



PERITONEAL EQUILIBRATION TEST

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INTRODUCTION

- **The peritoneal equilibration test (PET) is a semiquantitative assessment of peritoneal membrane transport function in patients on peritoneal dialysis.**
- **The solute transport rates are assessed by the rates of their equilibration between the peritoneal capillary blood and dialysate.**
- **The ratio of solute concentrations in dialysate and plasma (D/P ratio) at specific times (t) during the dwell signifies the extent of solute equilibration.**
- **This ratio can be determined for any solute that is transported from the capillary blood to the dialysate.**
- **Creatinine, urea, electrolytes, phosphate, and proteins are the commonly tested solutes for clinical use.**

INTRODUCTION

- **The fraction of glucose absorbed from the dialysate at specific times can be determined by the ratio of dialysate glucose concentrations at specific times (t) to the initial level in the dialysis solution (D_t/D_0).**
- **The PET also helps measure ultrafiltration and residual volumes.**

Procedure

- **The standardized four-hour PET procedure consists of the following sequential steps:**
 - 1. An overnight 8 to 12 hour pre-exchange is performed.**
 - 2. While the patient is in an upright position, the overnight exchange is drained (drain time not to exceed 25 minutes).**
 - 3. Two liters(1100ml/m²) of dialysis solution are infused over 10 minutes with the patient in the supine position.**
 - 4. The patient is rolled from side to side after every 400 mL infusion.**

Procedure

- ❑ **After the completion of infusion (0 time) and at 120 minutes dwell time, 200 mL of dialysate is drained.**
- ❑ **A 10 mL sample is taken and the remaining 190 mL is infused back into the peritoneal cavity.**
- ❑ **During the four-hour dwell time, the patient is upright and allowed to freely ambulate.**
- ❑ **A serum sample is obtained at 120 minutes.**
- ❑ **At the end of the dwell (240 minutes), the dialysate is drained in the upright position (drain time not to exceed 20 minutes).**
- ❑ **The drain volume is measured and a 10 mL sample is taken from the drain.**

Procedure

- **All the samples are sent for solute measurement (creatinine, urea, and glucose).**
- **The serum and dialysate creatinine concentrations are corrected for a high glucose level, which contributes to non-creatinine chromogens during the creatinine assay.**
- **The D_t/D_0 glucose, and the D/P ratios for creatinine, urea, and others, are calculated**



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- **The standardized test for clinical utility measures dialysate creatinine and glucose levels at 0, 2 and 4 hours of dwell, and serum levels of creatinine and glucose at any time during the test.**
 - **The extensive unabridged test, which was originally proposed by Twardowski et al, has become a very important research tool.**
 - **Peritoneal transport characteristics obtained within the first month of initiating PD may be relatively inaccurate.**

Table 26.1 The PET procedure in children

- ◆ Dwell period: 4 hours
- ◆ Fill volume: 1100 ml/m² BSA^a
- ◆ 2.3–2.4% anhydrous glucose dialysis solution (Europe)
- ◆ 2.5% dextrose dialysis solution (North America, Japan)
- ◆ Test exchange after prolonged (8 hours) dwell, if possible as follows:
 - Drain the overnight dwell
 - Record the length of the dwell and the volume drained. Also note the dextrose and volume infused
 - Infuse the calculated fill volume, note infusion time
 - Keep patient in supine position
 - Drain < 10% of dialysate solution into the drain bag at 0, 120, and 240 minutes
 - Invert bag for mixing and obtain sample. Reinfuse any remaining effluent
 - Obtain blood sample after 120 minutes
- ◆ Measure creatinine and glucose in each sample
- ◆ Calculate dialysate to plasma (D/P) creatinine and dialysate glucose to baseline dialysate glucose (D/D₀) concentration ratios
- ◆ Determine transporter state by comparing creatinine and glucose equilibration curves with pediatric reference percentiles (Figures 26.6 and 26.7)

^aIn early infancy, volume may not be tolerable; in these cases, conduct PET with regular daily exchange volume for evaluation.

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- **Significant differences were observed between the one and four week tests in the measurement of D/P urea, D/P creatinine and D/Do glucose; by comparison, there was general agreement between the four week and one year PET measurements.**
 - **we perform a PET test approximately one to two weeks after initiation of PD therapy (which is three to four weeks after catheter insertion) to use as a baseline value.**
 - **The test is repeated when clinical problems arise and when clinical suspicion of an alteration in membrane transport occurs**

