The hidden burden of high-flow fistulae in a home haemodialysis programme: outcomes of initiating arteriovenous fistula monitoring in the home haemodialysis population

Fiona A Chapman, Mary Ann Nicdao & Lukas Kairaitis

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Abstract

Home haemodialysis (HHD) is common in Australia. The majority of these patients dialyse using an arteriovenous fistula (AVF). AVFs are a potential source of morbidity: low fistula flow may result in inadequate dialysis; high flow may lead to cardiac failure. Whilst intradialytic measures of fistula performance are available in many haemodialysis centres, HHD patients are particularly vulnerable to unrecognised access dysfunction.

To address the needs of this population for access monitoring, a structured programme of surveillance utilising ultrasound dilution was introduced. This allowed us to determine the prevalence and type (high/low flow) of access dysfunction.

Over a three-year period, 141 patients had flow measurements, with cardiac output (CO) also measured where possible. All patients dialysed through an AVF. Forty-one patients (29%) were identified with access dysfunction. Nineteen patients (13.5%) had low-flow AVF (access flow (Qa) <500ml/min) and 22 patients (15.6%) had evidence of high flow (Qa >2L/min, CO >8L/min or Qa:CO >0.3). Upper arm AVF were more likely to be high flow than radiocephalic (p<0.001). Most patients with low-flow AVF underwent stenting (17/19), and 10 patients with high-flow AVF had banding to reduce the size.

We identified a high prevalence of undetected AVF dysfunction that could result in significant morbidity, particularly related to high-flow AVF that may be clinically silent. We support the use of regular AVF surveillance in the HHD population using ultrasound dilution as a simple and effective way of identifying dysfunctional AVF to allow early intervention and reduced future morbidity.

Keywords

Home haemodialysis; arteriovenous fistula; high-output cardiac failure.

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Introduction

Australia and New Zealand have some of the highest take-up rates of home haemodialysis (HHD) worldwide (Grassmann et al., 2005; Briggs et al., 2012). HHD is promoted as a cost-effective and reliable method of renal replacement therapy for patients with end-stage renal failure. It is associated with longer survival rates than hospital haemodialysis, and offers patients greater freedom, well-being and quality of life (Walker et al., 2015).

An arteriovenous fistula (AVF) is the recommended vascular access of choice for patients on haemodialysis, and is the most common type of access in HHD patients (Polkinghorne et al., 2013; Polkinghorne et al., 2014). Regular vascular access surveillance is recommended by clinical guidelines, although many of the established methods used are not applicable to the HHD population (National Kidney Foundation, 2006; Polkinghorne, 2008). Although the primary aim of access surveillance is often to identify low-flow AVF due to the associated complications of access thrombosis or access recirculation, it is increasingly recognised that patients with high-flow AVF are at risk of significant negative cardiovascular consequences. Compared to low-flow fistulae, high-flow fistulae are more likely to be clinically unrecognised as they typically do not cause difficulty with cannulation and do not trigger pressure alarms on dialysis.

Although patients attending an outpatient dialysis centre have regular assessment of their vascular access by trained staff, those at home do not. In addition, although many modern dialysis machines incorporate the ability to perform intradialytic flow measures, these are not available to patients undergoing treatment at home. HHD patients are, therefore, particularly vulnerable to the risk of undetected access dysfunction. This is particularly the case for high-flow fistulae, which can be potentially associated with adverse cardiovascular effects in a population already at significantly increased risk of cardiovascular disease.

In order to address the needs of this patient group for regular access surveillance, a structured programme of fistula surveillance was introduced to our population of HHD patients in Western Sydney Local Health District using a well-validated ultrasound dilution technique (National Kidney Foundation, 2006). This aimed to identify asymptomatic AVF dysfunction to guide the need for further investigation and possible intervention. The results of this programme are presented.

Methods

Patients undergoing HHD were scheduled to undergo a supervised dialysis session by the home training staff every six months. In addition to providing feedback on their technique, this supervised treatment enabled the assessment of access flow, recirculation and cardiac output.

The ultrasound dilution technique (Transonic™ HD03, Transonic system, Ithaca, NY, USA) is a well-validated means of measuring access flow, and is considered to be the gold standard (Polkinghorne, 2008). This technique was used in our study population to measure AVF flow, recirculation and cardiac output during the first hour of haemodialysis, and measurements were collected in a patient database. We were unable to measure cardiac output in all patients due to practical reasons.

