The role of automated peritoneal dialysis (APD) in an integrated dialysis programme

Paul Williams*, Linda Cartmel* and Jane Hollis†
*CAPD Unit, Ipswich Hospital, Ipswich, UK; †CAPD Unit, Addenbrooke’s Hospital, Cambridge, UK

While there is no doubt that renal transplantation would be the preferred option for all patients suffering from end stage renal disease, this is sadly an unrealistic aim for many patients in the UK. There is a shortage of donor organs and, with the increasing percentage of elderly patients on dialysis, under 50% of all dialysis patients are on the national transplant waiting list. Of the 12,000 or so patients on dialysis in the UK, approximately half receive haemodialysis and half peritoneal dialysis. In the last few years, there has been a resurgence of interest in automated peritoneal dialysis and just under 20% of the peritoneal dialysis population currently receive this mode of therapy. The advantages of automated peritoneal dialysis include the capacity for an increased dialysis prescription, increased freedom and quality of life and a decreased risk of peritonitis and intra peritoneal pressure related problems. These advantages may offset the increased cost of automated peritoneal dialysis and long-term patient morbidity and mortality may be diminished by its provision in an integrated dialysis programme.

In the UK there are currently approximately 12,000 patients receiving renal replacement therapy for end stage renal disease. Of these, about half have haemodialysis and half peritoneal dialysis, a ratio which has been largely static over the last few years. The absolute numbers of patients receiving dialysis has been increasing and recent studies have suggested that to reach a state of equilibrium where the number of patients dying is matched by the number of new patients will require a continued growth rate of 8% per year over the next 10 years. This has major financial implications and may require an increase in the cost of the end stage renal disease programme from £300 to £500 million per year. Many of these patients will be elderly with significant comorbidity and may not be suitable for renal transplantation or even home based dialysis, thus placing increasing demands on hospital dialysis facilities. This trend is already in evidence with hospital haemodialysis units largely full to overflowing with elderly patients, absolute home haemodialysis numbers declining and the rate of growth in patients receiving continuous ambulatory peritoneal dialysis (CAPD) also declining.
Renal transplantation is the preferred mode of treatment for patients with end stage renal disease, offering prolonged survival, increased rehabilitation and quality of life at a reduced cost per annum to the NHS compared to both haemodialysis and peritoneal dialysis. Unfortunately this option is not available to all patients due to an inadequate supply of donor organs and the perception that the elderly fare less well after renal transplantation. Figures from the United Kingdom Transplant Support Service Authority show that there were 5430 patients on the renal transplant waiting list at the end of December 1996, an increase of 5% over corresponding figures at the end of December 1995. In the year 1996, 1552 renal transplants were performed, a decrease of 7% compared to the previous year. The disparity between the number of patients waiting for a renal transplant and the number performed each year is growing and patients are having to wait longer on dialysis before receiving a transplant. The increased death rate of dialysis patients compared to those with renal transplants means that a number of dialysis patients will die while waiting for a transplant. This increase in mortality is largely due to cardiovascular disease and sepsis but the importance of adequacy of dialysis and nutrition in contributing to this increased mortality is now becoming more widely recognised. If patients are going to require longer periods on dialysis while waiting for a transplant, then adequacy of dialysis in terms of low molecular weight solute clearance becomes increasingly important. The limitations of CAPD in providing adequate dialysis in the long term, particularly in patients above 70 kg with no residual renal function, has been the subject of much comment recently and this may in part explain the fact that automated peritoneal dialysis (APD) has become the fastest growing dialysis modality in Europe and the US, with growth rates of over 20% per year over the last 2 years.

The advantages of APD as a dialysis technique offering increased flexibility of dialysis prescription with comparative freedom from CAPD exchanges are discussed below.

**Automated peritoneal dialysis (APD)**

APD is a peritoneal dialysis technique which uses a machine to perform the dialysis exchanges at night, therefore freeing the patient from the need to perform manual CAPD exchanges.

The technique was first introduced in the early 1960s by Boen and Lasker in the US and prior to the introduction of CAPD in 1976 by Popovich and Moncrieff, was used to treat limited numbers of patients by intermittent peritoneal dialysis, either once or twice weekly in
hospital or, more frequently, at home. In the late 1970s, Diaz-Buxo and Suki introduced the technique of continuous cyclic peritoneal dialysis (CCPD) where a machine carried out 3 or 4 nocturnal exchanges and instilled a final exchange into the patient’s abdomen in the morning. Despite the attractions of this as a technique, the size of the machines and the added expense meant that under 10% of peritoneal dialysis patients in the UK were maintained on CCPD. By the early 1990s, APD machines had become smaller and more efficient and there was an increased recognition of the limitations of CAPD. By the end of 1996, it was estimated that there were 4500 patients in Europe on APD which represented 20% of the total number maintained on peritoneal dialysis; the numbers for the UK were similar with over 800 patients on APD.

