The peritoneal equilibration test (PET)

and dialysis prescription

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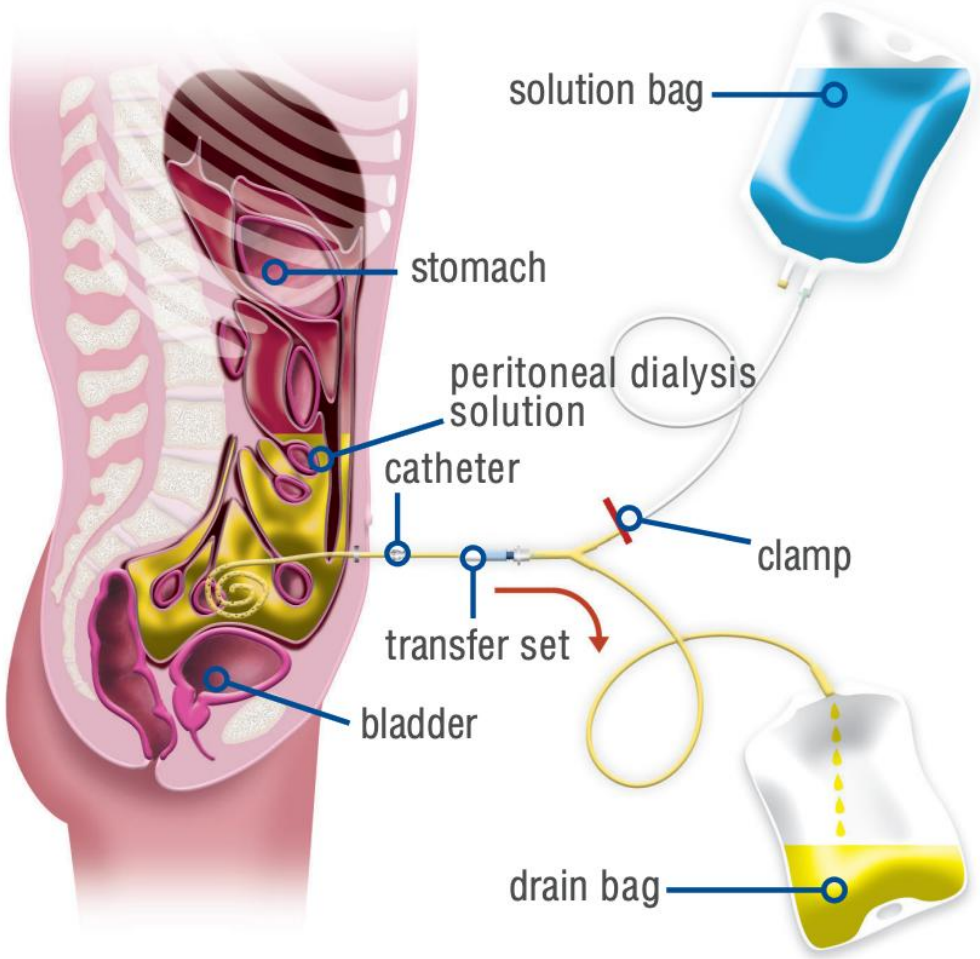

solution bag
stomach
peritoneal dialysis solution
catheter
clamp
transfer set
bladder
drain bag

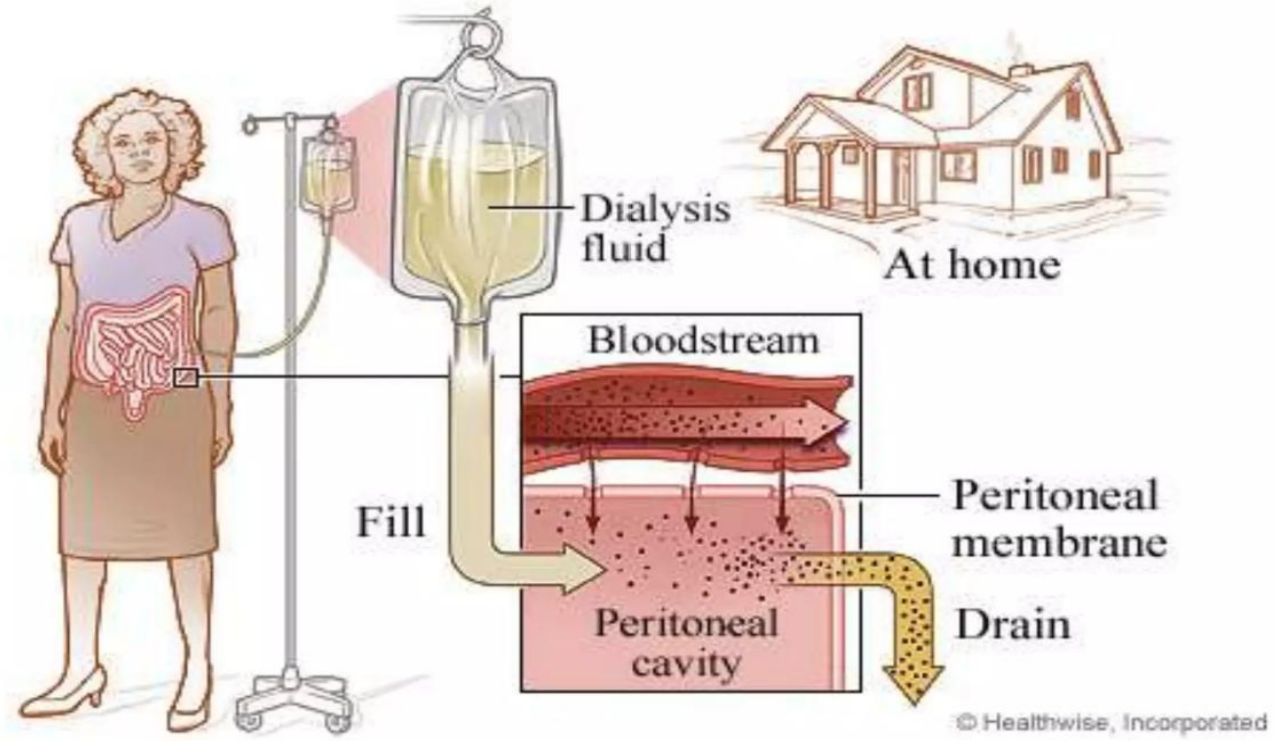


Fig:- Peritoneal Dialysis Access

- **Three distinct peritoneal transport processes occur and determine the success of fluid removal and solute clearance.**
- **These three processes are :**
  - **Diffusion,**
  - **Convective**
  - **Ultrafiltration,**
  - **Peritoneal Fluid Absorption.**