CLINICAL APPLICATIONS

Clinical applications of peritoneal equilibration test

Peritoneal membrane transport classification

Predict dialysis dose

Choose peritoneal dialysis regimen

Monitor peritoneal membrane function

Diagnose acute membrane injury

Diagnose causes of inadequate ultrafiltration

Diagnose causes of inadequate solute clearance

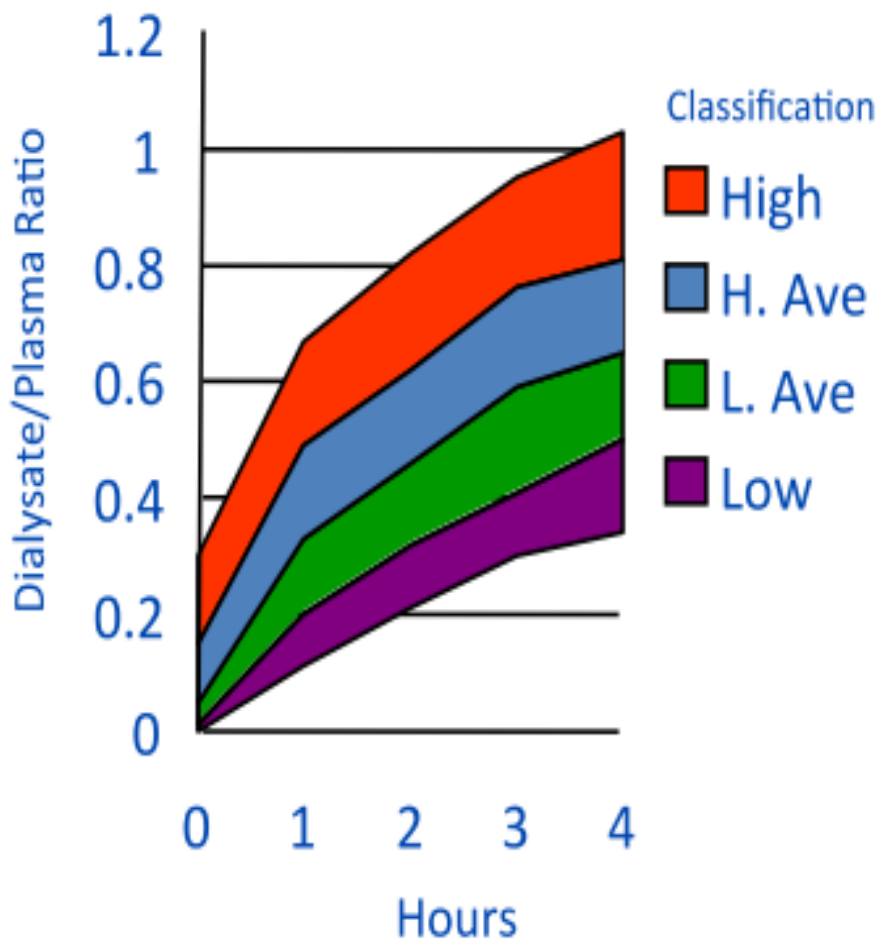
Estimate D/P ratio of a solute at a particular time

Diagnose early ultrafiltration failure

Assess influence of systemic disease on peritoneal membrane function

D/P ratio: dialysate to plasma ratio.

D/P Creatinine



D/D₀ Glucose

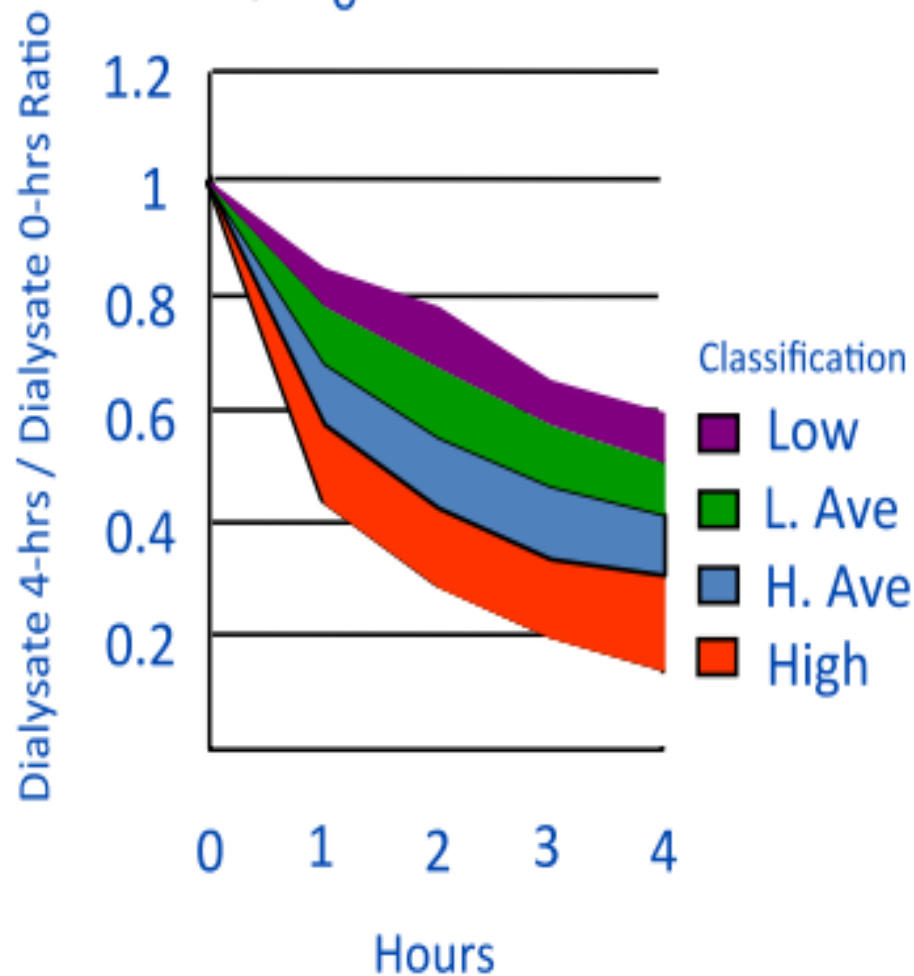


Figure 1: (Left) dialysate creatinine versus plasma creatinine at 4-hours (D/P creatinine); (Right) ratio of dialysate glucose at 4-hours versus dialysate glucose at time zero (D/D₀);

