TWO YEAR SEQUENTIAL HAEMODYNAMIC DATA ON POLYTETRAFLUOROETHYLENE (PTFE) GRAFTS USED FOR HAEMODIALYSIS

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Summary

Forty-one PTFE grafts were studied prospectively with measurement of intragraft pressure and flow. As well, cardiac function was assessed by measuring cardiac output, ejection times and ejection fraction. It was shown that graft failure was associated with changes in graft pressures and flow. No untoward effects of graft flows of 1–2L/min were found on cardiac function.

Introduction

With the increasing use of prosthetic materials for access to the circulation for long term haemodialysis, methods of assessing graft function in a prospective way become important so that abnormalities may be detected and corrected prior to graft failure by clotting. In addition the long term effects of these grafts on the circulation are unknown. This could be of importance because of potentially high shunt blood flows. This paper describes the results of graft assessment together with a sequential assessment of cardiac function.

Methods and Materials

The PTFE grafts were 6mm internal diameter, supplied by Impra Inc.*. Although some straight grafts (radial artery to antecubital vein) were made initially, the overall graft survival was poor and all subsequent grafts were forearm loops from the brachial artery subdivision into the forearm and back to antecubital vein. The arterial anastomosis was reduced in lumen whereas the venous was full diameter. The grafts were studied within one to two months after insertion and thereafter every six months. If abnormalities were found then angiography was performed followed by corrective surgery if deemed necessary. Forty-one grafts were studied

*Impra™ Graft, Impra Inc., Phoenix, Az 85040, USA

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in 33 patients from six to 36 months after insertion. During this follow-up 73% had functioning grafts.

Pressures at the arterial and venous ends of the graft and flow were measured as described previously using 19 gauge butterfly type needles. Pertechnetate was used as the indicator with samples taken at 20, 30, 60 and 80 seconds [1]. Cardiac output was determined after the flow measurements had been completed by injecting a bolus of $^{131}$I serum albumen through the venous needle and taking samples every second from the arterial needle for four to 24 seconds.

Systolic ejection times were measured from simultaneous ECG, carotid pulse wave and phonocardiogram records and ejection fractions from gated isotopic analysis. Other measurements employed standard techniques.

**Results**

Figure 1 shows sequential data over three years for a graft that had not been altered since insertion. The stability of graft pressures, cardiac output and graft flow is notable. However, a graft in which the pressure is increasing with a falling flow indicates venous obstruction. Likewise a low pressure with decreasing flow signifies inlet obstruction, and a difference of 25mmHg or more between arterial and venous ends suggests kinking within the graft. Grafts which were successful

![Graph showing parameters over months after insertion](image-url)
and which did not clot or require revision for six months after study were compared with those which failed and the results are shown in Table I. Grafts with inflow obstruction are excluded from this table and in successful grafts there is more than one determination. As expected, there are significantly higher pressures in grafts with outflow obstruction and also lower flows. We have found that flow below 1L/min will usually be followed by clotting whereas flows of 1–2L/min indicated good graft function.

In Table II are shown paired sets of observations from 17 individuals at the time of insertion of the graft and two years later. There is a significant decrease in graft flow and cardiac index during this period and graft flow as a percentage of cardiac output remains stable. Left ventricular ejection times expressed as a ratio of the pre-ejection period to the left ventricular ejection time [3] is also normal, as was ejection fraction. There was an increased frequency of ECG evidence of

**TABLE I.** Comparison of data from successful and unsuccessful grafts defined according to function over the succeeding six months

<table>
<thead>
<tr>
<th></th>
<th>Unsuccessful N = 16</th>
<th>Successful N = 64</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow L/min</td>
<td>1.01 ± 0.12*</td>
<td>1.74 ± 0.07</td>
</tr>
<tr>
<td>Arterial pressure mmHg</td>
<td>67 ± 5*</td>
<td>48 ± 2</td>
</tr>
<tr>
<td>Venous pressure mmHg</td>
<td>54 ± 6†</td>
<td>35 ± 2</td>
</tr>
</tbody>
</table>

* p < 0.001
† p < 0.005

**TABLE II.** Results

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>2 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood pressure mmHg</td>
<td>146/81</td>
<td>146/80</td>
</tr>
<tr>
<td>Heart size, cm</td>
<td>15.4</td>
<td>15.2</td>
</tr>
<tr>
<td>Cardiac index L/min</td>
<td>4.2</td>
<td>3.5*</td>
</tr>
<tr>
<td>Graft flow L/min</td>
<td>2.1</td>
<td>1.6*</td>
</tr>
<tr>
<td>Graft flow as % of cardiac output</td>
<td>28%</td>
<td>24%</td>
</tr>
<tr>
<td>LV+ on ECG</td>
<td>2/17 (12%)</td>
<td>7/17 (41%)</td>
</tr>
<tr>
<td>†PEP/LVET</td>
<td>–</td>
<td>0.28</td>
</tr>
<tr>
<td>Ejection Fraction</td>
<td>–</td>
<td>0.59</td>
</tr>
<tr>
<td>Blood volume, litres</td>
<td>5.4</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Minimum 17 pairs in each group
All values normal except for ECG evidence of left ventricular hypertrophy

* p < 0.05
† PEP – Pre-ejection period
LVET – Left ventricular ejection time

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**TABLE III.** Data on those who did as compared with those who did not develop left ventricular hypertrophy

