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CLINICAL USE OF AN ULTRASONIC DOPPLER FLOW METER IN ARTERIAL OCCLUSIVE DISEASES OF THE LOWER EXTREMITIES

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ABSTRACT

Diagnostic value of a transcutaneous Doppler flow meter in arterial occlusive diseases was studied. Ankle systolic pressures at rest and after exercise were measured by placing a flow probe over the dorsalis pedis artery and posterior tibial artery. A pressure index was obtained by comparing the ankle and brachial pressure. Exercise tolerance was determined by dorsoplantar flexion of ankle, 20 times per minute for 2 minutes, and two parameters, % fall of ankle pressure and recovery time, were calculated.

A pressure index was well correlated with the site of arterial occlusion and the degree of clinical symptoms. However, it was difficult to evaluate the circulatory insufficiency of the limbs between diseased and normal persons in the cases of below knee obstruction and clinically mild ones. Measurement of ankle pressure after exercise gave us better information of circulatory insufficiency in the lower extremities, especially in mild cases. The % fall of ankle pressure and recovery time were well correlated with the degree of clinical symptoms and few cases overlapped with normal subjects. Statistical exploration also revealed that the higher value between the ankle pressure measured over the dorsalis pedis artery and that over the posterior tibial artery, significantly refracted circulatory insufficiency in the lower extremities. Moreover, it was found that measurement of ankle pressure was useful in the assessment of reconstructive arterial surgery.

INTRODUCTION

Although arteriography provides precise information of the site and severity of arterial lesions in patients with arterial occlusive disease, it gives us no information of the degree of functional impairment. Therefore, various methods, such as venous occlusion plethysmography, Xenon-133 clearance method and thermography, have been used as functional tests in peripheral vascular diseases.

Recently, the usefulness in application of an ultrasonic Doppler flow meter to peripheral vascular diseases has been emphasized. This instrument has wide clinical applications, such as to evaluate functional disorder of the extremities by measuring flow velocity or ankle systolic pressure and by analyzing flow wave pattern, to assess

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the result of reconstructive arterial surgery and to follow the process of the disease.

In this report, we studied the relationship between the ankle systolic pressure, measured at rest and after ankle exercise by a Doppler flow meter, and the severity of the haemodynamic disorders in patients with arterial occlusive diseases of the lower extremities.

MATERIALS AND METHODS

Twenty seven limbs with thromboangitis obliterans (TAO), six limbs with arteriosclerosis obliterans (ASO) and twenty normal limbs were selected for this study. The locations of arterial occlusion were recognized by arteriography in all the diseased limbs.

Patients were made to lie in the spine position, and ankle systolic pressure was measured by placing a pneumatic cuff just above the malleolus. The probe was held on the skin over the site of the dorsalis pedis artery or the posterior tibial artery. The pressure index was determined as follows:

$$\text{Pressure index} = \frac{\text{Ankle systolic pressure}}{\text{Brachial systolic pressure}}$$

When there was a difference between the ankle pressure, measured over the dorsalis pedis artery and that over the posterior tibial artery, the one with the higher value was used for calculation. The brachial pressure was measured bilaterally and the higher value was also used.

The exercise tolerance was determined by dorsoplantar flexion of the ankle, 20 times per minute for 2 minutes, by using the equipment shown in figure 1. The ankle pressure was measured every 30 seconds for 5 minutes after exercise and then, every one minute until it returned to the pre-exercise level. Two parameters, % fall of ankle pressure and recovery time, were obtained.

