

# 4 Peritoneal dialysis

## Introduction

4.1 Peritoneal dialysis (PD) is a well-established treatment modality for end stage renal disease (ESRD), providing both patients and clinicians with additional choice and flexibility. On average, it is the initial treatment for 30–40% of patients in the UK, although local practice does vary.

## Equipment and fluids\*

### Standards

- ▶ A unit offering PD should provide not only continuous ambulatory peritoneal dialysis (CAPD) but also automated peritoneal dialysis (APD), in all its forms. It should have access to adequate back-up haemodialysis (HD) facilities and renal transplantation. **(Good practice)**
- ▶ All equipment used in the delivery and monitoring of therapies should comply with the relevant standards for medical electrical equipment (BS-EN 50072:1992, BS 5724-2.29:1992, IEC 60601-2-39:1998. Medical electrical equipment. Particular requirements for safety. Specification for peritoneal dialysis equipment). Tubing sets and catheters should carry the CE mark to indicate that the item conforms to the essential requirements of the Medical Devices Directive (93/42/EEC) and that its conformity has been assessed in accordance with the Directive. **(Good practice)**
- ▶ Fluids for PD are required to satisfy the current European quality standards as indicated in the European good manufacturing practice and the European Pharmacopoeia Monograph, *Solutions for peritoneal dialysis*. Manufacturing facilities are required to meet the relevant standards (ISO 9001/2 and EN 46001/2). Product registration files must be submitted to, and product approval given by, the Medicines Control Agency. **(Good practice)**
- ▶ The use of disconnect systems should be standard unless clinically contraindicated. **(A)**

### Recommendations

- ▶ The unit should be aware of the limitations of CAPD and related techniques. **(B)**
- ▶ In selected patients – those with high small solute transfer rates and little or no residual function – specialised solutions such as glucose polymers (icodextrin) are preferable to standard solutions. **(B)**
- ▶ APD should be available as clinically indicated and not constrained by financial considerations. **(C)**

\*See Appendix D for details of standards abbreviations used in this section.

## RATIONALE

4.2 Disconnect 'flush before fill' systems are superior to earlier systems. In controlled trials, their use results in a significantly lower incidence of peritonitis and a better quality of life.<sup>1,2</sup> In a recent systematic review, peritonitis occurred significantly less frequently using the Y-set/modified Y-set compared with the standard spike system. The former was also more cost-efficient if it is assumed that there is a higher technique failure rate with the spike or non-disconnect systems.<sup>3</sup> Such systems should be standard for all patients, unless they are incapable of managing this slightly more difficult technique. Extra costs should be partly offset by lower morbidity, hospital admission and peritoneal failure rates.<sup>4</sup>

4.3 In patients with large muscle mass and no or little residual renal function, it may be difficult to provide adequate dialysis.<sup>5</sup> The survival of PD patients is at least as good as those on HD over the first 2–4 years.<sup>6</sup> Positive reasons for opting for PD include preservation of residual renal function and vascular access sites, reduced delayed graft function following transplantation and increased patient autonomy. The last is of particular importance to patients who wish to travel or remain in employment, or to those caring for children/relatives, and is often further facilitated by the use of APD.

4.4 The use of cycling machines at home may be necessary for clinical reasons, for example, high transporter status of the peritoneum (10–15% of the dialysis population), or impaired filtration, or for psychosocial reasons; these three groups form 20–25% of the total CAPD population. In addition, patient preference should be considered when prescribing APD. As yet, there have been no studies on the long-term outcome of patients treated by APD as a first option, in comparison with CAPD. Monitoring of the dose of dialysis delivered is especially important in APD (see below and Appendix 1). Automated systems are more expensive than standard disconnect manual systems; their extra costs will need to be reflected in contracts negotiated with purchasers, but it should be noted that usually APD will be cheaper for such patients than the alternative, ie transfer to in-centre HD.

4.5 Icodextrin may have particular value in improving ultrafiltration in patients with high small-solute transfer rates and little or no residual function. It has been claimed that use of this fluid will extend time on PD.<sup>7,8</sup> Thus, the increased cost of icodextrin may be more than offset by the saving in total modality cost achieved by avoiding a transfer to HD. Other solutions with variations in the concentration of sodium, calcium, magnesium, osmotic agents and buffers (bicarbonate) may also be required. Such solutions are likely to be more expensive, so their selective use should be reflected in negotiations with commissioners.