Patients were referred for further evaluation by a nephrologist and/or vascular surgeon if access recirculation was >5%, access blood flow (Qa) was <500ml/min or >2L/min, cardiac output (CO) was >8L/min, or when the proportion of cardiac output represented by fistula flow (Qa:CO) was >30%. These cut-offs were selected based on accepted definitions for access recirculation using dilution techniques (nonurea-based), the minimal target flow rate to achieve effective dialysis, and flow rates that have been shown to increase the risk of high-output cardiac failure (Lee et al., 2011; Grace et al., 2012; MacRae et al., 2004). The decision-making process for access intervention (stenting for stenosis, banding for high-flow fistulae) was made by the nephrologist and vascular surgeon, depending on the individual patient circumstances.

Various measures were statistically compared between different patient subgroups. The comparison of continuous variables between groups was made using the student’s t-test for unpaired data (unequal variance), and the chi-square test was used for comparison between groups of categorical variables. Values of p<0.05 were considered significant. Statistical analysis was carried out using Microsoft Excel (2011).

Results

Ultrasound dilution measures of access flow were performed in 141 distinct HHD patients over a 3-year period. The average age of these patients was 53 years old (range 19–80 years).

The majority dialysed through a radiocephalic fistula (104 patients). Of the remaining patients, 33 dialysed through an upper arm (brachiocephalic or brachiobasilic) fistula, and four had saphenous vein loop fistulae of the thigh. Mean access flow was significantly higher for upper arm compared with radiocephalic fistulae (2076+/−223mL/minute vs 1138+/−83mL/minute, p<0.001) (Figure 1).

All patients attended for AVF surveillance at least once in the study period, but there was variable attendance for repeat measurements (reasons include inconvenience to patient,
and reluctance due to fear of intervention when happy with current dialysis). While the majority of measurements were done as routine surveillance, six patients attended for flow measurements due to difficulties with dialysis. Four patients were referred for AVF flow measurements by a nephrologist or vascular surgeon due to clinical suspicion of access dysfunction.

Of our study population, 41 patients (29%) were found to have access dysfunction: 19 patients (13.5%) with low flow and 22 patients (15.6%) with high flow. Four patients with low flow had self-presented due to dialysis difficulty and 15 patients were asymptomatic. Similarly, two patients with high flow had issues with dialysis and 20 were asymptomatic. Of the four patients referred by clinicians due to clinical suspicion of access dysfunction, three patients had high-flow fistulae and one a low-flow fistula. The overall prevalence of asymptomatic access dysfunction was therefore 25%, of which the majority were high flow.

Of the 19 patients with low access flow <500ml/min, the majority had radiocephalic AVF. Seventeen patients were subsequently recommended for surgical intervention after further assessment, and all interventions were associated with significant improvement of flow (Table 1). Two patients had no intervention, both with flow rates ≥420ml/min.

High-flow fistulae were identified in 22 patients, of which 60% had upper arm fistulae (Table 2). Access flow rates for these patients ranged from 2170 to 4100mL/minute. The prevalence of high flow for upper arm fistula was 39%, compared to 10%...
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for radiocephalic fistula (p < 0.001). This represented between 29–65% of resting cardiac output in the 15 patients who had measurement of cardiac output. Three patients had a resting cardiac output of more than 8L/minute.

For the 22 patients found to have high-flow access, 11 patients were recommended for flow reduction procedures (placement of a Dacron cuff close to the arterial anastomosis). Repeat access flow in all of these patients decreased following intervention (Table 2). Of the remaining patients, nine had no intervention: two patients received renal transplants before intervention could be considered; five patients had satisfactory repeat measurements; one patient subsequently died; one patient has refused follow-up. Two patients are awaiting repeat measurements prior to a decision.

Discussion

In this HHD population, we introduced a programme of AVF surveillance using ultrasound dilution and identified a high prevalence of unrecognised access dysfunction. It is of particular interest that the majority of dysfunctional AVF were high flow, given the associated avoidable cardiovascular risk. An AVF is the vascular access of choice for haemodialysis due to high flow rates, improved patency and reduced infection, with radiocephalic AVF being preferable to upper arm AVF. (Polkinghorne et al., 2013; National Kidney Foundation, 2006). Our study confirmed that upper arm AVF have a significantly greater chance of high flow than radiocephalic AVF, and the majority of patients with asymptomatic access dysfunction underwent intervention (either stenting or banding).

