Special Feature

Guidelines by an ad hoc European committee on adequacy of the paediatric peritoneal dialysis prescription

Michel Fischbach¹, Constantinos J. Stefanidis² and Alan R. Watson³ for the European Paediatric Peritoneal Dialysis Working Group

¹Centre Hospitalier Regional et Universitaire, Hôpital de Hautepierre, Strasbourg, France, ²A&K Kyriakou Children’s Hospital, Athens, Greece and ³Children and Young People’s Kidney Unit, Nottingham City Hospital, Nottingham, UK

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Introduction

Continuous ambulatory peritoneal dialysis (CAPD) has been used in children since 1978 and was rapidly adopted as a home dialysis method. In more recent years, the availability of reliable and portable machines has increased the usage of automated peritoneal dialysis (APD), which now exceeds the use of CAPD in most western countries

The prescription of APD is based on an assessment of the needs of the patient with monitoring of biochemistry at regular intervals. The age of the child, the residual renal function, the nutritional intake, the acceptability of the regime to the child and family are all part of the assessment. Historically, children were prescribed CAPD on an initial regime of four bag changes a day with fill volumes of 30–50 ml/kg body weight per bag.

Dialysis adequacy is a concept introduced in the late 1980s, first in haemodialysis and subsequently in peritoneal dialysis (PD), linking outcomes to adequacy targets. Satisfactory or good dialysis could be viewed as the dose of dialysis below which a significant increase in morbidity and mortality would occur. It should not be confused with optimal dialysis, which is the dose of blood purification beyond which no further improvement in the patient’s clinical well-being can be achieved.

Adequacy targets have been defined in adults because patient mortality and morbidity is much easier to define [2]. There are much smaller numbers of paediatric patients with varying body size and physical status who often spend shorter periods of time on dialysis before the favoured treatment of transplantation. There are few data to correlate the clinical outcomes with delivered dialysis dose in children [3,4].

The European Paediatric Peritoneal Working Group was established in 1999 by paediatric nephrologists with a major interest in PD. The group has already published guidelines on commencing elective chronic PD [5]. These guidelines were initiated and discussed at meetings of the group and developed by e-mail discussion to develop a consensus of opinion based upon cumulative clinical experience and reported studies. This paper will discuss factors influencing the dialysis prescription and how such a prescription can be modified for different clinical circumstances.

Peritoneal membrane characteristics

Area and fill volume

The efficiency of PD is to a large part dependent on the transference properties of the peritoneal membrane. The area of the peritoneal membrane is 2-fold larger in infants than in adults at 533 vs 284 cm²/kg body weight, respectively, although the surface area is age independent if expressed per m² body surface area [6].

Therefore, scaling of the dialysate fill volume by BSA, particularly in infants and small children has been proposed [7–10] to avoid the false perception of peritoneal hyperpermeability (as defined in a peritoneal equilibration test (PET)) [9–11] in children compared with adults when prescribing fill volume scaled simply to weight.
\textit{Vascular pore surface area}

The effective peritoneal membrane area available for dialytic exchange can be determined using the three-pore model [12]. This calculated area is the vascular surface area involved for the exchanges, thus called effective area.

- Age independency for children vs adult patients if fill volume scaled for BSA (m\(^2\)) [12–14].
- Fill volume and patient posture are factors of vascular pore area recruitment [14]: a fill volume of 1400 ml/m\(^2\) with the patient in the supine position, appears optimal both in terms of efficiency, (i.e. mass transfer coefficient) and in terms of tolerance, (i.e. peritoneal pressure) [9,15,16]. This optimal fill volume should only be considered as a maximal target and not a requirement to achieve adequacy of dialysis.