### Testing membrane function and dialysis adequacy

4.6 Observational studies have shown that solute clearance and membrane function are independent predictors of patient and technique survival, at least in CAPD patients. Hence, the following recommendations emphasise the need to measure membrane function and solute clearance, and give minimum targets for the latter. The relationship mentioned above between clinical outcome and solute clearance is, however, essentially due to the influence of residual renal function, and it is increasingly clear that residual renal and peritoneal clearances cannot be considered as equivalent.

## Recommendations

- ▶ A peritoneal equilibration test (PET) should be performed after 4–8 weeks on dialysis, and when clinically indicated, eg when biochemical indices or loss of ultrafiltration raise suspicion of changes in peritoneal transport characteristics, or when therapy is changed to APD. (C)
- ▶ A total weekly creatinine clearance (dialysis + residual renal function) of greater than 50 l/week/1.73 m<sup>2</sup> and/or a weekly dialysis *Kt/V* urea of greater than 1.7, checked eight weeks after beginning dialysis, are minima. Higher targets are desirable especially for high average and high transporters and APD patients. (B)
- ▶ At present both *Kt/V* and creatinine clearance are acceptable measures of adequacy until evidence accumulates to show the superiority of one over the other. Achieving either target is acceptable; creatinine clearance is more difficult to achieve in anuric patients with below average peritoneal solute transport. (C)
- ▶ These studies should be repeated at least annually, and more frequently if clinically indicated, particularly if suspicion arises that residual renal function has declined more rapidly than usual. (C)
- ▶ Careful attention to fluid balance, especially in anuric patients, is essential. The use of icodextrin in the day-time dwell combined with APD to achieve both adequate solute clearances and fluid removal is recommended. (B)

## RATIONALE

4.7 A peritoneal equilibration test (PET)<sup>9</sup> is used to assess peritoneal membrane function, in particular loss of ultrafiltration.<sup>10</sup> It measures the peritoneal membrane transporter status and the ultrafiltration capacity. It is essential in prescribing the appropriate PD regimen, but is not a measure of treatment adequacy. Membrane function takes 4–6 weeks after starting dialysis to stabilise.<sup>11</sup> Inadequate ultrafiltration should be suspected in patients with high solute transport or an ultrafiltration capacity <200 ml.<sup>12</sup> The standard permeability analysis (SPA), which uses a 3.86% glucose dwell (as opposed to the PET which uses 2.27%) over four hours, defines ultrafiltration failure as <400 ml ultrafiltration capacity, in the absence of fluid leak or catheter malfunction.<sup>13</sup> The additional measurement of the sodium dialysate/plasma (D/P) ratio at one hour gives an estimation of sodium sieving across the peritoneal vasculature, which if absent indicates poor ultrafiltration.

4.8 After 4–8 weeks, a PET should be done to assess peritoneal transport characteristics. Patients with high transport characteristics may not be suitable for standard CAPD exchanges, and will often require short-dwell APD. There is now good evidence that the outcome (patient and technique survival) is worse in high transporters.<sup>14–16</sup> In these patients greater emphasis on fluid control may be necessary.<sup>17</sup> Those with low transporter status may be unsuitable for APD altogether, unless they have good residual renal function (see 4.13 and 4.15). However, it has been demonstrated that patients with low transport have good outcomes on CAPD, probably because they ultrafiltrate well and are less likely to have fluid overload.

4.9 It is believed that the concept of adequacy, including the dose of dialysis, is very important. It has been shown in prospective studies to be a predictor of outcome in new

patients starting CAPD<sup>18–20</sup> and in patients already on CAPD treatment.<sup>21,22</sup> As with patients on HD, adequacy is a global concept, involving various levels of measurement, which include clinical assessment of well-being and physical measurements, measures of small molecule solute clearance and fluid removal, and the impact of the treatment on the patient's life. It is important that clinical aspects be taken into consideration in arriving at targets of small molecule solute clearance, which in general are the basis for measuring dialysis dose.

4.10 Prospective cohort studies in which peritoneal dialysis dose was unadjusted<sup>18–20</sup> have reported reduced survival in patients in whom creatinine and urea clearances were not maintained. In these studies, the influence of clearances on survival could be attributed almost entirely to the maintenance of residual renal function. These studies also identified an independent increased risk of patient death and technical failure as peritoneal solute transport increased. This observation is likely to be explained by impaired fluid balance in CAPD patients with higher solute transport. The implications of these findings are that PD patients who have lost residual renal function are at increased risk, due to a combination of reduced clearance and fluid removal.

