

Chapter 2

Peritoneal Equilibration Testing and Application

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Case Presentation

FW, a recently diagnosed patient with CKD Stage 5, is a 6-year-old boy who has been recommended to initiate chronic dialysis. His primary renal disorder is renal dysplasia. His nutritional evaluation reveals a weight of 18.1 kg (SDS -1.08), height 102 cm (SDS -2.64), and BSA 0.8 m^2 . His residual renal Kt/V is 0.3. A pre-dialysis biochemical evaluation showed BUN 70 mg/dl, creatinine 6.5 mg/dl, hemoglobin 9.4 g/dl, serum calcium 9.2 mg/dl, phosphorus 7.7 mg/dl, PTH 580 pg/ml, $25(\text{OH})\text{D}_3$ 14.5 ng/ml, and serum albumin 3.8 g/L; electrolytes were Na 138 meq/L, K 5.4 meq/L, Cl 101 meq/L, and serum CO_2 19.2 meq/L. Echocardiography showed a left ventricular mass index (LVMI) value of $45 \text{ g/m}^{2.7}$.

Peritoneal dialysis (PD) was initiated several weeks after PD catheter placement, with the fill volume reaching 700 ml/exchange (900 ml/m^2) 3 weeks after dialysis initiation. The PD modality used was continuous ambulatory peritoneal dialysis (CAPD), and FW's initial dialysis prescription consisted of Dianeal® 1.5%, four exchanges per day, with each exchange lasting 6 h. During the second month of PD, a 4-h peritoneal equilibration test (PET) was performed.

During the night prior to the test, an 800 ml ($1,100 \text{ ml/m}^2$) exchange of 2.5% dextrose dialysis solution was instilled for 8 h. On the day of the test, the overnight exchange was drained, and another exchange with Dianeal 2.5% was infused. Dialysate samples for creatinine and glucose were obtained at 0, 2, and 4 h of dwell time, and a blood sample for creatinine was obtained at 2 h. The 4-h results were as follows:

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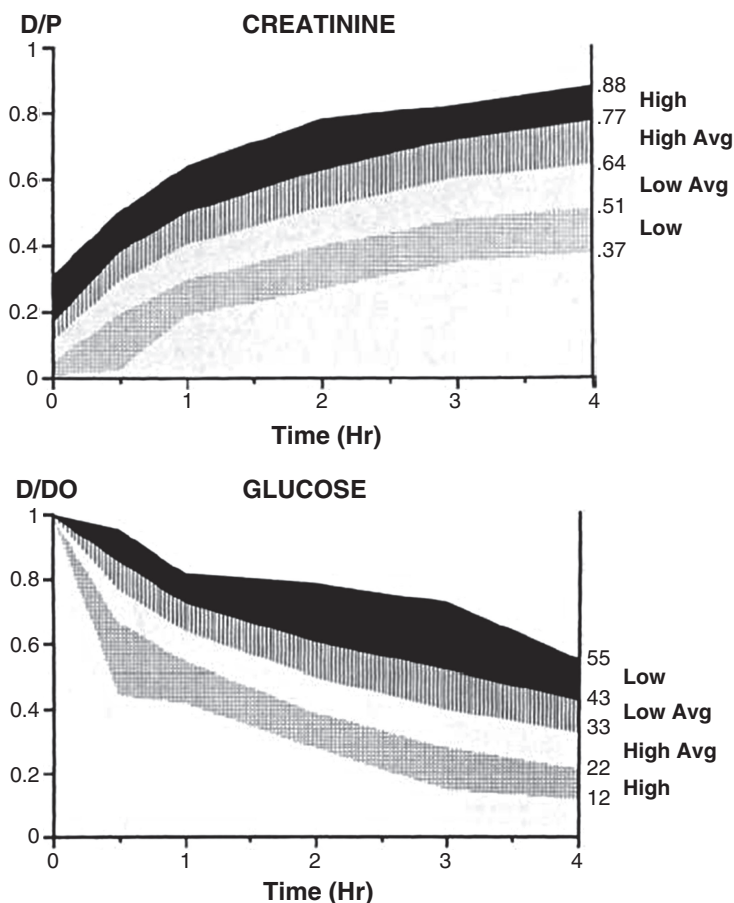


Fig. 2.1 Peritoneal equilibration test categories

D/P creatinine, 0.64, and D/D₀ glucose, 0.38. These results were compatible with a high-average transporter status (Fig. 2.1).

In view of these PET results, the PD modality was changed to nocturnal intermittent PD (NIPD). The prescription consisted of seven, 1-h exchanges nightly, with an 800 ml fill volume using Dianeal 1.5% peritoneal dialysis solution. Over the initial 18 months of PD, the patient experienced a single episode of peritonitis with a good response to antibiotic treatment. The PET was not repeated after this peritonitis episode.