Table 1 – Dialysis Regimens Based on PET Results

Transport Type	D/P Creatinine	Solute Clearance	Ultrafiltration	Preferred Regimen
High (Fast)	>0.80	Excellent	Poor	APD regimens (eg, NIPD, CCPD, PD Plus)
High-average	0.65-0.80	Adequate	Adequate	Any regimen
Low-average	0.55-0.64	Adequate/ Inadequate	Good	Standard dose CAPD
Low (Slow)	<0.55	Inadequate	Excellent	High dose, longer dwell CAPD (or hemodialysis)

**Adapted from reference 14*

**PET: Peritoneal equilibration test; APD: Automated Peritoneal Dialysis; NIPD: Nightly intermittent PD; CCPD: Continuous cyclic PD; CAPD: Continuous ambulatory PD*

PET (peritoneal equilibration test)

Transporter	Waste Removal	Water Removal	Best Type Of PD
High	Fast	Poor	Frequent Exchanges, Short Dwells – APD
Average	OK	OK	CAPD or APD
Low	Low	Good	CAPD, 5 Exchanges Daily + 1 Exchange At Night

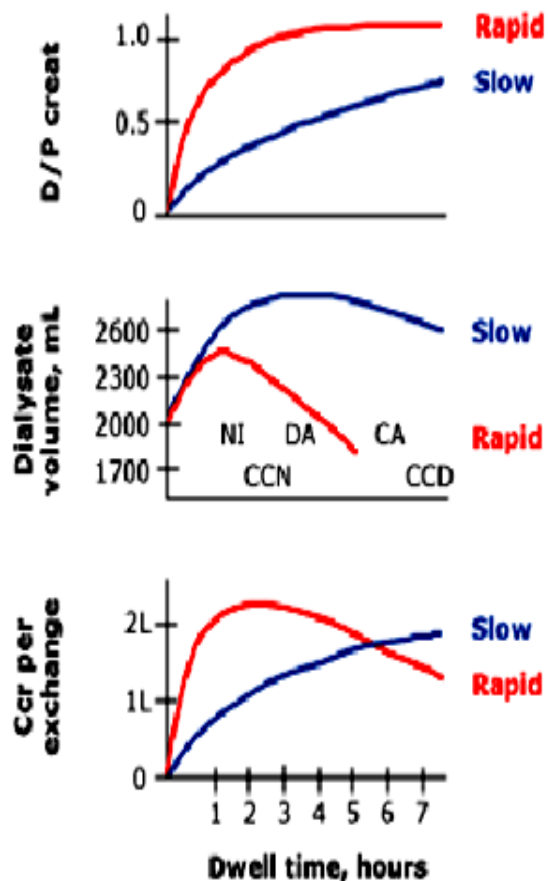
Classification

- Peritoneal dialysis patients are classified as having one of the following peritoneal membrane function characteristics based upon the results of the PET:
- High transporter — defined as a creatinine D/P greater than +1 SD from the mean, or a glucose D/Do of less than -1 SD from the mean.
- Low transporter — defined as a creatinine D/P of less than -1 SD from the mean or a glucose D/Do of greater than +1 SD from the mean.
- Average transporter — defined as a creatinine D/P and a glucose D/Do of between +1 SD and -1 SD around the mean.

