | 4.10 |
| 18 | 3.70 | 3.85 | 4.00 | 3.80 | 4.15 |
| 19 | 3.65 | 3.80 | 3.90 | 3.56 | 4.15 |
| 20 | 3.65 | 3.85 | 3.95 | 3.45 | 4.20 |

TABLE A8.2

T at rest (1-10 min) and after exercise (1-20 min) in the calf of a normal limb.

| PERCENTAGE CLEARANCE PER MINUTE (T) | | | | | |
|---|---|---|---|---|---|
| Time (Min) | Test 1 | Test 2 | Test 3 | Test 4 | Test 5 |
| 1 | 4.95 | 4.50 | 5.05 | 3.90 | 4.30 |
| 2 | 4.53 | 4.50 | 5.15 | 4.00 | 4.40 |
| 3 | 4.50 | 4.63 | 5.10 | 3.98 | 4.40 |
| 4 | 4.50 | 4.60 | 5.10 | 3.95 | 4.33 |
| 5 | 4.45 | 4.58 | 5.00 | 3.95 | 4.45 |
| 6 | 4.33 | 4.55 | 5.05 | 3.80 | 4.49 |
| 7 | 4.40 | 4.50 | 5.09 | 3.90 | 4.52 |
| 8 | 4.45 | 4.55 | 5.13 | 3.88 | 4.35 |
| 9 | 4.55 | 4.58 | 5.10 | 3.95 | 4.35 |
| 10 | 4.40 | 4.60 | 5.05 | 4.05 | 4.35 |
| 1 | 17.30 | 25.15 | 26.90 | 25.50 | 26.00 |
| 2 | 12.00 | 1055 | 10.90 | 11.00 | 10.33 |
| 3 | 4.45 | 4.60 | 4.95 | 4.00 | 4.50 |
| 4 | 4.45 | 4.60 | 5.15 | 4.05 | 4.50 |
| 5 | 4.60 | 4.60 | 5.10 | 3.98 | 4.55 |
| 6 | 4.45 | 4.50 | 5.05 | 3.95 | 4.50 |
| 7 | 4.53 | 4.58 | 5.05 | 3.90 | 4.48 |
| 8 | 4.55 | 4.66 | 5.10 | 3.95 | 4.30 |
| 9 | 4.50 | 4.70 | 5.08 | 4.00 | 4.33 |
| 10 | 4.60 | 4.50 | 5.03 | 4.03 | 4.40 |
| 11 | 4.50 | 4.83 | 5.09 | 4.05 | 4.45 |
| 12 | 4.40 | 4.62 | 5.10 | 4.00 | 4.50 |

TABLE A8.2... Continued/

| | PERCENTAGE CLEARANCE PER MINUTE (T) | | | | |
|---|---|---|---|---|---|
| Time (min) | Test 1 | Test 2 | Test 3 | Test 4 | Test 5 |
| 13 | 4.40 | 4.59 | 5.15 | 3.95 | 4.50 |
| 14 | 4.55 | 4.55 | 5.18 | 3.80 | 4.33 |
| 15 | 4.50 | 4.55 | 5.12 | 3.83 | 4.37 |
| 16 | 4.55 | 4.80 | 5.05 | 3.90 | 4.38 |
| 17 | 4.45 | 4.70 | 5.10 | 4.15 | 4.30 |
| 18 | 4.50 | 4.60 | 5.05 | 4.08 | 4..40 |
| 19 | 4.55 | 4.50 | 5.15 | 4.00 | 4.45 |
| 20 | 4.50 | 4.50 | 5.05 | 4.00 | 4.50 |

TABLE A8.3

T at rest (1-10 min) and after exercise (1-20 min) in the calf of a normal limb.

| | PERCENTAGE CLEARANCE PER MINUTE (T) | | | | |
|---|---|---|---|---|---|
| Time (Min) | Test 1 | Test 2 | Test 3 | Test 4 | Test 5 |
| 1 | 4.84 | 5.20 | 4.60 | 4.20 | 4.90 |
| 2 | 4.76 | 4.90 | 4.75 | 4.35 | 5.15 |
| 3 | 4. 92 | 5.15 | 4.80 | 4.15 | 5.00 |
| 4 | 4.85 | 5.00 | 4.65 | 4.20 | 5.00 |
| 5 | 4.60 | 4.85 | 4.70 | 4.40 | 5.20 |
| 6 | 4.78 | 4.70 | 4.70 | 4.25 | 5.15 |
| 7 | 4.93 | 4.90 | 4.95 | 4.25 | 5.10 |
| 8 | 4.80 | 5.00 | 4.80 | 4.30 | 5.05 |
| 9 | 4.30 | 4.80 | 4.75 | 4.35 | 4.90 |
| 10 | 4.65 | 5.10 | 4.65 | 4.25 | 5.05 |
| 1 | 26.35 | 27.80 | 25.90 | 26.85 | 27.10 |
| 2 | 10.20 | 11.45 | 12.00 | 11.00 | 10.50 |
| 3 | 5.80 | 5.00 | 4.90 | 5.00 | 5.05 |
| 4 | 4.90 | 4.75 | 5.1- | 4.25 | 5.20 |
| 5 | 4.45 | 5.15 | 4.70 | 4.30 | 5.10 |
| 6 | 4.70 | 5.05 | 4.50 | 4.30 | 5.15 |
| 7 | 4.85 | 4.90 | 4.60 | 4.15 | 5.20 |
| 8 | 4.93 | 5.10 | 4.75 | 4.23 | 5.18 |
| 9 | 4.38 | 5.10 | 4.75 | 4.28 | 5.30 |
| 10 | 5.05 | 4.80 | 4.60 | 4.15 | 5.05 |
| 11 | 4.80 | 4.90 | 4.65 | 4.40 | 5.10 |
| 12 | 4.60 | 4.95 | 4.80 | 4.32 | 5.15 |

TABLE A8.3 Continued.../

| | PERCENTAGE CLEARANCE PER MINUTE (T) | | | | |
|---|---|---|---|---|---|
| Time (min) | Test 1 | Test 2 | Test 3 | Test 4 | Test 5 |
| 13 | 4.75 | 5.10 | 4.60 | 4.25 | 5.25 |
| 14 | 4.38 | 5.00 | 4,55 | 4.20 | 5.15 |
| 15 | 4.85 | 4.75 | 4.70 | 4.15 | 5.00 |
| 16 | 4.95 | 5.25 | 4.70 | 4.25 | 4.95 |
| 17 | 4.60 | 5.10 | 4.65 | 4.32 | 5.05 |
| 18 | 4.75 | 4.95 | 4.50 | 4.28 | 5.23 |
| 19 | 4.50 | 5.15 | 4.60 | 4.25 | 5.15 |
| 20 | 4.80 | 4.95 | 4.65 | 4.25 | 5.10 |

TABLE A8.4

T at rest (1-10 min) and after exercise (1-20 min) in the calf of a normal limb.

| Time (Min) | PERCENTAGE CLEARANCE PER MINUTE (T) | | | | |
|---|---|---|---|---|---|
| | Test 1 | Test 2 | Test 3 | Test 4 | Test 5 |
| 1 | 4.70 | 4.55 | 4.15 | 4.95 | 4.05 |
| 2 | 4.80 | 4.55 | 4.20 | 4.80 | 3.95 |
| 3 | 4.75 | 4.63 | 4.25 | 5.00 | 4.15 |
| 4 | 4.60 | 4.78 | 4.25 | 5.00 | 4.10 |
| 5 | 4.80 | 4.50 | 4.28 | 4.95 | 4.10 |
| 6 | 4.83 | 4.56 | 4.19 | 5.05 | 4.08 |
| 7 | 4.77 | 4.50 | 4.15 | 5.05 | 4.05 |
| 8 | 4.72 | 4.55 | 4.25 | 4.88 | 4.10 |
| 9 | 4.65 | 4.53 | 4.20 | 5.00 | 4.05 |
| 10 | 4.70 | 4.50 | 4.18 | 4.90 | 4.00 |
| 1 | 26.05 | 27.05 | 25.90 | 26.00 | 25.30 |
| 2 | 10.70 | 11.00 | 11.33 | 10.70 | 11.50 |
| 3 | 4.90 | 4.55 | 4.20 | 4.83 | 4.00 |
| 4 | 4.85 | 4.70 | 4.20 | 5.00 | 4.00 |
| 5 | 4.70 | 4.60 | 4.20 | 4.90 | 4.00 |
| 6 | 4.80 | 4.55 | 4.32 | 4.95 | 4.05 |
| 7 | 4.65 | 4.58 | 4.37 | 5.05 | 4.10 |
| 8 | 4.70 | 4.70 | 4.35 | 5.05 | 3.95 |
| 9 | 4.83 | 4.68 | 4.30 | 4.90 | 3.98 |
| 10 | 4.80 | 4.63 | 4.25 | 4.88 | 3.95 |
| 11 | 4.77 | 4.61 | 4.19 | 4.96 | 4.00 |
| 12 | 4.80 | 4.72 | 4.18 | 4.90 | 4.15 |
| 13 | 4.65 | 4.70 | 4.20 | 5.00 | 4.05 |

TABLE A8.4... Continued/

| | PERCENTAGE CLEARANCE PER MINUTE (T) | | | | |
|---|---|---|---|---|---|
| Time (Min) | Test 1 | Test 2 | Test 3 | Test 4 | Test 5 |
| 14 | 4.75 | 4.65 | 4.20 | 5.05 | 4.03 |
| 15 | 4.70 | 4.55 | 4.25 | 4.90 | 3.95 |
| 16 | 4.75 | 4.50 | 4.25 | 4.98 | 3.95 |
| 17 | 4.88 | 4.55 | 4.22 | 4.95 | 4.10 |
| 18 | 4.65 | 4.52 | 4.20 | 4.99 | 3.98 |
| 19 | 4.69 | 4.43 | 4.15 | 5.00 | 4.00 |
| 20 | 4.70 | 4.53 | 4.20 | 5.05 | 4.03 |

TABLE A8.5

T at rest (1-10 min) and after exercise (1-20 min) in the calf of a normal limb.

| | PERCENTAGE CLEARANCE PER MINUTE (T) | | | | |
|---|---|---|---|---|---|
| Time (min) | Test 1 | Test 2 | Test 3 | Test 4 | Test 5 |
| 1 | 5.10 | 4.74 | 4.90 | 4.70 | 5.05 |
| 2 | 5.20 | 4.80 | 4.70 | 4.90 | 4.95 |
| 3 | 5.15 | 4.80 | 5.00 | 4.80 | 5.00 |
| 4 | 5.15 | 4.60 | 5.05 | 4.85 | 5.00 |
| 5 | 5.25 | 4.65 | 4.75 | 4.80 | 4.95 |
| 6 | 5.23 | 4.75 | 4.75 | 4.85 | 5.10 |
| 7 | 5.30 | 4.85 | 4.85 | 4.75 | 5.15 |
| 8 | 5.13 | 4.80 | 4.80 | 4.90 | 5.00 |
| 9 | 5.18 | 4.75 | 4.80 | 4.75 | 5.05 |
| 10 | 5.18 | 4.70 | 4.70 | 4.80 | 4.95 |
| 1 | 28.75 | 28.00 | 27.33 | 27.00 | 26.90 |
| 2 | 10.70 | 12.00 | 11.20 | 10.90 | 11.30 |
| 3 | 5.00 | 4.80 | 5.00 | 4.95 | 5.05 |
| 4 | 5.10 | 4.80 | 4.90 | 4.75 | 5.05 |
| 5 | 5.15 | 4.75 | 4.75 | 4.85 | 5.15 |
| 6 | 5.22 | 4.60 | 4.75 | 4.80 | 5.08 |
| 7 | 5.20 | 4.65 | 4.70 | 4.78 | 4.95 |
| 8 | 5.13 | 4.63 | 4.70 | 4.79 | 5.03 |
| 9 | 5.15 | 4.70 | 4.82 | 5.00 | 5.00 |
| 10 | 5.10 | 4.77 | 4.83 | 4.90 | 5.00 |
| 11 | 5.10 | 4.60 | 4.90 | 4.75 | 4.90 |
| 12 | 5.18 | 4.65 | 4.75 | 4.83 | 4.97 |
| 13 | 5.26 | 4.80 | 4.70 | 4.80 | 5.03 |
| 14 | 5.25 | 4.75 | 4.75 | 4.85 | 5.00 |

TABLE A8.5 .. Continued/

| | PERCENTAGE CLEARANCE PER MINUTE (T) | | | | |
|---|---|---|---|---|---|
| Time (Min) | Test 1 | Test 2 | Test 3 | Test 4 | Test 5 |
| 15 | 5.25 | 4.80 | 4.88 | 4.85 | 5.05 |
| 16 | 5.15 | 4.80 | 4.77 | 4.90 | 5.15 |
| 17 | 5.10 | 4.90 | 4.70 | 4.77 | 5.08 |
| 18 | 5.10 | 4.86 | 4.80 | 4.75 | 5.05 |
| 19 | 5.20 | 4.75 | 4.80 | 4.75 | 5.05 |
| 20 | 5.13 | 4.75 | 4.85 | 4.80 | 5.00 |

# A P P E N D I X A9

## THE COMPARISON OF $^{99m}$Tc AND $^{133}$Xe FOR MEASURING CHANGES IN BLOOD FLOW

AIM

The validity of $^{99m}$Tc as a local radioactive tracer for the measurement of the flow of blood was tested by comparing the results obtained by $^{99m}$Tc clearance to the results obtained by $^{133}$Xe clearance, at rest and after exercise.

MATERIAL AND METHOD

5 healthy volunteers without any evidence of arterial disease were studied. Their ages ranged between 21 and 30 years.

All the normal volunteers rested for 20 minutes before starting the test. Forty µCi of $^{99m}$Tc diluted in 0.2 ml of saline were injected into the thickest part of the right gastrocnemius; the probe of a 235-isotope localisation monitor (see Appendix A4) was placed at the site of the injection and the position was marked to enable accurate replacement of the probe after exercise. The output from the detector was recorded continuously on a double-pen CR-552 recorder for 10 minutes at rest. Then, the normal volunteers walked on the treadmill for 3 minutes at 4.5 Km per hour. The clearance curve was recorded for 20 minutes after the end of the exercise. From the clearance curves obtained the percentage clearance per minute (T) was calculated using equation 2.1 (see Section 2.22).

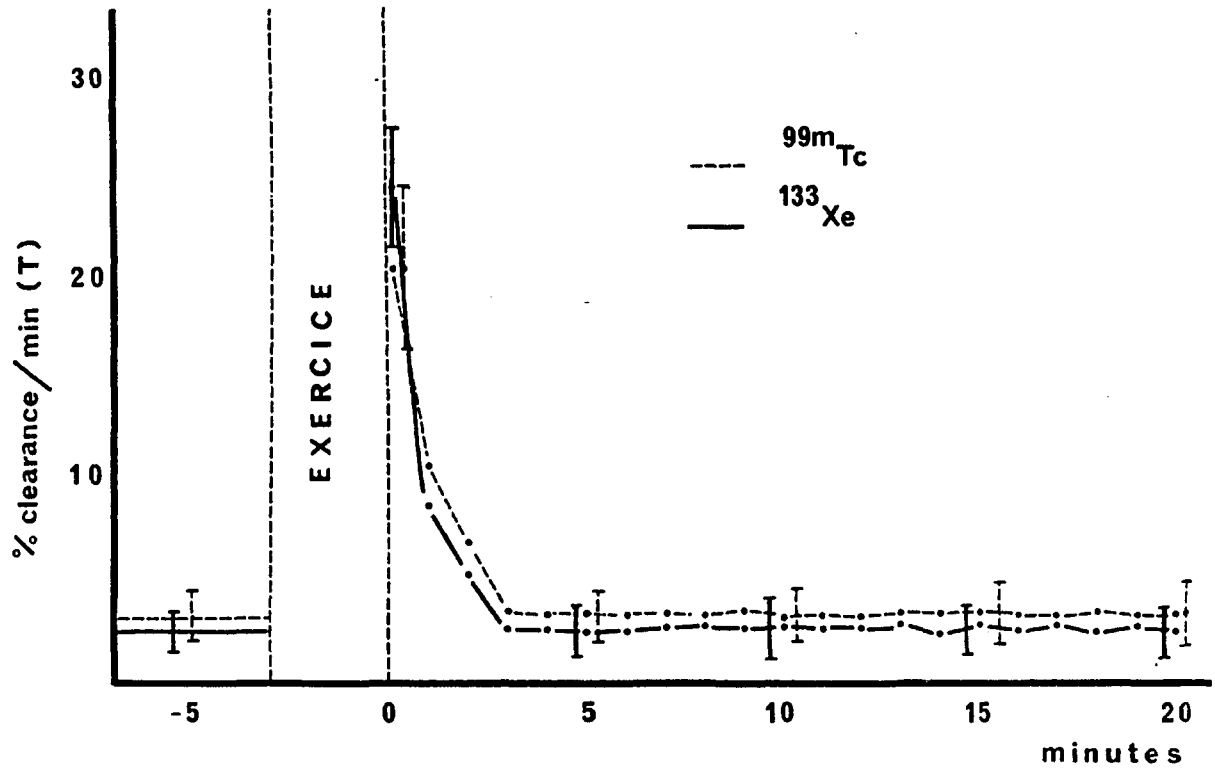
The following day, 100 µCi of $^{133}$Xe diluted in 0.2 ml of saline were injected into the same muscle at the site of the previous injection of $^{99m}$Tc. The same procedure was repeated.

