PART II

DIALYSIS 1

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NUTRITIONAL BLOOD FLOW TO THE LIMBS AFTER ACCESS PROCEDURES

M H R Sheriff, R B Naik, D J Warren

St Mary’s Hospital, Portsmouth, United Kingdom

Summary

We have measured the blood flow to skin and muscle in normal subjects, asymptomatic dialysis patients, and dialysis patients who complained of cold hands (symptomatic patients) in whom a radiocephalic fistula had been constructed. Mean skin blood flow in asymptomatic dialysis patients was identical to that in normal subjects. Skin blood flow in the fistula hand of symptomatic dialysis patients was greatly reduced but it was normal in the contralateral hand. Muscle blood flow at rest was lower in dialysis patients than in normal subjects, but was reduced still further in the fistula hand of symptomatic patients. Muscle hyperaemia in response to exercise was greatly impaired in the fistula hands of all patients, irrespective of symptoms. The haemodynamic consequences of arteriovenous fistulae may be a cause of pain, paraesthesiae, muscle wasting or Claudication in dialysis patients.

Introduction

The haemodynamic effects of arterio-venous fistulae in the upper limb may cause some of the reported complications such as digital gangrene [1], high output cardiac failure [2,3] and embolism [4]. Other symptoms such as neuropathy [5] may be due to oedema in the limb or secondary to neurovascular insufficiency. Many techniques have been developed for measuring total limb blood flow in haemodialysis patients including angiography [6], plethysmography [7], ultrasound [8] and the use of electromagnetic flow meters [9]. These have consistently shown an increase in total limb blood flow. No measurements of skin and muscle blood flow have been made in the hands of haemodialysis patients although such measurements may be more likely to indicate changes in tissue perfusion.

The radio-xenon technique is a simple and reproducible method for measuring flow in these peripheral tissues. We have measured skin and muscle blood flow in the hands of haemodialysis patients at rest and after physical exercise to determine the nutritional or capillary blood flow.
Methods

Informed consent to these studies was obtained from 26 normal members of our laboratory staff (control subjects), 18 patients being treated by intermittent haemodialysis who complained of no symptoms in the hands (asymptomatic patients) and from 15 dialysis patients who complained of cold hands, pain in the hands or paraesthesiae [5] (symptomatic patients). Flow in skin and muscle was measured following the intradermal or intramuscular injection of 0.1 ml of a solution of $^{133}$Xe in saline (1 mCi/ml; Radiochemical Centre, Amersham, England). The decay of radioactivity was plotted on a logarithmic flat bed recorder and blood flow calculated in a standard fashion [10]. Blood pressure was measured at 5 minute intervals using an Arteriosonde (Kontron Instruments). Skin blood flow was measured on the dorsum of the hand at a point midway along the third metacarpal. Muscle blood flow was measured following injection of $^{133}$Xe into the first dorsal interosseus. Muscle exercise consisted of adduction of thumb and forefinger against a fixed resistance twelve times per minute for two minutes.

Results are expressed as the mean ± the standard deviation from the mean (M ± SD). The significance of differences was calculated using the Wilcoxon Rank Sum Test.

Results

There were no significant differences between blood pressures in the two uraemic groups of patients, though blood pressure in uraemic patients was 18 ± 5 mmHg systolic and 12 ± 6 mmHg diastolic higher than in normal subjects. Skin blood flow (Figure 1) in the hands of normal subjects was $9.28 ± 3.39$ ml/100 g/min (right hand) and $9.16 ± 2.88$ ml/100 g/min (left hand), the correlation coefficient between right and left hands being 0.91. Skin blood flow in asymptomatic dialysis patients was $7.87 ± 3.21$ ml/100 g/min in the fistula hand and $10.21 ± 4.81$ ml/100 g/min in the control hand ($P > 0.05$). Skin blood flow in the fistula hand of symptomatic patients was $4.28 ± 2.31$ ml/100 g/min and in the control hand $10.12 ± 1.86$ ml/100 g/min ($P < 0.05$).

Muscle blood flow in the hands of normal subjects was $4.41 ± 1.58$ ml/100 g/min (right hand) and $4.62 ± 2.36$ ml/100 g/min (left hand $P > 0.05$). In asymptomatic dialysis patients muscle blood flow was $2.88 ± 1.4$ ml/100 g/min in the fistula hand and $2.61 ± 0.96$ ml/100 g/min in the control hand ($P > 0.05$). In dialysis patients complaining of cold hands muscle blood flow was $1.96 ± 0.31$ ml/100 g/min in the fistula hand and $2.71 ± 0.81$ ml/100 g/min in the control hand ($P < 0.01$).

