Haemodynamics of brachial arteriovenous fistula development

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ABSTRACT: This study observes the development of brachial arteriovenous fistulae, and assesses methods of predicting potential usefulness for haemodialysis. Creation of an adequate brachial fistula causes significant changes in blood flow to the forearm and hand.

A prospective study of fifteen consecutive patients undergoing brachial arteriovenous fistula formation for haemodialysis was undertaken. Clinical measurements and coloured flow Doppler measurements were performed pre operatively, immediately post operatively and at two and eight weeks after surgery. The morphology of the fistula was studied and the volume flow was measured. Digital pressure was measured pre and post exercise at each visit.

Fourteen fistulae worked well by eight weeks. There was an immediate large increase in brachial artery blood flow and by two weeks all fistulae that went on to develop well had a brachial artery flow of more than 700 mls/minute. The cephalic vein mean diameter pre operatively was 2.39 mm and increased to 5.4 mm by two weeks post operatively. Fistulae with flows over 400 mls/minute at two weeks had a good outcome. There were significant differences in digital pressure after fistula formation ($P \leq 0.05$). Digital mean arterial pressure dropped from 118 mm Hg pre-operatively to 98 mm Hg post operatively, at rest, and 89 mm Hg after exercise. Four patients developed forearm/hand claudication on exercise or signs of distal ischaemia. Three of these were diabetic with calcified vessels.

All patients with a suitable cephalic vein should have attempted fistula formation rather than recourse to use of a synthetic graft. In diabetics creating a shunt in an already marginally competent vascular tree exposes the patient to risk of significant hand ischaemia.

KEY WORDS: *Brachio-cephalic fistula, Fistula development, Fistula haemodynamics, Haemodialysis*

INTRODUCTION

Vascular access for chronic haemodialysis is a challenging problem. Increasing numbers of elderly and diabetic patients are being treated for end stage renal failure. In patients whom a traditional Brescia Cimino wrist fistula has failed or is not possible the brachiocephalic fistula is the next choice for access. The end to side cephalic vein to brachial artery fistula was first described by Gracz (1). This was an anastomosis between the perforating vein and the brachial artery. We have performed standard end cephalic vein to side brachial artery anastomoses. Little is known about the haemodynamic evolution and development of these fistulae as they become established. Creation of successful vascular access will cause significant changes in arterial blood flow distal to the anastomosis, as there is a low resistance short circuit through the newly created shunt. This prospective study aims to observe the development of the fistula, identifying measurements for predicting success and monitoring the changes in blood flow to the hand. Symptomatic ischaemia following arteriovenous fistula formation is reported in 3 - 7% of patients (2 - 5). These problems are debilitating and potentially limb threatening.

METHODS

Over a period of four months fifteen consecutive patients were considered suitable and underwent bra-

1129-7298/054-06$03.00/0

chiocephalic fistula formation for long term haemodialysis All patients were fully informed of the objectives of the study and agreed to participate. Clinical measurements including digital blood pressure, pulse oximetry and colourflow Doppler ultrasound were performed preoperatively, immediately post operatively and at two and eight weeks. The patients were then followed up for at least eight months. The patients demographics are shown in Table I.
Of the fifteen patients, eight had previously undergone radial fistula formation at the wrist but this had failed either immediately or early post operatively. All patients had patent radial arteries with ante grade flow at the site of their previous surgery. No patients had signs or symptoms of hand ischaemia or forearm claudication. The baseline measurements were made from the pulse in both arms and pulse oximetry in both index fingers. Those patients who had previously dialysed through subclavian lines were examined for oedema and venous collateral formation suggestive of subclavian vein stenosis/occlusion.