RESULTS

Figure A9.1 shows the mean values of T and standard deviation obtained from the muscle clearance curves of $^{99m}$Tc and $^{133}$Xe. It demonstrates that at rest, T for $^{99m}$Tc was stable but slightly higher than T for $^{133}$Xe. This difference was not significant. In contrast, during the first post-exercise minute, the values of T for $^{99m}$Tc were lower than the corresponding values of T for $^{133}$Xe (21 ± 3.9 and 25.1 ± 3.0 respectively). Finally, during the second post-exercise minute and thereafter T for $^{99m}$Tc was slightly, but not significantly, higher than the corresponding T for $^{133}$Xe.

DISCUSSION

These results demonstrate that flow measurements by means of 99m Tc and $^{133}$Xe muscle clearance, before and after exercise, do not show any significant difference at rest and after the first post-exercise minute. A significant difference exists in normal limbs at high flow rates, i.e. post-exercise hyperaemia.




Correlation of the mean values T and standard deviation obtained from the muscle clearance curves of $^{99m}Tc$ and $^{133}Xe$.

FIG. A9.1

# A P P E N D I X A10

## DERIVATION OF THE EQUATIONS FOR CALCULATING a, $Q_o$ AND $\lambda$

It has already been deduced (see Section 4.21) that in the 2-pool haemodynamic model the amount of blood ($W_n$) that leaves pool 2 via B (Fig. 4.1) from time t=0 to time t=n is proportional to the total percentage clearance ($D_n$) between t=0 and t=n. Thus,

$$W_n = K.D_n \qquad (4.15)$$

where K is the muscle to blood partition coefficient for the isotope used.

It has also been shown in the same section (Section 4.21: Equations 4.17, 4.18 and 4.19) that the amount of blood which leaves pool 2 via B after 5 ($D_5$), ten ($D_{10}$) and 20 ($D_{20}$) tiptoe cycles is:

$$KD_5 = Q_o(1 - \beta^5) + \frac{\lambda}{a}(5a - 1 + \beta^5) \qquad (A10.1)$$

$$KD_{10} = Q_o(1-\beta^{10}) + \frac{\lambda}{a}(10a-1+\beta^{10}) \qquad (A10.2)$$

$$KD_{20} = Q_o(1-\beta^{20}) + \frac{\lambda}{a}(20a-1+\beta^{20}) \qquad (A10.3)$$

Equation A10.1 can be rewritten as:

$$KD_5 - Q_o(1 - \beta^5) = \frac{\lambda}{a}(5a - 1 + \beta^5) \qquad (A10.4)$$

Similarly, equation A10.2 can be rewritten as:

$$KD_{10} - Q_o(1-\beta^{10}) = \frac{\lambda}{a}(10a-1+\beta^{10}) \qquad (A10.5)$$

and equation A10.3 can be rewritten as follows:

$$KD_{20} - Q_o(1-\beta^{20}) = \frac{\lambda}{a}(20a-1+\beta^{20}) \qquad (A10.6)$$

In order to eliminate $\lambda$, equation A10.5 is divided by equation A10.4; similarly, equation A10.6 is divided by equation A10.5. Thus,

$$\frac{KD_{10} - Q_o(1 - \beta^{10})}{KD_5 - Q_o(1 - \beta^5)} = \frac{10a - 1 + \beta^{10}}{5a - 1 + \beta^5} \qquad (A10.7)$$

$$\frac{KD_{20} - Q_o(1 - \beta^{20})}{KD_{10} - Q_o(1 - \beta^{10})} = \frac{20a - 1 + \beta^{20}}{10a - 1 + \beta^{10}} \qquad (A10.8)$$

Equation A12.7 can be rewritten as follows:

$$KD_{10}(5a - 1 + \beta^5) - Q_o(1 - \beta^{10})(5a - 1 + \beta^5) =$$
$$KD_5(10a - 1 + \beta^{10}) - Q_o(1 - \beta^5)(10a - 1 + \beta^{10}) \qquad (A10.9)$$

or:

$$Q_o[(1 - \beta^5)(10a - 1 + \beta^{10}) - (1 - \beta^{10})(5a - 1 + \beta^5)]$$
$$= KD_5(10a - 1 + \beta^{10}) - KD_{10}(5a - 1 + \beta^5) \qquad (A10.10)$$

Similarly, equation A10.8 can be rewritten as follows:

$$Q_o[(1-\beta^{10})(20a - 1 + \beta^{20}) - (1 - \beta^{20})(10a - 1 + \beta^{10})]$$
$$= KD_{10}(20a - 1 + \beta^{20}) - KD_{20}(10a - 1 + \beta^{10}) \qquad (A10.11)$$

In order to eliminate $Q_o$, equation A10.11 is divided by equation A10.10. Thus,

$$\frac{(1 - \beta^{10})(20a - 1 + \beta^{20}) - (1 - \beta^{20})(10a - 1 + \beta^{10})}{(1 - \beta^5)(10a - 1 + \beta^{10}) - (1 - \beta^{10})(5a - 1 + \beta^5)}$$
$$= \frac{D_{10}(20a - 1 + \beta^{20}) - D_{20}(10a - 1 + \beta^{10})}{D_5(10a - 1 + \beta^{10}) - D_{10}(5a - 1 + \beta^5)} \qquad (A10.12)$$

Assuming that a is small (i.e. $a^2 \ll a$) then equation A10.12 can be rewritten as:

$$\frac{(1+\beta^5)(20a - 1 + \beta^{20}) - (1 + \beta^{10})(1 + \beta^5)(10a - 1 + \beta^{10})}{(10a - 1 + \beta^{10}) - (1 + \beta^5)(5a - 1 + \beta^5)}$$
$$= \frac{D_{10}(20a-1+1-20a+190a^2) - D_{20}(10a-1+1-10a+45a^2)}{D_5(10a-1+1-10a+45a^2) - D_{10}(5a-1+1-5a+10a^2)} \qquad (A10.13)$$

Equation A10.13 can be rewritten as:

$$\frac{(1+1-5a)[(190a^2) - (2-10a)(45a^2)]}{45a^2 - (2-5a)(10a^2)} = \frac{190D_{10} - 45D_{20}}{45D_5 - 10D_{10}} \qquad (A10.14)$$

or:

$$\frac{(2-5a)(190a^2-90a^2)}{45a^2-10a^2} = \frac{38D_{10}-9D_{20}}{9D_5-2D_{10}} \qquad \text{(A10.15)}$$

or:

$$\frac{50}{7}(2-5a) = \frac{38D_{10}-9D_{20}}{9D_5-2D_{10}} \qquad \text{(A10.16)}$$

or:

$$a = \frac{1}{5}\left(2 - \frac{7}{50} \cdot \frac{38D_{10}-9D_{20}}{9D_5-2D_{10}}\right) \qquad \text{(A10.17)}$$

or:

$$a = \frac{1}{5}\left(\frac{900D_5-200D_{10}-266D_{10}+63D_{20}}{50(9D_5 - 2D_{10})}\right) \qquad \text{(A10.18)}$$

or:

$$a = \frac{63D_{20}-466D_{10}+900D_5}{250(9D_5 - 2D_{10})} \qquad \text{(A10.19)}$$

Then $Q_o$ can be calculated from equation A10.10, thus:

$$Q_o = \frac{K[D_5(10a-1+\beta^{10}) - D_{10}(5a-1+\beta^5)]}{(1-\beta^5)(10a-1+\beta^{10}) - (1-\beta^{10})(5a-1+\beta^5)} \qquad \text{(A10.20)}$$

Finally, $\lambda$ can be calculated from equation A10.4. Thus,

$$\lambda = \frac{[KD_5-Q_o(1-\beta^5)]}{10a} \qquad \text{(A10.21)}$$

In order to avoid escalation of errors, approximation for, a, is necessary to linearise the previous equations. Once, a, is calculated $Q_o$ and $\lambda$ are computed exactly without any approximation.

Equations A10.19, A10.20 and A10.21, are those used for the calculation of a, $Q_o$ and $\lambda$ from $D_5$, $D_{10}$ and $D_{20}$ obtained from the studies in Part III of this thesis.

# A P P E N D I X A11

## INTERACTION BETWEEN TWO RADIATION SOURCES IN THE LOWER LIMBS

AIM

The possible interaction between two radiation sources in the lower limbs was tested by measuring the radioactivity at the site of a single injection of $^{99m}$Tc in the calf and the radioactivity at a similar site of the non-injected calf.

MATERIAL AND METHODS

Five healthy volunteers without any evidence of arterial disease were studied. Their ages ranged between 22 and 31 years.

Forty µCi of 99m Tc as sodium pertechnate diluted in 0.2 ml of saline were injected into the thickest part of the right gastrocnemius and the normal volunteer stood up with his limbs placed 20 cm apart. The probes of two 235-isotope localisation monitors (see Appendix A4) in full collimation were placed above the point of the injection and at a similar site on the non-injected calf at a constant distance from the skin. The output from the detectors was recorded continuously on a CR552 double-pen recorder.

Clearance curves were obtained before, during and after five, ten and twenty movements on tiptoe which were separated by 3-minute resting intervals.

RESULTS

The amount of radioactivity in the non-injected calf indicated the sum of radioactivity due to re-circulation (see Appendix A7) and to the radiation effect produced by the injected calf. This was expressed as a percentage of the remaining radioactivity at the site of the injection

at any time. Calculations were carried out according to the following equation (see also Appendix A7):

$$S = \frac{R_n}{R_o} \times 100$$

where S = the sum of radioactivity at the non-injected calf due to re-circulation and to the radiation effect produced by the injected calf,

$R_n$ = the amount of radioactivity on the non-injected calf at the $n^{th}$ minute, and

$R_o$ = the amount of radioactivity at the site of injection at the $n^{th}$ minute.

The results demonstrated that S at rest was 0.55%; it was 0.73% at the end of the fifth tiptoeing session, 0.69% at the end of the tenth tiptoeing session and finally, 0.82% at the end of the twentieth tiptoeing session.

## DISCUSSION

The results suggest that the amount of radioactivity at the non-injected calf at any time was less than 1.0% in comparison to the remaining radioactivity at the site of the injection. Since this is the result of re-circulation and of the radiation effect produced by the injected adjacent calf it can be clearly deduced that re-circulation of $^{99m}$Tc and the interaction of two radiation sources is negligible for the studies in this thesis (see also Appendix A7).

# A P P E N D I X A12

## THE RELATIONSHIP OF $^{99m}$Tc MUSCLE CLEARANCE TO CALF FLOW MEASURED BY MERCURY STRAIN GAUGE PLETHYSMOGRAPHY DURING EXERCISE

AIM

Changes in muscle blood flow stimulated by active exercise determined by $^{99m}$ Tc muscle clearance and strain-gauge plethysnography in the same calf simultaneously are presented in this Appendix.

MATERIAL AND METHODS

Three healthy volunteers without any evidence of arterial disease were studied. They rested horizontally for 20 minutes before starting the test. Then, 40 µCi of 99m Tc as sodium pertechnate diluted in 0.2 ml of saline were injected into the thickest part of the right gastrocnemius. The probe of a Pitman 235-isotope lacalisation monitor (see Appendix A4) was placed at the site of the injection at a constant distance from the skin. The output from the detector was recorded continuously on a CR 552 recorder. A mercury strain-gauge was placed around the thickest part of the calf at the site of the injection. This was connected to the equipment supplied by Hokanson which incorporated automatic calibration facilities (Model EC-2). A 25 cm venous tourniquet was applied at the proximal part of the thigh which could be inflated rapidly (in less than 1 second) to 60 mm Hg for 5 seconds during which a reading was taken. (Siggaard Andersen and Petersen, 1969). Readings with the strain-gauge were obtained every minute, initially at rest and then after active plantar flexion and dorseflection of the foot against resistance for a total period of 20 minutes. The points at which these readings were taken were marked on the tracing of the clearance curve and thus it became possible to calculate the value of T that corresponded to each strain-gauge measurement. From the clearance curves obtained the percentage clearance per minute (T) was calculated using equation 2.1 (see Section 2.22). Strain-gauge measurements were expressed in ml per 100 ml per minute.

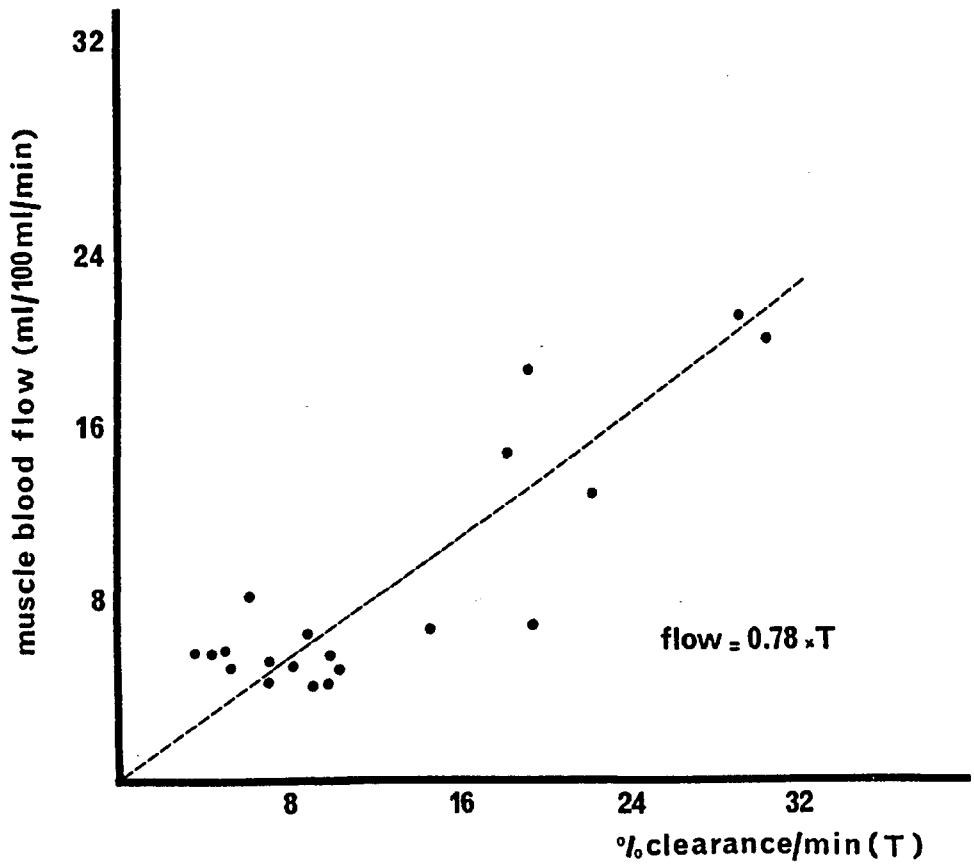
RESULTS

The results are demonstrated in Figure A12.1 where the mean values of the strain-gauge measurements expressed in ml per 100 ml per minute were plotted against the corresponding mean values of the percentage clearance per minute (T) for a total period of 20 minutes. They suggest that the muscle to blood partition coefficient (K) for $^{99m}Tc$ is approximately 0.8.