A number of studies published over the last 5 years have attested to the clinical and social benefits to be obtained from APD — these include increased delivery of dialysis as measured by weekly KT/V urea and creatinine clearances, increased ultrafiltration rates, decreased glucose absorption and protein losses, a decreased incidence of peritonitis and a reduction in intraperitoneal pressure related problems such as hernias or subcutaneous leaks. A reduction in hospital admission rates and an improvement in patients’ sense of well-being and quality of life have also been reported. These advantages combine to make APD an attractive alternative to both CAPD and hospital haemodialysis. The annual cost of APD usually falls between the latter two techniques.

There seem to be two major groups of patients who benefit from APD rather than CAPD. The first broad category is social — patients who find that their quality of life or that of their carers’ is significantly improved on APD. These include children, those in full time education or with demanding jobs and the elderly patient who may be dependant on relatives or other carers to perform their dialysis for them. The second group comprises those who could be regarded as CAPD failures, for example patients who can no longer achieve adequate dialysis when their residual renal function has declined after 2 or 3 years on dialysis, those with recurrent episodes of peritonitis or intraperitoneal pressure related problems.

APD prescription

While patients retain significant residual renal function in the first few years of dialysis, the contribution of that residual renal function to total weekly urea and creatinine clearance may be up to 30%. During this time peritoneal dialysis prescription is relatively easy and underdialysis should be rare — the majority of patients can be safely maintained on so
called standard CAPD which is usually $4 \times 2$ litre exchanges per day. However, when residual renal function is lost, particularly in patients of high body mass and who are low transporters on a standard peritoneal equilibration test, underdialysis becomes a significant problem and changes in the dialysis prescription become necessary. For CAPD patients this may mean an increase in the number and/or volume of exchanges, which may not be well tolerated either socially or with regard to the rise in intraperitoneal pressure seen with increased exchange volume. If it is decided to transfer the patient to APD, the individualisation of the dialysis prescription becomes increasingly important, both to achieve adequate dialysis and to optimise cost. Recent publications such as the CANUSA study have emphasised the importance of small solute clearance to patient survival on peritoneal dialysis and recommendations are now that one should aim for a KT/Vurea $>2.0$ per week and a creatinine clearance of $>60 \text{l/1.73m}^2 \text{BSA/week}$. APD prescription is more complex than for CAPD and the prescription needs to be tailored to take account of the patient's body size, peritoneal equilibration test status, residual renal function and social needs.

The fill volume for the nocturnal exchanges can be larger than that conventionally used for CAPD, as there will be a lower intraperitoneal pressure at any given fill volume in the supine position than the erect position leading not only to better patient tolerance but also increased dialysis efficiency. Providing there have not been any recent problems with subcutaneous dialysate leakage, hernia formation or recent surgery it is appropriate to use a maximum tolerated fill volume up to an optimum level of $2.0 \text{l/1.73 m}^2 \text{BSA}$. If there is any doubt about the patient's capacity to tolerate any proposed fill volume it is possible to measure the intraperitoneal pressure—a level below $18 \text{cm water}$ is usually acceptable.

The duration of a nocturnal APD cycle is made up of fill, dwell and drain times. The fill and drain times are largely governed by the characteristics of the peritoneal dialysis catheter but the dwell time needs to be individualised depending on the function of the patient's peritoneal membrane as assessed on a standardised peritoneal equilibration test. So called low transporters will require long dwell times to achieve adequate small solute equilibration—up to $3 \text{h}$ and hence only 3 or 4 exchanges per night. At the other end of the spectrum of peritoneal function efficiency, the fast transporters will require shorter dwell times to achieve efficient dialysis with dwell times of $60-90 \text{min}$ and, hence, 6–8 exchanges per night.

The duration of therapy overnight is, in part, governed by the patient's wishes and normal behaviour but the great majority of patients will require $8-10 \text{h}$ of therapy at night, particularly patients with elevated
body mass and no residual renal function. Again the majority of patients will require a ‘wet day’, i.e. the presence of dialysate fluid in the abdomen during the day. Many APD machines can perform this function automatically, leaving the patient free from dialysis related activities until it is time to reconnect to the machine the next night. If adequacy targets are still not achieved with prescriptions as suggested above, then some patients will need to do an extra dialysis exchange at some time in the day. If targets are still not achieved despite therapy optimisation, then it may be necessary to switch the patients to haemodialysis. In large anuric peritoneal dialysis patients, it is often easier to reach the KT/V target than the creatinine clearance target, as the short dwell times on APD favour fuller equilibration of urea which has a lower molecular weight than creatinine. In this situation, where the KT/V target is met but not the creatinine clearance target, the correct course of action is unclear — if the patient is thought to be clinically and nutritionally well it may be acceptable to continue on APD.