Ultrasound Assessment

A single experienced operator (MG) performed all the measurements using B mode ultrasound duplex scanning. An ATL high 10-5 MHz linear probe was used. This was held at a consistent angle of 60 degrees to the vessel being studied. The duplex was used to evaluate the morphology, diameter, maximum and minimum velocity, resistive index and the volume flow in the brachial artery, radial artery, ulnar artery and cephalic vein. When lesions were detected in the cephalic vein or at the anastomosis they were described by location and degree of narrowing as a percentage of the diameter reduction. At time immediately post operative, two and eight weeks the anastomosis was also assessed. The cephalic vein measurements once the fistula was formed were all 10 cm above the elbow crease, where the flow is more uniform. All patients had their subclavian veins assessed for spontaneous phasic flow, and wall movement to exclude central stenosis. The technologist did not have the previous results available when rescanning.
The brachial artery volume flow (BF) is automatically calculated according to:
Volume (ml/min) = A (cm2) x TA mean (cm/sec) x 60 sec;
A= measured cross-sectional area;
TA = mean time averaged mean velocity (average of intensity weighted mean velocity);
The operation was performed by a Consultant Surgeon as a day case under local anaesthetic.
All fistulae were performed standard end cephalic vein to side radial artery. Distal tributaries of the cephalic vein were ligated to improve mobilisation and a tension free anastomosis. No patients received anti platelet drugs.
Digital blood pressure was measured using a neonatal sygmomanometer cuff (size 1 or 2) as appropriate. Hand grip strength was measured using a standard grip strength monitor.
Patients were asked to perform hand exercise using a squeezy ball for two minutes.

RESULTS

Fifteen patients were followed up for at least eight months.
Paired T-test was used for statistical analysis and $P \leq 0.05$ was significant.

Summary of pre operative observation

All patients had patent subclavian veins with no evidence of stenosis on duplex scanning, on the side being used for surgery. Two patients had abnormally high divisions of the brachial artery, a feature seen in 14% of individuals (6). One patient had a calcified brachial artery. 50% of the diabetic patients had calcified radial and ulna vessels.

TABLE I - DEMOGRAPHIC INFORMATION

Total	15	(Male 8, Female 7)	
Age	mean = 65	range 20 - 80	
Cause of renal failure:	Obstructive uropathy		4
	Diabetes:	NIDDM	2
		IDDM	2
	Myeloma, TB, stones, polycystic, hypertension		7