DISCUSSION

The results supported the suggestion made by Veall (N. Veall, 1977) that the partition coefficient, K, for $^{99m}$ Tc for the first 20 minutes after injection is approximately 0.8. However, it should be pointed out that T is proportional to fluctuations of flow in the muscle while the strain gauge plethysmography measures flow in the muscle and other expandable tissues. For this reason this cannot be used as a method of verification of the value of K but a very rough indication of its possible value.

As pointed out in Section 4.32, the partition coefficient K is proportional to $Q_o$ (see Equation 4.21) and thus a 50 per cent error can lead to an equal 50 per cent error in the estimation of the amount of blood in pool 2 of the 2-pool haemodynamic model. This error will be the same and in the same direction in all limbs studied and it will not invalidate the results which, after all, are used to indicate changes on exercise or differences in the various groups studied. Very little use is made of absolute values.




Correlation of the mean values of the strain-gauge measurements and the percentage clearance per minute (T).

FIG. A12.1

# A P P E N D I X A13

## SIMULTANEOUS MEASUREMENTS OF $^{99m}Tc$ MUSCLE CLEARANCE AT THE SITE OF A SINGLE INJECTION IN THE CALF USING HEAVY AND LIGHT PROBES

Aim

Initially, a, Qo and λ were calculated (see section 4.3) from clearance curves obtained with heavy probes using the Pitman 235-isotope localisation monitors (see Appendix A4). When the dual channel analysers and the light probes (see Appendix A5) became available they were used instead of the 235- isotope localisation monitors. In order to test the accuracy and correlation of these instruments clearance curves were obtained at the site of a single injection in the calf using light and heavy probes simultaneously.

Material and Method

Three healthy volunteers without any evidence of arterial disease and two patients with long occlusion of the superficial femoral artery shown on the aortogram were studied. The ages of the normal volunteers ranged between 21 and 26 years; the ages of the two patients, with arterial disease were 46 and 54 years respectively.

Forty μCi of $^{99m}Tc$ as sodium pertechnate diluted in 0.2 ml of saline were injected into the thickest part of the gastrocnemius and the point was marked to enable accurate replacement of the probes. Then the normal volunteers and the patients stood up, and the heavy probe of a 235- isotope localisation monitor was placed at the site of the injection at a constant distance from the skin. This was ensured by marking the position of the foot on the floor. A light probe attached on a dual channel analyser was strapped on the same calf at the site of the injection. The output from the detectors was recorded continuously on a double-pen CR 552 recorder.

Clearance curves were obtained before, during and after five, ten and twenty movements on tiptoe separated by resting intervals.

From each clearance curve the total percentage clearance $D_5$, $D_{10}$ $D_{20}$ was calculated as shown in figure 5.8. Finally, from these measurements a, Qo and $\lambda$ were calculated using the equations developed in section 4.21.

Results

The results are shown in table A13.1. They demonstrated that the values of a, Qo and $\lambda$ calculated from clearance curves obtained with the heavy probe did not show any significant difference in comparison to the corresponding values of a, Qo and $\lambda$ calculated from clearance curves obtained with the light probe.

Discussion

These results suggested that the light probes, strapped on the leg, could be used instead of the heavy probes, not attached to the leg, without affecting the calculations of a, Qo and $\lambda$. In fact, the light probes had the advantage, that the measures taken to ensure that the distance between the skin and the heavy probes remained constant at the end of each period of exercise, could now be ignored.

TABLE A13.1

The values of a, Qo and λ calculated from clearance curves obtained with heavy and light probes.

| | LIGHT PROBE (DUAL CHANNEL ANALYSER) | | | HEAVY PROBE (235-ISOTOPE LOCALISATION MONITOR) | | |
|---|---|---|---|---|---|---|
| No of Limb | a | Qo | λ | a | Qo | λ |
| 1 (Normal) | 8.6 | 19.98 | 2.16 | 8.5 | 19.83 | 2.26 |
| 2 (Normal) | 0.5 | 19.42 | 2.09 | 0.4 | 19.35 | 2.08 |
| 3 (Normal) | 7.1 | 20.78 | 2.26 | 7.1 | 20.93 | 2.19 |
| 4 (Superficial femoral artery occlusion) | 17.6 | 4.36 | 0.50 | 16.8 | 4.10 | 0.49 |
| 5 (Superficial femoral artery occlusion) | 13.4 | 4.80 | 0.49 | 14.3 | 4.48 | 0.43 |

# A P P E N D I X A14

## THE USE OF CDC 6400 COMPUTER FOR THE CALCULATIONS AND PLOTTING OF GRAPHS OF $^{99m}Tc$ MUSCLE CLEARANCE.

## Introduction

From the clearance curves obtained with $^{99m}Tc$ muscle clearance method the percentage clearance per minute (T), maximum post-exercise T, total excess T, Hyperaemic Index, a,Qo and λ were calculated using the equations developed in previous sections (see sections 2.22, 4.21 and 4.32). These calculations, though not difficult, were tedious, time consuming and subject to human error. All these were done by a computer with considerable advantages.

The computing facilities and listings of the programs used in the various clinical studies are given below.

## Computing Facilities

A CDC 6400 computer was employed based at Imperial College, London University. This was connected via a dedicated line to a teletype input terminal and a video display unit located at the Vascular Laboratory, St. Mary's Hospital.

The computer language employed in interactive computations was Basic and in batch processing was Fortran IV.

## Data Acquisition - I+O Facilities

The results of the tests carried out on normal volunteers and patients with peripheral arterial and venous diseases were recorded on a double-pen CR 552 recorder (see sections 2.21, 2.211, 3.52 and 4.31). The values of points from the clearance curves were entered via the Keyboard of the teletype interactively as requested by the

computer during the execution of the programs. The results were printed on the teletype output at the end of the programms.

PROGRAM NICOS AND NICOS 2

Program for the evaluation of T before and after exercise, maximum post-exercise T, total excess post-exercise T and the Hyperaemic Index. (See section 2.21)

The program NICOS 2 (see p. 358), evaluated the percentage clearance per minute (T) before and after exercise, maximum post-exercise T, total excess post-exercise T and the Hyperaemic Index from data supplied from a given curve (values of points from the clearance curve at one minute intervals). Thirty numbers were supplied and the evaluations were carried out according to equation 2.1 (see section 2.22).

In order to compare these results with Lassen's formula (see Appendices A2 and A3) the same data was employed but equation A3.12 (see Appendix A3) was used instead. (Program NICOS - see p. 363).

The outputs of NICOS and NICOS 2 contained the following: (i) the input points (ii) the percentage clearance per minute (T) before and after exercise (iii) the table of differences between the mean value of T at rest and its values after exercise (iv) from the above, the mean value of T at rest (MEAN), the total excess post-exercise T (EXCESS) the maximum post-exercise T (HEIGHT) and the Hyperaemic Index (INDEX) were printed.

Listing of programs NICOS and NICOS 2 with example of input and output for data pertinent to thigh and calf measurements for a normal

volunteer and for patients with peripheral arterial disease are shown in figures A14.1 to A14.10.

PROGRAM MEAN

Program for the evaluation of the mean values of T before and after exercise, maximum post-exercise T, total excess post-exercise T and the Hyperaemic Index (see sections 2.22 and 2.23) was called "MEAN".

The entire set of results were divided into 4 groups : group A (normal limbs); group B (limbs with iliac occlusion only); group C (limbs with superficial femoral artery occlusion only) and group D (limbs with combined proximal and distal arterial lesions ) (see section 3.22).

The mean values of T before and after exercise, maximum post-exercise T, total excess post-exercise T and the Hyperaemic Index were calculated for each of these groups individually by the program MEAN (see p. 368). The input to the program was the appropriate values for the entire group (e.g. group 0 = normal limbs).

Listing of program MEAN with examples of input and output are shown in figures A14.11 to A14.15.

PROGRAM CLEAR

Program for the evaluation of T before, during and after exercise (see section 2.3) was called "CLEAR".

The program CLEAR (see p. 373) evaluated the percentage clearance per minute (T) from data supplied before, during and after exercise

from a given curve. Eighty sets of points were employed in these calculations, and the calculations proceeded in accordance with equation 2.1 (see section 2.22). The results of the calculations were stored in an array and then plotted against time using a line printer with the plotting subroutine appearing at the end of the program CLEAR (Fig A14.16).

Examples of the results for T before, during and after exercise are shown in figures A14.17 to A14.24. In these figures the input data values before, during and after exercise, and the computed clearance values for the same periods are shown.

PROGRAM K6

Program for the evaluation of a, Qo and λ (see section 5.22).

This program (Fig A14.25) computed the parameters a, Qo and λ in accordance with equations 4.20, 4.21 and 4.22 (see sections 4.21 and 4.32).

The values, $D_5$, $D_{10}$ and $D_{20}$ (see section 4.21) were required for the calculations of the above parameters.

The output from the program contained the given values of $D_5$, $D_{10}$ and $D_{20}$ and the required parameters a, Qo and λ. Examples are in figures A14.26.

```
010 PROGRAM NICOS(INPUT,OUTPUT,TAPE1,TAPE2)
020 DIMENSION A(31),T(31),D(31)
030 10 CONTINUE
040 DO 50 I=1,31
050 READ(,END.=999,1,11)J,A(I)
055 11 FORMAT(I2,1X,F8.2)
060 50 CONTINUE
070 DO 60 I=1,30
080 A1=(A(I)-A(I+1))/(A(I)+A(I+1))
090 T(I)=A1*200.
105 IF(I.EQ.11)T(I)=0.
110 60 CONTINUE
115 T1=0.
120 DO 70 I=1,10
130 T1=T1+T(I)
140 70 CONTINUE
150 T2=T1/10.
155 D1=0.
160 DO 80 I=11,30
170 IF(T(I).LT.T2)D(I)=0.
180 IF(T(I).LT.T2)GO TO 190
190 D(I)=T(I)-T2
200 190 D1=D1+D(I)
205 80 CONTINUE
210 R=AMAX1(D(11),D(12),D(13),D(14),D(15),D(16),D(17),D(18),D(19),D(20),
215+D(21),D(22),D(23),D(24),D(25),D(27),D(28),D(29),D(30))
220 R1=D1/R
230 PRINT 91,(A(I),I=1,31)
240 PRINT 92,(T(I),I=1,30)
250 PRINT 93,(D(I),I=11,30)
260 PRINT 94,T2
270 PRINT 95,D1
280 PRINT 96,R
290 PRINT 97,R1
300 91 FORMAT(6HINPUT ,/,6(F5.1,2X),/,6(F5.1,2X),/,6(F5.1,2X),/,6(F5.1
310+,2X),/,6(F5.1,2X),/,2(F5.1,2X))
320 92 FORMAT(/,9HCLEARANCE,/,6(F8.4,1X),/,6(F8.4,1X),/,6(F8.4,1X),/,
321+6(F8.4,1X),/,6(F8.4,1X),/,F8.4)
330 93 FORMAT(/,9HDIFFERENC,/,5(F8.4,1X),/,5(F8.4,1X),/,5(F8.4,1X),
331+/,5(F8.4,1X))
340 94 FORMAT(/,5HMEAN ,F9.4)
350 95 FORMAT(7HEXCESS ,F9.4)
360 96 FORMAT(7HHEIGHT ,F9.4)
370 97 FORMAT(6HINDEX ,F9.4,/)
380 DO 100 I=1,10
381 WRITE(2,98)I,T(I)
382 98 FORMAT(I2,1X,F8.4)
383 100 CONTINUE
384 WRITE(2,99)
385 99 FORMAT(2H11,1X,2H0.,/,2H12,1X,2H0.,/,2H13,1X,2H0.)
386 DO 101 I=12,30
387 WRITE(2,98)I+2,T(I)
388 101 CONTINUE
389 GO TO 10
400 999 STOP
410 END
```

FIG. A14.1

Program NICOS 2 for the evaluation of T before and after exercise, maximum post-exercise T, total excess port-exercise T and the Hyperaemic Index according to equation 2.1 (see Section 2.22).

```
INPUT (THIGH)
190.0  181.0  172.5  164.3  156.5  149.1
142.1  135.4  129.0  122.9  117.1   84.0
 63.8   57.6   54.0   51.4   48.9   46.6
 44.4   42.3   40.3   38.4   36.6   34.9
 33.2   31.6   30.1   28.7   27.4   26.1
 24.8

CLEARANCE
  4.8407   4.8433   4.8462   4.8373   4.8484   4.8419
  4.8443   4.8349   4.8525   4.8435        0  27.2881
 10.3130   6.3626   5.0484   4.8459   4.8352   4.8555
  4.8432   4.8414   4.8533   4.8273   4.8425   4.8480
  4.8419   4.8559   4.8250   4.8502   4.8671   4.8340


DIFFERENC
       0  22.4448   5.4697   1.5193    .2051
   .0027        0    .0123        0        0
   .0100        0        0    .0047        0
   .0127        0    .0069    .0238        0

MEAN     4.8433
EXCESS   29.7119
HEIGHT   22.4448
INDEX    1.3238

INPUT (CALF)
188.0  181.1  174.4  167.9  161.7  155.7
150.0  144.4  139.1  134.0  129.0   92.0
 68.6   60.4   56.1   53.4   51.3   49.4
 47.6   45.9   44.2   42.5   41.0   39.5
 38.0   36.6   35.2   33.9   32.7   31.5
 30.3

CLEARANCE
  3.7609   3.7702   3.7630   3.7555   3.7736   3.7615
  3.7631   3.7664   3.7645   3.7644        0  29.1407
 12.7297   7.3832   4.9886   3.8586   3.7706   3.7503
  3.7655   3.7543   3.7832   3.7609   3.7558   3.7707
  3.7544   3.7872   3.7594   3.7532   3.7724   3.7553


DIFFERENC
       0  25.3764   8.9654   3.6189   1.2243
   .0943    .0063        0    .0012        0
   .0139        0        0    .0064        0
0        0    .0081        0

MEAN     3.7643
EXCESS   39.3431
HEIGHT   25.3764
INDEX    1.5504
```

FIG. A14.2

Inputs to and outputs from program NICOS 2 for a normal limb.

```
INPUT (THIGH)
196.0  190.0  184.2  178.6  173.1  167.8
162.7  157.7  152.9  148.2  143.7  134.6
119.3  107.0   97.2   89.2   82.7   77.4
 73.1   69.5   66.4   63.7   61.4   59.4
 57.6   55.8   54.1   52.5   50.9   49.3
 47.8

CLEARANCE
  3.0983   3.1050   3.1037   3.1049   3.1031   3.1041
  3.1021   3.1033   3.1014   3.1033        0  12.0854
 10.8744   9.5509   8.5940   7.5988   6.5975   5.7697
  4.9951   4.6080   4.0590   3.7084   3.3113   3.0943
  3.1035   3.1105   3.0960   3.1162   3.0947   3.1099


DIFFERENC
       0   8.9825   7.7714   6.4479   5.4910
  4.4958   3.4946   2.6668   1.8922   1.5051
   .9561    .6055    .2083        0    .0006
   .0076        0    .0133        0    .0070

MEAN     3.1029
EXCESS    44.5458
HEIGHT     8.9825
INDEX     4.9592

INPUT (CALF)
172.5  168.0  163.6  159.4  155.2  151.1
147.2  143.4  139.6  136.0  132.4  123.6
114.2  106.5   99.8   94.0   89.2   84.8
 81.0   77.7   74.7   72.2   70.1   68.1
 66.2   64.5   62.8   61.2   59.6   58.0
 56.5

CLEARANCE
  2.6432   2.6477   2.6381   2.6387   2.6440   2.6411
  2.6430   2.6431   2.6413   2.6450        0   7.8796
  7.0040   6.5455   5.9036   5.3281   4.9897   4.6326
  4.1089   3.8964   3.4295   3.0220   2.8662   2.7846
  2.6626   2.6398   2.6297   2.6503   2.6363   2.6546


DIFFERENC
       0   5.2371   4.3615   3.9029   3.2611
  2.6856   2.3471   1.9901   1.4664   1.2538
   .7870    .3795    .2237    .1421    .0201
       0        0    .0078        0    .0120

MEAN     2.6425
EXCESS    28.0778
HEIGHT     5.2371
INDEX     5.3614
```

