

ASSESSMENT OF ARTERIOVENOUS FISTULAS FROM PRESSURE AND RECIRCULATION STUDIES: CLINICAL EXPERIENCE IN 215 UPPER LIMB FISTULAS

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Summary

Using a new technique to measure useful fistula flow (FF) – the maximum blood flow available for twin needle dialysis within acceptable pressure limits and without recirculation – we recently reported our preliminary experience in 69 forearm fistulas [1]. We now report our experience in 185 forearm and 30 upper arm fistulas. In haemodynamic terms, differences between satisfactory (FF >400ml/min) forearm and satisfactory upper arm fistulas are negligible. In unsatisfactory fistulas (FF <400ml/min) the cause, be this due to vessel stenosis or inappropriate needling, can be determined with a high degree of confidence using this technique.

Introduction

We have previously argued that to allow flexibility of treatment in end-stage renal failure arteriovenous fistulas should be capable of supplying blood flows of at least 400ml/min using twin needles within acceptable pressure limits and without recirculation, i.e. useful fistula flow (FF) should exceed 400ml/min. We have recently shown that 'normal' forearm fistulas can supply flow rates in excess of this figure. Fistulas which cannot, invariably have stenoses which require surgical correction or they are being needled inappropriately [1].

Since 1982 we have carried out fistula studies in 215 upper limb fistulas. This large experience allows us to compare the haemodynamic measurements obtained in forearm and upper arm fistulas. It also allows recognition of the commonest haemodynamic abnormalities encountered in unsatisfactory fistulas and the causes underlying them.

Material and methods

Patients and fistulas Studies were carried out in 185 forearm and 30 upper arm fistulas in 108 patients. Fistulas were regarded as being different if they had

been surgically revised even if the revised fistula remained in the same site. Similarly, a fistula studied because it was clinically unsatisfactory having previously been satisfactory was regarded as being a different fistula.

One hundred and ninety-seven of the 215 fistulas have been divided into four main clinical groups:

- (1) Ninety-six fistulas thought to be satisfactory on the basis of clinical examination, intra-dialysis blood flow, ease of needling and the patient's biochemical control.
- (2) Thirty-one fistulas in patients with poor biochemistry as evidenced by unacceptably high pre-dialysis levels of plasma urea ($>30\text{mmol/L}$) and/or creatinine ($>1.50\text{mmol/L}$) and/or potassium ($>6.0\text{mmol/L}$).
- (3) Forty fistulas in patients who could not consistently achieve blood flows above 200ml/min for dialysis.
- (4) Thirty fistulas which were reported to be difficult to needle.

Fifteen fistulas were studied before being regularly used for dialysis. Two fistulas were studied because of bleeding from needle sites and one because of post-operative concern about its viability.

Equipment and procedure To measure FF the conventional dialysis circuit is modified to include arterial line pressure (P_A) in addition to venous line pressure (P_V) monitoring (Figure 1). Standard 15G fistula needle sets (Hospal) are used.

Fistula studies are usually carried out at the beginning of a routine dialysis session after insertion of the fistula needles in the sites normally used by the patient. P_A and P_V are first recorded with the blood pump stationary. These are referred to as basal intra-fistula pressures (BIFP). Blood flow is then increased in 100ml/min increments to a maximum of 500ml/min or until limits for P_A and P_V are exceeded. These are pre-set at -200mmHg and $+200\text{mmHg}$ respectively. P_A and P_V are plotted against blood flow rate. These plots are referred to as pressure flow characteristics (PFC).

Tests for recirculation are then made at each flow rate increment using a thermal dilution technique [2]. Arterial and venous line blood temperatures are recorded as a 2ml bolus of cold saline is injected into the venous line. Any decrease in arterial line temperature indicates recirculation.

Results

Satisfactory fistulas Fistula flow $>400\text{ml/min}$ was obtained in 148 fistulas. Recordings of P_A and P_V at blood flow rates of 0, 200 and 400ml/min are plotted in Figure 2a. BIFP_A was $27.58 \pm 18.36\text{mmHg}$ (mean \pm SD) and BIFP_V was $21.61 \pm 13.60\text{mmHg}$ (mean \pm SD). In no instance did P_V exceed P_A . We conclude from these results that in the majority of satisfactory fistulas BIFP is less than 60mmHg at the arterial and venous needle sites. Values above this suggest stenosis between the needle(s) recording high pressure and the patient's right atrium (proximal obstruction).