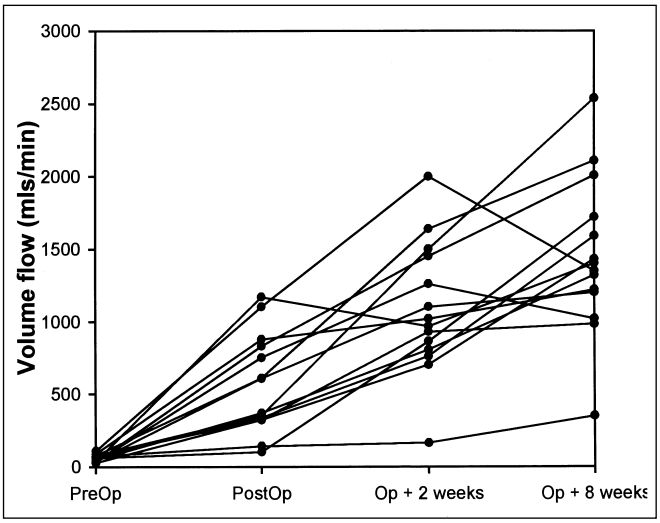

Fig. 1 - *Brachial artery volume flow.*

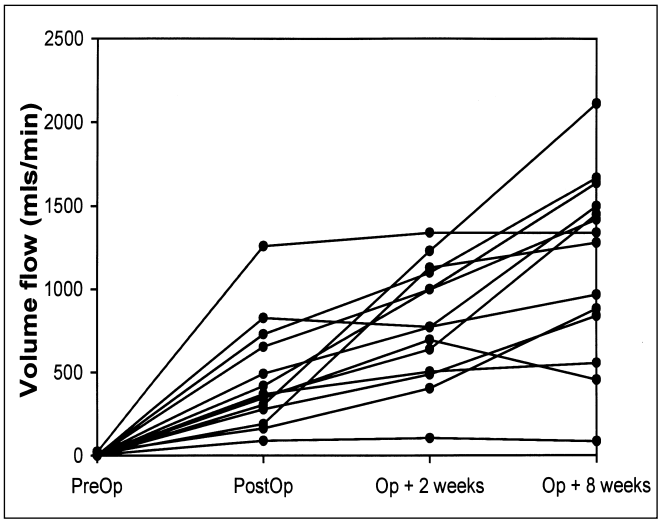

Fig. 2 - *Cephalic vein volume flow.*

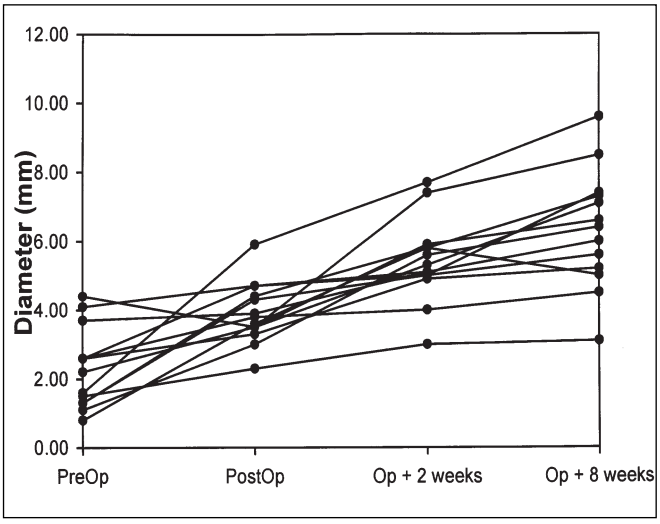

Fig. 3 - *Cephalic vein diameter.*

Duplex results

A combination of vessel diameter and blood velocity increases resulted in huge changes in volume flow. There was an immediate increase in brachial artery volume flow post operatively and this continued to increase during the study period. At two weeks all fistulas that went on to develop well had a brachial artery flow of greater than or equal to 700 mls/min, one at 323 mls/min failed to develop. Brachial artery volume flow is shown in Figure 1. There was a similar increase in cephalic vein volume flow (shown in Fig. 2) and at two weeks all those above 400mls/min went on to develop well.

Cephalic vein diameter (shown in Tab. II and illustrated in Fig. 3) increased steadily from 2.29 to 6.31 over the study period.

There was an increase in flow speed along the brachial artery from the mean of 89 cm/sec pre-op to 215 cm/sec at eight weeks. Radial artery maximum velocity was decreased. There was no significant difference between cephalic vein flow immediately post operatively and at eight weeks. The mean maximum velocity is shown in Table III.

Clinical Results

86% of fistulae developed well, but 50% of patients experienced complications. One patient had excessive swelling of the hand and forearm despite a nor-

TABLE II - VESSEL MEAN DIAMETER (MM)

	pre op	post op	+2 weeks	+8 weeks
Cephalic vein	2.29	3.89	5.40	6.31
Brachial artery	3.76	4.40	5.12	5.39
Radial artery	1.91	1.98	1.91	1.86

mal duplex scan of the draining veins. This patient also developed high output cardiac failure that resolved when the fistula was later ligated. One patient had a cephalic vein stenosis which represented 50% at two weeks and 75% (grade IV) at eight weeks. This fistula failed to develop.

Digital mean arterial pressure in the fistula and control hand is shown in Figure 4.

Ischaemic symptoms were reported by four patients on exercise. One patient who had calcified brachial, radial and ulna arteries had an immediate thrombosis and developed a critically ischaemic hand and underwent bypass grafting.

The other three patients who developed ischaemic hand problems were diabetic and had calcified radial and ulna arteries.

There was no difference in grip strength or pulse oximetry in any of the patients during the study.

There were significant differences between the pre op digital blood pressure and the pressure after formation of the fistula. There were also significant differences between the fistula hand and the control at 8 weeks. There were also significant differences post exercise at 8 weeks. The full results are shown in Table IV.

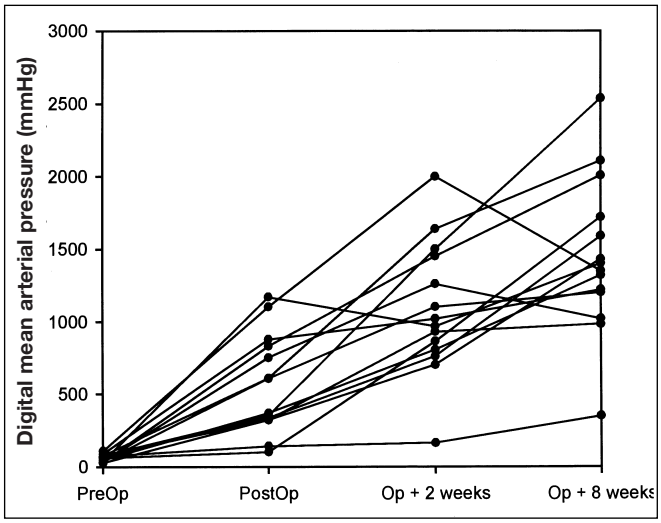

Fig. 4 - ***Digital mean arterial pressure in fistula hand (F) and control hand (C).***