After 2 years of PD, the patient's blood pressure was 110/76 mmHg (95th percentile), and the residual renal Kt/V decreased to a value of 0.2. Echocardiography demonstrated an increased LVMI with a value of 54 g/m^{2.7}. As a result of the clinical evidence of hypervolemia and the desire to provide the best PD prescription for both

solute and fluid management, a repeat PET was performed. The treating physician chose not to conduct a short PET. Results showed a 4-h D/P creatinine of 0.45 and a 4-h D/Do glucose of 0.58, findings now compatible with a low transporter status. Based on this result, FW had his PD prescription changed to a long dwell PD schedule, specifically the use of CAPD with a 1,000-ml fill volume and four, 6-h exchanges daily.

Clinical Questions

1. Is the PET a useful tool in pediatric peritoneal dialysis?
2. What is the importance of the duration of the exchange preceding the PET?
3. What is the importance of the fill volume in the PET?
4. How should the results of the PET be used to help select the PD modality and prescription?
5. Are both the Short PET and the Classical PET appropriate for use in children?
6. When should the PET be repeated?

Diagnostic Discussion

1. The success of peritoneal dialysis therapy is based on the ability of the peritoneal membrane to serve as a semipermeable membrane for solute transport and ultrafiltration. The properties of this membrane are also key determinants of the patient's outcome [1–4].

The peritoneal equilibration test (PET) represents a semiquantitative means to assess the peritoneal membrane permeability in dialyzed patients, and the resultant data aids in the individualized prescription of peritoneal dialysis therapy. In pediatrics, a considerable experience with the PET has been accumulated during the past 20 years [4, 5]. The PET helps tailor the PD prescription to meet the specific needs of the patient in terms of

- (a) Fill volume
- (b) Length of each exchange
- (c) Number of daily cycles
- (d) Dextrose concentration of peritoneal dialysis solution

- *The PET is performed in children in the following manner:*

1. An overnight 3–8h exchange is performed.
2. The overnight exchange is drained upon arrival to the PD unit the following morning.
3. A transfer Y-type set is installed.
4. A 1,100-ml/m₂ fill volume, 2.5% glucose peritoneal dialysis solution is infused, and patient is rolled from side to side during the infusion.

5. After concluding the infusion, dialysis solution is maintained in the peritoneal cavity for a 2- (short PET) or 4-h (classical PET) dwell time.
6. Dialysate samples are taken at 0, 2, and 4 h for the classical PET. A 10-ml volume is sent for glucose and creatinine measurement.
7. A serum sample is obtained at the midpoint of the PET (at 1 or 2 h, dependent on length of PET).
8. The dialysate to plasma (D/P) hour 2 if short PET, hour 4 if classical PET for creatinine, and dialysate hour 2 (if short PET) or hour 4 (if classical PET) to dialysate hour 0 (D2-4/D0) glucose ratios are calculated.

- *Interpretation of the PET*

Patients are categorized as low, low-average, high-average, or high transporters according to the PET results [6].

A low transport state is diagnosed when the D/P creatinine ratio is below -1 standard deviation (SD), and the glucose D/D₀ ratio is above $+1$ SD of the mean normative value; a low-average transport capacity corresponds to a D/P creatinine ratio between the mean and -1 SD and a D/D₀ glucose ratio between the mean and $+1$ SD; a high-average transport capacity is diagnosed when the D/P creatinine ratio is between the mean and $+1$ SD and the D/D₀ glucose is between the mean and -1 SD; and a high transport capacity corresponds to a D/P creatinine ratio more than $+1$ SD and a D/D₀ glucose ratio less than -1 SD of the mean value. Pediatric reference PET data have been published [7].