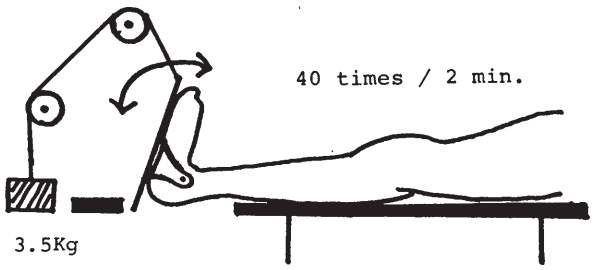


FIG. 1. Schematic representation of ankle exercise

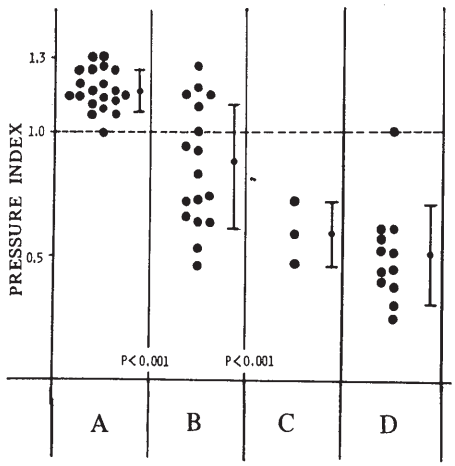
$$\% \text{ fall of ankle pressure} = \frac{\text{Pre-exercise ankle pressure} - \text{Post-exercise minimal ankle pressure}}{\text{Pre-exercise ankle pressure}} \times 100(\%)$$

Recovery time = minutes for return to pre-exercise ankle pressure

RESULTS

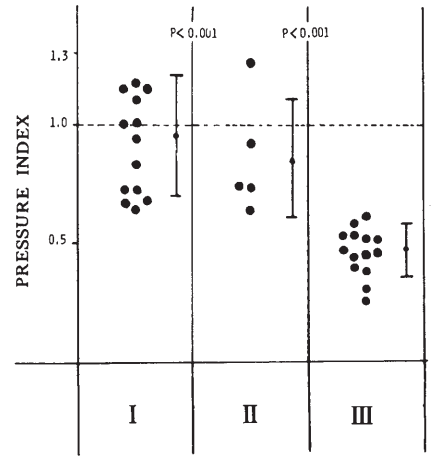
1) Pressure index

The pressure index of the normal limb was 1.17 ± 0.084 and that of the diseased limb was 0.71 ± 0.27. Figure 2 shows the relationship between the pressure index and site of arterial occlusion. There were significant differences among normal limbs, limbs with below knee obstruction and limbs with above knee obstruction. ($p<0.001$)



A NORMAL LIMBS
B LIMBS WITH BELOW KNEE OBSTRUCTION
C LIMBS WITH ABOVE KNEE OBSTRUCTION, SEGMENTAL
D LIMBS WITH ABOVE KNEE OBSTRUCTION, DIFFUSE

FIG. 2. Relationship between the pressure index and the site of arterial occlusion



I LIMBS WITHOUT CLAUDICATION
II LIMBS WITH CLAUDICATION (100m>)
III LIMBS WITH CLAUDICATION (100m≦)

FIG. 3. Relationship between the pressure index and clinical symptoms

As shown in figure 3, the subjects were classified into three groups according to their clinical symptoms.

Group 1 limbs without claudication
Group 2 limbs with claudication (claudication distance >100m)
Group 3 limbs with claudication (claudication distance $\leqq 100$m)

Values of the pressure index in Group 1 were significantly differentiated from those in Group 2 ($p < 0.001$) and also values in Group 2 were different from those in Group 3 ($p < 0.001$). Thus the pressure index was well correlated with the severity of clinical symptoms, but its value in several mild cases overlapped with the normal subjects.

2) Post-exercise change of ankle pressure

In normal subjects, the ankle pressure dropped less than 10 % of pre-exercise level and returned to normal within 1.27 minutes after the ankle exercise for 2 minutes.

In patients with arterial occlusive diseases, the ankle exercise caused a significant drop of ankle pressure and a delayed return to pre-exercise level (Figure 4-(2), (3)). The values of two parameters, % fall of ankle pressure and recovery time, were well correlated with the severity of clinical symptoms (two parameters, $p < 0.001$ among three groups) and few cases overlapped with the normal subjects, compared with the assessment only by the pressure index (Figure 5).