In response to standard exercise muscle blood flow in the fistula hand of 14 dialysis patients increased from $1.69 ± 0.31$ ml/100 g/min to $4.92 ± 3.1$ ml/100 g/min and in the control hand from $4.82 ± 1.16$ ml/100 g/min to $16.98 ± 1.62$ ml/100 g/min. The difference between exercise blood flows in the two hands was highly significant ($P < 0.005$).
Figure 1. Skin (SBF) and muscle (MBF) blood flow in normal subjects, dialysis patients with no symptoms in the fistula hand, and dialysis patients complaining of cold hands. Measurements were made in the left (L) and right (R) hands of normal subjects, and in the fistula (F) and control (C) hands in dialysis patients.

Discussion

Previous studies have clearly shown that an increase in total limb blood flow occurs in the limbs following the creation of arteriovenous fistulae for haemodialysis. Since the blood flow through a Brescia-Cimino fistula is about 300 ml/minute, it is clear that this accounts for a large proportion of the increased flow. Careful plethysmography [11] on the digits of limbs in which fistulae have been created show that although total forearm blood flow is increased blood flow is decreased in the thumb of those patients showing digital ischaemia due to radial artery steal syndrome. Subsequent studies have demonstrated retrograde flow through the superficial hand veins, and an increase in skin temperature in the radial side of the hand and forearm on the side of the fistula [12]. Although it is possible that the increased total blood flow bypasses the tissues because of shunting through the fistula and hand veins, there has been no evidence to date of a change in nutritional blood flow to the tissues of the hands and it was the purpose of this study to make such an evaluation.
Although any effects might be of no clinical significance following creation of a radio-cephalic fistula it is possible that the larger access procedures currently carried out in the upper forelimb or in the thigh might cause sufficient shunting of blood to cause ischaemic change and severe symptoms.

These preliminary studies show that, even in patients with no symptoms in the fistula hand, abnormal tissue perfusion may occur. Skin blood flow is unchanged in asymptomatic patients although increased blood flow through hand veins and a temperature gradient from the radial to the ulnar side of the hand has been shown [12]. It seems clear that the increased shunting of blood through superficial veins does not result in increased blood flow to the skin and our experiments give further support to the view that creation of a fistula decreases blood flow to the capillary circulation of the skin and may predispose not only to symptoms of cold hands but in susceptible patients skin necrosis.

Reduction of muscle blood flow occurred in asymptomatic dialysis patients and in the control hands of symptomatic patients though it was largest in the fistula hand of symptomatic patients. The reasons for this significant reduction in muscle blood flow in the hands of all dialysis patients is not clear and persists even when patients are matched with control subjects for blood pressure. It may reflect established vascular disease due to hyperlipidaemia. The large effect of the creation of a radio-cephalic fistula on muscle hyperaemia in response to exercise may limit the capacity for repetitive muscular exercise in the operated limb and suggests that wherever possible arteriovenous fistulae should be created in the first place in a non-dominant limb. Further studies using graded exercise are required in patients who have undergone major access procedures in the upper forelimb or in the thigh to determine the extent to which such procedures compromise exercise tolerance in the operated limbs in dialysis patients. The creation of arteriovenous fistulae in the limbs of dialysis patients and especially of larger capacity access procedures may be a significant cause of symptoms as the result of reduced tissue perfusion.

References

10. Lassen, NA, Lindbjerg, J and Munck, O (1964) Lancet, i, 686
Open Discussion

PARSONS (London) Have the authors corrected their measurements for the presence of oedema — a factor which affects tracer clearance? Did they measure volume changes in the limb after exercise?

WARREN We have not corrected our data for changes in limb volume after exercise, but the magnitude of the changes that we have observed are such that oedema alone is unlikely to explain the whole of the difference.

McGGEWOWN (Belfast) We have had five patients with long term transplants who have had persistent arteriovenous fistulae. Several of these have had serious and chronic nail bed infections that would not clear up with antibiotics. Once the fistula was tied off these healed completely. Have you had any experience of that?

WARREN We have not seen that. The only interference that we have had to make was to decompress the carpal tunnel in four patients to relieve symptoms.

SCHWARZBECK (Mannheim) Could you give us some information on the type of fistula which you used?

WARREN The vast majority of our fistulae now are end-to-side, vein to artery.

ROBINSON (Birmingham) May I ask whether you have done any measurements during dialysis, because we find this is the time at which many of our patients have their most severe symptoms. I wonder if you have any observations on the probable haemodynamic changes which take place then?

WARREN We have not done $^{133}$Xenon clearance measurements during dialysis because I was a bit anxious about the problem of injecting xenon into the muscles of heparinised patients. In some previous studies we showed that during haemodialysis the hand volume in the fistula hand increased significantly and we felt that this may have something to do with the development of carpal tunnel symptoms during dialysis and probably explains other symptoms which occur during dialysis.