\textbf{Fill volume}

\textit{Low peritoneal fill volume: a risk factor?}

A low fill volume is correlated to a hyperpermeable state as defined in a PET [7,9,10]. A hyperpermeable state is a risk factor for ultrafiltration failure [10,17] and increased mortality and morbidity in adults [17]. In children a hyperpermeable state has been linked to impaired statural growth rate despite an enhanced acquisition of body weight [18]. In this study the mean fill volume prescribed for the APD patients (58\%) was 824 ± 125 ml/m\(^2\) BSA and for the CAPD patients (42\%) 1019 ± 174 ml/m\(^2\). This is in fact a low-range fill volume prescription for the APD patients with potential impact on peritoneal permeability [7,9,10]. Nevertheless, in this study [18] the adequacy parameters referring to the guidelines were in a normal high range for Kt/V urea, i.e. 2.42 per week, contrasting with a normal low range for creatinine clearance, i.e. 55 l/1.73 m\(^2\) BSA per week. Such discrepancy [18] between urea and creatinine parameters of adequacy is often described in case of a hyperpermeable peritoneal state even in adults [19]. Therefore, we speculated that prescribing a low fill volume [18] should be considered as a potential risk factor able to induce a hyperpermeable peritoneal state with potential impact on growth [18]. This speculation should be validated by studies.

\textit{High peritoneal fill volume: a risk factor?}

An excessive fill volume may contribute to patient morbidity by causing the following complications: pain, dyspnoea, hydrothorax, hernia formation [20], gastro-oesophageal reflux with anorexia, loss of ultrafiltration by enhanced lymphatic drainage [21]. Such morbidity could result in patient non-compliance. Increasing the fill volume over a so-called peak volume [22,23] will not improve dialysis efficiency, but may even reduce it [22].

\textbf{Optimal peritoneal fill volume}

The historical prescription of 30–50 ml/kg body weight should be replaced by a fill volume scaled for BSA, taking into account the age of the patient, the modality of PD used, i.e. CAPD or APD and the time already spent on PD, which leads to greater patient tolerability. In practice the fill volume is lower in infants compared with children, is lower per day, i.e. CAPD, compared with night, i.e. APD. A fill volume of over 1400 ml/m\(^2\) BSA may increase morbidity without demonstrable gain and a too low fill volume could be a risk of hyperpermeability [23].

The fill volume should, therefore, be adapted individually under clinical control, (i.e. i.p. pressure measurements) [15,16] and biological adequacy parameters, (i.e. urea and creatinine levels at follow up clinic visits).

\textbf{Peritoneal permeability}

A standardized PET is now used to categorize the solute transport capacity of an individual patient [4,7]. The determination of a patient’s transporter state is of immediate clinical use in choosing the most appropriate PD modality and guiding the prescription in the individual patient. It is important to note that the reproducibility of PET tests depends upon standardized test conditions. It is also important to consider the new concept of functional vs organic hyperpermeable peritoneal state [23,24]:

- organic hyperpermeability: effective vascular pore area increment, i.e. neoangiogenesis, high pore density;
- functional hyperpermeability: as seen in case of low fill volume prescription [9,10,15]. This condition is presumably related to the ratio between a normal vascular pore surface area, i.e. normal pore density, and a low amount of fill volume [14].

\textit{How to perform a PET}\(^\dagger\)

The results of a PET are in part dependent from the fill volume used [4,7,10,15]. Therefore, standardized test conditions are of importance. In Europe [4], a fill volume of 1000 ml/m\(^2\) BSA and in USA [7] a fill volume of 1100 ml/m\(^2\) BSA were used to develop ‘normal’ charts. This standardized fill volume permits definition of the initial peritoneal permeability and monitoring of changes with time. The dextrose concentration used for standard curves determinations was 2.5% glucose dialysate. The use of 3.86/4.25% glucose solution should be preferred to improve the accuracy of ultrafiltration assessment and analyse the sieving of sodium [25–30].

\(^\dagger\)Supporting material is available to subscribers with the on-line version of the journal at the journal website.
The PET should be performed at least after a delay of 1 month from the surgical catheter implantation or from a peritonitis episode. The frequency of PET testing has not been determined but may be as often as two to four times per year. A more complete, but also more complicated test could allow [13,14] an effective peritoneal membrane area to be determined.