4.11 There is some evidence that CAPD patients are chronically fluid overloaded,<sup>17</sup> and this impacts on cardiovascular outcomes.<sup>23</sup> In addition, patients who have no residual renal function (Canada and USA Collaboration Study (CANUSA)) or those with high peritoneal solute transport have a less favourable outcome.<sup>24</sup> This may in part reflect poor fluid control, increased hypertension and left ventricular hypertrophy (LVH).<sup>25</sup> There is no simple, direct way of assessing fluid status in PD patients, but studies of body composition suggest that greater attention to fluid balance is necessary. Loss of ultrafiltration is not uncommon in long-term PD patients.<sup>19</sup> Recently, management guidelines by the International Society for Peritoneal Dialysis (ISPD) have been published<sup>26</sup> which outline the approach to managing a PD patient with fluid overload. Particular care should be taken in anuric patients treated with APD, due to the risk of fluid re-absorption during the day-time dwell. A randomised study of APD patients, comparing day-time ultrafiltration with 2.27% glucose versus icodextrin, found that the latter achieved better fluid removal.<sup>27</sup> A recent, uncontrolled study demonstrated improvement in body fluid composition in APD patients switched to icodextrin during the day-time dwell.<sup>28</sup>

4.12 Prescribing of dialysis dose and measurement of adequacy of dialysis are best done during the initiation phase immediately after starting CAPD, and in a subsequent phase when the dose is assessed and monitored. Since the PET takes 4–6 weeks to stabilise (see 4.7), values obtained earlier than this may not be representative of membrane transport characteristics in the longer term. Hence the initial CAPD regimen should be prescribed assuming normal transport characteristics, the measured residual renal function (RRF) and body surface area. Subsequently, in the light of PET results, the definitive prescription is arrived at, and is adjusted to meet targets of solute clearance (see 4.14) and fluid removal according to fluctuations in dwell times, fill volumes, glucose concentration and change to APD.

4.13 The weekly  $Kt/V$  for urea and the weekly creatinine clearance are both used at present as measures of small solute clearance. Each is the sum of the clearance achieved

by the dialysis and that due to the RRF. Renal and peritoneal clearance are not equal, although this is assumed when compensating for the loss of RRF by increasing peritoneal clearances. At present, the two measures ( $Kt/V$  and creatinine clearance) are regarded as being equivalent and either can be used. Creatinine clearance is greatly affected by RRF and declines more as RRF decreases. Also, these two measurements differ in their susceptibility to manipulation; in practice, creatinine clearance is much more difficult to increase than  $Kt/V$  for urea; the National Kidney Foundation Dialysis Outcome Quality Initiative (DOQI) guidelines in the USA have given preference to  $Kt/V$  measurements.<sup>29</sup>

4.14 A weekly  $Kt/V < 1.65$  was reported to be associated with poor outcomes.<sup>30,31</sup> A weekly  $Kt/V > 2.0$  (dialysis + RRF) or total weekly creatinine clearance of  $>60$  l/week/1.73 m<sup>2</sup> of body surface area has been advocated for standard CAPD.<sup>29</sup> The Canadian guidelines recommend a minimum target  $Kt/V$  of 2.0 but a creatinine clearance of 60 l/week/1.73 m<sup>2</sup> for high and high average transporters, and 50 l/week/1.73 m<sup>2</sup> for low and low average transporters.<sup>32</sup> Higher clearances have been suggested.<sup>33,34</sup> It must be emphasised also that all these studies were based largely on theoretical predictions, even though these have been validated to some extent against actual experience,<sup>35</sup> and that there is no final proof that achieving these targets will result in improved outcome.<sup>36</sup> The recently reported Mexican Adequacy randomised control trial (ADEMEX)<sup>37</sup> showed no difference in outcome after two years in patients maintaining a creatinine clearance of 46 litres per week compared with those achieving 57 litres per week. This study therefore provides a firmer evidence base and justifies the minimum target of creatinine clearance of 50 litres per week and a  $Kt/V$  greater than 1.7. In the CANUSA study,<sup>18</sup> three-quarters of the deaths during treatment within two years of starting CAPD were from cardiovascular causes, some in well dialysed patients. Solute clearance also affects morbidity (hospitalisations, peritonitis), although the level of solute clearance where this becomes relevant is uncertain. The link between adequacy and nutrition is present, but hitherto has been based on cross-sectional data of a significant correlation between  $Kt/V$  and protein catabolic rate (PCR), which is a mathematical artifact of the use of  $V$  to calculate both parameters;<sup>38</sup> it should not be used to assess the impact of adequacy of dialysis on nutrition. There is evidence that increasing the delivered dialysis dose is feasible, and has modest beneficial effects in malnourished patients, without co-morbidity,<sup>39</sup> and in reducing hospitalisation rates.<sup>40</sup>