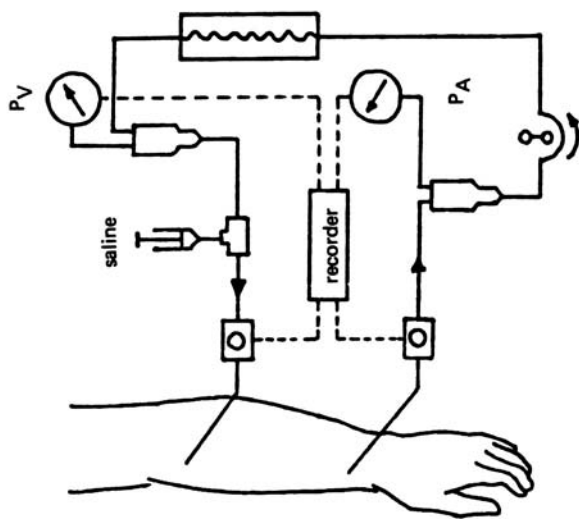
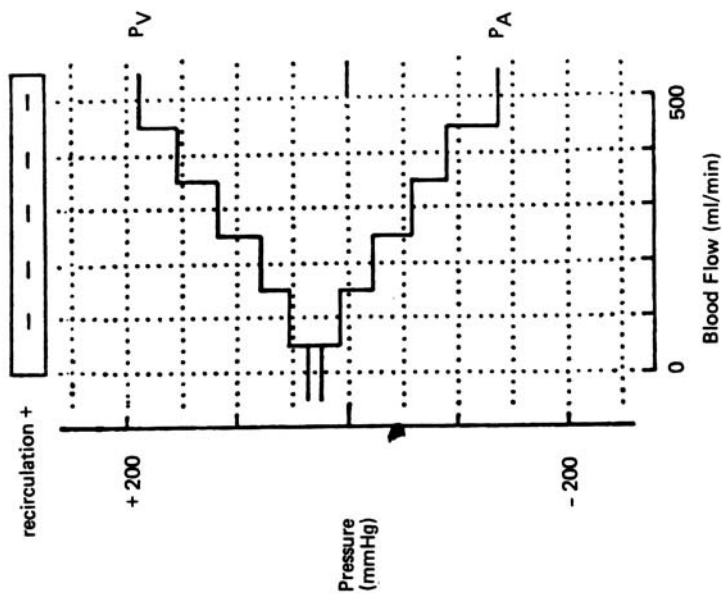


Figure 1. The test circuit showing arterial and venous line pressure and temperature monitoring and saline injection port. Basal intra-fistula pressures (BIFPA always exceeds BIFPV) and pressure flow characteristics (PFC) are recorded together with the presence or absence of recirculation