It is of importance to note first that this standardized fill volume could be different from the prescribed fill volume. Secondly, that the PET is conducted in a patient in a supine position. Therefore, the use of a ‘standardized’ PET for PD prescription assistance remains a matter of debate.

Some teams [9,31,32] use the APEX time ultrafiltration time and the purification phosphate time, both obtained from a PET as a help for PD prescription.

### Urea and creatinine adequacy parameters

The recommendations for adult patients [2] are given in Table 1. In children, a \( \text{Kt/V}_{\text{urea}} \) over 2 has to be achieved, but this may be difficult in those who are anephric or with minimal residual function unless additional dialysis is employed [26]. There are no data evaluating the reality or not of the risks related to an ‘over dialysis’. As urea purification capacity, \( \text{Kt/V} \) is expressed per litre body water, i.e. correlated to body weight and on the contrary creatinine clearance is expressed per BSA, an age influence on these two adequacy parameters is presumed. Thus, in small children and in infants \( \text{Kt/V}_{\text{urea}} \) is likely to be in a higher range than creatinine clearance for a given prescription compared to older children, because of the age impact on scaling for body weight or body surface area. This discrepancy between urea and creatinine adequacy parameters in small children and in infants might be explained by the result of the higher ratio of BSA/weight in this age group. In addition there are no data of optimal adequacy parameters in this age group. Therefore, the adult dose recommendations for PD adequacy might not be relevant for these patients.

| Table 1. The adult dose recommendations (DOQI guidelines; 1997 from ref. [2]) for peritoneal dialysis adequacy |
|-------------------------------------------------|-----------------|-----------------|
| CAPD | CCPD | NIPD |
| Weekly \( \text{Kt/urea} \) (whole body urea clearance) | 2.0 | 2.1 | 2.2 |
| Weekly \( \text{CrCl} (1.73 \, \text{m}^2/\text{week}) \) (creatinine clearance) | 60 | 63 | 66 |

CAPD, continuous ambulatory peritoneal dialysis; CCPD, continuous peritoneal dialysis cyclic; NIPD, Nocturnal intermittent peritoneal dialysis. Note that 1 ml/1.73 m\(^2\)/min of \( \text{CrCl} \) is equal to 10 l/1.73 m\(^2\)/week; 0.1 Kt/V urea per week appears equal to 3 l/1.73 m\(^2\)/week \( \text{CrCl} \).

### Discrepancy between urea and creatinine adequacy parameters

Although urea clearance appears to be mostly related to the total dialysate volume and, therefore, directly influenced by the fill volume per cycle and the number of cycles, the evidence is that phosphate and other solutes like creatinine are predominantly affected by the duration of the dwell time [22,34–36]. In fact a discrepancy between urea and creatinine parameters of PD adequacy [36] is often noted in APD patients [19,34–36] when one is using a high amount of total dialysate volume despite reduced dwell times. The same discrepancy between urea and creatinine purification parameters is also noted when there is a hyperpermeable peritoneal state [17,18] or when one is using a high amount of total dialysate volume despite reduced dwell times [36–38]. Children with a significant amount of residual renal function tend to have a high ratio of total creatinine clearance over \( \text{Kt/V} \), where as anuric patients have a lower ratio [37].

### Practical guidelines for prescription

#### CAPD prescription

CAPD is a simple method to use and is usually effective in patients with residual renal function. The existence of a large abdominal volume during daytime activities is often a source of discomfort for patients and there may be body image issues in older children. Prolonged peritoneal contact induces a degree of continuous hyperglycaemia with repercussions for the appetite and metabolism, particularly lipids.