FIG. A14.3

Inputs to and outputs from program NICOS 2 for a limb with iliac occlusion only.

```
INPUT (THIGH)
168.0  161.4  155.1  149.0  143.1  137.5
132.1  126.9  121.9  117.1  112.5   88.5
 67.5   61.4   57.3   53.7   51.1   48.8
 46.8   45.0   43.2   41.5   39.9   38.3
 36.8   35.4   34.0   32.7   31.4   30.1
 29.0

CLEARANCE
  4.0016   4.0071   4.0132   4.0062   4.0060   4.0065
  4.0081   4.0113   3.9995   4.0150        0  27.0431
  9.4674   7.0471   6.3829   5.0402   4.4852   4.2035
  3.9870   4.0137   4.0128   3.9799   4.0144   4.0192
  3.9895   4.0080   3.9915   4.0299   3.9999   3.9938


DIFFERENC
       0  23.0357   5.4599   3.0396   2.3754
  1.0328    .4778    .1960        0    .0062
   .0054        0    .0069    .0117        0
   .0006        0    .0225        0        0

MEAN     4.0074
EXCESS   35.6705
HEIGHT   23.0357
INDEX     1.5485

INPUT (CALF)
172.5  166.6  161.0  155.5  150.2  145.1
140.2  135.4  130.8  126.4  122.1  116.6
114.8  112.1  107.6  100.5   91.6   83.1
 76.3   70.6   65.9   62.0   58.7   55.9
 53.4   51.3   49.4   47.7   46.1   44.5
 43.0

CLEARANCE
  3.4502   3.4554   3.4568   3.4540   3.4604   3.4560
  3.4615   3.4480   3.4603   3.4614        0   1.5384
  2.4064   4.0789   6.8356   9.2836   9.6917   8.6126
  7.7533   6.8912   6.0539   5.4175   4.9378   4.5371
  4.1072   3.7148   3.5012   3.4545   3.4658   3.4506


DIFFERENC
       0        0        0    .6225   3.3792
  5.8272   6.2353   5.1562   4.2969   3.4348
  2.5975   1.9611   1.4814   1.0807    .6508
   .2584    .0448        0    .0094        0

MEAN     3.4564
EXCESS   37.0361
HEIGHT    6.2353
INDEX     5.9398
```

FIG. A14.4

Inputs to and outputs from program NICOS 2 for a limb with superficial femoral artery occlusion only.

```
INPUT (THIGH)
182.0  175.5  169.2  163.1  157.2  151.6
146.2  140.9  135.9  131.0  126.3  114.0
 99.2   88.9   81.8   75.9   70.8   66.2
 62.3   59.1   56.3   54.1   52.2   50.3
 48.5   46.8   45.1   43.5   41.9   40.4
 39.0

CLEARANCE
  3.6592   3.6503   3.6537   3.6586   3.6524   3.6471
  3.6574   3.6490   3.6573   3.6457        0  13.9338
 10.8453   8.3138   7.4910   7.0197   6.7314   5.9757
  5.3360   4.7640   4.0373   3.6500   3.6491   3.6636
  3.6532   3.6364   3.6585   3.6543   3.6691   3.6547

DIFFERENC
        0  10.2808   7.1922   4.6608   3.8379
  3.3666   3.0783   2.3227   1.6829   1.1109
   .3842        0        0    .0105    .0001
        0    .0055    .0012    .0160    .0016

MEAN    3.6531
EXCESS   37.9523
HEIGHT   10.2808
INDEX    3.6916

INPUT (CALF)
175.4  169.8  164.4  159.1  154.0  149.1
144.4  139.7  135.3  131.0  126.8  113.5
 99.4   88.0   78.4   70.6   64.3   58.8
 54.1   49.9   46.3   43.0   40.3   38.0
 36.2   34.9   33.8   32.7   31.6   30.6
 29.7

CLEARANCE
  3.2445   3.2438   3.2519   3.2443   3.2458   3.2438
  3.2452   3.2432   3.2449   3.2512        0  13.2457
 12.1891  11.4650  10.5207   9.4179   8.8582   8.3813
  8.0416   7.5291   7.2564   6.6515   5.8545   4.8557
  3.6312   3.2398   3.2501   3.2328   3.2429   3.2504

DIFFERENC
        0   9.9998   8.9433   8.2191   7.2748
  6.1720   5.6123   5.1355   4.7957   4.2832
  4.0106   3.4056   2.6087   1.6098    .3854
        0    .0042        0        0    .0045

MEAN    3.2459
EXCESS   72.4644
HEIGHT    9.9998
INDEX    7.2466
```

FIG. A14.5

Inputs to and outputs from program NICOS 2 for a limb with combined proximal and distal arterial lesions.

```
010 PROGRAM NICOS(INPUT,OUTPUT,TAPE1,TAPE2,TAPE3)
020 DIMENSION A(31),T(31),D(31),AV(31),TOT(31),AINDEX(31)
021 DIMENSION AVC(31),TOTC(31),AINDEC(31)
030 10 CONTINUE
040 DO 50 I=1,31
050 READ(,END.=999,1,)J,A(I)
055 11 FORMAT(I2,1X,F8.2)
060 50 CONTINUE
070 DO 60 I=1,30
080 A1=ALOG10(A(I))
090 A2=ALOG10(A(I+1))
100 T(I)=2.30259*100.*(A1-A2)
105 IF(I.EQ.11)T(I)=0.
110 60 CONTINUE
115 T1=0.
120 DO 70 I=1,10
130 T1=T1+T(I)
140 70 CONTINUE
150 T2=T1/10.
155 D1=0.
160 DO 80 I=11,30
170 IF(T(I).LT.T2)D(I)=0.
180 IF(T(I).LT.T2)GO TO 190
190 D(I)=T(I)-T2
200 190 D1=D1+D(I)
205 80 CONTINUE
210 R=AMAX1(D(11),D(12),D(13),D(14),D(15),D(16),D(17),D(18),D(19),D(20),
215+D(21),D(22),D(23),D(24),D(25),D(27),D(28),D(29),D(30))
220 R1=D1/R
230 WRITE(3,91)(A(I),I=1,31)
240 WRITE(3,92)(T(I),I=1,30)
250 WRITE(3,93)(D(I),I=11,30)
260 WRITE(3,94)T2
270 WRITE(3,95)D1
280 WRITE(3,96)R
290 WRITE(3,97)R1
300 91 FORMAT(/,1H ,6HINPUT ,/,6(F5.1,2X),/,6(F5.1,2X),/,6(F5.1,2X),/,6(F5.1
310+,2X),/,6(F5.1,2X),/,2(F5.1,2X))
320 92 FORMAT(/,1H ,9HCLEARANCE,/,6(F8.4,1X),/,6(F8.4,1X),/,6(F8.4,1X),/,
321+6(F8.4,1X),/,6(F8.4,1X),/,F8.4)
330 93 FORMAT(/,1H ,9HDIFFERENC,/,5(F8.4,1X),/,5(F8.4,1X),/,5(F8.4,1X),
331+/,5(F8.4,1X))
340 94 FORMAT(/,1H ,5HMEAN ,F9.4)
350 95 FORMAT(8H EXCESS ,F9.4)
360 96 FORMAT(8H HEIGHT ,F9.4)
370 97 FORMAT(7H INDEX ,F9.4)
380 DO 100 I=1,10
381 WRITE(2,98)I,T(I)
382 98 FORMAT(I2,1X,F8.4)
383 100 CONTINUE
384 WRITE(2,99)
385 99 FORMAT(2H11,1X,2H0.,/,2H12,1X,2H0.,/,2H13,1X,2H0.)
386 DO 101 I=12,30
387 WRITE(2,98)I+2,T(I)
388 101 CONTINUE
389 GO TO 10
400 999 STOP
410 END
```

FIG. A14.6

Program NICOS for the evaluation of T before and after exercise, maximum post-exercise T, total excess post-exercise T and the Hyperaemic Index according to equation A3.11 (see Appendix A3).

```
INPUT (THIGH)
190.0  181.0  172.5  164.3  156.5  149.1
142.1  135.4  129.0  122.9  117.1   84.0
 63.8   57.6   54.0   51.4   48.9   46.6
 44.4   42.3   40.3   38.4   36.6   34.9
 33.2   31.6   30.1   28.7   27.4   26.1
 24.8

CLEARANCE
  4.8417   4.8442   4.8471   4.8383   4.8493   4.8428
  4.8452   4.8358   4.8534   4.8444        0  27.4594
 10.3222   6.3647   5.0495   4.8469   4.8361   4.8565
  4.8441   4.8424   4.8542   4.8283   4.8435   4.8489
  4.8429   4.8569   4.8260   4.8512   4.8681   4.8349


DIFFERENC
       0  22.6152   5.4780   1.5205    .2052
    .0027        0    .0123        0        0
    .0100        0        0    .0047        0
    .0127        0    .0069    .0238        0

MEAN     4.8442
EXCESS   29.8919
HEIGHT   22.6152
INDEX    1.3218

INPUT (CALF)
188.0  181.1  174.4  167.9  161.7  155.7
150.0  144.4  139.1  134.0  129.0   92.0
 68.6   60.4   56.1   53.4   51.3   49.4
 47.6   45.9   44.2   42.5   41.0   39.5
 38.0   36.6   35.2   33.9   32.7   31.5
 30.3

CLEARANCE
  3.7614   3.7706   3.7635   3.7559   3.7740   3.7619
  3.7635   3.7669   3.7649   3.7649        0  29.3497
 12.7469   7.3866   4.9896   3.8591   3.7710   3.7507
  3.7660   3.7548   3.7836   3.7614   3.7562   3.7711
  3.7548   3.7877   3.7598   3.7536   3.7729   3.7557


DIFFERENC
       0  25.5849   8.9822   3.6219   1.2249
    .0944    .0845        0    .0012        0
    .0189        0        0    .0064        0
    .0230        0        0    .0081        0

MEAN     3.7648
EXCESS   39.5720
HEIGHT   25.5849
INDEX    1.5467
```

FIG. A14.7

Inputs to and outputs from program NICOS for a normal limb.

```
 INPUT (THIGH)
196.0  190.0  184.2  178.6  173.1  167.8
162.7  157.7  152.9  148.2  143.7  134.6
119.3  107.0   97.2   89.2   82.7   77.4
 73.1   69.5   66.4   63.7   61.4   59.4
 57.6   55.8   54.1   52.5   50.9   49.3
 47.8

 CLEARANCE
  3.0985   3.1053   3.1040   3.1052   3.1033   3.1044
  3.1023   3.1035   3.1017   3.1035        0  12.1002
 10.8851   9.5582   8.5993   7.6024   6.5999   5.7714
  4.9961   4.6088   4.0596   3.7089   3.3116   3.0945
  3.1038   3.1108   3.0962   3.1165   3.0950   3.1101


 DIFFERENC
       0   8.9970   7.7819   6.4550   5.4961
  4.4993   3.4968   2.6682   1.8930   1.5057
   .9564    .6057    .2084        0    .0006
   .0076        0    .0133        0    .0070

 MEAN     3.1032
 EXCESS   44.5918
 HEIGHT    8.9970
 INDEX     4.9563

 INPUT (CALF)
172.5  168.0  163.6  159.4  155.2  151.1
147.2  143.4  139.6  136.0  132.4  123.6
114.2  106.5   99.8   84.0   89.2   84.8
 81.0   77.7   74.7   72.2   70.1   68.1
 66.2   64.5   62.8   61.2   59.6   58.0
 56.5

 CLEARANCE
  2.6433   2.6478   2.6383   2.6388   2.6442   2.6413
  2.6431   2.6433   2.6415   2.6452        0   7.8837
  7.0069   6.5478   5.9053   5.3294   4.9907   4.6335
  4.1095   3.8969   3.4298   3.0222   2.8664   2.7848
  2.6627   2.6400   2.6298   2.6505   2.6364   2.6547


 DIFFERENC
       0   5.2410   4.3642   3.9051   3.2626
  2.6867   2.3480   1.9908   1.4668   1.2542
   .7872    .3796    .2238    .1421    .0201
       0        0    .0079        0    .0120

 MEAN     2.6427
 EXCESS   28.0920
 HEIGHT    5.2410
 INDEX     5.3601
```

FIG. A14.8

Input to and output from program NICOS for a limb with iliac occlusion only.

```
INPUT (THIGH)
169.0  161.4  155.1  149.0  143.1  137.5
132.1  126.9  121.9  117.1  112.5   88.5
 67.5   61.4   57.3   53.7   51.1   48.8
 46.8   45.0   43.2   41.5   39.9   38.3
 36.8   35.4   34.0  -32.7   31.4   30.1
 29.0

CLEARANCE
  4.0011   4.0066   4.0126   4.0056   4.0054   4.0059
  4.0076   4.0108   3.9990   4.0145        0  26.8794
  9.4603   7.0442   6.3807   5.0391   4.4845   4.2028
  3.9865   4.0132   4.0123   3.9794   4.0138   4.0186
  3.9889   4.0075   3.9910   4.0294   3.9993   3.9932


DIFFERENC
       0  22.8725   5.4534   3.0372   2.3738
  1.0322    .4776    .1959        0    .0062
   .0054        0    .0069    .0117        0
   .0006        0    .0225        0        0

MEAN     4.0069
EXCESS   35.4960
HEIGHT   22.8725
INDEX    1.5519

INPUT (CALF)
172.5  166.6  161.0  155.5  150.2  145.1
140.2  135.4  130.8  126.4  122.1  116.6
114.8  112.1  107.6  100.5   91.6   83.1
 76.3   70.6   65.9   62.0   58.7   55.9
 53.4   51.3   49.4   47.7   46.1   44.5
 43.0

CLEARANCE
  3.4498   3.4550   3.4564   3.4537   3.4601   3.4556
  3.4612   3.4476   3.4599   3.4610        0   1.5383
  2.4062   4.0783   6.8329   9.2769   9.6841   8.6073
  7.7494   6.8885   6.0521   5.4161   4.9368   4.5363
  4.1066   3.7144   3.5008   3.4542   3.4654   3.4502


DIFFERENC
       0        0        0    .6222   3.3769
  5.8209   6.2280   5.1512   4.2934   3.4324
  2.5960   1.9601   1.4807   1.0803    .6505
   .2583    .0448        0    .0094        0

MEAN     3.4560
EXCESS   37.0051
HEIGHT    6.2280
INDEX    5.9417
```

FIG. A14.9

Inputs to and outputs from program NICOS for a limb with superficial femoral artery occlusion only.

```
INPUT (THIGH)
182.0  175.5  169.2  163.1  157.2  151.6
146.2  140.9  135.9  131.0  126.3  114.0
 99.2   88.9   81.8   75.9   70.8   66.2
 62.3   59.1   56.3   54.1   52.2   50.3
 48.5   46.8   45.1   43.5   41.9   40.4
 39.0

CLEARANCE
  3.6596   3.6507   3.6541   3.6590   3.6528   3.6475
  3.6578   3.6494   3.6578   3.6461        0  13.9565
 10.8560   8.3186   7.4945   7.0226   6.7340   5.9775
  5.3372   4.7649   4.0379   3.6505   3.6495   3.6640
  3.6536   3.6368   3.6590   3.6547   3.6695   3.6551


DIFFERENC
        0  10.3030   7.2025   4.6652   3.8410
  3.3691   3.0805   2.3240   1.6838   1.1114
   .3844        0        0   .0105    .0001
        0   .0055    .0012   .0160    .0016

MEAN     3.6535
EXCESS   37.9998
HEIGHT   10.3030
INDEX    3.6882

INPUT (CALF)
175.4  169.8  164.4  159.1  154.0  149.1
144.4  139.7  135.3  131.0  126.8  113.5
 99.4   88.0   78.4   70.6   64.3   58.8
 54.1   49.9   46.3   43.0   40.3   38.0
 36.2   34.9   33.8   32.7   31.6   30.6
 29.7

CLEARANCE
  3.2448   3.2441   3.2522   3.2446   3.2461   3.2441
  3.2455   3.2435   3.2452   3.2515        0  13.2651
 12.2043  11.4776  10.5304   9.4249   8.8640   8.3863
  8.0459   7.5327   7.2596   6.6539   5.8562   4.8566
  3.6317   3.2341   3.2504   3.2331   3.2432   3.2507


DIFFERENC
        0  10.0189   8.9581   8.2314   7.2842
  6.1787   5.6178   5.1401   4.7997   4.2865
  4.0135   3.4078   2.6101   1.6105    .3855
        0    .0042        0        0    .0045

MEAN     3.2462
EXCESS   72.5516
HEIGHT   10.0189
INDEX    7.2414
```

