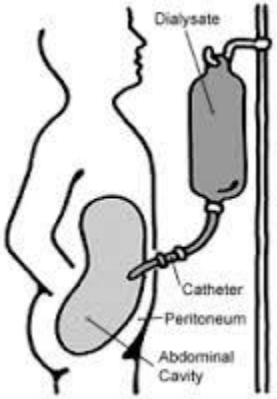
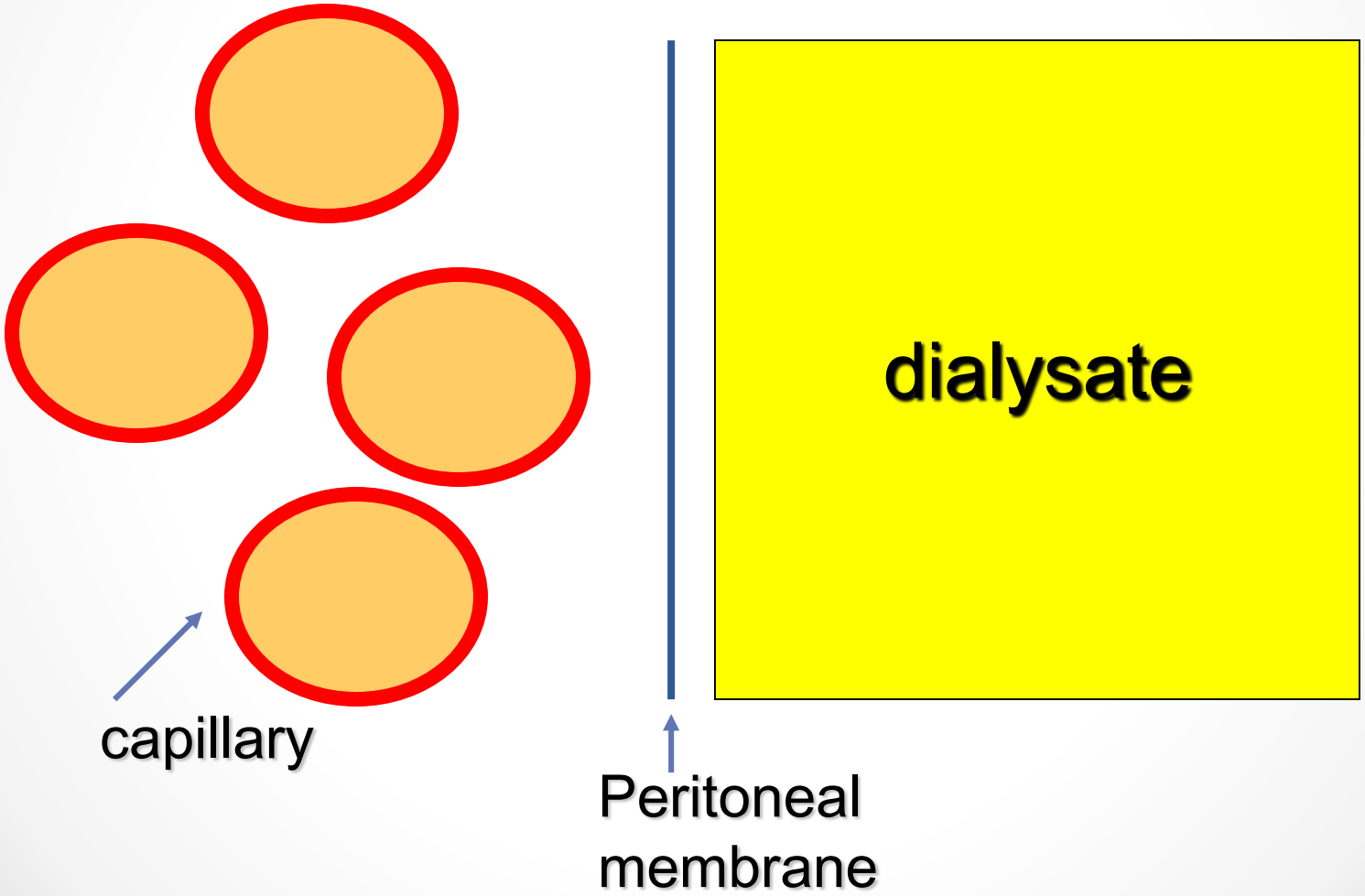