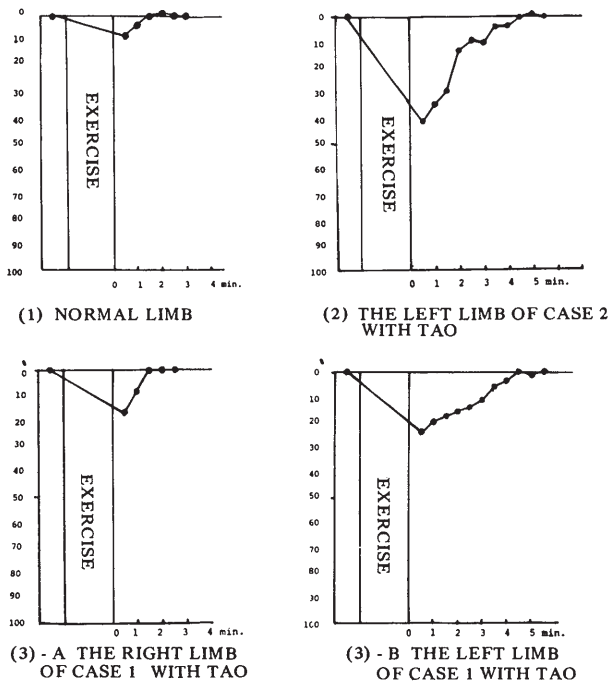


FIG. 4. Changes of ankle pressure after exercise in a normal limb, case 1 and case 2.

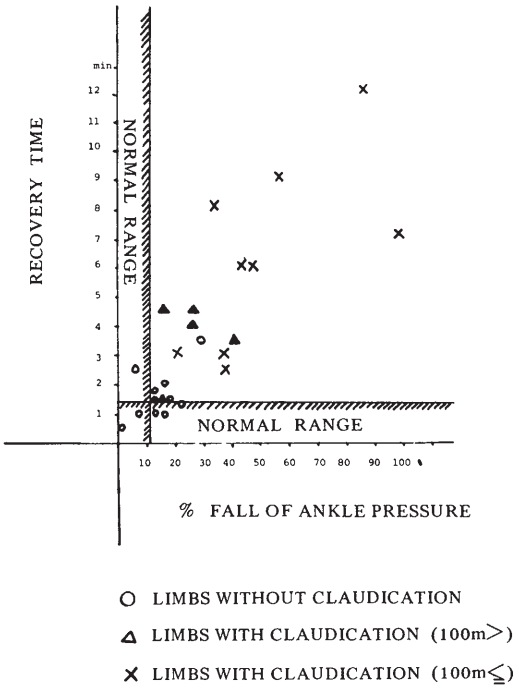


FIG. 5. Relationship between the values of two parameters, obtained by the ankle exercise method, and clinical symptoms

3) The assessment of ankle pressure measured on two different sites

As mentioned above, we used the higher value of ankle pressure between the value, measured on the dorsalis pedis artery, and that on the posterior tibial artery. When the higher value was used for calculation, there were significant differences between the value of pressure index in Group 1 and Group 2 + 3 ($p < 0.001$) and between the value in Group 2 and 3 ($p < 0.001$). However, in the use of the lower value there were no significant differences between Group 2 and 3 (Figure 6). From these facts, the higher value of ankle pressure measured on the two sites agreed better with the clinical symptoms. The difference of these two would refract the disorder of individual tibial arteries. In normal subjects, the difference was below 10.7 mmHg and in cases in which the disorder of one artery predominated over the other, the difference was above 30 mmHg.