**Initial prescription**
- **Number of exchanges per day**: four, sometimes three or five, according to the age and residual renal function.
- **Fill volume per exchange**: 600–800 ml/m\(^2\)/day, 800–1000 ml/m\(^2\) overnight according to age and tolerance.
- **Dialysis solutions**: glucose solution with lowest concentration (1.36%) wherever possible; if additional ultrafiltration is necessary then hypertonic glucose dialysis should be added for the longest dwell time, i.e. overnight. Increasing the need for ultrafiltration will require hypertonic solutions during the day.
- **Disconnectable system with double bag type Y set preferred**.

#### Adapted prescription

- **Number of exchanges can be increased to five per day** but this has limited acceptability due to the chronic work demands placed upon the family and difficulties arranging exchanges at school.
Fill volume per exchange increase:
this can be done by gradual increase and
assessing clinical response or by i.p. pressure
measurement [15]:
1000–1200 ml/m² for the day exchanges, sometimes
1400 ml/m² for the night exchange [22].

Dialysis solutions: if there is inadequate filtration
overnight due to high glucose reabsorption, then
icodextrin dialysis solutions could be considered.
However, there is limited experience of the long-term
use in children [39].

Nutritional requirements of children are best met by
oral supplements or gastrostomy/nasogastric feeding
[40]. Amino acid dialysis solutions have a place in
certain situations [41].

Solutions containing lower amounts of calcium
may be required when hypercalcaemia is noted,
especially with the use of calcium carbonate
phosphate binders.

Sodium supplements (orally given) are most often
needed in young infants. This may be due to loss
of sodium in the residual urine volume in children
with uropathies and/or the ultrafiltrate sodium
content.

Notes
Individual prescription for each patient on CAPD is
recommended in terms of tolerance and effective-
ness; this individual prescription has to be adapted to
the changes of the patient’s condition especially the
progressive reduction of the residual renal function
with time. There may be difficulties achieving the dry
weight related to inadequate ultrafiltration, which are
likely to be secondary to a hyperpermeable peritoneal
membrane state. Shorter dwell times can be tried, but
it is difficult to increase the number of exchanges
because of the burden upon the families. In these cases
APD modalities should be considered.

Adapted prescription

Fill volume: 800–1000 ml/m² according to age and
tolerance.

Number of exchanges per session: 5–10. In young
infants it often needs 10 exchanges.

Dialysis solutions: 1.36% glucose and higher hyper-
tonic glucose solutions depending upon the ultra-
filtration requirements. Usually 2.25% or greater
dialysis solution is limited to one-third of the total
amount of dialysate used for the session in order
to limit the negative impact of glucose on the
peritoneal membrane.

APD prescription

This is the main PD modality used in children
principally because of freedom for school and social
activities during the day. It can be adapted quickly to
their needs with short durations of dwell times, dif-
ferent types of modalities such as continuous cycling
peritoneal dialysis (CCPD), nocturnal intermittent
peritoneal dialysis (NIPD), continuous optimal peri-
toneal dialysis (COPD) and tidal peritoneal dialysis
(TPD).

The use of APD enables the dialysis prescription to be
tailored more closely to the individual patient,
especially those with peritoneal hyperpermeability.
Technical advances of cyclers, e.g. reduction in their
size, have made the APD treatment even more
attractive. The use of computerized cards in cyclers
enables accurate measurement of the delivered dialysis
dose and assessment of patient compliance.

Initial prescription

NIPD if significant residual urine volume, or CCPD
with initially half volume daytime dwell if little or no
residual function.

Number of sessions per week: it should be
performed daily, but in those with urine output an
occasional night off for social reasons should be
considered.

Duration of a session: 9–12 h.

Fill volume: 800–1000 ml/m²

Number of exchanges: 5–10. In young
infants it often needs 10 exchanges.

Dialysis solutions: 1.36% glucose and higher hyper-
tonic glucose solutions depending upon the ultra-
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Conclusions

In recent years the dialysis prescription has become more individually adapted to each patient. The availability of new dialysis solutions and the increased utilization of automated PD dialysis have allowed us to tailor proposed dialysis dose to the patient’s nutritional requirements and residual renal function.

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References


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