FIG. A14.10

Inputs to and outputs from program NICOS for a limb with combined proximal and distal arterial lesions.

```
00100 PROGRAM MEAN(INPUT,OUTPUT,TAPE1,TAPE2)
00105 DIMENSION STAN(31)
00110 DIMENSION AMEAN(31),ACUM(31),SQACUM(31)
00111 IND=0
00112 WRITE(2,113)
00113 113 FORMAT(/,'THIGH',/,/)
00120 DO 1 I=1,31
00130 SQACUM(I)=0.
00140 ACUM(I)=0.
00150 1 CONTINUE
00160 INUM=0
00170 5 CONTINUE
00180 DO 10 I=1,31
00190 READ(.END.=100,1,11)I1,A1
00200 11 FORMAT(I2,3X,F6.2)
00210 ACUM(I)=ACUM(I)+A1
00220 SQA=A1*A1
00230 SQACUM(I)=SQACUM(I)+SQA
00240 10 CONTINUE
00250 INUM=INUM+1
00260 DO 15 I=1,31
00270 READ(.END.=100,1,11)I1,A1
00280 15 CONTINUE
00290 GO TO 5
00300 100 CONTINUE
00310 DO 40 I=1,31
00320 AMEAN(I)=ACUM(I)/INUM
00330 40 CONTINUE
00340 DO 50 I=1,31
00350 RMEAN=AMEAN(I)**2
00360 BMEAN=RMEAN*INUM
00370 CMEAN=SQACUM(I)-BMEAN
00375 STANB=CMEAN/INUM
00380 STAN(I)=SQRT(STANB)
00390 206 FORMAT(I2,5X,F12.2,5X,F12.2)
00400 WRITE(2,206)I,AMEAN(I),STAN(I)
00410 50 CONTINUE
00420 F(IND .EQ. 1)GO TO 150
00430 IND=1
00440 REWIND 1
00450 WRITE(2,261)
00460 261 FORMAT(/,/,'CALF',/,/)
00470 DO 60 I=1,31
00480 READ(.END.=105,1,11)I1,A1
00490 60 CONTINUE
00500 GO TO 5
00510 105 CONTINUE
00520 150 STOP
00530 END
```

FIG. A14.11

Program MEAN for the evaluation of the mean values of T before and after exercise, maximum post-exercise T, total excess post-exercise T and the Hyperacmic Index.

```
INPUT (THIGH)
160.4  153.2  146.4  139.8  133.6  127.6
121.9  116.5  111.3  106.4  101.6   74.9
 57.9   51.0   47.8   45.3   43.2   41.2
 39.4   37.6   36.0   34.4   32.9   31.4
 30.0   28.7   27.4   26.2   25.1   24.0
 22.9

CLEARANCE
  4.5847   4.5726   4.5699   4.5716   4.5632   4.5598
  4.5544   4.5560   4.5478   4.5479        0  25.6140
 12.6206   6.5614   5.2649   4.8373   4.6457   4.5415
  4.5449   4.5109   4.5203   4.5211   4.5122   4.5255
  4.4959   4.4888   4.5090   4.4826   4.5260   4.4786


DIFFERENC
       0  21.0512   8.0578   1.9986    .7021
   .2745    .0829        0        0        0
       0        0        0        0        0
       0        0        0        0        0

MEAN     4.5628
EXCESS    32.1669
HEIGHT    21.0512
INDEX      1.5280

INPUT (CALF)
166.2  159.3  152.8  146.5  140.4  134.7
129.1  123.9  118.8  113.9  109.3   81.6
 62.4   55.7   52.3   49.7   47.5   45.5
 43.6   41.8   40.1   38.5   36.9   35.4
 34.0   32.6   31.3   30.0   28.8   27.7
 26.5

CLEARANCE
  4.2090   4.2106   4.1976   4.1963   4.1944   4.1921
  4.1817   4.1873   4.1771   4.1669        0  26.7139
 11.2268   6.4253   5.1010   4.5717   4.3057   4.2008
  4.1457   4.1504   4.1481   4.1379   4.1471   4.1204
  4.1441   4.0995   4.1415   4.1121   4.1076   4.0952


DIFFERENC
       0  22.5226   7.0355   2.2340    .9098
   .3804    .1144    .0096        0        0
       0        0        0        0        0
       0        0        0        0        0

MEAN     4.1913
EXCESS    33.2063
HEIGHT    22.5226
INDEX      1.4744
```

FIG. A14.12

Mean values of T before and after exercise, maximum post-exercise T, total excess post-exercise T and of the Hyperaemic Index in Group A (normal limbs)(from program MEAN).

```
 INPUT (THIGH)
191.4  184.4  177.6  171.0  164.7  158.7
152.9  147.3  141.9  136.7  131.7  120.8
106.8   96.2   88.1   81.4   75.9   71.3
 67.5   64.2   61.4   59.0   52.6   50.7
 48.9   47.2   45.5   43.9   42.3   40.8
39.4

 CLEARANCE
  3.7630   3.7523   3.7524   3.7468   3.7414   3.7428
  3.7320   3.7286   3.7266   3.7265        0  12.3730
 10.3957   8.8402   7.8511   7.0336   6.2248   5.5502
  4.9376   4.4098   4.0863  11.5053   3.6614   3.5959
  3.6027   3.6054   3.5806   3.5954   3.5826   3.5887

 DIFFERENC
        0   8.6317   6.6544   5.0989   4.1099
  3.2924   2.4836   1.8089   1.1964    .6686
   .3450   7.7641        0        0        0
        0        0        0        0        0

 MEAN     3.7412
 EXCESS   42.0538
 HEIGHT    8.6317
 INDEX    4.8720

 INPUT (CALF)
180.5  174.3  168.2  162.4  156.8  151.4
146.2  141.2  136.3  131.7  127.2  115.6
103.1   93.5   85.8   79.4   74.1   69.6
 65.8   62.5   59.7   57.2   52.9   51.0
 49.2   47.5   45.9   44.4   42.9   41.5
 40.1

 CLEARANCE
  3.5182   3.5157   3.5144   3.5149   3.5041   3.5014
  3.4938   3.4955   3.4929   3.4855        0  11.4599
  9.8049   8.5845   7.6901   6.9587   6.2507   5.6441
  5.0981   4.5987   4.2596   7.8311   3.6963   3.5533
  3.4736   3.4025   3.4097   3.3902   3.3886   3.4076

 DIFFERENC
        0   7.9563   6.3013   5.0809   4.1864
  3.4550   2.7471   2.1404   1594     1.0951
   .7560   4.3275    .1926    .0496        0
        0        0        0        0        0

 MEAN     3.5036
 EXCESS   39.8827
 HEIGHT    7.9563
 INDEX    5.0127
READY.
```

FIG. A14.13

Mean values of T before and after exercise, maximum post-exercise T, total excess post-exercise T and of the Hyperaemic Index in Group B. (Limbs with iliac occlusion only) (From program MEAN).

```
 INPUT (THIGH)
158.5  151.9  145.6  139.5  133.7  128.2
122.9  117.8  112.9  108.2  103.7   82.3
 62.5   56.9   53.3   50.3   47.9   45.8
 43.8   42.0   40.3   38.6   37.0   35.5
 34.0   32.6   31.2   29.9   28.7   27.5
 26.3

 CLEARANCE
  4.2466   4.2494   4.2515   4.2382   4.2384   4.2468
  4.2482   4.2416   4.2444   4.2491        0  27.5685
  9.3743   6.4632   5.8903   4.8711   4.4196   4.3728
  4.2629   4.2539   4.2355   4.2605   4.2242   4.2633
  4.2381   4.2333   4.2532   4.2327   4.2378   4.2734


 DIFFERENC
       0  23.3231   5.1289   2.2178   1.6449
   .6256    .1741    .1274    .0175    .0085
       0    .0150        0    .0179        0
       0    .0078        0        0    .0279

 MEAN     4.2454
 EXCESS   33.3364
 HEIGHT   23.3231
 INDEX     1.4293

 INPUT (CALF)
149.6  144.4  139.5  134.7  130.0  125.5
121.2  117.0  113.0  109.1  105.3   93.7
 91.6   89.0   85.0   79.3   70.3   63.7
 58.3   53.8   50.0   46.9   44.3   42.1
 40.3   38.7   37.3   36.0   34.7   33.5
 32.4

 CLEARANCE
  3.5032   3.5012   3.5094   3.5062   3.5141   3.5100
  3.5009   3.5128   3.5031   3.5068        0   2.2995
  2.8467   4.5515   6.9253  12.0386   9.8828   8.9054
  8.0515   7.2265   6.4379   5.7008   5.0913   4.5413
  4.0046   3.7144   3.5235   3.5081   3.5163   3.4900


 DIFFERENC
       0        0        0   1.0447   3.4186
  8.5318   6.3760   5.3986   4.5447   3.7197
  2.9311   2.1940   1.5846   1.0345    .4978
   .2076    .0167    .0014    .0096        0

 MEAN     3.5068
 EXCESS   41.5114
 HEIGHT    8.5318
 INDEX     4.8655
```

FIG. A14.14

Mean values of T before and after exercise, maximum post-exercise T total excess post exercise T and of the Hyperaemic Index in Group C. (Limbs with superficial femoral artery occlusion only)(From program MEAN).

```
INPUT (THIGH)
173.0  166.7  160.6  154.7  149.1  143.6
138.4  133.3  128.5  123.8  119.3  107.4
 94.5   84.7   76.8   70.2   64.7   60.3
 56.5   53.5   50.9   48.8   47.0   45.3
 43.7   42.1   40.6   39.2   37.8   36.5
 35.2

CLEARANCE
  3.7385   3.7279   3.7236   3.7199   3.7243   3.7094
  3.7097   3.7047   3.7018   3.7016        0  12.8579
 10.8717   9.8588   8.9276   8.0925   7.1846   6.3533
  5.5813   4.8659   4.2511   3.8847   3.6655   3.6216
  3.6152   3.6030   3.6099   3.5863   3.6099   3.6028


DIFFERENC
        0   9.1417   7.1556   6.1427   5.2115
  4.3764   3.4684   2.6372   1.8652   1.1498
   .5349    .1686        0        0        0
        0 Y      0        0        0        0

MEAN     3.7161
EXCESS    41.8519
HEIGHT     9.1417
INDEX     4.5781

INPUT (CALF)
169.2  163.6  158.2  153.0  148.0  143.1
138.4  133.9  129.5  125.3  121.2  112.9
106.0  100.6   95.6   90.7   85.4   80.1
 74.7   69.4   64.7   60.8   57.5   54.6
 52.1   49.8   47.9   46.1   44.5   43.0
 41.7

CLEARANCE
  3.3589   3.3555   3.3478   3.3421   3.3388   3.3313
  3.3266   3.3252   3.3119   3.3098        0   6.2400
  5.3049   5.0466   5.3259   5.9291   6.4649   7.0053
  7.3313   6.9809   6.2151   5.5617   5.1181   4.7592
  4.4139   4.0733   3.7897   3.5336   3.2907   3.2346


DIFFERENC
        0   2.9052   1.9701   1.7119   1.9911
  2.5943   3.1301   3.6705   3.9965   3.6461
  2.8803   2.2269   1.7834   1.4244   1.0791
   .7385    .4549    .1988        0        0

MEAN     3.3348
EXCESS    36.4021
HEIGHT     3.9965
INDEX     9.1085

STOP

 CP        0.692 SECS.

RUN COMPLETE.
```

FIG. A14.15

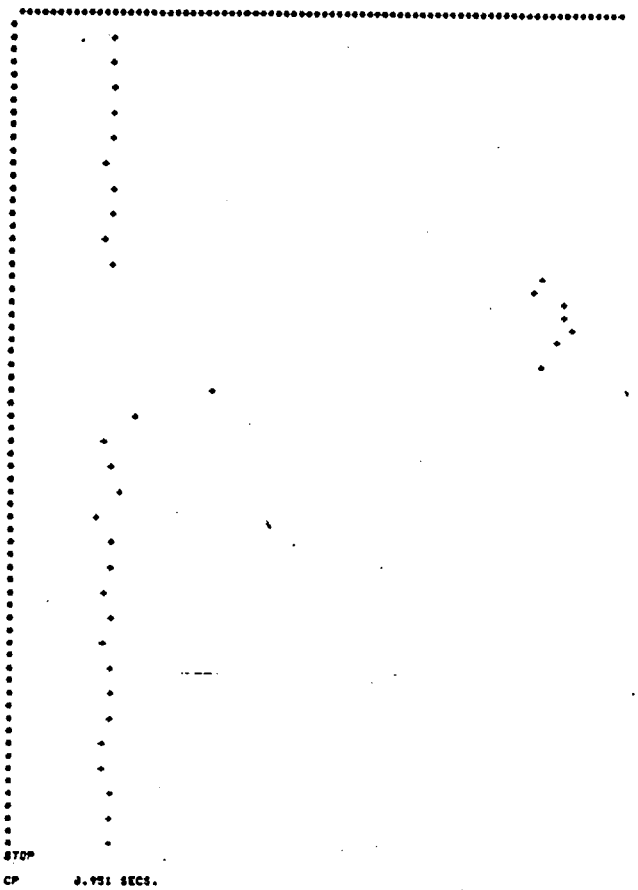
Mean values of T before and after exercise, maximum post-exercise T, total excess post-exercise T and of the Hyperaemic Index in Group D. (Limbs with combined severe aortoiliac and femoropopliteal lesions).

```
010 PROGRAM CLEAR(INPUT,OUTPUT,TAPE1)
020 DIMENSION A(60),T(60)
025 DIMENSION G(60)
026 DIMENSION JI(80)
027 DIMENSION AJI(80)
030 PRINT 5
040 5 FORMAT('ENTER VALUES BEFORE EXERCISE')
050 DO 10 I=1,11
060 READ 11,A(I)
070 11 FORMAT(F6.2)
080 10 CONTINUE
100 PRINT 6
110 6 FORMAT(' ENTER VALUES DURING EXERICES')
120 DO 15 I=12,18
130 READ 11,A(I)
140 15 CONTINUE
150 PRINT 7
160 7 FORMAT('ENTER VALUES AFTER EXERCISE')
170 DO 20 I=19,39
180 READ 11,A(I)
190 20 CONTINUE
200 DO 25 I=1,10
210 A1=(A(I)-A(I+1))/(A(I)+A(I+1))
220 T(I)=A1*200.
230 25 CONTINUE
240 DO 30 I=12,17
250 A1=(A(I)-A(I+1))/(A(I)+A(I+1))
260 T(I)=A1*200.
270 30 CONTINUE
280 DO 40 I=19,38
290 A1=(A(I)-A(I+1))/(A(I)+A(I+1))
300 T(I)=A1*200.
310 40 CONTINUE
315 T(11)=0.$T(18)=0.$T(39)=0.
320 PRINT 45,(T(I),I=1,10)
330 PRINT 46,(T(I),I=12,17)
340 PRINT 47,(T(I),I=19,38)
350 45 FORMAT('CLEARANCE BEFORE EXERCISE',/,5(F6.2,2X),/,5(F6.2,2X))
360 46 FORMAT('CLEARANCE DURING EXERCISE',/,5hF6.2,2X),/,5(F6.2,2X))
370 47 FORMAT('CLEARANCE AFTER EXERCISE ',/,5(F6.2,2X),/,5(F6.2,2X))
380 DO 50 I=1,39
390 G(I)=(T(I)*2.5)
400 JI(I)=G(I)+1
410 50 CONTINUE
420 PRINT 48
430 48 FORMAT(/,'GRAPH OF RESULTS',/,/)
440 PRINT 60
450 60 FORMAT(1H ,79(1H*))
460 AJI(1)=1H*
465 DO 90 J=1,38
470 70 DO 75 I=2,80
480 AJI(I)=1H
505 75 CONTINUE
506 AJI(JI(J)+1)=1H+
510 IF(J .LT. 11)GO TO 80
520 IF(J .EQ. 11)GO TO 89
530 IF(J .LT. 18)GO TO 81
540 IF(J .EQ. 18)GO TO 89
550 80 PRINT 86
551 PRINT 85,(AJI(K),K=1,80)
560 GO TO 89
570 81 CONTINUE
580 86 FORMAT(1H*)
585 PRINT 85,(AJI(K),K=1,80)
590 GO TO 89
600 85 FORMAT(80A1)
610 89 CONTINUE
620 90 CONTINUE
630 STOP
640 END
```