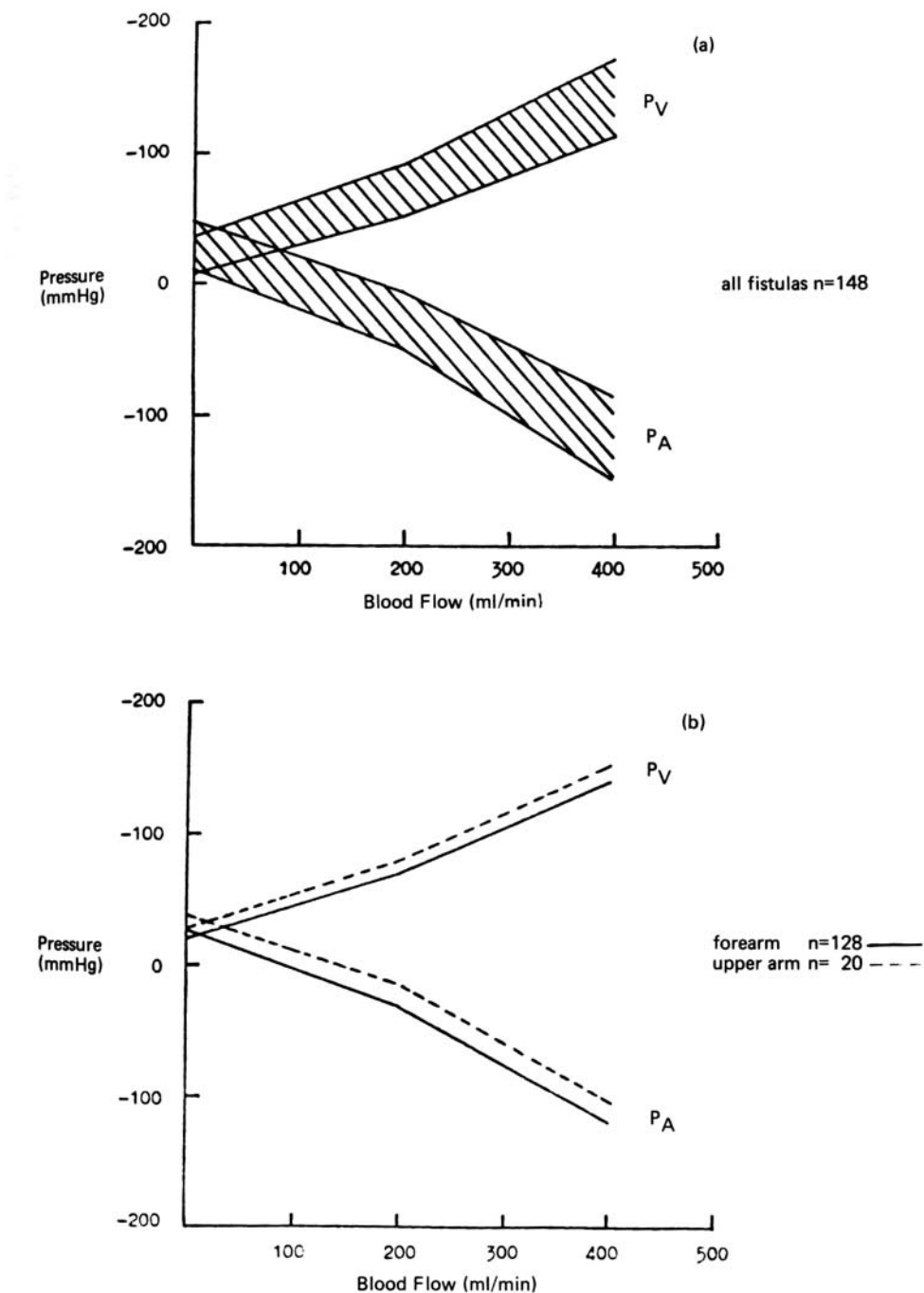


Figure 2. (a) Pressure flow characteristics (PFC) in 148 fistulas with FF >400ml/min. The shaded area represents the mean \pm one standard deviation of P_A and P_V at flow rates of 0, 200 and 400ml/min. (b) Means of pressures P_A and P_V in 128 forearm and 20 upper arm fistulas

Mean values of P_A and P_V recorded in 128 forearm and 20 upper arm fistulas are shown in Figure 2b. Although upper arm fistulas generally have higher intra-fistula pressures than forearm fistulas, these differences are small, the maximum differences in the means being 17.72mmHg for P_A at a blood flow of 200ml/min and 11.79mmHg for P_V at a blood flow of 400ml/min.

The symmetrical divergence of the pressure flow characteristics in haemodynamically satisfactory fistulas indicates that arterial and venous line pressures are determined by pressure drops across the needles rather than pressure changes occurring in the fistulas. This is an important observation because any divergence away from this pattern indicates either failure of the fistula to supply the extra-corporeal blood flow (source failure) or to allow free return of blood to the circulation (high venous resistance).

Unsatisfactory fistulas Fistula flow <400 ml/min was obtained in 67 fistulas either because excessive values of P_A and P_V were obtained with increasing blood flow or because of recirculation (Figure 3).

- (1) Excessive fall in P_A : this occurred in 33 fistulas. In the majority (31) normal BIFP indicated source failure. In two fistulas BIFP was high suggesting a combination of source failure and proximal obstruction. Multiple stenoses were found at angiography in these two cases.