Classification

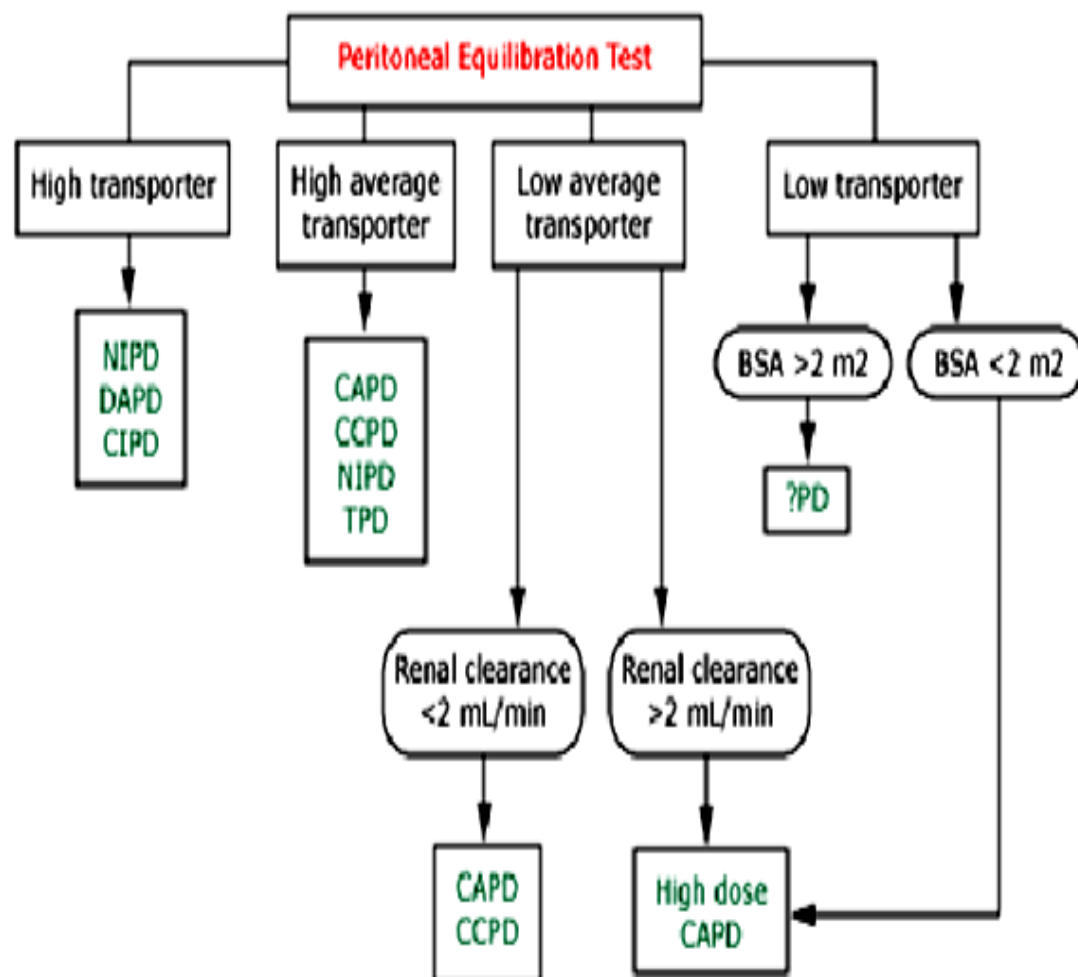
- **In the original series, approximately two-thirds of patients had average transport rates on the baseline PET.**
- **The remaining one-third consisted almost equally of high and low transporters.**

Rapid versus slow transport in PD



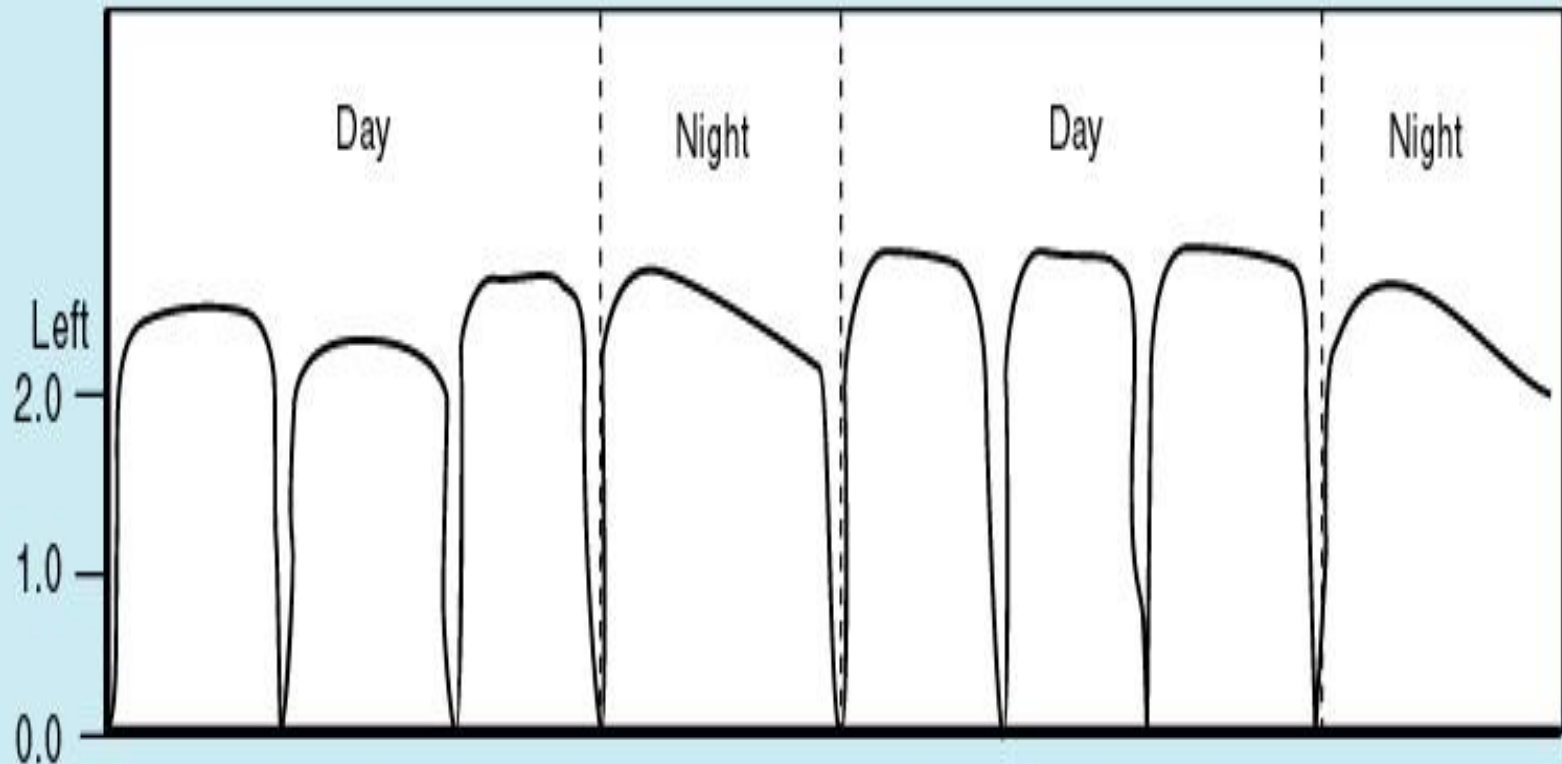
Differences between rapid and slow transporters during PD. Rapid transporters reach creatinine equilibration more quickly (dialysate-to-plasma creatinine equals one, top panel), have a gradual reduction in dialysate volume after two hours due to glucose absorption (middle panel), and have a reduction in creatinine clearance (Ccr) after four hours due to absorption of creatinine with the glucose and fluid (lower panel). Thus, short dwell times are most efficient in these patients. Values are shown for the major types of PD: nightly intermittent with short dwells (NI); daytime (DA) and continuous ambulatory (CA); and continuous cycling at night (CCN) with short dwells and during the long daytime dwell (CCD).