4.15 As mentioned in the introduction to this chapter, APD comprises a number of regimes involving varying amounts of fluid and dwell times. These include continuous cyclical assisted PD (CCPD), nocturnal intermittent PD (NIPD), NIPD with 'wet' days (dialysis done during the day), and tidal PD. There are few data on either solute clearances or impact on outcome of such regimes. With the current recommendation for solute clearance,<sup>29</sup> it seems that a 'wet day' is going to be necessary to augment clearances. At present, there is no evidence to support the higher targets of solute clearance advocated for APD regimes, most of which are continuous therapies.

4.16 Thus, the recommendations given immediately above can be regarded as approximate targets for which to aim, and can be refined in the light of future data. Again we emphasise that the general condition of the patient must be taken into account when prescribing the quantity of CAPD; a well nourished patient with good biochemistry and haemoglobin but apparently unsatisfactory clearance is preferable to an ill patient with poor metabolic control but apparently good clearance.

4.17 As emphasised above, decline in RRF has an important bearing on the adequacy of dialysis. Consequently, RRF should be assessed at least annually as part of the assessment of total adequacy, or whenever under-dialysis is suspected.<sup>41</sup> Measurement of RRF is described in Appendix 1. There is evidence that the regular use of a loop diuretic can maintain urine volume for longer, without affecting clearances, although whether this will affect outcome is unknown.<sup>42</sup> A loop diuretic may be prescribed, if there is no contraindication, to all PD patients.

## **Infective complications**

4.18 Infection continues to be the most important complication of PD. This is especially the case for peritonitis, which still causes between 30% and 50% of technical failures.

### **Recommendations**

- ▶ Peritonitis rates should be <1 episode/18 patient months. (A)
- ▶ The negative peritoneal fluid culture rate in patients with clinical peritonitis should be less than 15%. (B)
- ▶ The initial cure rate of peritonitis should be more than 80% (without necessitating catheter removal). (B)
- ▶ Mupirocin should be used as part of routine exit-site care; daily or on alternate days. (B)
- ▶ Nasal application of mupirocin in *Staphylococcus aureus* carriers should be undertaken twice daily for five consecutive days every four weeks. (A)

### **RATIONALE**

4.19 Peritonitis is the major and most serious complication of CAPD. Apart from the immediate deleterious effects and distress of the acute episode, there is mounting evidence that repeated attacks of peritonitis are associated with earlier failure of the peritoneal membrane. How the frequency of episodes of peritonitis should be measured and expressed remains a subject of controversy. In some studies, episodes within a short and variable period of either catheter insertion or beginning dialysis are excluded, and in other studies included. In general an actuarial analysis of time free of peritonitis is the best way to express the peritonitis rate,<sup>1,43</sup> and we advocate its use, but this has been little used in clinical practice. Despite its theoretical and practical disadvantages, the number of episodes/unit time remains in widest use, and the recommendation is couched in these terms.

4.20 Peritonitis rates are improving with the introduction of disconnect systems.<sup>7</sup> The successful diagnosis and management of peritonitis requires high quality microbiological facilities and close liaison with the microbiology department. Protocols for managing peritonitis episodes have been published.<sup>44,45</sup> It must be noted that the use of vancomycin as a first-line 'blind' antibiotic has been curtailed recently because of the emergence of vancomycin-resistant organisms,<sup>46</sup> and alternative regimens have not been evaluated so extensively.<sup>47</sup> With the occurrence of more unusual organisms causing peritonitis the initial cure rate may fall.

4.21 Guidelines for the insertion of peritoneal access catheters and their subsequent care have been published<sup>48</sup> and we advocate the use of these. The essential guidelines from this report are:

- 1 Overall no catheter appears to be superior to the standard double cuff Tenckhoff catheter.
- 2 A downward directed exit site decreases the incidence of catheter-related infections.
- 3 The insertion must be done by a competent and experienced operator.