Diffusion vs Convection

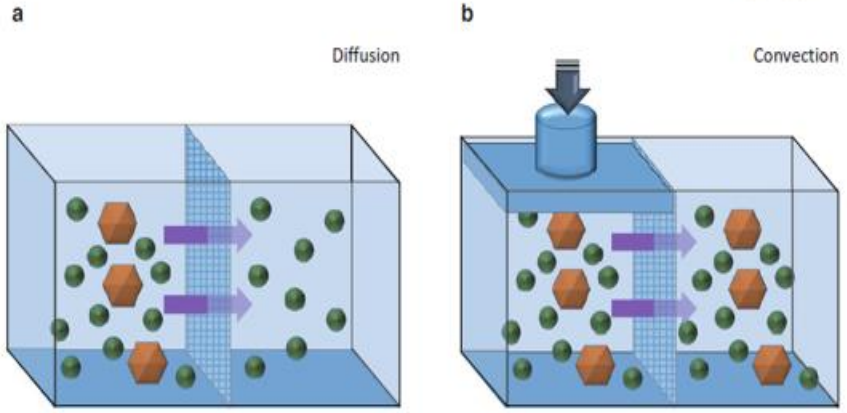
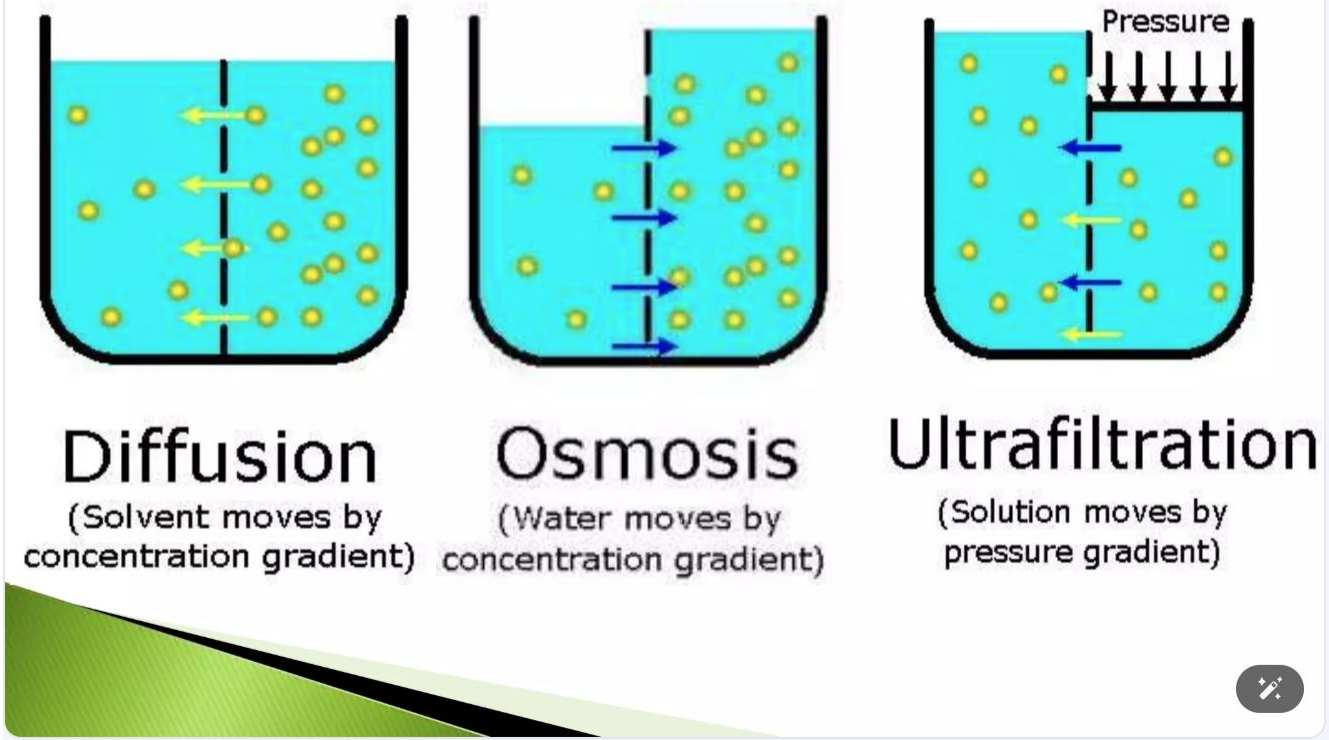


Fig. 1 The principles of diffusion (a) and convection (b) across a semi-permeable membrane