DISCUSSION

Long term satisfactory haemodialysis access is an increasingly difficult problem in an ageing population. An established Brescia Cimino fistula is well

TABLE III - MEAN MAXIMUM VELOCITY (CM/SEC)

	pre op	post op	+2 weeks	+8 weeks
Brachial artery	89.0	154.4	205.1	215.7
Radial artery	57.5	43.2	43.4	39.2
Cephalic vein	6.9	141.0	125.8	157.1
Anastomosis		466.5	514.4	545.0

TABLE IV - DIGITAL MEAN ARTERIAL PRESSURE (mm Hg)

	pre op		pre op		+8 weeks			
	pre exercise fist	control	post exercise fist	control	pre exercise fist	control	post exercise fist	control
mean	118.8	128.8	116.4	104.2	98.7	127.5	89.8	118.
1 S.D.	20.2	24.6	18.1	32.9	19.1	16.7	15.0	11.4
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Paired T-test:

*Significant differences p<0.05 at *, **, ***, ****, ****

accepted as the ideal primary access. It is only agreed in the UK that an AV fistula at the elbow is better than synthetic grafting for secondary access. The Gracz fistula or elbow fistula has a patency of 84% at one year, which compares favourably with wrist fistulae (7).

The mean age of the patients in this study was 65 . These patients have a high incidence of arterial disease and diabetes, and may not be candidates for transplantation. Very few studies have looked at the evolution of brachiocephalic fistulae development and whether it is possible to predict the potential usefulness of such a fistula at an early stage. For a fistula to develop satisfactorily there must be no anatomic obstruction in the inflow or outflow vessels.

The diameter of the cephalic vein for radial fistula construction needs to be greater than 1.6 mm (8). Koo (9) excludes all patients from elbow fistula formation if the cephalic vein is less than 3 mm. This is based on studies of the failure rate of wrist fistulae, however these fistulae may fail because of the small radial artery and low flow not because of the size and quality of the vein.

There is a fundamental problem with this approach as the resistance to flow varies with the fourth power of the radius[1] and therefore the much higher flow in the brachial artery can provide the driving force for very small cephalic veins to develop. In elderly patients the peripheral arteries are often atherosclerotic and have lost compliance. In this study the veins were used regardless of size; it was not a predictor of success. Irrespective of initial size the cephalic vein developed well over time. In our study only three of fifteen patients had a vein diameter of 3 mm or more, but thirteen developed good fistulae. We suspect that the artery is the more limiting factor than the vein. In this series only two fistulae failed; the only patient with a calcified brachial artery, impalpable radial and ulna pulses and a patient with a duplex detected venous stenosis at two weeks. Clinical assessment of the patients prior to surgery is obviously an essential but in those patients who were diabetic or have equivocal cephalic veins a duplex scan is extremely useful in avoiding either central or cephalic vein stenosis and providing non invasive assessment of function once the fistula is fashioned (10).

Wong et al (11) reported intraoperative blood flow measurement in wrist fistulae and did not find a relationship between early flow rate and outcome, however Johnson et al (12) showed that fistula flow greater than 400 mls/min have an enhanced primary patency. Our findings agree with this. Flows over 400 mls/min at two weeks predict a fistula that will go on provide good dialysis.

Creation of arteriovenous fistulae in the brachiocephalic region undoubtedly cause significant change in blood flow to the hand and this may not be clinically significant, however in the diabetic patient creating a shunt in a marginally competent tree can cause symptomatic ischaemia.

In conclusion, the size of the cephalic vein is of secondary importance in the formation of a brachial haemodialysis fistula. Flow measurements at two weeks can predict whether the fistula will develop satisfactorily and will therefore provide more efficient management of these patients rather than awaiting a trial by needling. If a stenosis is detected early interventional angioplasty may facilitate development of the fistula. Diabetic patients who are more likely to undergo proximal brachiocephalic fistula formation should be warned about potential ischaemia which can be limb threatening. Those at higher risk appear to be those with calcified distal vessels, which is detectable by duplex scanning.

ACKNOWLEDGEMENTS

This material has been presented in part at South-West Surgeons Annual Meeting April 1999.

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[1] *Poiseuille's Law*

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