Other recommendations relate to details of post-operative care, management of catheter-related infections and non-infectious (mechanical) catheter-related complications.

4.22 Catheter-related infections (exit-site, tunnel) with subsequent peritonitis account for up to 20% of transfers to HD.<sup>49</sup> Their prevention is important. Nasal carriage of *Staphylococcus aureus* (the most common organism causing catheter infections) is now strongly linked with exit-site infections.<sup>50</sup> Antibiotic prophylaxis (application of mupirocin ointment to the exit-site) in carriers has shown up to 50% reduction in catheter-related infections and, in these patients, is of clear value.<sup>51</sup> Regular screening for nasal *S. aureus* carriage is time consuming, however, and an alternative strategy of using mupirocin as part of the routine exit-site care in all patients has been advocated. A recent sequential prospective study using this approach has shown a dramatic reduction in exit-site infections and peritonitis when compared to historical controls.<sup>52</sup> This approach is advocated, but clinicians will need to work with their local microbiologists to implement it, and caution needs to be exercised with respect to development of resistance to mupirocin; this has not been shown to occur in 12 months of prophylactic use at the exit-site.<sup>53</sup> Studies to date have followed patients for up to 18 months. It is not yet clear whether several years usage of mupirocin is necessary or desirable.

## Paediatric section

### Equipment, fluids and personnel

#### Standard

- ▶ All children requiring PD should be treated in a designated paediatric nephrology and dialysis centre. **(Good practice)**

#### Recommendations

- ▶ It is essential that the child and family are prepared for PD by a renally trained children's nurse with appropriate written information. Preparation by the nurse and/or play specialist will also include aids such as dolls or videos.<sup>54</sup> **(Good practice)**
- ▶ Problems with needle phobia will require referral to a child psychologist. **(Good practice)**
- ▶ Insertion of the chronic peritoneal catheter should be by an appropriately trained surgeon. **(Good practice)**
- ▶ Training in the management of PD should be supervised by a paediatric renal nurse. **(Good practice)**

- ▶ The child's nutritional status needs to be managed and monitored by a paediatric renal dietitian.<sup>55</sup> **(Good practice)**
  - ▶ Since the home environment and the impact on the family are so important for the success of PD, psychosocial support such as liaison visits to the home, nursery or school and GP should be provided by the dialysis nurse and other team members such as social workers.<sup>54</sup> **(Good practice)**
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## RATIONALE

4.23 The greater use of PD has enabled infants with ESRD to be treated from birth when appropriate. These infants require additional intensive medical and nutritional support and their associated urological abnormalities emphasise the need for management in paediatric nephrology and dialysis centres.<sup>56</sup> Families should be actively involved in the choice of therapy, taking into account the difficulties of vascular access in small children, large distances from the paediatric dialysis centre, co-morbidity factors and the level of family support available.

4.24 There is increasing awareness of the unfavourable properties of glucose as an osmotic agent. Since the preferred treatment modality in children is APD, dwell times are usually short. This makes the application of a pH neutral dialysis solution for the standard nightly prescription highly desirable, but such solutions still need to be evaluated. If ultrafiltration is insufficient using the standard regimen, then the addition of a long daytime dwell with polyglucose solutions should be considered. Long-term studies of this subject in paediatrics are lacking. The place of amino acid-containing dialysis fluid still has to be determined in paediatric PD.<sup>57</sup>

4.25 Continuous peritoneal dialysis (CPD) is the favoured dialysis modality in children of all ages in the UK, with 79 children under 15 years of age on PD compared with 56 on HD in the UK in 2000.<sup>58</sup> Overnight APD is the commonest and most appropriate form of PD for young children. This is because the predominantly fluid diet means that the dialysis must remove large volumes of fluid, which is best achieved during the long hours that a young child spends asleep. APD has also been advocated for children as this gives greater freedom during the day for school and social activities, which are an important part of their development.

### Testing membrane function and dialysis adequacy

#### Recommendations

- ▶ A PET and measurement of adequacy parameters should be undertaken annually but should be considered sooner if there is growth failure. **(Good practice)**
  - ▶ Standards of adequacy recommended for adult patients should be regarded as the minimum for children.<sup>59</sup> **(Good practice)**
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## RATIONALE

4.26 PD adequacy targets have been recommended in adults because patient mortality and morbidity have been much easier to define. There are few data to correlate clinical

outcomes with delivered dialysis dose in children because of the smaller number of paediatric patients with varying body size and physical status who often spend shorter periods of time on dialysis before transplantation.