Clinical results with APD

Despite the recent increases in the number of patients being treated with APD, there is, as yet, little data on long term morbidity and mortality in comparison with other modes of renal replacement therapy. Most registry reports combine the results for CAPD and APD. The data that do exist consist largely of single centre data, which show that the technique is well tolerated by patients and is associated with a decrease in the incidence of peritonitis and intra-abdominal pressure related problems. A decrease in the frequency of dialysis related hospital admission has been documented as has an increase in quality of life assessment scores.9-14

We have offered APD as a treatment option since 1992, initially reserving it for patients who were inadequately dialysed on CAPD and who did not wish to transfer to haemodialysis. With increasing experience and increasing patient awareness of the options available, it became apparent that there were many patients who would benefit from APD for largely social reasons and some of these have started APD as an initial treatment, others switching from CAPD to APD as more machines became available.

From August 1992 until the end of December 1996, we have treated 70 patients with APD. There were 44 males and 26 females with a mean age of 46.7 years, (range 16 to 74 years). The causes of renal failure were glomerulonephritis (33 patients), diabetes mellitus (10 patients),
hypertension (10 patients), polycystic kidneys (6 patients), tubulointerstitial nephritis (6 patients), and other or unknown (5 patients).

The reasons for choosing APD were dialysis adequacy in 56% of the patients, social in 21%, dialysate leak related in 16% and ultrafiltration failure in 7%. These patients had a mean of 23.7 months (range 0–118 months) on CAPD prior to APD, and have had a combined total of 804 patient months exposure to APD, mean 11.5 months (range 1–50 months).

**Outcome**

38 patients remain on APD, 11 have received renal transplants, 10 have died, 5 have transferred to haemodialysis, 3 to CAPD and 3 have moved to other centres still on APD. Treating transplantation, dialysis modality change and relocation as censored observations, this gives a 4 year actuarial patient survival of 83% and treating transplantation and relocation as censored observations, the technique survival is 71%. The causes of death were sepsis in 4 patients, cardiovascular or cerebrovascular in 4 patients and liver failure and cancer in one patient each. The reasons for transfer to haemodialysis were peritonitis in 3 patients, ultrafiltration failure in one patient and pleural leak in one patient. The reasons for returning to CAPD were dislike of APD in 2 patients and an inability to master the technique of APD in one patient.

**Peritonitis**

70 patients have had 26 episodes of peritonitis in a total of 804 patient months, giving a peritonitis rate of one episode every 31 patient months. This compares favourably with our experience of CAPD patients using disconnect systems between 1985 and 1996 who had a peritonitis rate of one episode every 29 patient months and for patients on non disconnect systems during the same time period who had a rate of one episode every 13 patient months. The organisms causing these episodes of APD peritonitis were *Staphylococcus aureus* (7), *Staphylococcus epidermidis* (7), Gram-negative (6), and no growth (6). Peritonitis was treated according to local protocols, initial treatment usually including intraperitoneal vancomycin and gentamicin or, more recently, intraperitoneal vancomycin and oral ciprofloxacin with subsequent modification of antibiotics according to sensitivities obtained. The success rate of eradicating peritonitis without catheter removal in the APD patients was
The role of APD in an integrated dialysis programme

88%, the three treatment failures were caused by *S. aureus*, *Pasturella multocida* and *Klebsiella oxytoca*.

