Diabetologia 15, 9–11 (1978)

Diabetologia

Originals

Tilted and Non-Tilted Postischaemic Exercise Peak Blood Flow in the Legs of Long-Term Diabetic and Normal Subjects

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Summary. A tilting procedure, that increases the leg blood flow after maximal ischaemic exercise by 65% in normal persons, was used in a series of long-term juvenile diabetics both with and without radiologically demonstrable linear calcification in the leg arteries. Using this procedure decreased blood flow capacity was demonstrable even before radiologically linear calcification had developed. The decrease in postischaemic leg blood flow, observable in recumbent long-term juvenile diabetics with linear arterial calcification was exaggerated by the tilting procedure.

Key words: Diabetes, muscle blood flow, postischaemic peak flow, tilting.

The postischaemic exercise peak blood flow of the leg muscles, i. e. the flow immediately after cessation of maximal ischaemic work, may be low in long-term diabetic patients [2]. This was so, however, only when radiologically demonstrable linear calcification of the leg arteries was present. In such patients the decrease of the peak flow was correlated to the duration of diabetes.

Recently we have shown that when the ischaemic exercise test is carried out with the patient on a tilting table, in a 45° feet down position, the peak blood flow of the leg muscles is considerably increased [9]. It seemed therefore of interest to reexamine the flow in long-term diabetic patients, but at an earlier stage, that is when linear calcification was not yet visible in the leg arteries at x-ray examination.

Patients and Methods

The study included 21 juvenile long-term diabetic patients (9 women, 12 men), and 11 non-diabetic controls (4 women and 7 men). The diabetics were divided into two subgroups: 12 patients with calcification in the leg arteries as determined on low voltage radiograms [8], and 9 patients without calcification.

The mean duration of diabetes (± SEM) in the two subgroups was 24 ± 6 and 19 ± 5 years respectively. The mean age was 41 and 36 years, with a range from 20 to 50 years. The mean age of the controls was 33 years, individually ranging from 20 to 50 years. All diabetics received insulin treatment. Retinopathy was present in 66% of the patients without arterial calcification and in 83% of the patients with such calcification. None of the diabetic patients had a history of intermittent claudication and none had ulceration on the leg or foot. None of the patients received antihypertensive drugs except thiazides.

The leg blood flow capacity was estimated as the peak flow in the anterior tibial muscle induced by maximal ischaemic exercise. Ischaemia was obtained by rapid insufflation of a thigh cuff to 290 mm Hg, and this was maintained for five minutes. Exercise involved rythmical elevation of a 2 kg weight fixed to the forefoot, until rendered impossible by pain. Flow was measured by the Xe^{133} radioisotope clearance technique [5, 6, 7].

All subjects were studied one day in a horizontal position and another day in a 45° feet down tilted position. The sequence of tests was chosen at random.

The tilt test was performed on a tilt table. The table was kept horizontal until the end of the ischaemic exercise period. Just before cuff release it was rapidly turned to the 45° position, and remained there for the remainder of the test, i. e. during the measurement of peak flow.

Systemic blood pressure was measured indirectly in the arm while resting and ½, 1, 3, and 5 minutes after cuff release, i. e. during the peak flow.

Statistical analysis was carried out using Student's t-test.

Results

The peak blood flow in the leg muscles after maximal ischaemic exercise measured in the traditionally recumbent position was 76 ± 14 ml/100 g muscle/

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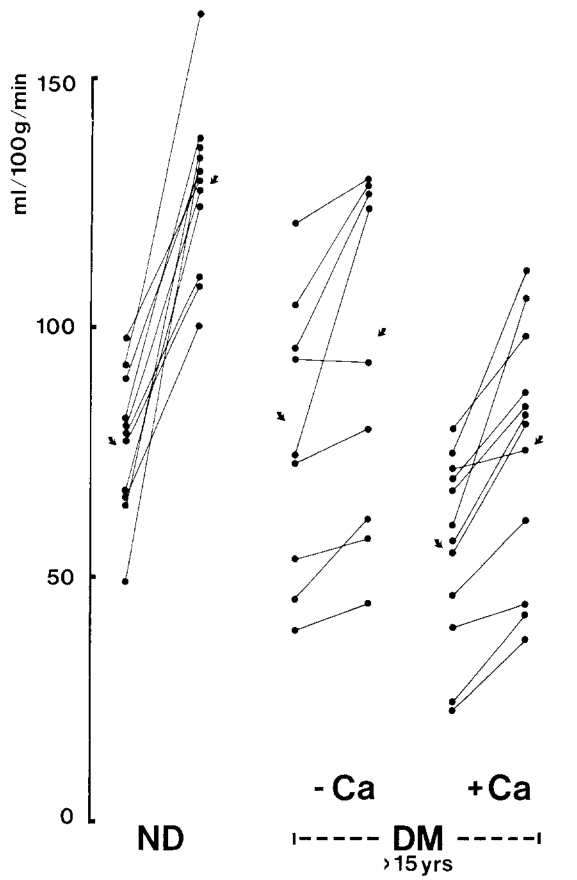

Fig. 1. Tilted and non-tilted postischaemic exercise peak flow in the leg of normals (ND), long-term diabetic patients without media calcification (DM, − Ca) and long-term diabetic patients with media calcification (DM, + Ca). In each group of patients the non-tilted peak flow values are to the left, and the tilted peak flow values to the right. The arrows indicate mean values for each group

min (mean ± SD) in the controls. In long-term diabetic patients without radiologically demonstrable media calcification in the leg arteries this flow was 81 ± 28 ml/100 g muscle/min and did not differ from that of the controls. In long-term diabetics with media calcification the non-tilted postischaemic peak blood flow averaged 56 ± 18 ml/100 g/min and was significantly reduced in comparison with the controls. ($p < 0.0025$).