Table 2: Patients with high-flow AVF (Qa >2L/min or Qa:CO >30%) and outcomes

<table>
<thead>
<tr>
<th>Patient</th>
<th>AVF location</th>
<th>Initial measured flow (ml/min)</th>
<th>Cardiac output (ml/min)</th>
<th>Qa:CO</th>
<th>Intervention</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Radiocephalic</td>
<td>2710</td>
<td>7510</td>
<td>0.36</td>
<td>Banded</td>
<td>repeat flow 1800ml/min</td>
</tr>
<tr>
<td>2</td>
<td>Radiocephalic</td>
<td>2270</td>
<td>-</td>
<td>-</td>
<td>Banded</td>
<td>repeat flow 2030ml/min</td>
</tr>
<tr>
<td>3</td>
<td>Radiocephalic</td>
<td>2860</td>
<td>8600</td>
<td>0.33</td>
<td>Banded</td>
<td>repeat flow 1600ml/min</td>
</tr>
<tr>
<td>4</td>
<td>Radiocephalic</td>
<td>2780</td>
<td>-</td>
<td>-</td>
<td>Awaiting review</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Radiocephalic</td>
<td>2370</td>
<td>-</td>
<td>-</td>
<td>Awaiting review</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Radiocephalic</td>
<td>2880</td>
<td>5600</td>
<td>0.51</td>
<td>No intervention</td>
<td>repeat flow 1360ml/min</td>
</tr>
<tr>
<td>7</td>
<td>Radiocephalic</td>
<td>2230</td>
<td>-</td>
<td>-</td>
<td>No intervention</td>
<td>repeat flow 1600ml/min</td>
</tr>
<tr>
<td>8</td>
<td>Radiocephalic</td>
<td>2800</td>
<td>-</td>
<td>-</td>
<td>No intervention</td>
<td>repeat flow 1130ml/min</td>
</tr>
<tr>
<td>9</td>
<td>Radiocephalic</td>
<td>4100</td>
<td>-</td>
<td>-</td>
<td>No intervention</td>
<td>refused follow-up</td>
</tr>
<tr>
<td>10</td>
<td>Brachioccephalic</td>
<td>3550</td>
<td>9900</td>
<td>0.36</td>
<td>Banded</td>
<td>repeat flow 1900ml/min</td>
</tr>
<tr>
<td>11</td>
<td>Brachioccephalic</td>
<td>2170</td>
<td>7360</td>
<td>0.29</td>
<td>Banded</td>
<td>repeat flow 1130ml/min</td>
</tr>
<tr>
<td>12</td>
<td>Brachioccephalic</td>
<td>3390</td>
<td>7300</td>
<td>0.46</td>
<td>Banded</td>
<td>repeat flow 1120ml/min</td>
</tr>
<tr>
<td>13</td>
<td>Brachioccephalic</td>
<td>3400</td>
<td>6490</td>
<td>0.52</td>
<td>Banded</td>
<td>repeat flow 1370ml/min</td>
</tr>
<tr>
<td>14</td>
<td>Brachioccephalic</td>
<td>2760</td>
<td>4220</td>
<td>0.65</td>
<td>Banded</td>
<td>repeat flow 1500ml/min</td>
</tr>
<tr>
<td>15</td>
<td>Brachioccephalic</td>
<td>3050</td>
<td>6300</td>
<td>0.48</td>
<td>Banded</td>
<td>repeat flow 1100ml/min</td>
</tr>
<tr>
<td>16</td>
<td>Brachioccephalic</td>
<td>2520</td>
<td>5400</td>
<td>0.47</td>
<td>Banded</td>
<td>repeat flow 1030ml/min</td>
</tr>
<tr>
<td>17</td>
<td>Brachioccephalic</td>
<td>3180</td>
<td>7900</td>
<td>0.4</td>
<td>Awaiting banding</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Brachioccephalic</td>
<td>3610</td>
<td>7060</td>
<td>0.51</td>
<td>No intervention</td>
<td>transplanted</td>
</tr>
<tr>
<td>19</td>
<td>Brachioccephalic</td>
<td>2330</td>
<td>-</td>
<td>-</td>
<td>No intervention</td>
<td>repeat flow 1800ml/min</td>
</tr>
<tr>
<td>20</td>
<td>Brachioccephalic</td>
<td>3330</td>
<td>6100</td>
<td>0.55</td>
<td>No intervention</td>
<td>transplanted</td>
</tr>
<tr>
<td>21</td>
<td>Brachioccephalic</td>
<td>2460</td>
<td>7000</td>
<td>0.35</td>
<td>No intervention</td>
<td>Patient deceased</td>
</tr>
<tr>
<td>22</td>
<td>Brachioccephalic</td>
<td>3950</td>
<td>9300</td>
<td>0.42</td>
<td>No intervention</td>
<td>repeat flow 1690ml/min</td>
</tr>
</tbody>
</table>
The high prevalence of access dysfunction shown here highlights the need for regular access surveillance in this population. Although some of our patients were experiencing difficulties with dialysis, which precipitated their assessment, the majority were not. Low-flow AVF may cause problems with cannulation or low pressure alarms, as was the case with some of our population. However, patients with high-flow AVF tend not to have difficulties; therefore, there is a real risk that these dysfunctional fistulae will go unnoticed and, in time, lead to significant cardiovascular morbidity. We have demonstrated that the use of biannual access flow measurements using ultrasound dilution is a simple, non-invasive, effective way of detecting access dysfunction and would support this method for screening the HHD population.