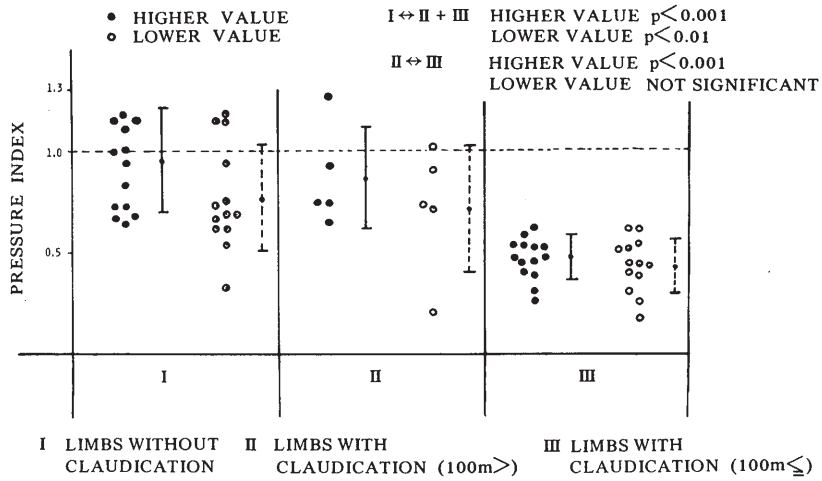


FIG. 6. Significance of the use of higher value in ankle pressure

4) Use of a Doppler flow meter in reconstructive arterial surgery

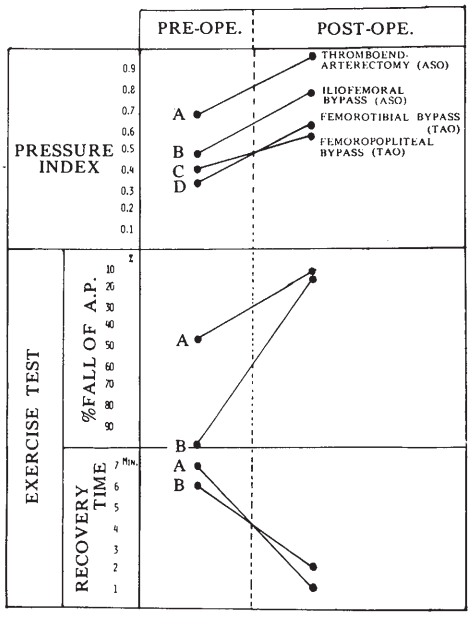


FIG. 7. Pressure index and two parameters in ankle exercise method before and after the reconstructive arterial surgery

A Doppler flow meter is useful to monitor the patency of the graft in reconstructive arterial surgery and also to assess the effect of operation objectively. In two limbs with ASO and two limbs with TAO, the ankle pressure was measured before and after operation (Figure 7). The pressure index after operation improved remarkably in all cases. The % fall of ankle pressure and recovery time showed high abnormality in two limbs with severe claudication before operation in the cases of ASO. After the operation of iliac thromboendarterectomy or ilio femoral bypass, the value of two parameters improved to almost normal level with the disappearance of claudication.

CASE REPORT

Case 1. 33 year-old male TAO

The patient visited our clinic with complaints of coldness in both limbs and intermittent claudication in the left foot.

Arteriography of both limbs showed obstruction of the anterior tibial artery in the middle portion of the lower leg and the posterior tibial artery at ankle level, and there seemed to be little difference between the left and right limbs arteriographyically (Plate 1).

The pressure indexes were 0.72 in the right and 0.74 in the left and also showed little difference. However, % falls of ankle pressure were 18.3 % in the right and 27.3 % in the left and recovery times were 1.5 minutes in the right and 4.5 minutes in the left (Figure 4-(3)- A, B). This result showed that the change of ankle pressure after exercise well reflected the circulatory insufficiency in the limbs.

Case 2. 44 year-old male TAO

The patient complained of intermittent claudication in the left calf. Arteriography revealed obstruction of the anterior and posterior tibial arteries (Plate 2).

The pressure index in the left limb was 1.26, which was within normal range. However, both % fall of ankle pressure and recovery time showed high abnormalities (40.8 % and 3.5 minutes, respectively) (Figure 4-(2)). We can know that the exercise method is useful especially in the evaluation of clinically mild cases or cases with below knee obstruction.

DISCUSSION

Measurement of flow velocity and analysis of flow wave pattern, obtained by the ordinary Doppler flow meter in peripheral vascular diseases, have limitations in the quantitative assessment of haemodynamic disorders of the extremities, because the angle between the probe and different vessels cannot be reproduced exactly.[1] Although measurement of ankle pressure in cases with arterial occlusive disease has been already studied by plethysmography or other methods[2], no tests can be accepted for general clinical use because of the need for special equipment and

training for instrumentation. Moreover, it was recognized that blood pressure measurement by a Doppler flow meter best agreed with the true arterial pressure among the various methods[3),4)].

Another advantage of a Doppler flow meter is that we can know the occlusive process of individual tibial arteries. Carter[5)] reported that the differences in the ankle pressure obtained by listening over the dorsalis pedis artery or the posterior tibial artery did not exceed 10 mmHg or more in normal limbs and the pressure measured over the vessel with more severe occlusive process was lower than 15 mmHg or more.