Optimal PD regimen and peritoneal equilibration test



Algorithm showing how the results of the peritoneal equilibration test may help guide the choice of an optimal peritoneal dialysis regimen.

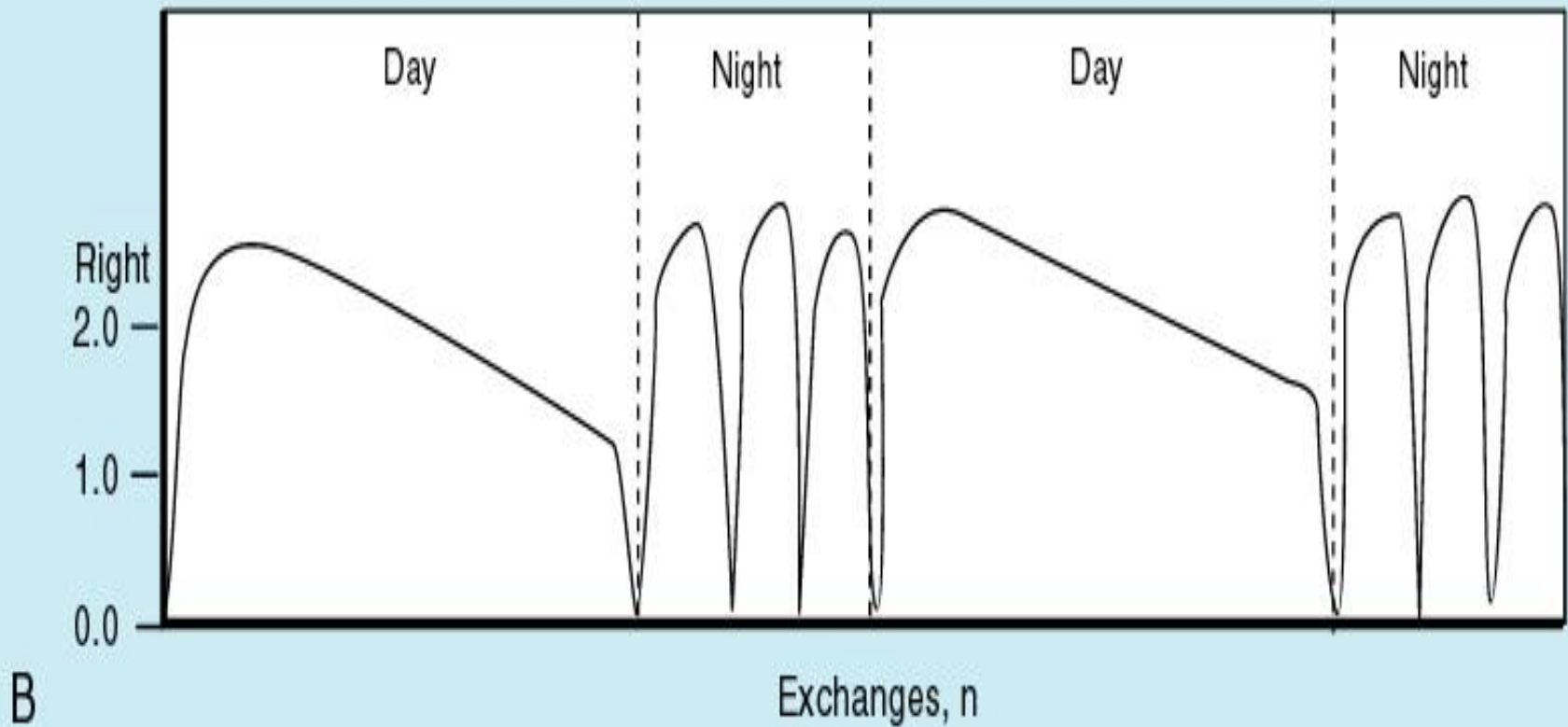
CAPD – Continual Ambulatory Peritoneal Dialysis