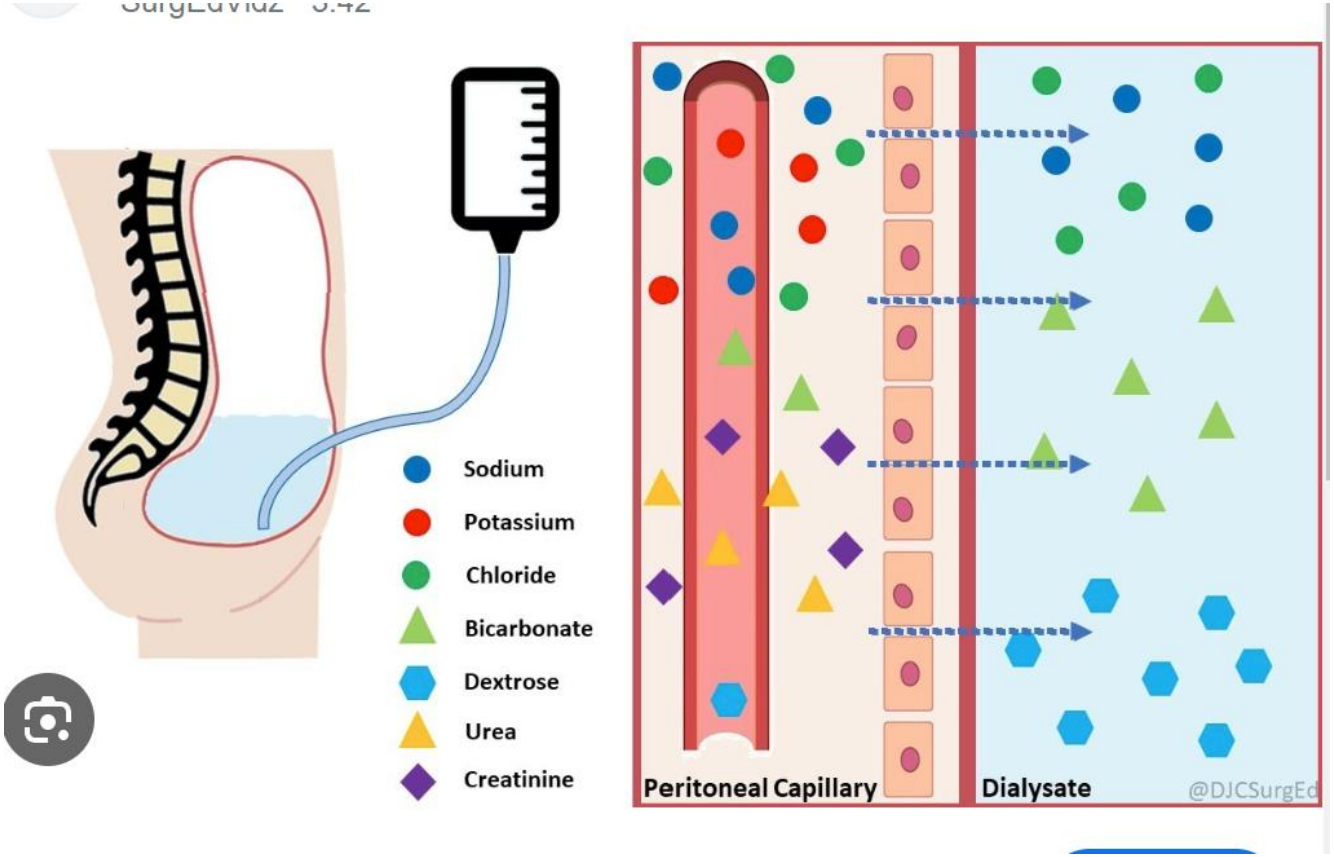
- Principles of dialysis:-
  - The principles of **diffusion, osmosis, & ultrafiltration** are involved in dialysis.

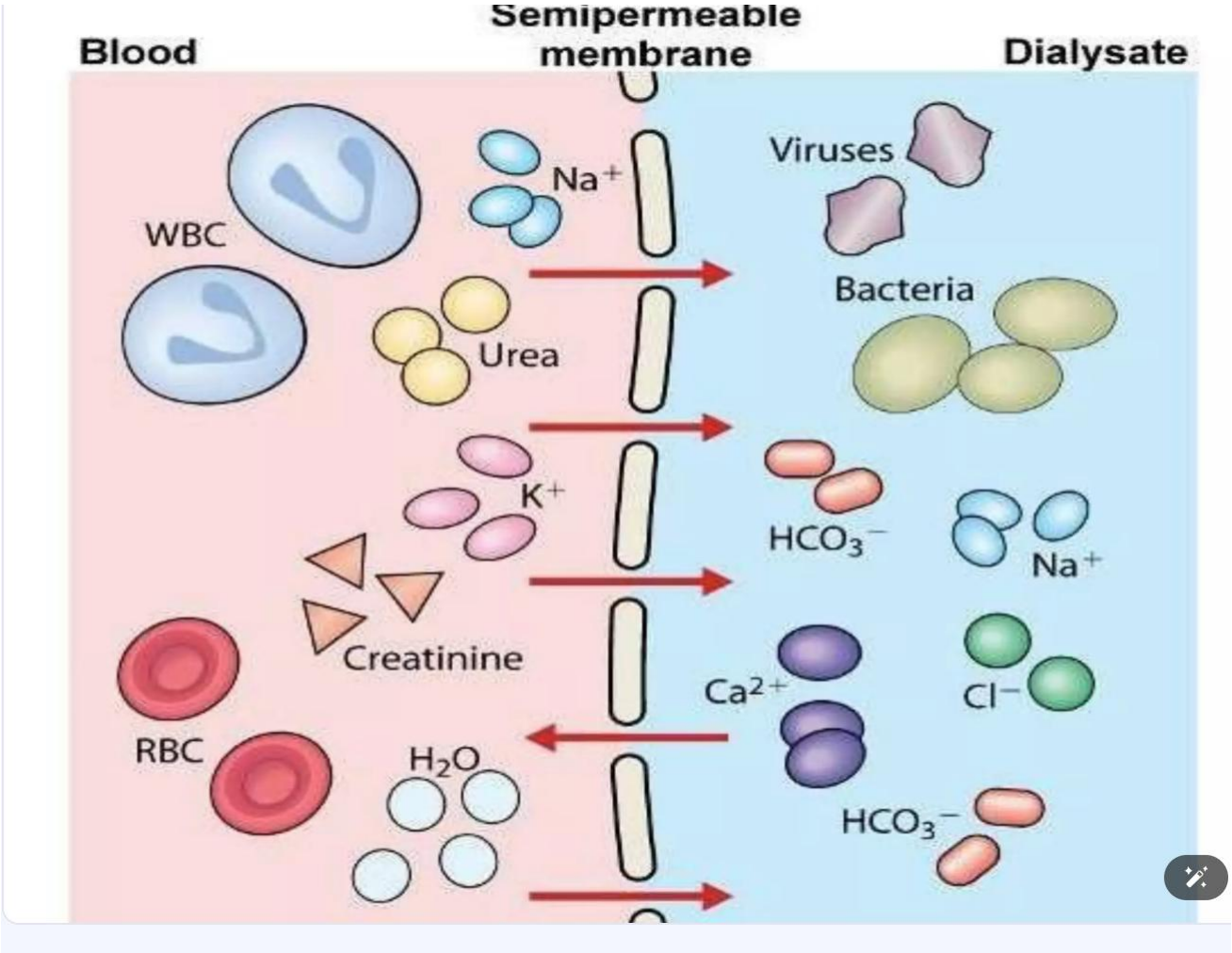


PERITONEAL TRANSPORT

- **Diffusion :concentration gradient,. the mass transfer area coefficient (MTAC){ ability of the membrane to transport the solute concerned}**

- **Ultrafiltration: in achieved by osmotic or oncotic forces.**


Sodium
Potassium
Chloride
Bicarbonate
Dextrose
Urea
Creatinine
Peritoneal Capillary
Dialysate
@DJCSurgEd


Blood
Semipermeable membrane
Dialysate
WBC
Na+
Viruses
Urea
Bacteria
K+
HCO3−
Na+
Creatinine
Ca2+
Cl−
RBC
H2O
HCO3−