The pressure index (leg/arm) gives us reliable information about the process of arterial occlusive disease. Yao[7)] and Carter[8)] reported that the pressure index agreed well with the site of arterial occlusion and the severity of clinical symptoms. However, most of their materials were arteriosclerosis obliterans in which the usual sites of arterial occlusion were above the knee and the values of pressure index in their reports were always below 1.0. In thromboangitis obliterans, which is more frequently seen than arteriosclerosis obliterans in Japan, there were observed many cases with below knee obstruction and our studies showed that the pressure index in these cases sometimes overlapped with normal subjects. Therefore, exercise studies may be necessary to evaluate the borderline cases and to demonstrate the haemodynamic disorders of the limbs quantitatively. We could know the circulatory insufficiency of the limbs, which was impossible to demonstrate by arteriography or the study of pressure index, by studying the post-exercise change of ankle pressure, as shown in case reports.

The reduction of ankle pressure after exercise would be due to the shunting of blood to the exercising muscle before it reaches ankle level. In normal limbs the intramuscular vessels, which are compressed by muscles during exercise, dilate after exercise with the reduction of resistance and allow blood to be shunted to the muscles, maintaining the sufficient supply of blood to ankle.

In the study of five minutes treadmil exercise[2),6),9)], ankle pressure rises slightly after exercise and returns to pre-exercise values immediately in normal limbs. However, in our study of ankle exercise for two minutes, ankle pressure after exercise showed a slight drop and rapid return in normal subjects and a similar report was made by Allan[10)]. These paradoxical data would be probably because the magnitude of muscle exercise concerning the lower legs may be higher in our study than in treadmil exercise.

In the obstructed limbs, blood goes distal to the obstruction through the collateral arteries with high resistance. After exercise, shunting volume of blood to muscle cannot be enough and is delayed to reach the muscle with poor supply of blood to ankle level. Therefore, fall of ankle pressure and recovery time may be affected by the length of arterial occlusion and the number of effective collateral channels.

The usefulness of a Doppler flow meter in reconstructive arterial surgery has

been already emphasized by Yao[7], Carter[5] and other authors. In deciding the indication for reconstructive arterial surgery, they judged the case, in which the pressure index was above 0.5, to be good run-off.

It is also useful as an objective method for the follow up after operation because it can be carried out repeatedly and easily anywhere.

REFERENCES

1) Strandness, Jr, D. E., McCutcheon, E. P. & Rushmer, R. F.: Application of a transcutaneous Doppler flow meter in evaluation of occlusive arterial disease. *Surg. Gynec. Obst.*, **122**, 1039, 1966.
2) Sumner, D. S. & Strandness, Jr, D. E.: The relationship between calf blood flow and ankle blood pressure in patients with intermittent claudication. *Surgery*, **65**, 763, 1969.
3) Kemmerer, W. T., Ware, R. W. & Stegall, H. F.: Indirect measurement of human blood pressure by the Doppler ultrasonic technique. *Surg. For.*, **13**, 163, 1967.
4) Stegall, H. F., Kardon, M. B. & Kemmerer, W. T.: Indirect measurement of arterial blood pressure by Doppler ultrasound sphyngmomanometry. *J. Appl. Physiol.*, **25**, 793, 1968.
5) Carter, S. A.: Clinical measurement of systolic pressure in limbs with arterial occlusive disease. *JAMA.*, **207**, 1869, 1969.
6) Yao, S. T.: Experience with the Doppler ultrasound flow velocity meter in peripheral vascular disease. *Modern trends in vascular surgery*, Buttermorth Co. Ltd. London, vol **I**: 281, 1970.
7) Yao, S. T.: Haemodynamic studies in peripheral arterial disease. *Brit. J. Surg.*, **57**, 761, 1970.
8) Carter, S. A.: Indirect pressures and pulse waves in arterial occlusive disease of the lower extremities. *Circulation*, **37**, 624, 1968.
9) Skinner, J. S. & Strandness, Jr, D. E.: Exercise and intermittent claudication. I. Effect of repetition and intensity of exercise. *Circulation*, **36**, 15, 1967.
10) Allan, J. S. & Terry, H. J.: The evaluation of a ultrasonic flow detector for the assessment of peripheral vascular disease. *Cardiovasc. Res.*, **3**, 503, 1969.

Plate 1. Arteriography in both limbs of Case 1. The anterior tibial artery occluded in the middle portion of lower leg and the posterior tibial artery occluded at ankle level in both limbs.

Plate 2. Arteriography in the left limb of Case 2. The anterior and posterior tibial arteries occluded in the middle of lower leg and at ankle level, respectively.