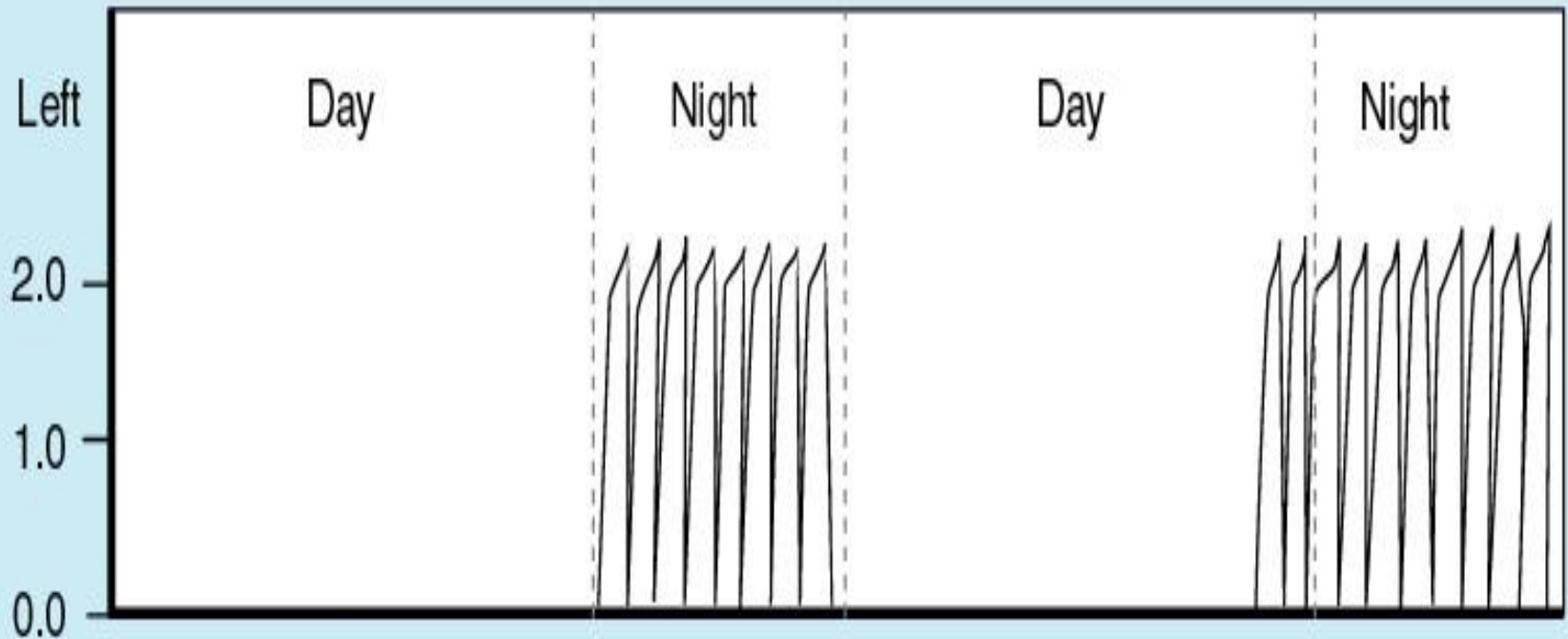
A

Manual Exchanges

CCPD – Continual Cyclic PD



NIPD – Night Intermittent Peritoneal Dialysis (Cycler)