4.27 The efficiency of CPD is to a large part dependent upon the transference properties of the peritoneal membrane. The area of the peritoneal membrane is two-fold larger in infants than in adults at 533 cm<sup>2</sup>/kg body weight compared with 284 cm<sup>2</sup>/kg body weight respectively, although the surface area is age independent, if expressed per m<sup>2</sup> body surface area (BSA).<sup>60</sup> Therefore scaling of the dialysate fill volume by BSA has been proposed in children to avoid false perception of peritoneal hyperpermeability (as defined in the PET) compared with adults when prescribing fill volumes scaled simply to weight.<sup>61</sup> Exchange volumes should be 1,100–1,400 ml/m<sup>2</sup> BSA, taking into account the tolerance of the volume, the age of the patient, the modality of PD used, ie CAPD or APD, and the time spent on PD.<sup>62</sup>

4.28 A PET is of clinical use in choosing the most appropriate PD modality and guiding the prescription in the individual patient. As in adults, the PET in children should be delayed at least one month from catheter implantation or after a peritonitis episode, and should be performed if membrane failure is suspected or if there is poor growth. There is no firm recommendation for frequency of testing in children but twice per year has been suggested in order to optimise growth.<sup>62</sup>

4.29 Studies in adult patients on PD have characterised dialysis adequacy in terms of small solute clearance and have been based on clinical evidence provided by prospective studies. There are no comparable data available for patients treated by APD. It has been recommended that the delivered dose of nocturnal intermittent peritoneal dialysis (NIPD) should be 8% higher than that of CAPD and that of CCPD should be intermediate between CAPD and NIPD.<sup>63</sup> The few data that are available suggest better growth with better dialysis adequacy.<sup>64</sup> It has been suggested that the recommendations for adults should be regarded as the lower limit of PD prescriptions in children. However, adult adequacy targets should be regarded only as tentative guidelines for children at present; assessment of growth may provide further useful information of dialysis adequacy. Difficulties of 24-hour urine collections in young children make assessment of residual renal function inaccurate. The benefits of increasing PD doses have to be balanced against the cost in terms of the child's social rehabilitation and quality of life.

## Infective complications

### Standard

► A minimum peritonitis rate of <1 episode per 14 patient months is recommended, averaged over three years. (Good practice)

### RATIONALE

4.30 Peritonitis rates show a great variation between units on an annual audit because of the small number of patients in any one centre and the distorting effect of some patients, eg infants. Gastrostomies, vesicostomies and ureterostomies are not contra-indications to CPD in children. Peritonitis rates in children have improved in recent years with rates in Europe currently being <1 episode in 20 patient months,<sup>65</sup> although a recent German

multicentre trial reported a rate of one episode per 13.7 patient months.<sup>66</sup> We await definitive British data but a minimum standard of <1 episode per 14 patient months is recommended, averaged over three years.

4.31 There is no firm agreement on the best catheter configuration to use in children, as there are no conclusive data on the impact on peritonitis rates. However, different sizes of catheter are required in children of different body weights.<sup>54,67</sup> Data from the North American Registry suggest that children should have PD catheters that have swan neck tunnels, two cuffs and downward pointing exit sites.<sup>68</sup> All catheter connections should be luerlock. Although there are no specific paediatric studies, disconnect 'flush before fill' systems such as Y-sets should be routine for CAPD. There are no conclusive studies on the standard care of the PD catheter exit site in children. In general, adult recommendations are followed.<sup>67</sup> After a successful renal transplant, rejection episodes requiring a return to dialysis are rare after the first month, but catheter-related infections increase at this time.<sup>69</sup> The recommended time for removal of the PD catheter is therefore 3–6 weeks following successful transplantation.

#### Psycho-social support

See the standards and recommendations on p.32, Chapter 3.