FIG. A14.16

Program CLEAR for the evaluation of T before, during and after exercise.

```
 77/09/04. 15.10.40.
PROGRAM   CLEAR
   488  C CHANGE OF TYPE IN STATEMENT - DOMINANT TYPE USED
ENTER VALUES BEFORE EXERCISE
? 190.
? 181.
? 172.5
? 164.3
? 156.5
? 149.
? 142.1
? 135.4
? 129.
? 123.
? 117.
ENTER VALUES DURING EXERICES
? 83.
? 63.
? 48.
? 26.
? 27.
? 28.2
? 15.2
ENTER VALUES AFTER EXERCISE
? 84.
? 63.8
? 57.5
? 54.
? 51.9
? 49.
? 46.5
? 44.5
? 42.3
? 40.3
? 38.5
? 34.6
? 34.7
? 33.2
? 31.4
? 30.
? 28.7
? 27.4
? 26.1
? 24.8
? 23.4
CLEARANCE BEFORE EXERCISE
  4.05    4.81    4.87    4.84    4.91
  4.74    4.83    4.84    4.76    5.00
CLEARANCE DURING EXERCISE
 27.48   27.83   28.57   28.57   28.81
 28.25
CLEARANCE AFTER EXERCISE
 27.33   18.39    6.28    4.74    4.98
  5.24    4.48    5.07    4.84    4.57
  5.06    4.76    4.99    4.94    5.19
  4.49    4.63    4.84    5.11    4.96

GRAPH OF RESULTS
```



```
STOP
CP       0.951 SECS.
```

FIG. A14.17

Graphical output from program CLEAR for the thigh of a normal limb.

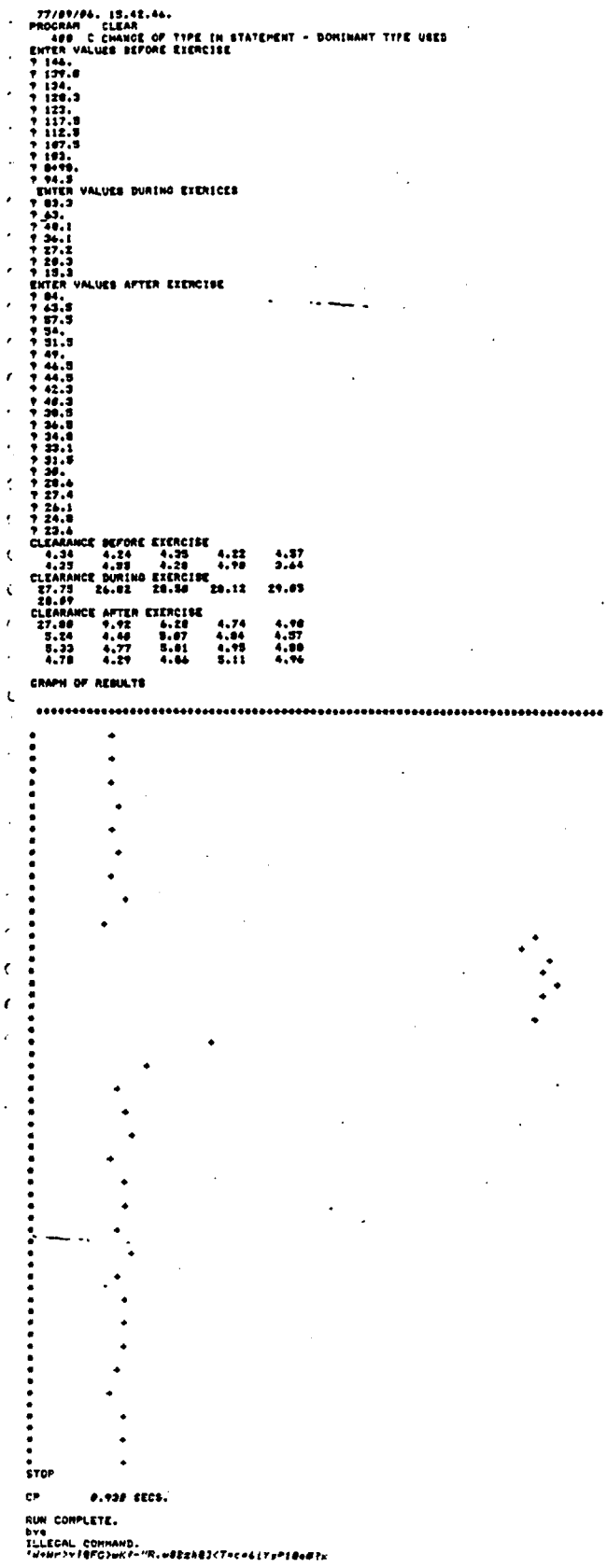
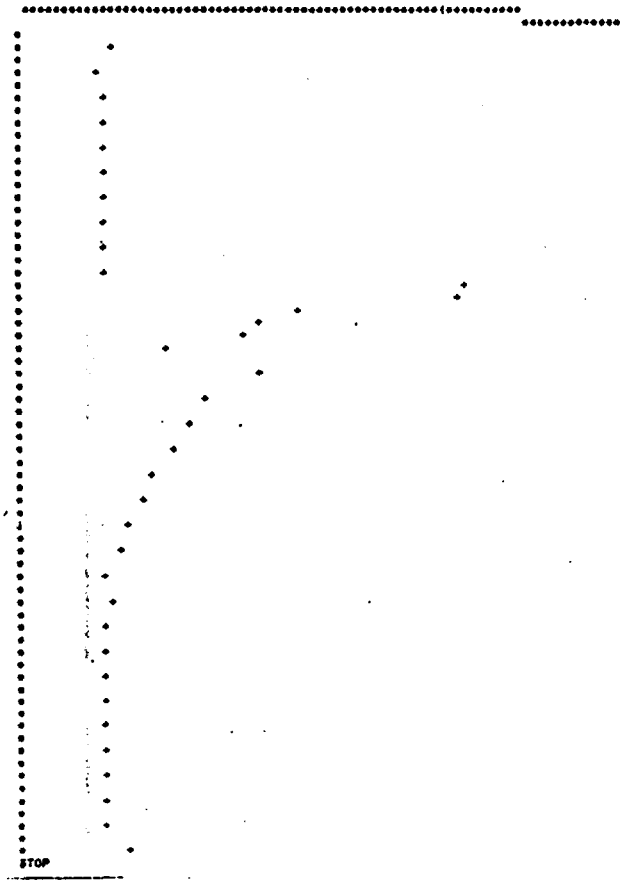



FIG. A14.18

Graphical output from program CLEAR for the calf of a normal limb.

```
 77/09/08. 09.48.09.
PROGRAM   CLEAR
    400   C CHANGE OF TYPE IN STATEMENT - DOMINANT TYPE USED
ENTER VALUES BEFORE EXERCISE
? 152.
? 145.
? 139.9
? 133.7
? 128.1
? 122.7
? 117.9
? 112.6
? 107.9
? 103.4
? 99.
 ENTER VALUES DURING EXERICES
? 94.8
? 79.3
? 66.
? 52.
? 46.
? 41.
? 38.
ENTER VALUES AFTER EXERCISE
? 98.8
? 88.
? 72.9
? 66.9
? 62.
? 58.
? 76.6
? 71.6
? 69.3
? 67.2
? 65.1
? 63.2
? 61.4
? 59.7
? 58.6
? 56.6
? 54.9
? 53.4
? 52.
? 50.7
? 29.1
CLEARANCE BEFORE EXERCISE
   4.71     3.87     4.25     4.28     4.31
   4.33     4.24     4.24     4.24     4.35
CLEARANCE DURING EXERCISE
  22.93    22.62    14.29    12.24    11.49
   7.39
CLEARANCE AFTER EXERCISE
  12.32     9.29     8.58     7.68     6.67
   6.84     5.26     4.95     4.33     4.55
   4.30     4.26     4.19     4.36     4.38
   4.21     4.39     4.28     4.15     5.35

GRAPH OF RESULTS
```



```
STOP
```

FIG. A14.19

Graphical output from program CLEAR for the thigh of a limb with iliac occlusion only.

```
 77/09/08. 09.39.04.
PROGRAM   CLEAR
    469  C CHANGE OF TYPE IN STATEMENT - DOMINANT TYPE USED
ENTER VALUES BEFORE EXERCISE
? 182.
? 175.
? 148.2
? 141.7
? 139.4
? 149.4
? 143.6
? 136.1
? 132.7
? 127.7
? 122.7
 ENTER VALUES DURING EXERICES
? 94.8
? 79.3
? 61.
? 53.5
? 47.5
? 43.
? 41.9
ENTER VALUES AFTER EXERCISE
? 189.6
? 99.4
? 91.1
? 84.2
? 78.5
? 73.9
? 78.1
? 66.8
? 64.
? 61.8
? 89.1
? 54.8
? 50.6
? 52.8
? 50.5
? 48.8
? 46.6
? 44.8
? 43.1
? 41.9
? 40.1
CLEARANCE BEFORE EXERCISE
   3.92     3.94     3.94     3.97     3.98
   3.96     3.98     3.99     3.84     3.99
CLEARANCE DURING EXERCISE
  24.99    20.98    19.18    11.80     9.94
   3.53
CLEARANCE AFTER EXERCISE
   9.76     8.71     7.87     7.01     6.84
   5.28     4.82     4.28     3.98     3.98
   3.97     3.75     3.92     3.88     4.84
   4.89     3.94     3.87     2.82     4.39

GRAPH OF RESULTS
```

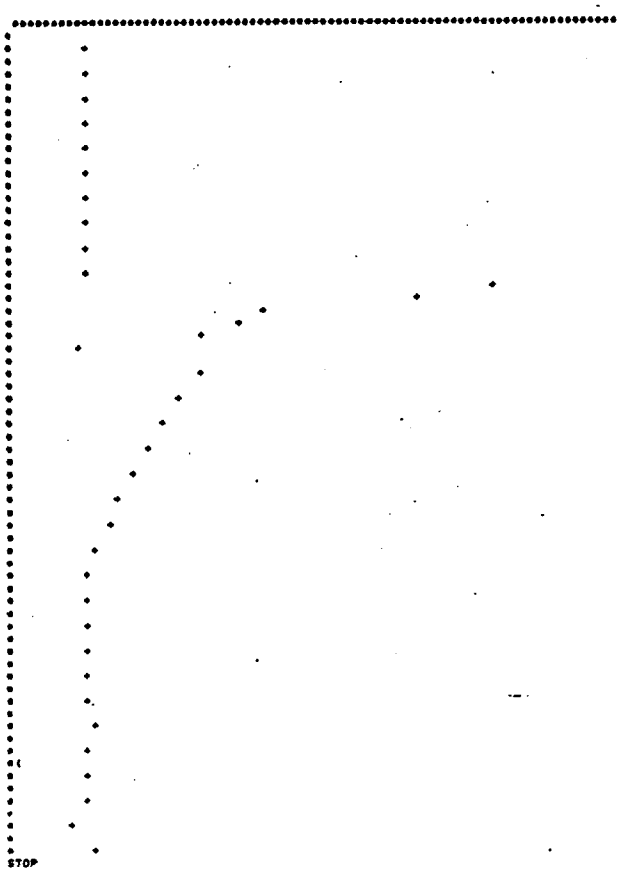
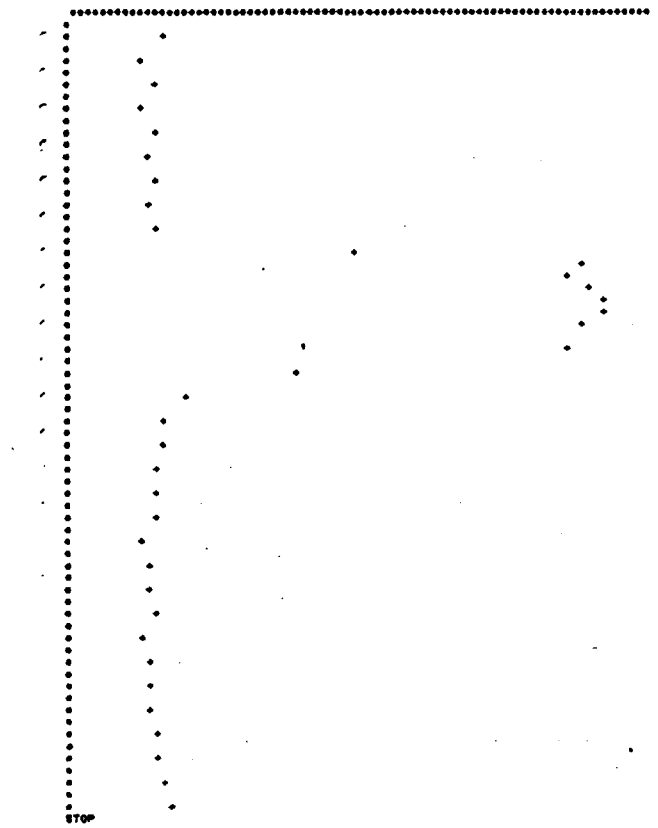



FIG. A14.20

Graphical output from program CLEAR for the calf of a limb with iliac occlusion only.

```
 77/07/04. 10.31.26.
PROGRAM    CLEAR
    488  C CHANGE OF TYPE IN STATEMENT - DOMINANT TYPE USED
ENTER VALUES BEFORE EXERCISE
? 146.
? 139.
? 134.
? 128.
? 123.
? 117.5
? 112.5
? 107.5
? 103.
? 98.5
? 94.3
 ENTER VALUES DURING EXERCISE
? 63.5
? 43.
? 48.
? 36.+*.1
? 27.
? 26.5
? 19.3
ENTER VALUES AFTER EXERCISE
? 43.
? 48.
? 42.5
? 40.
? 38.
? 34.1
? 34.5
? 33.
? 31.5
? 30.3
? 29.
? 27.5
? 26.5
+? +++29.5
? 26.5
? 23.3
? 22.5
? 21.5
? 20.5
? 19.5
? 18.5
CLEARANCE BEFORE EXERCISE
   4.91    3.66    4.38    3.90    4.57
   4.35    4.59    4.20    4.47   15.38
CLEARANCE DURING EXERCISE
 27.99   27.83   29.38   28.84   28.81
 27.41
CLEARANCE AFTER EXERCISE
 27.83   12.13    6.86    5.13    5.13
  4.53    4.44    4.63    3.88    4.38
  4.23    4.79    3.85    4.86    4.17
  4.33    4.35    4.76    3.99    5.26

GRAPH OF RESULTS
```