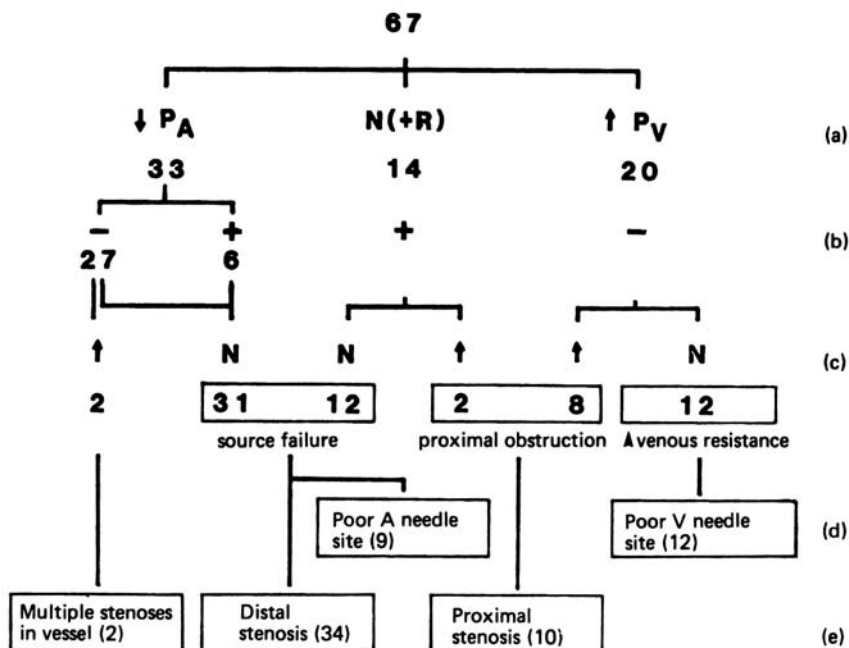


Figure 3. Details of flow studies in 67 fistulas with unsatisfactory FF (<400 ml/min). The causes of the haemodynamic abnormalities detected are shown. (a)=pressure flow characteristics; (b)=recirculation; (c)=basal intra-fistula pressures; (d)=cause, needling; (e)=cause, anatomical requiring surgery

- (2) Recirculation with normal pressure flow characteristics: recirculation invariably indicates low flow between the needles. In two of the 14 fistulas in this category BIFP were high indicating proximal obstruction. In the remainder normal BIFP indicated source failure.
- (3) Unacceptably high P_V : this occurred in 20 fistulas. In eight high BIFP indicated proximal obstruction. Typically it was upward displacement rather than an increase in the slope of the venous normal pressure flow characteristics which caused the pressure limit for P_V to be exceeded. By contrast, in the 12 fistulas with normal BIFP there was a steep rise in venous pressure with flow rate indicating high resistance to venous return. There was no recirculation in this group.

Correlation of results with clinical situation

- (a) In the patients thought to have clinically satisfactory fistulas 15 of 96 fistulas were unexpectedly found to have unsatisfactory FF.
- (b) In patients with poor biochemical control 14 of 31 fistulas were haemodynamically unsatisfactory. In nine of these cases recirculation was present at blood flow rates used by the patients for routine dialysis.
- (c) In 21 of the 40 fistulas producing poor flows unsatisfactory FF was confirmed and the cause determined. Surprisingly, in 19 cases fistula flows were satisfactory.
- (d) Nineteen of 30 fistulas in which there were needling difficulties were haemodynamically satisfactory. Both patients and staff could be encouraged to persevere with these fistulas.

Discussion

We have developed a simple technique for assessing fistula performance at the bedside. Not only does it identify unsatisfactory fistulas but it is a powerful diagnostic tool in defining the cause. Knowledge of BIFP is critical for interpretation of the studies. Although we have shown that upper arm fistulas generally have higher intra-fistula pressures than forearm fistulas, the differences are small and for practical purposes we can regard the 'normal' range for BIFP to be the same for both. The upper limit of normal is approximately 60mmHg.

It is reassuring that the interpretation of fistula flow studies has become simpler with increasing experience. This is not just due to familiarity. Some haemodynamic situations, while theoretically possible, have not actually been observed (e.g. excessive P_V with recirculation). Some occur very infrequently (e.g. excessive fall in P_A with high BIFP). Only three haemodynamic abnormalities – source failure and proximal obstruction alone and high venous resistance are commonly encountered in practice (Figure 3).

The diagnostic process is further simplified by the fact that all the cases of high venous resistance were due to inappropriate needling. Furthermore, all fistulas with proximal obstruction were found to have venous stenoses which

required surgical correction. Our experience to date suggests that only in source failure is there more than one diagnostic possibility. In nine of the 43 fistulas with source failure, clinical inspection of the fistula veins and needling sites suggested that the problem was caused by inappropriate needle position. This was usually confirmed at the same sitting. In the majority (34) there was distal stenosis (i.e. between the arterial needle and the anastomosis).

The necessity for surgery is mainly determined from fistula studies. Angiography is carried out pre-operatively in selected cases. Dependence on angiography for diagnostic purposes has declined since introducing this technique and unnecessary angiography has been eliminated.

Equipment note

A purpose-built instrument has been developed which employs an optical technique to detect recirculation. This has superseded the thermal dilution technique used in these studies. The instrument is produced by Gambro and is compatible with standard AK10 dialysis systems.

References

- 1 Greenwood RN, Aldridge C, Goldstein L et al. *Clin Nephrol* 1985; 23: 189
- 2 Aldridge C, Greenwood RN, Barrett RV, Cattell WR. *J Med Eng Technol* 1984; 8: 118