It is generally accepted that a minimum flow rate of 500mL/min is required for adequate haemodialysis, with clinical guidelines suggesting further assessment for stenosis when AVF flow falls below this level (National Kidney Foundation, 2006). The risk of low flow includes access thrombosis and recirculation, and ultimately ineffective dialysis with time. A reasonable proportion (13%) of our total screened population had insufficient flow, and the majority have undergone intervention.

Surprisingly, the majority of our dysfunctional fistulae were found to be high flow. The creation of an AVF always has cardiovascular consequences. Following AVF creation there is an immediate reduction in peripheral vascular resistance, with a subsequent increase in cardiac output (through rising stroke volume and heart rate) and eventually an increase in blood volume. Over time, rising pressure in the right atrium and pulmonary vasculature can lead to higher left ventricular end-diastolic pressure. Patients are often asymptomatic until left ventricular dilatation and myocardial decompensation can lead to left ventricular failure (MacRae et al., 2004).

Cardiovascular disease is an important cause of mortality and morbidity in patients with renal disease, and the proportion of patients commencing renal replacement therapy in Australia with coronary and peripheral vascular disease is rising (Grace et al., 2012). Renal disease is itself also a vascular risk factor (Muntner et al., 2002). Therefore, it is important to identify and manage all modifiable cardiovascular risk factors, including the potential negative consequences of a high-flow AVF. It is recognised that in patients with high-output cardiac failure secondary to an AVF, reduction in AVF flow can restore left ventricular function, and ultimately the condition is reversible (Chapman et al., 2012; Engleberts et al., 1995; Young et al., 1998). Early intervention is, therefore, an important way of preventing future morbidity.

In our population, 22 patients had high-flow AVF of >2L/min. Our results are consistent with previous studies in demonstrating that upper arm AVF have higher mean flow rates than radiocephalic AVF, and have an increased risk of high flow (Basile et al., 2008). Cardiac output measurements demonstrated that 14 patients had a second indicator of high-output cardiac failure of Qa:CO > 0.3. As we do not have measurement of cardiac output in all patients, this may be an underestimate. Only three patients in our study met criteria for the traditional definition of high cardiac output of >8L/min (Anand & Florea, 2001). However, this definition assumes normal cardiac function and, therefore, may not be applicable to renal patients as it is likely that at least some will be unable to compensate for increasing AVF blood flow by increasing their cardiac output to this extent due to pre-existing cardiovascular disease. When considering high-output cardiac failure due to an AVF, the use of the Qa:CO ratio may, therefore, be more appropriate.

There can be reluctance amongst both patients and clinicians to intervene with seemingly well-functioning fistulae that are achieving good haemodialysis when there are no symptoms of disease. However, there is sufficient evidence to suggest a high risk of future cardiovascular morbidity and, therefore, intervention can be justified.

Our study has several limitations. Firstly, although all HHD patients attended once for flow measurements over the study period, we had difficulty encouraging patients to return for repeat measurements. Patients who select HHD do so partly because of the freedom it gives them, and may be reluctant to attend the dialysis unit regularly for AVF surveillance. We have limited clinical data at the time of AVF flow measurements, and no echocardiogram data, which could support our findings and may have influenced management. We also do not have routine follow-up measurements of fistula flow and cardiac output in the high-flow patients.

In summary, we have described a viable method for meeting the needs of the HHD population for AVF surveillance. The high prevalence of access dysfunction, and high-flow AVF in particular, demonstrates the necessity of such an approach. High-output cardiac failure is easily preventable, and can be reversible; therefore, the risk to this population must not be overlooked. We were able to offer early intervention for asymptomatic patients, hopefully reducing future morbidity. Further studies are required to better determine the appropriate time interval for access monitoring, to allow the development of clinical guidelines for the HHD population.
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References