<table>
<thead>
<tr>
<th></th>
<th>No.</th>
<th>†BP 0 2 yr</th>
<th>πCO 0 2 yr</th>
<th>fCI 0 2 yr</th>
<th>Flow 0 2 yr</th>
<th>Bl. Vol. 0 2 yr</th>
<th>PEP/LVET 2 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients who developed left</td>
<td>150/86*</td>
<td>142/84</td>
<td>7.0</td>
<td>5.6</td>
<td>2.1</td>
<td>1.6</td>
<td>5.4</td>
</tr>
<tr>
<td>ventricular hypertrophy</td>
<td>5</td>
<td>±15/6</td>
<td>±13/5</td>
<td>±0.3 ±0.7</td>
<td>±0.1 ±0.4</td>
<td>±0.4</td>
<td>±0.3 ±0.3</td>
</tr>
<tr>
<td>Patients who did not</td>
<td>144/78*</td>
<td>144/75</td>
<td>7.5</td>
<td>7.2</td>
<td>4.1</td>
<td>3.6</td>
<td>2.05</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>±7/5</td>
<td>±7/5</td>
<td>±0.7 ±0.6</td>
<td>±0.3 ±0.2</td>
<td>±0.2</td>
<td>±0.2</td>
</tr>
<tr>
<td>p</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

* Mean ± SEM
†BP — Blood pressure
πCO — Cardiac output
fCI — Cardiac index

left ventricular hypertrophy, with five individuals developing this during the two years’ interval. Analysis of those with these changes, as compared with those without, revealed no differences in graft flow, cardiac output, etc., (Table III) suggesting that the graft was not responsible for the ECG findings.

**Conclusions**

Haemodynamic data have been examined prospectively in PTFE grafts and shown to be valuable in assessing graft function. With graft flows of 1–2L/min there was no evidence of adverse effects on left ventricular function after a two year interval.

**References**


**Open Discussion**

SLOOF (Gröningen) I would ask you what was the nature of your venous outlet obstruction of the graft?

KAYE. It is usually just a fibrous junction or stenosis; it is similar to what has been described with bovine grafts. It occurs at the anastomosis, it is treated either
by a diamond-shaped patch or bypass. Sometimes we have just put a bypass to the vein higher up and left the actual original anastomotic site — very satisfactory.

SLOOF Do you not think from the observations you have made, that in the cases with pre-existing cardiac disease the Impra graft with this kind of flow is contra-indicated.

KAYE Well this is a very important point. All of our patients I think you have to say have coronary heart disease, but the method that I am trying to pass on is that if you do not allow the flow to be above two litres a minute we do not think you are going to get into any trouble. Now we have one patient who had an aortocoronary bypass prior to going on dialysis, and his graft flow was 3.2 litres a minute and he developed congestive failure. We narrowed the arterial inlet — this was before we were routinely narrowing the arterial anastomosis — and brought his flow down to about 1500ml/min and he has had his graft now for about two and a half years and is fine. We have patients in their seventies with undoubted coronary disease who have these grafts.

DRUEKE (Paris) I was rather surprised by the very high mean blood flow of your functioning grafts. Dr Lévy in Paris has recently developed a method using ultrasound and doppler methods to evaluate graft blood flow and the mean blood flow of functioning grafts was much lower in our patients, about 800 or 700ml/min. This method was validated, at least in some patients, by measurements of blood flow during the reduction of excessive fistula blood flow in some patients by measuring blood flow with an electromagnetic flow meter. This method will soon be published in the American Journal of Physiology. We have much lower mean values than you have.

KAYE I think there are several things you have to bear in mind. First of all, when were the measurements taken? Most people who have measured flows have done it with flow meters and it is done at the time of operation. There is a marked rise in flow in the days and weeks following the insertion of these devices, so that the values I have given you are not at the time of operation. They are at least a month, sometimes a couple of months post operatively and then of course sequentially. We have looked at these flows with a doppler (that is in the Clinical Nephrology paper) and there is a correlation coefficient of about 0.8 with the doppler, but the doppler is not as accurate as a direct flow and nor do I believe is the ultrasound, because this is a straight isotope dilution technique. We were surprised at the size of these flows, but in actual fact nobody has been able to measure the flow with any ease in the intact situation and in a fistula it is very difficult because you have got all the branches.

ROODVOETS (Haarlem) We have had considerable oedema of the lower arm after PTFE and not after a bovine carotid graft. Is that your experience?

KAYE Yes, you may get it. The reason, actually in a way what stimulated the whole of our three year study was the development of this oedema. What is even more frightening is the arm may become quite reddened and to the inexperienced it looks as if you have a cellulitis. This is in the early days — maybe a week or even a month post operatively. It is due to the large arterial inflow into a venous system that cannot accept it. It will invariably disappear once the
venous system has dilated up. If you angiogram them you will see that the con-
trast material goes into the vein and then floods back distally, retrograde into
the forearm, and it is due to the difficulty in egress of venous blood from the
forearm created by the high flow from the fistula. The answer to it is several
fold. One is, do not have too large a flow, certainly if you go up high enough
you are going to have a lot of trouble. Secondly, put your venous anastomosis
into a fairly good sized vein. If you go higher in the upper arm or even if you
make an upper arm PTFE you have much less trouble with swelling. Thirdly,
just wait and it will go.

KRAMER (Göttingen) At a flow rate of 1.6 litres per minute in a tubing 0.6cms
in diameter, I expect to have a contact time between your isotope and the blood
of less than a second to get mixed up, so I doubt whether you have complete
mixing with blood. Do you get a correct estimation of the diluting process?

KAYE Well this has been determined by our rheologist, and the Reynolds co-
efficient and all the rest of it, and he said there should be no problem. I think
our answer to that is that if you look at our clinical nephrology paper we took
about eight values and what happens is that after about twenty seconds every
dot is horizontal, which has to indicate that mixing is complete. Remember you
have quite a large distance for mixing to take place. The other thing is the in-
jection speed is very high; 30ccs per minute. So you have a tremendous jet going
in, with a large jet coming down and it is a sort of explosive mixing affair.