THE MASS TRANSFER AREA COEFFICIENT (MTAC)

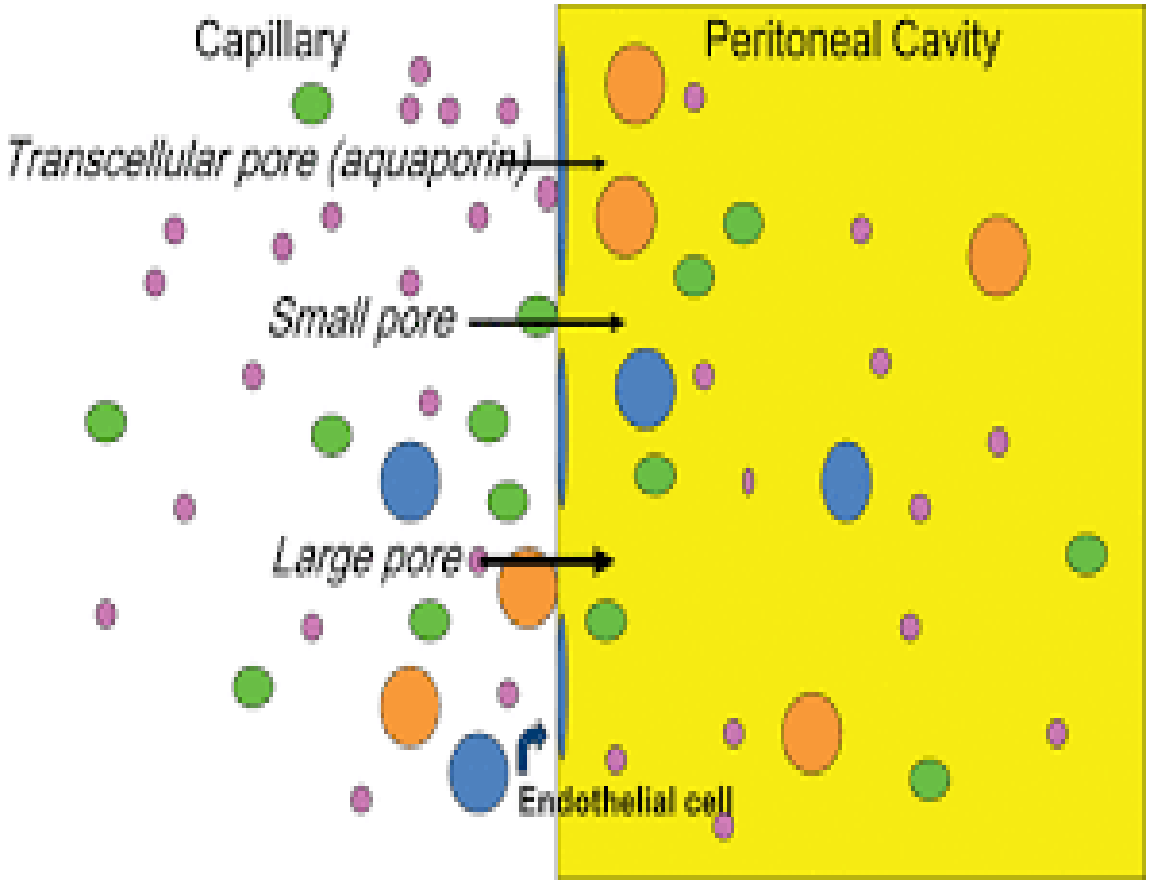
Definition	The capacity of a membrane for solute transport is given by the product of the permeability to that solute and its effective surface area. This is called the mass transfer area coefficient

The coefficient of ultrafiltration (K_{UF})

- Water permeability of a membrane is defined by its ultrafiltration coefficient, which is displayed in the notice of the given membrane.
- The coefficient of ultrafiltration (K_{UF}) was first defined by the amount of fluid (V) in mL crossing the dialyser or peritoneal membrane per time (T) in hours and pressure (P) in mmHg

$$K_{UF} = \frac{V}{T \times P}$$

- **In standard PD, the osmotic gradient for glucose is the key determinant of fluid removal.**
- **Fluid Absorption: During the course of a PD dwell, there is constant removal of fluid from the peritoneal cavity through the lymphatics back into the peritoneal circulation.**
- **That peritoneal fluid absorption occurs at a rate that is somewhere in the range of 1 to 2 mL/min or 250 to 500 mL during a 4-hour peritoneal dwell**


Capillary
Peritoneal Cavity
Transcellular pore (aquaporin)
Small pore
Large pore
Endothelial cell

- **We recognized, however, that the major site of resistance to peritoneal transport is provided by the peritoneal capillary.The interstitium also plays a significant role, especially in patients undergoing long-term PD.**
- **The distribution of peritoneal capillaries within the submesothelial matrix of the membrane is a major determinant of differences between patients in their peritoneal transport characteristics.**