B

Cycler

Accelerated Peritoneal Examination (APEX) Point

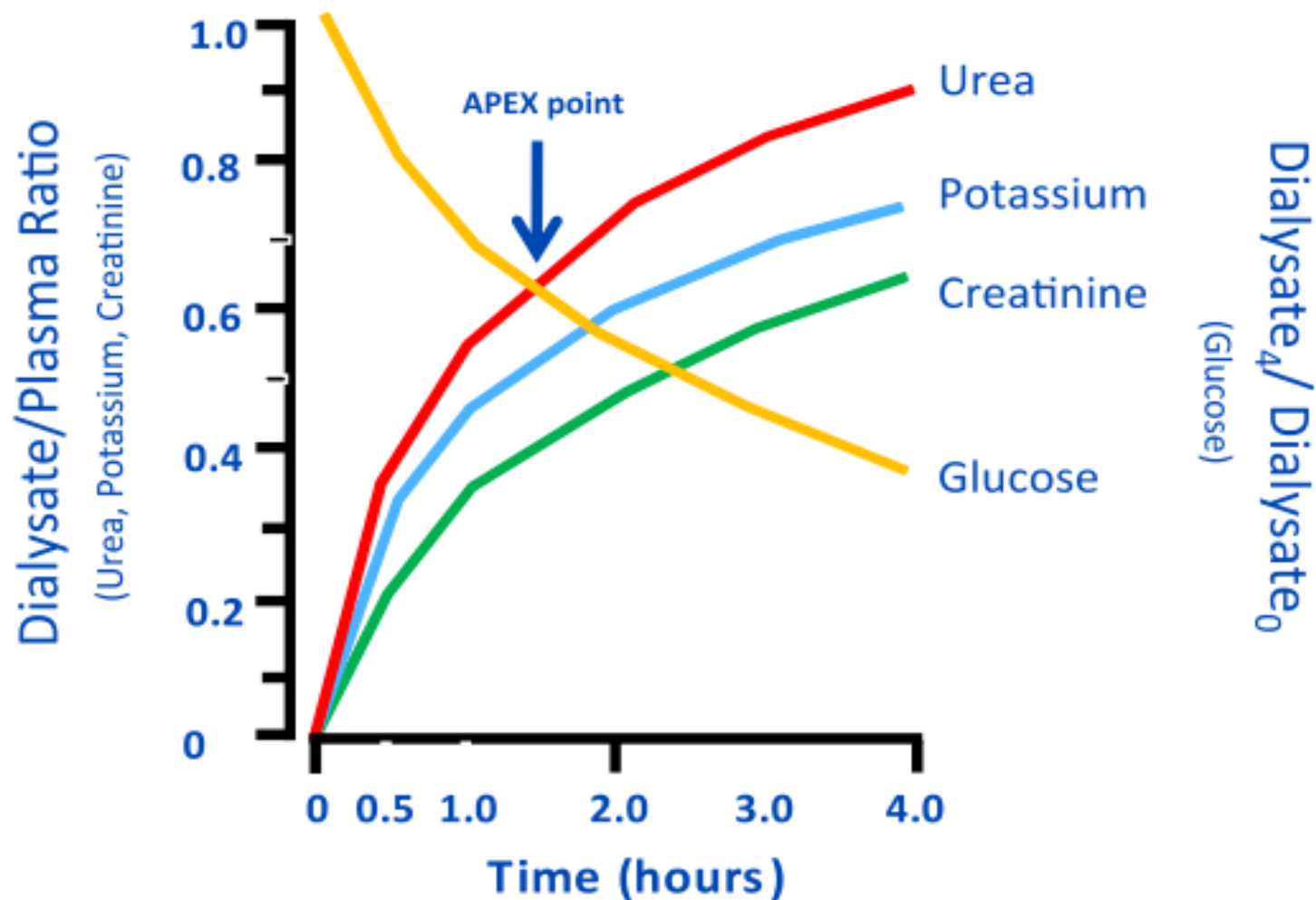


Figure 2: Illustration of APEX time, the crossing point of dialytic urea appearance (red), and glucose disappearance curve (yellow). APEX time indicates the optimal dwell time for ultrafiltration

Selection of peritoneal dialysis regimen

- **High transporter — The clearance per exchange over long dwell is less in patients with high transport rates. During the shorter dwell, high transporters capture maximum UF and completely equilibrate small solutes.**
- **These patients are therefore best treated with techniques using short-dwell exchanges, such as NIPD or day time ambulatory PD (DAPD).**
- **Average transporter — Patients with average transport rates can be effectively treated with either short- or long-dwell exchange techniques.**

Diagnosis of membrane injury

- **Although many patients with acute peritonitis display altered peritoneal membrane function, it is not customary to perform a PET during or after an episode of peritonitis since acute changes are usually reversible after recovery.**
- **However, many patients with acute peritonitis require a change in their dialysis prescriptions due to the increased transport of both large and small solutes, and reduced drain volumes**