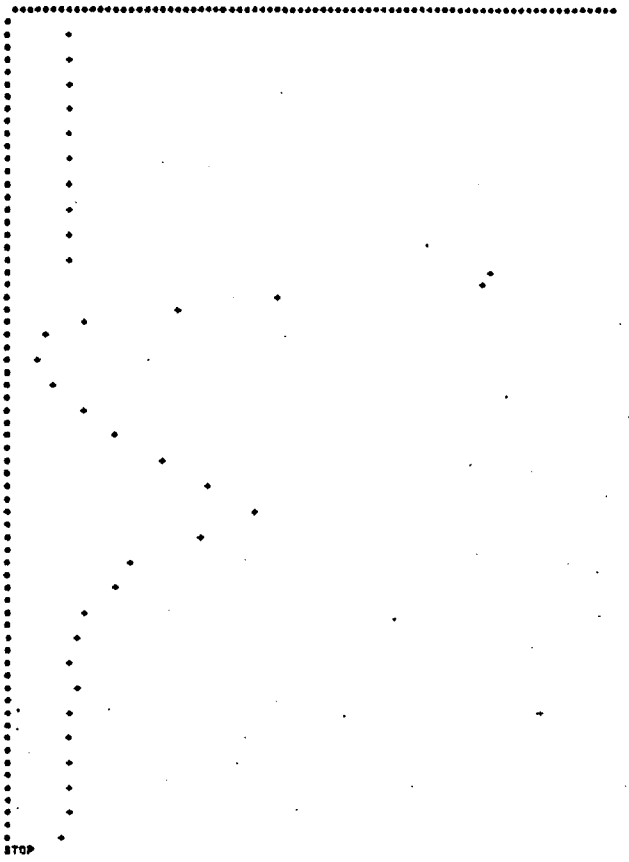


```
STOP

CP       0.966 SECS.

RUN COMPLETE.
old:clear
ready.
```

Fig A14.21

Graphical output from program CLEAR for the thigh of a limb with superficial femoral artery occlusion only.

```
 77/09/06. 10.04.53.
PROGRAM   CLEAR
   400  C CHANGE OF TYPE IN STATEMENT - DOMINANT TYPE USED
ENTER VALUES BEFORE EXERCISE
? 172.
? 164.9
? 161.9
? 157.1
? 152.5
? 147.9
? 143.6
? 139.3
? 135.2

? 131.1
? 127.2
 ENTER VALUES DURING EXERICES
? 114.
? 88.8
? 69.
? 68.
? 55.
? 53.
? 52.
ENTER VALUES AFTER EXERCISE
? 121.3
? 119.6
? 117.
? 112.9
? 104.7
? 8+98.6
? 89.
? 78.4
? 71.
? 66+4.6
? 63.
? 60.6
? 58.3
? 56.7
? 54.9
? 53.3
? 51.7
? 50.2
? 48.7
? 47.2
? 45.9
CLEARANCE BEFORE EXERCISE
   3.01    3.04    3.01    2.97    3.04
   2.95    3.04    2.99    3.00    3.02
CLEARANCE DURING EXERCISE
  23.19   24.76   13.95    8.76    3.76
   1.98
CLEARANCE AFTER EXERCISE
   1.41    2.28    3.92    5.29    7.89
  10.23   12.66    9.91    6.48    5.56
   3.88    3.53    3.12    3.23    2.96
   3.89    2.94    3.83    3.13    2.79

GRAPH OF RESULTS
```

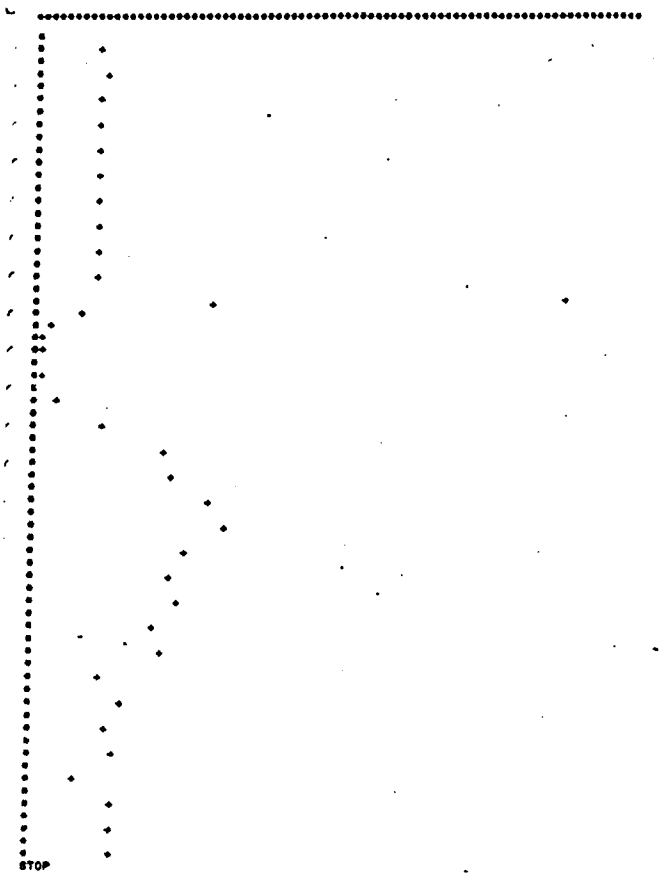


```
STOP
CP       0.997 SECS.
RUN COMPLETE.
```

Fig A14.22

Graphical output from program CLEAR for the calf of a limb with superficial femoral artery occlusion only.

```
 77/09/08. 10.36.37.
PROGRAM   CLEAR
   488  C CHANGE OF TYPE IN STATEMENT - DOMINANT TYPE USED
ENTER VALUES BEFORE EXERCISE
? 162.5
? 157.2
? 152.5
? 148.1
? 143.5
? 139.2
? 134.9
? 130.8
? 126.8
? 123.
? 119.2
 ENTER VALUES DURING EXERICES
? 130.
? 98.8
? 98.+.
? 88.
? 87.3
? 87.2
? 87.1
ENTER VALUES AFTER EXERCISE
? 117.3
? 117.
? 115.8
? 112.1
? 105.1
? 99.
? 89.5
? 81.
? 75.
? 70.
? 45.
? 41.
? 37.
? 33.
? 52.5
? 50.5
? 48.3
? 47.5
? 45.4
? 43.8
? 42.
CLEARANCE BEFORE EXERCISE
   3.13    9.23    2.93    3.14    3.84
   3.14    3.89    3.11    3.84    3.14
CLEARANCE DURING EXERCISE
  27.57    9.02    2.23     .87     .23
     .23
CLEARANCE AFTER EXERCISE
    .24    1.83    3.25    6.45    6.99
   9.87    9.97    7.49    6.98    7.41
   6.35    6.78    3.57    4.65    3.88
   4.84    2.88    4.88    4.83    4.28

GRAPH OF RESULTS
```

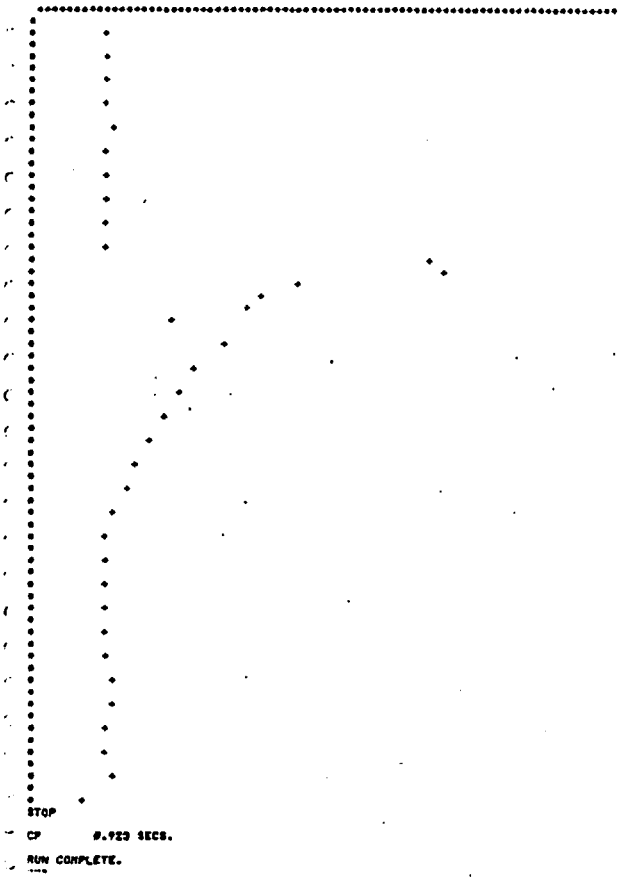


```
STOP

CP       0.967 SECS.

RUN COMPLETE.
```

Fig A14.23

Graphical output from program CLEAR for the calf of a limb with combined severe aortoiliac and femoral lesions.

```
77/09/08. 16.11.42.
PROGRAM   CLEAR
  400  C CHANGE OF TYPE IN STATEMENT - DOMINANT TYPE USED
ENTER VALUES BEFORE EXERCISE
? 182.
? 179.
? 168.2
? 161.7
? 153.34
? 149.4
? 143.6
? 138.1
? 132.7
? 127.6
? 122.7
 ENTER VALUES DURING EXERICES
? 93.
? 75.
? 60.
? 52.
? 46.
? 41.
? 38.
ENTER VALUES AFTER EXERCISE
? 107.6
? 99.
? 91.
? 84.2
? 78.3
? 73.7
? 70.1
? 66.8
? 64.
? 61.5
? 59.1
? 56.8
? 54.6
? 52.3
? 50.2
? 48.5
? 46.5
? 44.8
? 43.1
? 41.4
? 40.4
CLEARANCE BEFORE EXERCISE
  3.92    3.94    3.94    3.88    4.03
  3.96    3.98    3.99    3.92    3.92
CLEARANCE DURING EXERCISE
 21.43   22.22   14.29   12.24   11.49
  7.59
CLEARANCE AFTER EXERCISE
 10.16    8.42    7.76    7.81    6.84
  5.28    4.85    4.28    3.98    3.90
  3.97    3.98    3.92    3.88    4.04
  4.21    3.72    3.97    4.02    2.44

GRAPH OF RESULTS
```



```
STOP
CP       0.923 SECS.
RUN COMPLETE.
```

Fig A14.24

Graphical output from program CLEAR for the thigh of a limb with combined severe aortoiliac and femoral lesions-

```
 77/09/12. 10.51.24.
PROGRAM   K6
010 PROGRAM LAMDA1(INPUT,OUTPUT,TAPE1,TAPE2)
015 REAL B,A,Q1,Q2,Q3,Q4,Q
020 5 CONTINUE
030 PRINT 10
040 10 FORMAT(' ENTER D5:')
050 READ 11,D5
055 IF(D5 .EQ. 0.)GO TO 200
060 11 FORMAT(F12.6)
070 PRINT 12
075 12 FORMAT(' ENTER D10:')
076 READ 11,D10
081 PRINT 75
082 75 FORMAT(' ENTER D20:')
083 READ 11,D20
100 A=((900.*D5)-(466.*D10)+(63.*D20))/(250.*((9.*D5)-(2.*D10)))
110 PRINT 13,A
120 13 FORMAT(' A IS:',F12.6)
130 B=1.-A
135 Q1=D5*((10.*A)-1.+(B**10.))
138 Q2=D10*((5.*A)-1.+(B**5.))
140 Q3=(1.-(B**5.))*((10.*A)-1.+(B**10.))
142 Q4=(1.-(B**10.))*((5.*A)-1.+(B**5.))
150 Q=(0.8*(Q1-Q2))/(Q3-Q4)
160 95 CONTINUE
165 45 CONTINUE
170 PRINT 14,Q
180 14 FORMAT(' Q IS:',F15.5)
190 Z=((0.8*D5)-(Q*(1.-(B**5.))))/(10.*A)
220 PRINT 15,Z
230 15 FORMAT(' Z IS:',F12.6)
240 WRITE(1,25)D5,D10,A,Q,Z
245 25 FORMAT(5F15.5)
250 GO TO 5
260 200 STOP
270 END
```

Fig A14.25

Program $K_6$ for evaluation of a, Qo and $\lambda$ by employing three numbers ($D_5$,$D_{10}$ and $D_{20}$) (See section 4.21).

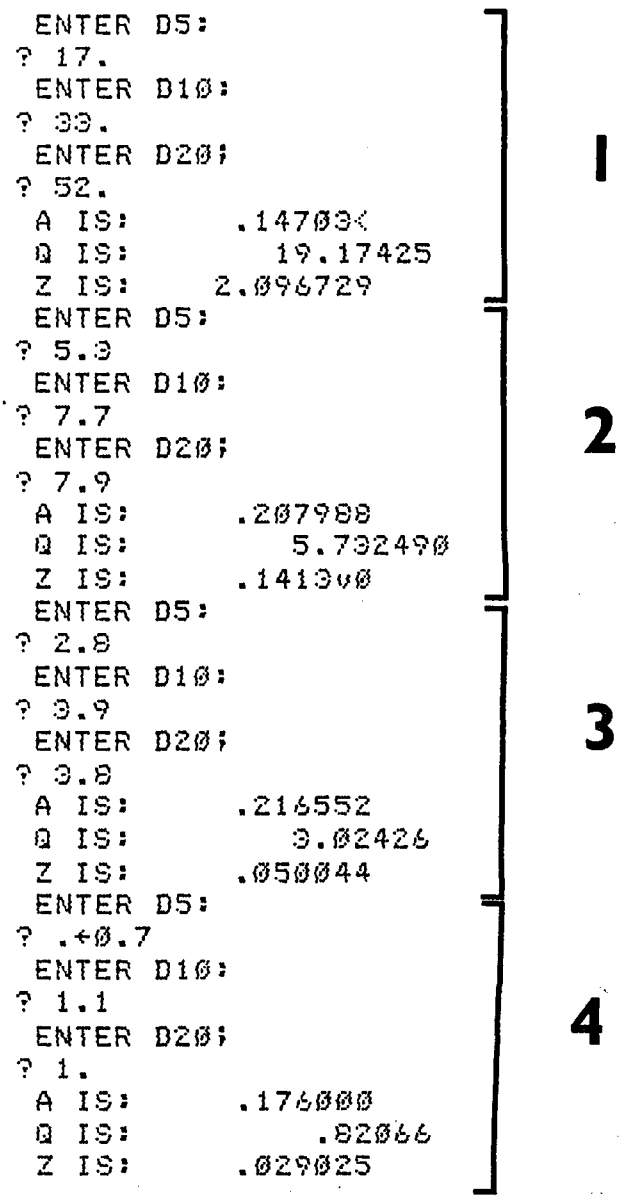



Fig A14.26

Values of a, Qo and λ for a normal limb (1), a limb with iliac occlusion only (2), a limb with superficial femoral artery occlusion only (3) and a limb with combined aortoiliac and femoropopliteal occlusion (4).
(Output from program K6).

# A P P E N D I X A15

## DERIVATION OF AN ADVANCED HAEMODYNAMIC MODEL.

Aim

The information obtained from the simultaneous clearance studies from the thigh and calf (Part II) and from the 2-pool haemodynamic model (Part III), was used to develop the 3-pool heamodynamic model presented in this Appendix.

Theoretical Considerations and Development of the 3-Pool Haemodynamic Model.

In order to elucidate the position and the significance of combined aortoiliac and femoropopliteal lesions, the arterial tree of the lower limb is considered to be composed of three pools of blood (Fig 4.2) : Pool 1, is an infinite pool containing the amount of blood above the proximal lesion. Pool 2 is a limited pool containing the amount of blood (Q) between the proximal lesion and the point of an intramuscular injection of $^{99m}Tc$ in the thigh. Finally, pool 3 is a limited pool also, containing the amount of blood (U) between the distal arterial lesion and the point of an intramascular injection of $^{99m}Tc$ in the calf (Fig A15.1). The thigh is chosen as the site of the proximal injection of $^{99m}Tc$, so that the isotope clearance is measured distal to an aortoiliac lesion, similarly, the calf is chosen as the site of the distal injection, so that the clearance of the isotope is measured distal to a femoropopliteal lesion.