Peritoneal Membrane Preservation

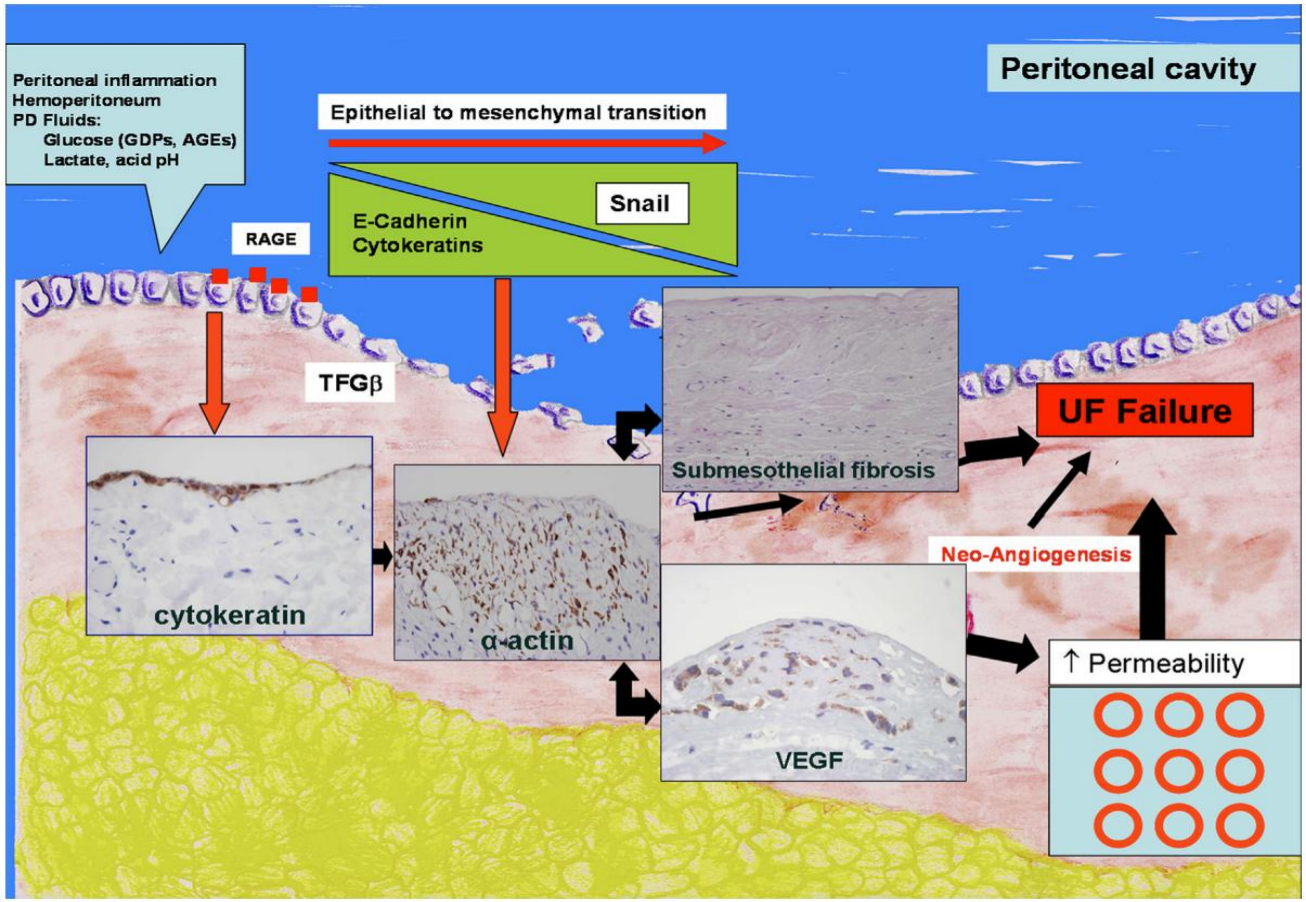


Figure 1. Pathogenesis proposal for ultrafiltration failure and acquired peritoneal hyperpermeability. RAGE, receptor for advanced gylcation end products. Adapted with permission from López-Cabrera et al.[38]

The peritoneal equilibration test (PET)

- The peritoneal equilibration test (PET) is a semiquantitative assessment of peritoneal membrane transport function in patients on peritoneal dialysis .
- 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.
- The PET also helps measure ultrafiltration and residual volumes .

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
- ***PET test perform approximately one to two weeks after initiation of PD therapy to use as a baseline value. The test is repeated*** every 6–12months,or ***when clinical problems arise and when clinical suspicion of an alteration in membrane transport occurs .***

Procedure

- The standardized four-hour PET procedure consists of the following sequential steps:
- An overnight 8 to 12 hour pre-exchange is performed. THEN , the overnight exchange is drained .
- Two liters of dialysis solution (1,100 ml/m2) are infused over 10 minutes with the patient in the supine position.
- The patient is rolled from side to side after every 400 mL infusion. After the completion of infusion (0 time) and at 120 minutes dwell time, 200 mL of dialysate is drained.

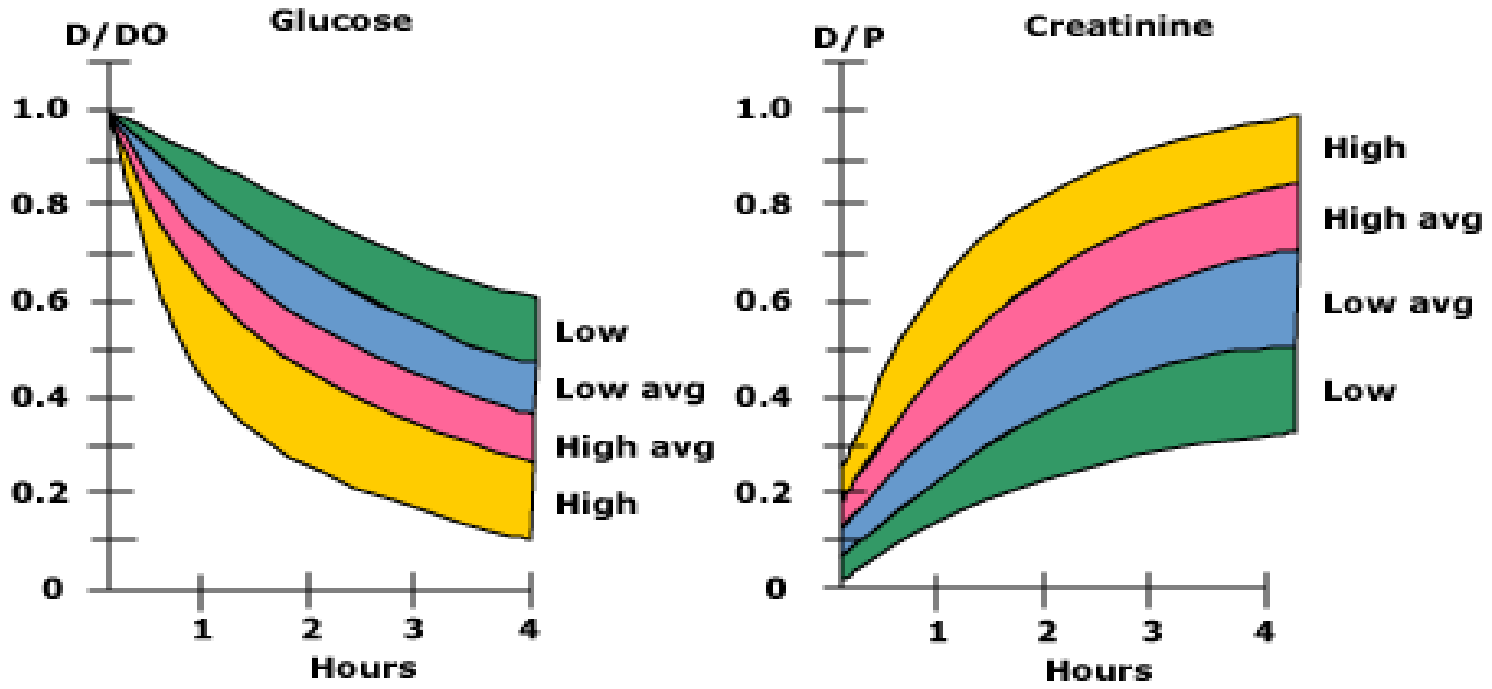
- A 10 mL sample is taken and the remaining 190 mL is infused back into the peritoneal cavity.
- A serum sample is obtained at 120 minutes.
- At the end of the dwell (240 minutes), the dialysate is drained in the upright position . The drain volume is measured and a 10 mL sample is taken from the drain.
- All the samples are sent for solute measurement (creatinine, urea, and glucose).
- The Dt/D0 glucose, and the D/P ratios for creatinine, urea, and others, are calculated.