2. The importance of the long-dwell exchange prior to the PET relates to the desire to obtain plasma-peritoneal solute equilibrium. In the original description of the PET, the dwell time of the preceding exchange was approximately 8 h [6]. Whereas this long-dwell exchange is easily performed in CAPD patients, pediatric patients are often prescribed automated peritoneal dialysis (APD); therefore, a nocturnal long-dwell exchange represents an important change in their dialysis regimen. In turn, Lilaj et al. [8] subsequently showed that the absence of a prior long exchange had a significant influence on the D/P ratios of small solutes, urea, creatinine, and proteins. Twardowski et al. [9] confirmed that a prior exchange with a dwell time between 3 and 8 h results in only a small and nonsignificant influence on the D/P ratios of creatinine and urea, as well as on the D/D₀ glucose. Therefore, each center should define a standard preceding exchange duration prior to the PET test and implement it uniformly in order to be able to draw conclusions and compare results [10].
3. The peritoneal membrane surface area in children has been determined to be twice as large as the surface area in adults when expressed per kg body weight. In contrast, the peritoneal membrane surface areas of children and adults are more comparable when the scaling factor is body surface area (BSA). In turn, when weight is used to calculate fill volume, infants and children with low body weight will receive less dialysate in proportion to their peritoneal surface area, and the PET results will give the artifactual impression of a high peritoneal membrane transport capacity because of rapid equilibration of solutes between plasma and dialysate in the setting of a small fill volume. As shown by Warady et al. [11], this phenomenon is explained by the concept of "geometry of diffusion." Therefore,

the PET fill volume in children should be prescribed in terms of BSA to avoid a diagnosis of functional hyperpermeability and to provide the most accurate information upon which to base the dialysis prescription [12].

4. The optimal dialysis prescription in terms of solute and fluid removal will differ according to the peritoneal transporter type. In the case of fast transporters, short-dwell time exchanges should be prescribed to obtain adequate ultrafiltration and urea purification.

Clinically, a patient with a high peritoneal membrane transport capacity using long-duration dwell times will limit ultrafiltration and will show signs of volume overload, such as edema, hypertension, and cardiovascular deterioration.

Conversely, in slow transporters, long-dwell exchanges and large fill volumes are required to optimize solute clearance. At the same time, the slow transport results in maintenance of the glucose gradient and the achievement of adequate ultrafiltration.

Therefore, APD regimens are indicated for fast transporters, and CAPD is often the best PD modality choice for patients with low peritoneal membrane transport capacity [13–15].

High-average and low-average transporters will benefit from the use of a mixed dialysis regimen, such as with the use of CCPD, using short-time dwells during the night and keeping 1 or 2 long-dwell exchanges during the day.

5. Twardowski et al. [9, 16] previously measured D/P creatinine and D/D₀ glucose during a 2-h (short) and a 4-h (classical) PET. Those authors found that for both solutes, equilibration curves were almost identical irrespective of test duration. Thus, the short PET was considered a valid study to classify membrane characteristics as established in the original PET study.

In pediatrics, Warady et al. [17] characterized peritoneal membrane transport capacity comparing a 2- vs 4-h D/P creatinine and 2- vs 4-h D/D₀ glucose values in a retrospective experience in 20 children on PD. Results were consistent with the previous adult findings indicating that the short and classical PET provide equal characterizations of peritoneal membrane transport capacity. These conclusions were supported in a prospective multicenter pediatric study of 84 PET studies in 74 PD patients [18].

Together, these data suggest that, like in adult patients, a short version of the PET can be applied to the pediatric population.

6. The K-DOQI Guidelines on peritoneal dialysis adequacy [14] are one of the most comprehensive set of recommendations published to date on the care of patients receiving peritoneal dialysis. For adults patients, the recommendations suggest that total urea Kt/V (dialysis Kt/V + residual renal Kt/V) and peritoneal transport characteristics should be measured 1 month after starting PD. Whereas there is no need to routinely repeat the PET since peritoneal transport is stable over time in most patients, the PET should be repeated when one of the following situations arises:
 - Unexplained volume overload
 - Edema, hypertension, or increased LVMI
 - Unexplained decreasing drain volume
 - Unexplained worsening of uremia symptoms

- Changes in Kt/V
- Increasing needs for hypertonic dialysis solution to maintain ultrafiltration

The findings generated by the PET in these settings will assist the care provider in appropriately modifying the patient's dialysis prescription in terms of fill volume, exchange duration, and dextrose concentration of the dialysis solution [1, 2, 4, 15, 19].

Clinical Pearls

1. The peritoneal equilibration test (PET) has been validated to be the best method to evaluate peritoneal membrane transport capacity in children and adults.
2. The PET permits patients to be categorized as low, low-average, high-average, or high transporters which, in turn, helps determine the best PD prescription characteristics in terms of fill volume, length of each exchange, and dextrose concentration of the dialysis solution.
3. Changes in peritoneal transport should be evaluated with a repeat PET when there is clinical evidence of changes in dialysis efficiency, especially when the changes have the potential of influencing cardiovascular morbidity and mortality in uremic children.

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Pediatric Dialysis Case Studies

A Practical Guide to Patient Care

Warady, B.A.; Schaefer, F.; Alexander, S.R. (Eds.)

2017, XIV, 351 p. 45 illus., 32 illus. in color., Hardcover

ISBN: 978-3-319-55145-6