Diagnosis of membrane injury

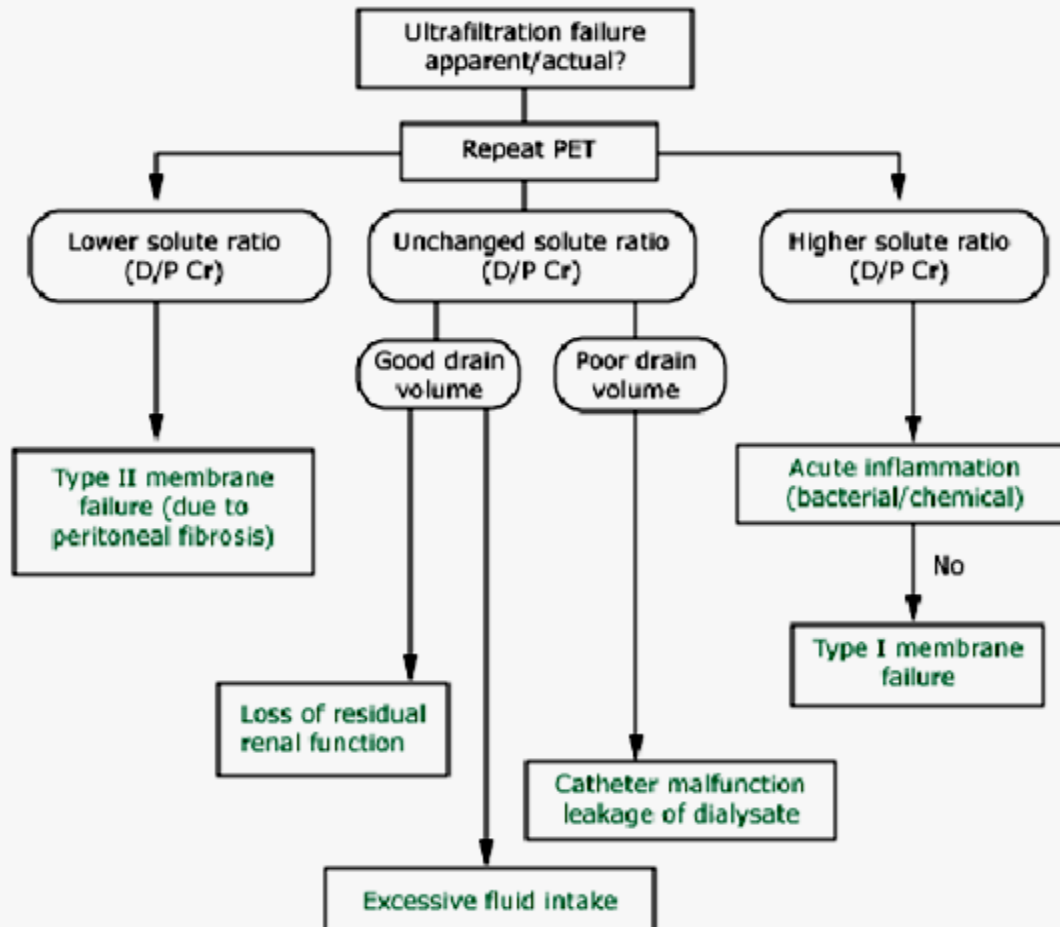
- **The change in prescription usually involves increasing the glucose tonicity or shortening the dwell time to obtain improved UF.**
- **Some severe peritonitis episodes result in irreversible membrane changes due to extensive intraabdominal adhesions; these adhesions compromise solute and water transport due to reduced membrane fluid contact .**
- **In this setting, the PET will show a low D/P creatinine ratio and drain volume.**
- **The diagnosis is confirmed by CT scan with intraperitoneal contrast or by infusion of an intraperitoneal radioisotope and peritoneal scintigraphy.**


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Diagnosis of causes of inadequate ultrafiltration and solute clearance


Utility of PET in ultrafiltration failure



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- **If the drain volume is verifiably reduced, the clinician should repeat a PET, preferably with 4.25 percent dextrose.**
 - **When PET results are unaltered from the baseline values, UF failure is due to either loss of dialysate outside the peritoneal cavity (excessive lymph absorption or dialysis solution leak into the abdominal wall or thoracic cavities) or failure to drain the dialysate because of catheter malfunction.**

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- When PET results suggest that membrane transport (solute clearance) has increased, bacterial or chemical peritonitis should be suspected.**
 - If peritonitis is absent, the constellation of inadequate UF and increased solute clearance is termed type I membrane failure; this condition occurs in some patients in whom PD has been continuous for prolonged periods and, as reported by some studies but not others, in some patients with frequent prior peritonitis episodes.**

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- **In type I membrane failure, the inability to generate sufficient UF is gradual and permanent.**
 - **Patients report using an increasing percentage of hypertonic solutions to maintain dry body weight.**
 - **Cycler dialysis with short-dwell exchanges may occasionally restore fluid balance.**
 - **In some, temporary cessation of PD may transiently restore UF capacity and allow remesotheliazation.**

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- **Decreased solute and fluid removal with repeat PET is termed type II membrane failure.**
 - **This condition may be due to severe, recurrent, or smoldering peritonitis, extensive adhesions resulting from previously severe peritonitis, or an extremely rare disorder, sclerosing encapsulated peritonitis (SEP).**
 - **SEP is a progressive condition, which continues to evolve even after cessation of PD.**
 - **Progressive intraabdominal adhesions may eventually lead to intestinal obstruction and death.**

Diagnosis of early ultrafiltration failure

- **During the unabridged PET in normal patients, the sodium D/P curve typically exhibits an initial drop due to the high rate of ultrafiltration. Because of sodium sieving, the ultrafiltrate is initially low in sodium.**
- **As a result, the dialysate sodium concentration is diminished, thereby resulting in a fall in the D/P sodium ratio.**

Diagnosis of early ultrafiltration failure

- **To best assess ultrafiltration failure, some recommend that a modified PET be performed, rather than the standard PET.**
- **The modified test replaces the 2.5 percent dextrose solution with a 4.25 percent dextrose solution, resulting in a maximal osmotic drive.**
- **With this test, failure is defined as an ultrafiltration volume of less than 400 mL after a four hour dwell with two liters of 4.25 percent dextrose (3.86 percent glucose).**