Peritoneal membrane function classification

Drain volumes correlate positively with dialysate glucose and negatively with D/P creatinine at four-hour dwell times.

- 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
- {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. }
- ***High transporter status may be associated with poor treatment outcome,and has been identified as a significant risk factor for inadequate weight control, poor statural growth and low-turnover bone disease.***

Time-dependent changes during peritoneal dialysis in dialysate (D) concentration of glucose (left panel) or creatinine (right panel) as a proportion of original dialysate glucose concentration (DO) or plasma creatinine concentration (P), respectively. The absorption of glucose from the dialysate gradually lowers the D/DO ratio, while the diffusion of creatinine into the dialysate raises the D/P ratio. Slow transporters may be inadequately dialyzed due to diminished solute removal. Rapid transporters can achieve a D/P creatinine ratio above 0.8 and a D/DO glucose below 0.3 at four hours; they may be predisposed to malnutrition from increased amino acid losses in the dialysate and to decreased fluid removal due to absorption of glucose.



Prediction of dialysis dose

- The effective peritoneal dialysis dose is customarily measured by calculating the clearance of creatinine, which is the product of the D/P creatinine and the drain volume:

- $Ccr = (D/P) \times V$

Solute clearance and ultrafiltration vary with peritoneal membrane function:

- Low transporter — The solute D/P ratio increases almost linearly during a long-dwell exchange in a low transporter. In addition, the ultrafiltrate (UF) continues to be generated late during the dwell. Clearance per exchange therefore increases almost linearly throughout the long-dwell exchange .
- High transporter — In high transporters, intraperitoneal volume begins to diminish after three to four hours since UF and solute equilibration are attained early. The clearance per exchange begins to diminish beyond this time.
- Average transporter — Peak clearances for average transporters are attained for approximately between eight to ten hours.

DIALYSIS PRESCRIPTION

- How to choose between the modalities:
- At the start of dialysis when patients have some residual renal function, most patients could do any PD technique and usually be able to achieve the Kt/V and volume control targets.
- However, once residual kidney function is negligible, modality choice may need to match peritoneal transport characteristics to optimize solute clearance and ultrafiltration.

Rapid transporters

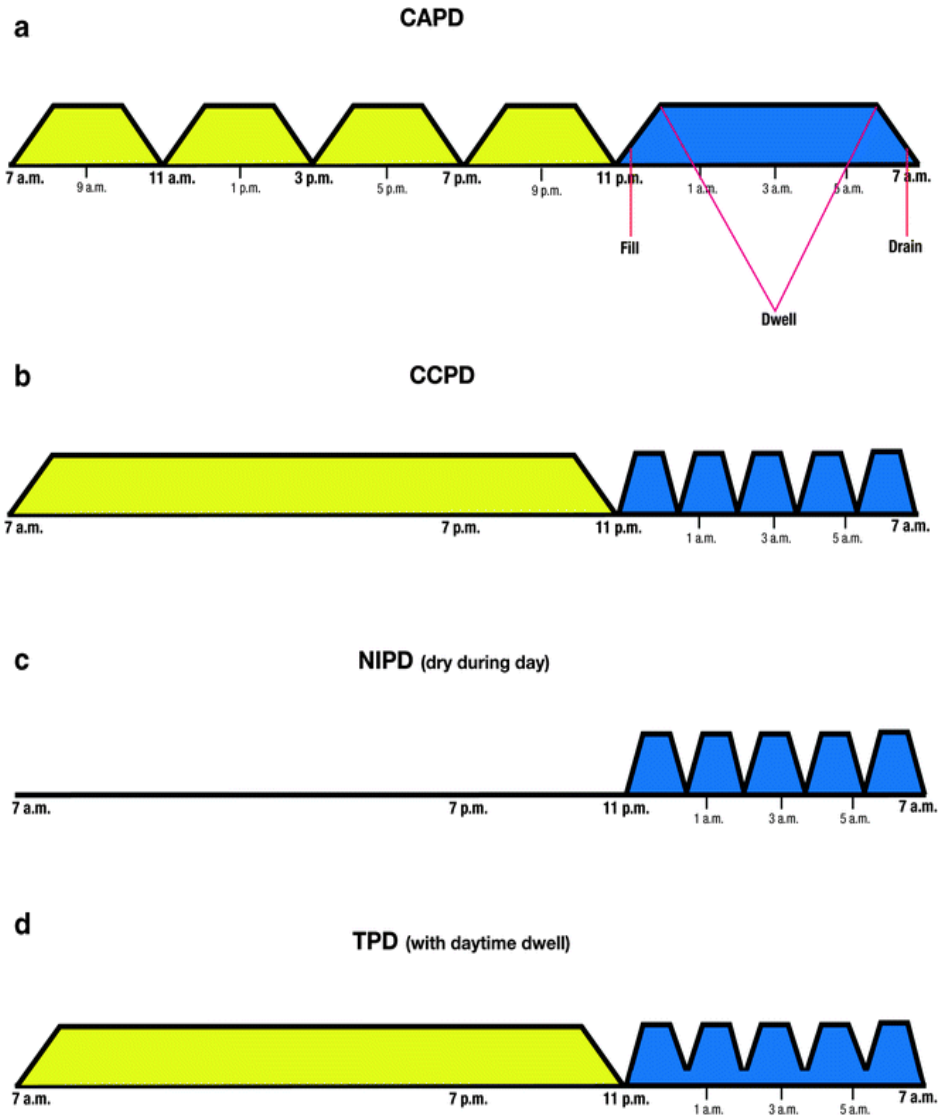
- These patients achieve almost total equilibration between plasma and dialysate for urea and creatinine in a few hours.
- They also are rapid absorbers of dialysate glucose, thereby removing the osmotic stimulus to ultrafiltration .
- The net effect is that they begin to absorb dialysate with the glucose leading, after two to three hours, to reductions in ultrafiltration volume and net solute clearance (as the solutes that have diffused into the dialysate are also absorbed back into the systemic circulation).
- In this setting, standard CAPD, which utilizes prolonged dwell times, might not produce sufficient fluid or solute removal.
- A better alternative in many cases is multiple short dwells with standard dialysate as with NIPD.