Current patients

38 patients remain on APD as of 31 December 1996, representing 21% of the total peritoneal dialysis population. They have a mean weight of 78 kg and 81% are effectively anuric. Prescription details and laboratory results are shown in Tables 1 and 2. We have attempted to maintain adequate dialysis in an ever changing population by means of regular monitoring of KT/V and creatinine clearance and consequent changes in dialysis prescription if dialysis targets have not been met. These changes have been made depending on the patients’ weight, peritoneal equilibration test status, residual renal function, social needs and degree of compliance. Comparing current prescription variables with previous audits performed on a 6 monthly basis, there has been a trend for the fill volume to increase (1.9 to 2.0 l) while total therapy volume has decreased slightly (13.5 to 13.2 l). Increasing the fill volume per cycle enables more efficient dialysis to take place without an increase in total dialysate volume and hence therapy cost. Of current patients, 50% have a KT/V >2.0 but only 25% have a creatinine clearance of >60 l/week. As previously mentioned, it is easier to achieve the KT/V target than the creatinine clearance target. Previous targets for peritoneal dialysis patients were 1.7 for KT/V and 50 l/week for creatinine clearance and 86% and 64% of the patients achieved these targets, respectively. Our current target for haemoglobin is >10 g/dl and 81% of patients achieved this figure with or without the use of erythropoetin. We consider patients to be at risk from the nutritional standpoint if their albumin is below 35 g/l when measured by the BCG method and 78% of patients currently exceed this level. We are also using intraperitoneal amino acid solutions to provide nutritional support to hypoalbuminaemic patients and Icodextrin solutions for long daytime dwells to provide extra ultrafiltration and clearance. Preliminary experience with both of these new solutions has been beneficial.

Conclusions

APD is a dialysis technique which may benefit certain groups of patients with end stage renal disease. It has the flexibility of prescription to enable the delivery of adequate dialysis clearance once residual renal function has been lost and can increase the quality of life and social
Table 1  Current APD therapy prescription variables

<table>
<thead>
<tr>
<th>Therapy prescription</th>
<th>Mean ± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Night treatment duration (h)</td>
<td>9.28 ± 1.14</td>
<td>7–12.5</td>
</tr>
<tr>
<td>Total therapy volume (l)</td>
<td>132 ± 3.0</td>
<td>5.4–18.4</td>
</tr>
<tr>
<td>Fill volume per cycle (l)</td>
<td>20 ± 0.54</td>
<td>0.9–3.0</td>
</tr>
<tr>
<td>Dwell time per cycle (min)</td>
<td>724 ± 153</td>
<td>43–106</td>
</tr>
</tbody>
</table>

Table 2  Selected laboratory results for current APD patients

<table>
<thead>
<tr>
<th>Laboratory results</th>
<th>Mean ± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>KT/V urea/week</td>
<td>2.17 ± 0.44</td>
<td>1.02–3.25</td>
</tr>
<tr>
<td>Creatinine clearance (l/1.73m² BSA/week)</td>
<td>56.1 ± 12.5</td>
<td>27.6–81.1</td>
</tr>
<tr>
<td>Albumin (g/l)</td>
<td>37 ± 5</td>
<td>29–43</td>
</tr>
<tr>
<td>Haemoglobin (g/dl; 64% on EPO)</td>
<td>121 ± 26</td>
<td>88–157</td>
</tr>
<tr>
<td>Urea (mmol/l)</td>
<td>20.6 ± 5.8</td>
<td>8–29</td>
</tr>
<tr>
<td>Creatinine (μmol/l)</td>
<td>1066 ± 268</td>
<td>496–1652</td>
</tr>
<tr>
<td>Potassium (mmol/l)</td>
<td>4.7 ± 0.8</td>
<td>3.3–6.6</td>
</tr>
<tr>
<td>Calcium (mmol/l)</td>
<td>2.6 ± 0.16</td>
<td>2.21–2.88</td>
</tr>
<tr>
<td>Phosphate (mmol/l)</td>
<td>1.87 ± 0.63</td>
<td>0.76–3.17</td>
</tr>
</tbody>
</table>

rehabilitation of patients while they wait for a renal transplant, which must remain the optimum treatment for end stage renal disease.

The importance of optimum urea and creatinine clearance to patients' long term survival on dialysis cannot be overemphasised—achieving current clearance targets is feasible in the majority of patients with APD, but constant monitoring of clearance results and prescription modification in the light of these results is essential.

Acknowledgements

We wish to acknowledge the unfailing support of the peritoneal dialysis teams in Cambridge and Ipswich over the last decade.

References

2 United Kingdom Transplant Support Service Authority. Annual Report. London; HMSO, 1996,
The role of APD in an integrated dialysis programme

10 de Fijter CWH, Oe LP, Nauta JJP et al. Clinical efficacy and morbidity associated with continuous cyclic compared with continuous ambulatory peritoneal dialysis Ann Intern Med 1994; 120. 264–71
11 King LK, Kingswood JC, Sharpstone P. Comparison of the efficacy cost and complication rate of automated peritoneal dialysis and continuous ambulatory peritoneal dialysis as long-term outpatient treatments for renal failure. Adv Perit Dial 1992; 8: 123–6
16 Oreopoulos DG. Let us raise our targets: entering a new era in CAPD Perit Dial Int 1996; 16: 432–3