It is assumed, that during a period of repeated elevations of the heel from the ground (tiptoeing), the same amount of blood ($\chi$) is brought into pool 2 from Pool 1 (Fig A15.1) during each tiptoe cycle. It is also assumed that a constant proportion ($\bar{a}$) of the blood contained in Pool 2 leaves via exits $A_1$ and $A_2$ during each tiptoe cycle, which is a fraction of the amount of blood in Pool 2 at time n

($Q_n$). A fraction (a) of $\bar{a}$ leaves via exit $A_1$ and enters into Pool 3, while another fraction ($\bar{a}$-a) leaves via exit $A_2$ into the thigh veins. Finally, it is assumed that a constant proportion ($\beta$) of the blood contained in Pool 3 leaves via exit B during each tiptoe cycle; $\beta$, is a fraction of the amount of blood in pool 3 at time n ($U_n$). The amount of blood ($Q_1$) in Pool 2 at the end of the first tiptoe cycle equals the amount of blood in Pool 2 at rest ($Q_o$), minus the amount that left Pool 2 ($\bar{a}.Q_o$), plus the amount that entered Pool 2 ($X_1$), thus

$$Q_1 = Q_o - \bar{a} \cdot Q_o + X_1 \qquad \text{(A15.1)}$$

Equation A15.1 can be rewritten as

$$Q_1 = (1 - \bar{a}) \cdot Q_o + X_1 \qquad \text{(A15.2)}$$

At the end of the second cycle

$$Q_2 = (1 - \bar{a}) \cdot Q_1 + X_2 \qquad \text{(A15.3)}$$

Substituting $Q_1$ from equation A15.2, equation A15.3 can be rewritten as

$$Q_2 = (1 - \bar{a}) [(1 - \bar{a}) \cdot Q_o + X_1] + X_2 \qquad \text{(A15.4)}$$

or

$$Q_2 = (1 - \bar{a})^2 \cdot Q_o + (1 - \bar{a}) X_1 + X_2 \qquad \text{(A15.5)}$$

Similarly at the end of the third cycle

$$Q_3 = (1 - \bar{a}) Q_2 + X_3 \qquad \text{(A15.6)}$$

Substituting $Q_2$ form equation A15.5, equation A15.6 can be rewritten as

$$Q_3 = (1-\bar{a}) \left[(1-\bar{a})^2 \cdot Q_o + (1-\bar{a})\, X_1 + X_2\right] + X_3 \qquad \text{(A15.7)}$$

or

$$Q_3 = (1-\bar{a})^3 \cdot Q_o + (1-\bar{a})^2\, X_1 + (1-\bar{a})\, X_2 + X_3 \qquad \text{(A15.8)}$$

So, at the end of the $n^{th}$ cycle :

$$Q_n = (1-\bar{a})^n \cdot Q_o + (1-\bar{a})^{n-1}\, X_1 + (1-\bar{a})^{n-2}\, X_2 \ldots\ldots X_n \qquad \text{(A15.9)}$$

Assuming that the same amount of blood enters Pool 2 during each tiptoe cycle, then,

$$X_1 = X_2 = X_3 \ldots\ldots\ldots X_{n=\lambda}$$

and

$$\boxed{Q_n = Q_o\,(1-\bar{a})^n + \frac{1-(1-\bar{a})^n}{\bar{a}} \cdot \lambda} \qquad \text{(A15.10)}$$

The amount of blood ($U_1$) in Pool 3 at the end of the first tiptoe cycle equals the amount of blood in Pool 3 at rest ($U_o$), minus the amount that left Pool 3 ($\beta . U_o$), plus the amount that entered Pool 3 ($a.Q_o$), thus

$$U_1 = (1-\beta)\, U_o + a\, Q_o \qquad \text{(A15.11)}$$

At the end of the second cycle

$$U_2 = (1-\beta) \left[(1-\beta)\, U_o + a\, Q_o\right] + a\, Q_o\, (1-\bar{a}) + \left[\frac{1-(1-\bar{a})}{\bar{a}}\right].\lambda \qquad \text{(A15.12)}$$

or

$$U_2 = (1-\beta)^2\, U_o + a(1-\beta)Q_o + a(1-\bar{a})\, Q_o + \left[\frac{1-(1-\bar{a})}{\bar{a}}\right].\lambda \qquad \text{(A15.13)}$$

$$U_3 = (1-\beta)\, U_2 + aQ_o(1-\bar{a})^2 + \left[\frac{1-(1-\bar{a})^2}{\bar{a}}\right] . \lambda \qquad (A15.14)$$

or

$$U_3 = (1-\beta)^3 U_o + a\,(1-\beta)^2 Q_o + a\,(1-\bar{a}) . (1-\beta)\, Q_o + (1-\beta)\left[\frac{1-(1-\bar{a})}{\bar{a}}\right] . \lambda + a(1-\bar{a})^2 Q_o + \left[\frac{1-(1-\bar{a})^2}{\bar{a}}\right] .\lambda \qquad (A15.15)$$

Therefore, at the $n^{th}$ cycle

$$U_n = (1-\beta)^n U_o + a.\, Q_o \left[(1-\beta)^{n-1} + (1-\bar{a})\,(1-\beta)^{n-2} + \ldots\ldots \right.$$

$$\ldots\ldots\ldots + (1-\bar{a})^{n-2}\,(1-\beta) + (1-\bar{a})^{n-1}$$

$$+ \left( \left[\frac{1-(1-\bar{a})}{\bar{a}}\right] . \lambda\,(1-\beta)^{n-2} + \left[\frac{1-(1-\bar{a})^2}{\bar{a}}\right] . \lambda\,(1-\beta)^{n-3} \right.$$

$$\left. \left. + \ldots\ldots + \frac{1-(1-\bar{a})^{n-2}}{\bar{a}}\, \lambda\,(1-\beta) + \frac{1-(1-\bar{a})^{n-1}}{\bar{a}} . \lambda \right) \right) \qquad (A15.16)$$

because

$$\left[(1-\beta)^{n-1} + (1-a) . (1-\beta)^{n-2} + \ldots\ldots\ldots + (1-\bar{a})^{n-1}\right]$$

is a geometric series with first term

$$A = (1-\beta)^{n-1} \quad \text{and common ratio} \quad R = \left(\frac{1-\bar{a}}{1-\beta}\right) ,$$

$$\text{Sum of series} = A\ \frac{1-R^n}{1-R}$$

$$= (1-\beta)^{n-1}\ \frac{1-\left(\frac{(1-\bar{a})^n}{(1-\beta)}\right)}{1-\frac{1-\bar{a}}{1-\beta}}$$

$$= (1-\beta)^{n-1} \quad \frac{(1-\beta)^n - (1-\bar{a})^n}{\left(\frac{1-\beta}{1-\beta}\right)^n \quad (1-\beta) - (1-\bar{a})}$$

or

$$\boxed{\text{Sum of series} = \frac{(1-\beta)^n - (1-\bar{a})^n}{(\bar{a}-\beta)}} \qquad \text{(A15.17)}$$

Similarly, the series in curly brackets in equation A15, 16 can be rewritten as

$$\frac{\lambda}{\bar{a}} \left[ \left( \left( (1-\beta)^{n-2} + (1-\beta)^{n-3} + \ldots\ldots\ldots + (1-\beta) + 1 \right) \right) \right.$$

$$-(1-\bar{a}) \left\{ (1-\beta)^{n-2} + (1-\bar{a}) \cdot (1-\beta)^{n-3} + \ldots\ldots\ldots \right.$$

$$\left. \left. + (1-\bar{a})^{n-3} (1-\beta) + (1-\bar{a})^{n-2} \right) \right] \qquad \text{(A15.18)}$$

The series in double curly brackets in equation (A15, 18) is a geometric series with first element A = 1 and ratio R = (1-β) (counting backwards)

$$\text{Sum of series} = 1 \cdot \frac{1-(1-\beta)^{n-1}}{1-(1-\beta)}$$

or

$$\boxed{\text{sum} = \frac{1-(1-\beta)^{n-1}}{\beta}} \qquad \text{(A15.18a)}$$

The series in single curly brackets in equation (A15.18) is a geometric series also, with first element $A = (1-\beta)^{n-2}$ and common ratio $R = \left(\frac{1-\bar{a}}{1-\beta}\right)$.

$$\text{Sum of series} = (1-\beta)^{n-2} \left[ \frac{1 - \left(\frac{1-\bar{a}}{1-\beta}\right)^{n-1}}{1 - \left(\frac{1-\bar{a}}{1-\beta}\right)} \right]$$

or

$$\boxed{\text{Sum} = \left\{ \frac{(1-\beta)^{n-1} - (1-\bar{a})^{n-1}}{(\bar{a}-\beta)} \right\}} \qquad \text{(A15.19)}$$

Therefore, by inserting equations A15.18, A15.18a and A15.19 into equation A15.16, this can be rewritten as

$$\boxed{\begin{aligned} U_n = (1-\beta)^n U_o + aQ_o \left\{ \frac{(1-\beta)^n - (1-\bar{a})^n}{(\bar{a}-\beta)} \right\} \\ + \frac{\lambda}{\bar{a}} \left[ \frac{1-(1-\beta)^{n-1}}{\beta} \right] - \frac{\lambda}{\bar{a}} (1-\bar{a}) \left[ \frac{(1-\beta)^{n-1} - (1-\bar{a})^{n-1}}{(\bar{a}-\beta)} \right] \end{aligned}} \qquad \text{(A15.20)}$$

Let, $W_n$ be the amount of blood that has left Pool 2 from the beginning of the first to the end of the $n^{th}$ tiptoe cycle. $W_n$, equals to the amount of blood $(n.\lambda)$ that has entered Pool 2, plus the amount of blood $(Q_o)$ in it at rest, minus the amount of blood $(Q_n)$ that remains in Pool 2 at the end of the $n^{th}$ cycle, thus

$$W_n = n.\lambda + Q_o - Q_n$$

Substituting $Q_n$ from equation A15.10

$$W_n = n.\lambda + Q_o - Q_o\,(1-\bar{a})^n - \left[\frac{1-(1-\bar{a})^n}{\bar{a}}\right]\cdot\lambda$$

Let, $1-\bar{a} = \sigma$ (A15.21)

Then

$$W_n = n\lambda + Q_o - Q_o\sigma^n - \left[\frac{(1-\sigma)^n}{\bar{a}}\right]\cdot\lambda \qquad \text{(A15.22)}$$

or

$$\boxed{W_n = \frac{\lambda}{\bar{a}}\,(\bar{a}n - 1 + \sigma^n) + Q_o\,(1-\sigma^n)} \qquad \text{A15.23}$$

Let, $S_n$ be the amount of blood that has left Pool 3 from the beginning of the first to the end of the $n^{th}$ tiptoe cycle. $S_n$, equals to the amount of blood $\left[\left(\frac{a}{\bar{a}}\right) W_n\right]$ that has entered Pool 3, plus the amount of blood ($U_o$) in it at rest., minus the amount of blood ($U_n$) that remains in Pool 3 at the end of the $n^{th}$ cycle, thus

$$S_n = \left[\left(\frac{a}{\bar{a}}\right) \cdot W_n\right] + U_o - U_n$$

or

$$\boxed{\begin{aligned} S_n = {} & \frac{a\lambda}{\bar{a}^2}\,(\bar{a}n - 1 + (1-\bar{a})^n) + \frac{aQ_o}{\bar{a}}\,(1-(1-\bar{a})^n) \\ & + [1-(1-\beta)^n]\,U_o - aQ_o\left\{\frac{(1-\beta)^n - (1-\bar{a})^n}{(\bar{a}-\beta)}\right\} \\ & - \frac{\lambda}{\bar{a}}\left[\frac{1-(1-\beta)^{n-1}}{\beta}\right] + \frac{\lambda}{\bar{a}}\,(1-\bar{a})\left[\frac{(1-\beta)^{n-1} - (1-\bar{a})^{n-1}}{(\bar{a}-\beta)}\right] \end{aligned}}$$

(A15.24)

The amounts of blood $W_n$ and $S_n$ that leave Pool 2 and Pool 3 respectively from time t = 0 to time t = n, i.e. by the end of the $n^{th}$ cycle, are proportional to the total percentage clearance for the thigh and calf respectively; between t =0 and t = n, i.e. total percentage clearance for thigh = $D'_n$ and total percentage clearance for calf = $D''_n$ .

Therefore

$$W_n = K.\ D'_n \qquad \text{(A15.25)}$$

and

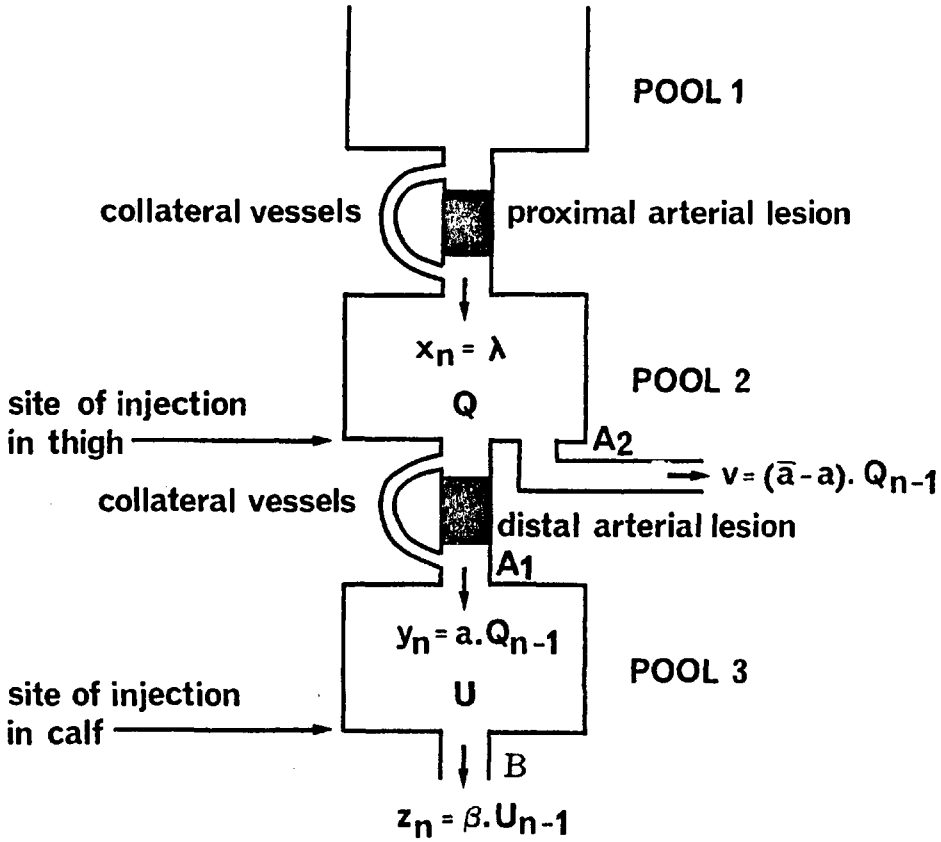
$$S_n = K\ .\ D''_n \qquad \text{(A15.26)}$$

Where K is the muscle to blood partition coefficient for the isotope used.

$W_n$ can be substituted in equation A15.25 from equation A15.23. Similarly, $S_n$ can be substituted in equation A15.26 from equation A15.24. Therefore, by solving 6 equations of the form $W_n = KD'_n$ and $S_n = K.D''_n$ for 3 values of n, the unknowns of the 3 pool haemodynamic model, a, $\bar{a}$, $\beta$, $Q_o$, $U_o$ and $\lambda$, can be determined.

The 3-pool heamodynamic model can be validated by doing the standard tiptoing exercise of 5, 10 and 20 movements used in the 2 - pool haemodynamic model, with the measurement of the simultaneous clearance from the thigh and calf.

The decrease in radioactivity during each one of the 3 exercises (5, 10 and 20 tiptoe movements) would provide 3 values for the thigh and 3 values for the calf from which the equations can be solved and the values of a, $\bar{a}$, $\beta$, $Q_o$, $U_o$ and $\lambda$ can be found.




Three-pool Haemodynamic Model

Fig. A15.1