Slow transporters

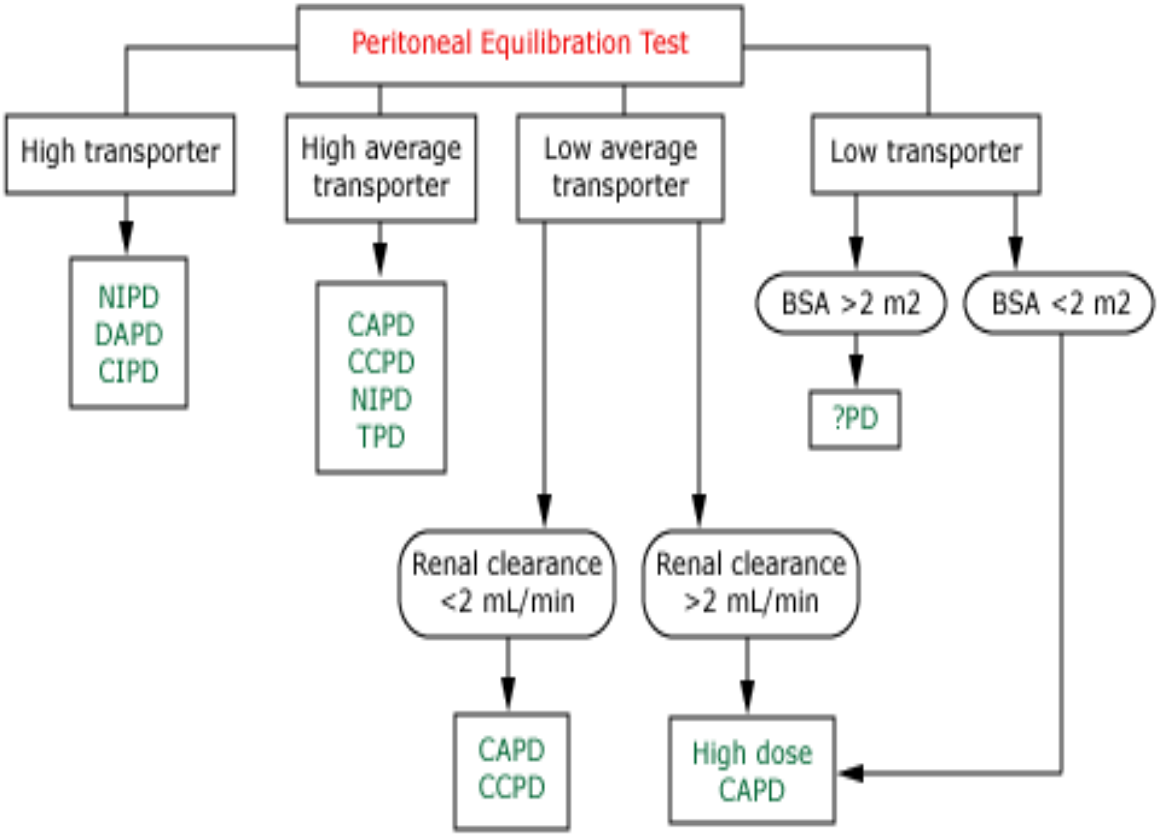
- The findings are different in "slow" transporters who need long dwell times to adequately remove small solutes.
- Ultrafiltration is not a problem in this setting, since glucose is also slowly absorbed.

TYPES OF PD

- PD can be performed in a continuous or intermittent fashion.
- ***Continuous ambulatory peritoneal dialysis (CAPD)*** involves multiple exchanges during the day (usually three) followed by an overnight dwell.
- ***Continuous cycler peritoneal dialysis (CCPD)*** has a long daytime dwell and several cycles overnight.
- ***nightly intermittent peritoneal dialysis (NIPD) or intermittent peritoneal dialysis (IPD),*** *multiple short dwellsat night and dry abdomen during the day.*
- ***DAPD:****Day time ambulatory PD*
- ***tidal peritoneal dialysis (TPD),*** consists of exchanges in which the peritoneal cavity always contains at least some dialysate (usually one-half full), a feature that improves comfort and facilitates drainage in some patients


a
CAPD
7 a.m.
9 a.m.
11 a.m.
1 p.m.
3 p.m.
5 p.m.
7 p.m.
9 p.m.
11 p.m.
1 a.m.
3 a.m.
5 a.m.
7 a.m.
Fill
Drain
Dwell
b
CCPD
7 a.m.
7 p.m.
11 p.m.
1 a.m.
3 a.m.
5 a.m.
7 a.m.
c
NIPD (dry during day)
7 a.m.
7 p.m.
11 p.m.
1 a.m.
3 a.m.
5 a.m.
7 a.m.
d
TPD (with daytime dwell)
7 a.m.
7 p.m.
11 p.m.
1 a.m.
3 a.m.
5 a.m.
7 a.m.

CONTINUOUS AMBULATORY PERITONEAL DIALYSIS (CAPD) , CONTINUOUS CYCLIC PERITONEAL DIALYSIS (CCPD), NIGHTLY INTERMITTENT PD (NIPD), DAY TIME AMBULATORY PD (DAPD)



Problems with solute clearance and ultrafiltration in continuous peritoneal dialysis

- INADEQUATE SOLUTE CLEARANCE
- INADEQUATE ULTRAFILTRATION
- INADEQUATE SOLUTE CLEARANCE AND ULTRAFILTRATION FAILUR

INADEQUATE SOLUTE CLEARANCE

- Inadequate solute clearance is defined as an increasing BUN and plasma creatinine concentration or the appearance of uremic symptoms despite seemingly successful CAPD.
- There are several discrete causes of this syndrome, which can be distinguished in part by performing a peritoneal equilibration test (PET) .
- ***Poor compliance*** — Poor compliance with the prescribed CAPD regimen may be the most common cause of underdialysis. The PET findings in this setting will be stable, suggesting unchanged pertinent transport. Treatment is directed at examining the reasons for noncompliance, including patient motivation.

- ***Hypercatabolism*** — A high protein intake or a hypercatabolic state (as with increased tissue breakdown or metabolic acidosis) can raise the BUN despite good clearances. Thus, the PET will again reveal stable values. Treatment of the underlying cause for hypercatabolism will lower the BUN to the expected values.