#### Research and audit

##### *Recommendation*

► Each paediatric renal unit should maintain mortality and morbidity data for patients on CPD. All PD-related problems, such as catheter malfunction rates, exit-site and tunnel infections and peritonitis rates, and results of dialysis adequacy parameters and their relationship to growth, should be maintained by each unit. The data should be submitted to the British Paediatric Renal Registry. (**Good epidemiological practice**)

## Appendix 1: Methods for assessment of membrane function and solute clearance in peritoneal dialysis

### Assessment of membrane function

A number of methods to assess the peritoneal membrane have been developed, the most commonly used being the peritoneal equilibration test (PET), supported by clinical observation. This test measures two aspects of membrane function: low molecular weight solute transport (expressed as the dialysate:plasma ratio of creatinine at four hours), and the ultrafiltration capacity of the membrane. In the PET as originally described, ultrafiltration capacity is the net volume of ultrafiltration achieved at four hours using a 2.27% glucose exchange.<sup>9</sup> In the simplified standard permeability analysis (SPA) test, it is the net volume of ultrafiltration using a 3.86% exchange.<sup>13</sup>

The clinical value of assessing membrane function is as follows:

- ▶ Solute transport rates vary considerably in the PD population and inform dialysis prescription, allowing optimisation of both solute clearance and ultrafiltration.
- ▶ In CAPD patients, high solute transport is associated with reduced technical and patients survival. These patients may benefit from APD and polyglucose solutions.<sup>15,16</sup> Solute transport can change with time on treatment, and is the most common cause of ultrafiltration failure.<sup>54</sup> Using a standard PET, an ultrafiltration capacity of <200 ml is associated with a 50% risk of achieving <1,000 ml ultrafiltration in anuric patients.<sup>55</sup> Using an SPA test, an ultrafiltration capacity of <400 ml indicates ultrafiltration failure.<sup>13</sup>

The methods of performing PET and SPA tests are well described in the literature. The following points should be remembered in the interpretation of results:

- ▶ High concentrations of glucose interfere with many assays for creatinine. It is important to work with the local biochemists to ensure that the appropriate correction for measurement of creatinine in dialysate has been taken into account. The patient should follow their usual dialysate regimen, draining out as completely as possible before the test dwell. Large residual volume of dialysate will affect the results. Intra-patient variability of the ultrafiltration capacity (~20%) is greater than for the solute transport (<10%). Results of the PET/SPA, in particular the ultrafiltration capacity, should always be interpreted in the light of additional exchanges performed during the same 24–48 hour period (usually collected to assess solute clearance – see below). The PET/SPA tests are not surrogates for measuring solute clearance.

### Measurement of solute clearance

In measuring solute clearance and planning changes to the dialysis regimen, three clinical parameters are essential. These are estimates of:

- 1 Patient size
- 2 Peritoneal solute transport
- 3 RRF.

In each case, the choice of surrogate 'toxin', urea or creatinine, interacts with each of these parameters in different ways. At present, there is no clear evidence from the literature that one surrogate is superior to another. Where possible, clinicians should measure both, attempt to reach at least one of the targets, and understand why there appears to be a discrepancy. A number of commercial computer programs exist that are designed to aid dialysis prescription. Whilst some have been validated, good practice dictates that a change in dialysis prescription is checked for efficacy by repeating clearance studies.

### Patient size

In calculating urea clearances, patient size is expressed as an estimate of the total body water (volume of distribution of urea). It is recommended that the Watson formula is used for this:

Males:  $V = 2.447 - 0.09156 \times \text{age (years)} + 0.1074 \times \text{height (cm)} + 0.3362 \times \text{weight (kg)}$

Females:  $V = -2.097 + 0.1069 \times \text{age (years)} + 0.2466 \times \text{weight (kg)}$

Alternatively 58% of body weight (kg) may be used; this is less precise, and will give lower values for  $Kt/V$ , especially in obese patients. Creatinine clearances should be corrected for body surface area, normalising to 1.73 m<sup>2</sup>.

### Peritoneal solute transport

Solute transport rates have an important influence on peritoneal creatinine clearance, but not on urea clearance. This means that it is easier to achieve creatinine clearance targets in high transport patients. It should be remembered, however, that these patients might have less satisfactory ultrafiltration. In designing optimum dialysis regimens, patients with low solute transport will require equally spaced medium length dwells, such as are achieved with CAPD and single extra night exchanges (eg 5 × 2.5 litre exchanges). Those with high transport are more likely to achieve targets with short dwells (APD) plus polyglucose solutions (eg 4 × 2.5 litre exchanges overnight, 1 × 2.5 litre evening exchange and 1 × 2.5 litre daytime icodextrin).

### Residual renal function (RRF)

This is the single most important parameter in PD patients, and also the one most likely to change with time. Clinically significant changes can occur within three months. Because secretion of creatinine by the kidney at low levels of function over-estimates residual creatinine clearance, it is recommended that this should be expressed as the mean of the urea and creatinine clearances.

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