Tilting to a 45° feet down position increased the postischaemic exercise peak blood flow of the leg in all groups of patients investigated, but to a different degree (Fig. 1). In the controls the flow increased from 76 ± 14 ml/100 g/min to 128 ± 19 ml/100 g/min ($p < 0.0005$). In comparison to this, tilting disclosed reduced flow capacity in the leg of the diabetics without arterial calcification. Their tilted peak blood flow was 99 ± 36 ml/100 g/min, differing significantly from that of the normals ($p < 0.025$). In the long-term diabetic patients with arterial calcification the flow capacity measured in the tilted position was further reduced, averaging 76 ± 24 ml/100 g/min. This tilted peak blood flow differed significantly from both controls and diabetics without arterial calcification ($p < 0.0005$ and $p < 0.05$ respectively).

The time required to induce ischaemic pain was in the recumbent position 2.5 ± 0.7 min (mean ± SD) in the controls, 2.3 ± 0.4 in the long-term diabetics without arterial calcification, and 2.6 ± 0.5 in the patients having arterial calcification. In the tilt test the values were 2.5 ± 0.7, 2.4 ± 0.5, and 2.6 ± 0.2 respectively.

Systemic blood pressure measured during the peak flow in the non-tilted and in the tilted position did not differ significantly in any of the groups investigated. Resting blood pressure was increased in both groups of long-term diabetics. Diastolic blood pressure in controls was 85 ± 15 mm Hg, 96 ± 14 in diabetics with ($p < 0.05$) and 100 ± 14 in diabetics without media calcification ($p < 0.05$).

Discussion

The peak blood flow measured immediately after maximal ischaemic work by the Xe^{133} clearance technique has been used for many years as an estimate of the flow capacity of muscular arteries [1, 5, 6, 7]. A special advantage of the ischaemic exercise is the fact that the peak flow in the postischaemic period is independent of autonomic nervous control [11].

Christensen studied series of long-term diabetic patients in the traditionally used recumbent position, employing this technique. He found the peak blood flow after maximal ischaemic exercise reduced, but only in patients with radiologically demonstrable linear calcification of the leg arteries [2]. Linear calcification, localized to the media of large arteries, is known to be the characteristic abnormality in advanced large vessel disease of long-term diabetic patients [4, 8], and this type of calcification is related quantitatively to the degree of carbohydrate intolerance in elderly non-diabetics [8].

The results obtained in the present study clearly establish that feet down tilting increases the sensitivity of the postischaemic peak flow test and make possible earlier detection of peripheral vascular abnormalities in diabetic patients. Using the tilting table technique a pronounced reduction of the post-ischaemic peak blood flow, i. e. of the blood flow capacity, was demonstrated in patients, in whom medial calcification was not yet visible. This functional abnormality was not detectable in the horizontal position. The advantage of the tilting procedure also appears from the fact, that the abnormality in the patients, who do have calcifications, becomes even more pronounced, when these patients are examined in the feet down tilted position (Fig. 1).

The high postischaemic leg blood flow obtained in the tilted position may be explained by changes in driving pressure, i. e. the arteriovenous difference, and/or vascular resistence. In an earlier study [9] it was shown, that the postischaemic leg vein pressure increased with the hydrostatic pressure within a few seconds of cuff release in the tilted position, and the pressure was constant before the beginning of the monoexponential clearance curve from which the peak flow is calculated. Furthermore it was shown that the effect of tilting is independent of the vein filling prior to the test. Thus the arteriovenous pressure difference had not changed after tilting. But in the tilt test both the arterial and the venous pressures were increased with the hydrostatic pressure and the higher intravascular mean pressure may induce a passive dilatation of the blood vessels resulting in decreased resistance and increased blood flow. Active vasodilatation seems improbable because the ischaemic stress is the same in the horizontal as in the tilted position. Moreover, if functional activity was playing a role, vasoconstriction rather than dilatation would have been expected, when assuming an upright position [10]. Thus passive vasodilatation is most likely the mechanism leading to higher flow in the tilted position.

The results obtained by Christensen [2, 3] and those obtained in the present study indicate that the macrovascular abnormality in long-term diabetic patients, leading eventually to a radiologically demonstrable media calcification of the large arteries, are of importance for the function of the vascular system. At present it is not possible to explain the mechanism leading to the reduced blood flow capacity and the partial loss of the flow increase at tilting. It is reasonable to assume, that these functional disturbances are due to structural changes in collagen and elastin in the vessel wall, limiting the dilatation of the vessels in the tilted position. It must be remembered that the tonal neuro-muscular factor is excluded in the postischaemic peak flow test and that only the physical condition of the vessel wall is determining the peak flow.

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Received: Oktober 25, 1977,
and in revised form: January 23, 1978

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