- ***Decreased peritoneal permeability*** — In this setting, the PET findings typically reveal low or low-average equilibration values. The exact incidence of reduced peritoneal transport, which is usually due to peritoneal sclerosis or extensive adhesions, is not known; however, reduced transport may play a contributory role in those CAPD patients who switch to hemodialysis because of inadequate dialysis .

Rx of INADEQUATE SOLUTE CLEARANCE

- The initial treatment for inadequate solute clearance caused by low peritoneal transport consists of a more intensive dialysis regimen. This can be achieved by increasing the volume of exchanges, the number of exchanges per day, or both. If these measures fail to sufficiently improve solute clearances, then transfer of the patient to hemodialysis should be considered.

INADEQUATE ULTRAFILTRATION

- The quantity of peritoneal ultrafiltration is usually inversely proportional to the peritoneal transport of solutes except in conditions of loss of surface area due to severe scarring/adhesions .
- Rapid lymphatic absorption
- Peritonitis, because of an increase in the transport of the peritoneal membrane to solutes of all sizes, including large proteins.
- CAPD of greater than two years duration (even in the absence of peritonitis),
- diabetes mellitus and the use of beta blockers

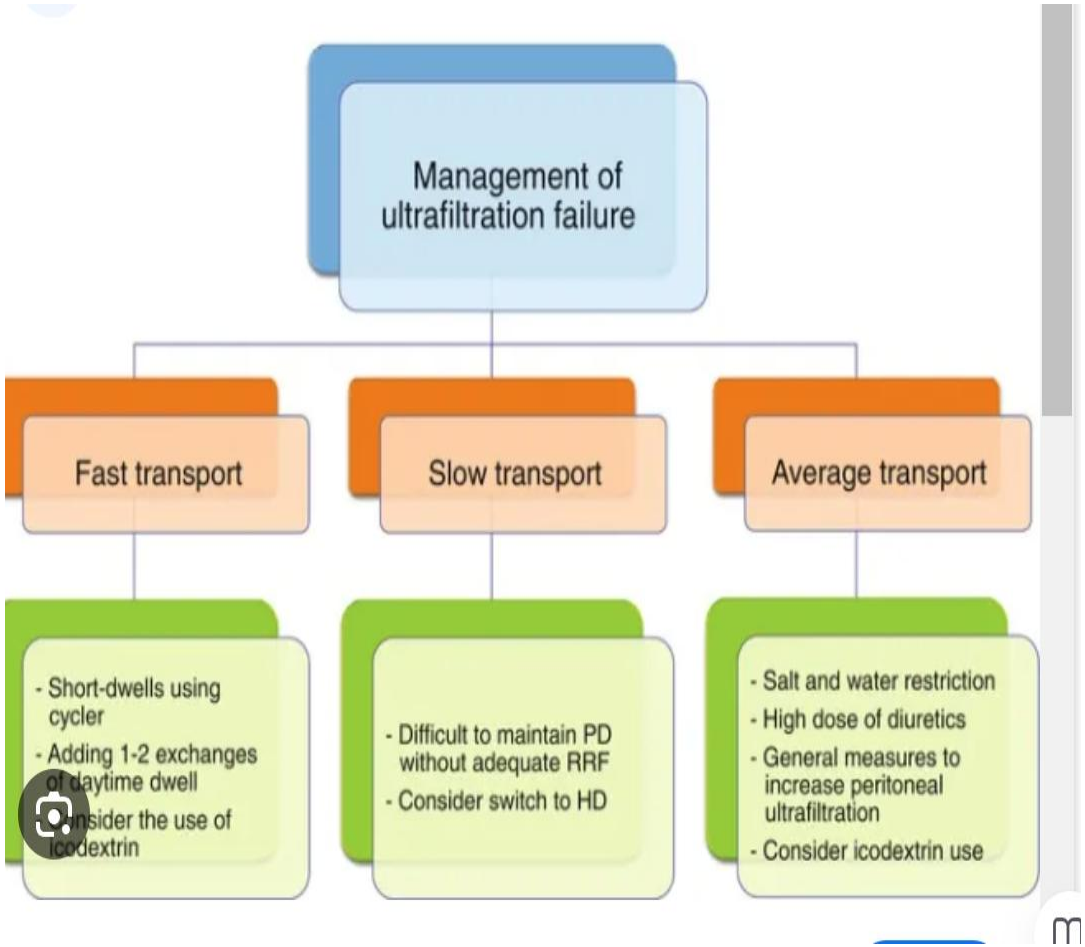
RX OF INADEQUATE ULTRAFILTRATION

- One method to treat increased peritoneal solute transport is to shorten the dwell time of each exchange, thereby limiting the dialysis period to the time during which the osmotic gradient promoting ultrafiltration is maximized.
- temporarily switching to maintenance hemodialysis:The strategy consists of the discontinuation of peritoneal dialysis for four weeks, with the instillation of 100 to 200 mL of 1.36 percent dialysate containing 3500 IU of heparin twice per week.
- Icodextrin dialysate — Instillation (usually once daily overnight exchange) of icodextrin dialysate, a glucose polymer, may enhance ultrafiltration in patients with increased solute transport .(side effects including rash and culture-negative peritonitis)
- In patients with significant residual renal function, the administration of diuretics can be used to increase the urine output

INADEQUATE SOLUTE CLEARANCE AND ULTRAFILTRATION FAILURE

- peritoneal catheter malfunction or extraperitoneal dialysate leakage
- Enhanced absorption by peritoneal lymphatic vessels (peritoneal lymphatic flow test, a maneuver that involves the instillation of macromolecules into the peritoneal cavity followed by measurement of the subsequent rate of their disappearance from the peritoneal cavity.)
- Decline in the peritoneal ultrafiltration coefficient (Sclerosing encapsulating peritonitis)

Although frequently unsuccessful, the treatment of sclerosing peritonitis most commonly entails cessation of peritoneal dialysis with transfer to hemodialysis, bowel rest with total parenteral nutrition (TPN), and (possibly) immunosuppressive therapy and/or surgery


Management of ultrafiltration failure
Fast transport
Slow transport
Average transport
- Short-dwells using cycler
- Adding 1-2 exchanges of daytime dwell
- Consider the use of icodextrin
- Difficult to maintain PD without adequate RRF
- Consider switch to HD
- Salt and water restriction
- High dose of diuretics
- General measures to increase peritoneal ultrafiltration
- Consider icodextrin use