Peritoneal Dialysis: An Overview

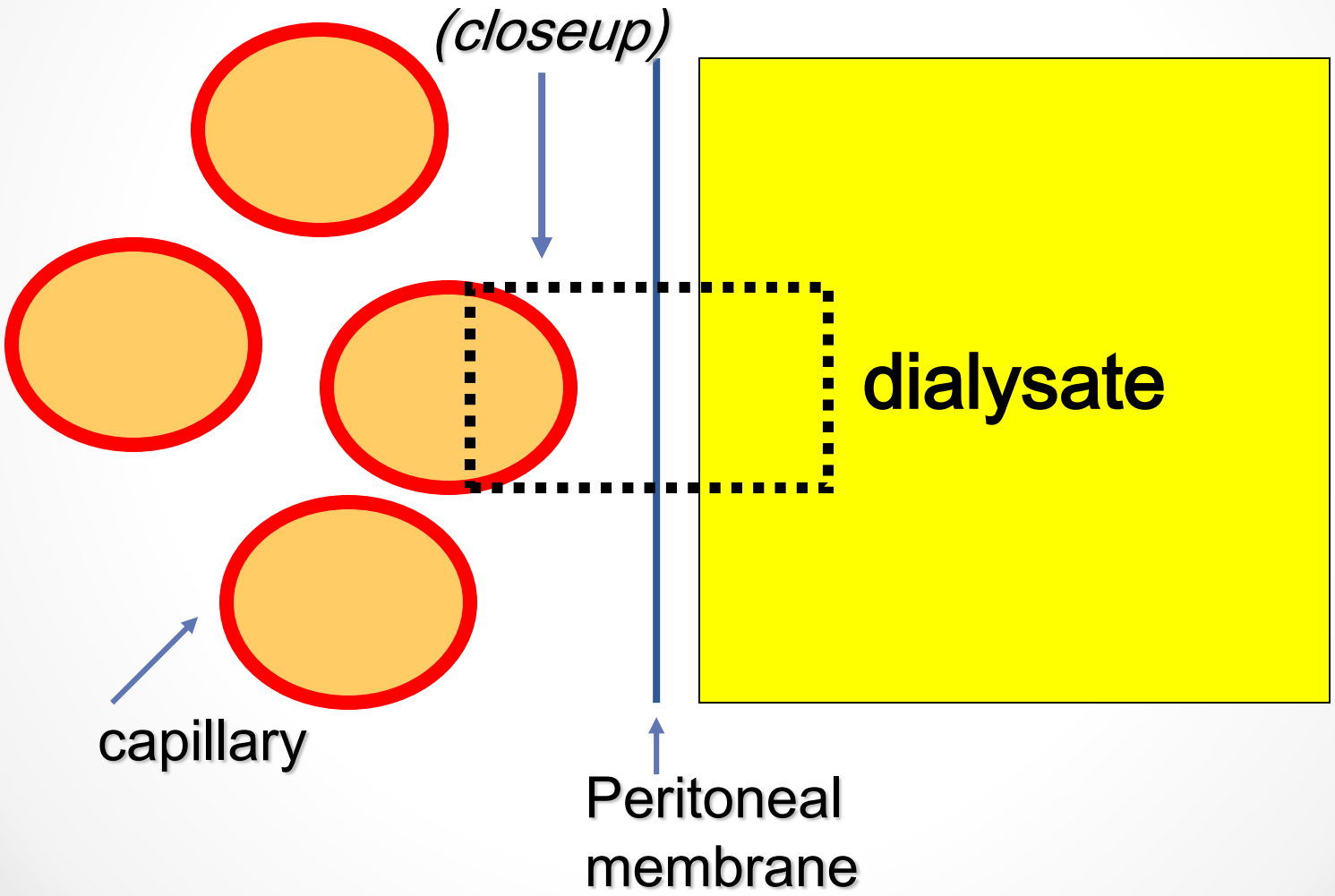
Budapest Nephrology School 2013

Joanne M Bargman MD FRCPC
Director, Home Peritoneal Dialysis Unit
University Health Network, Toronto

The Peritoneal-Vascular Interface

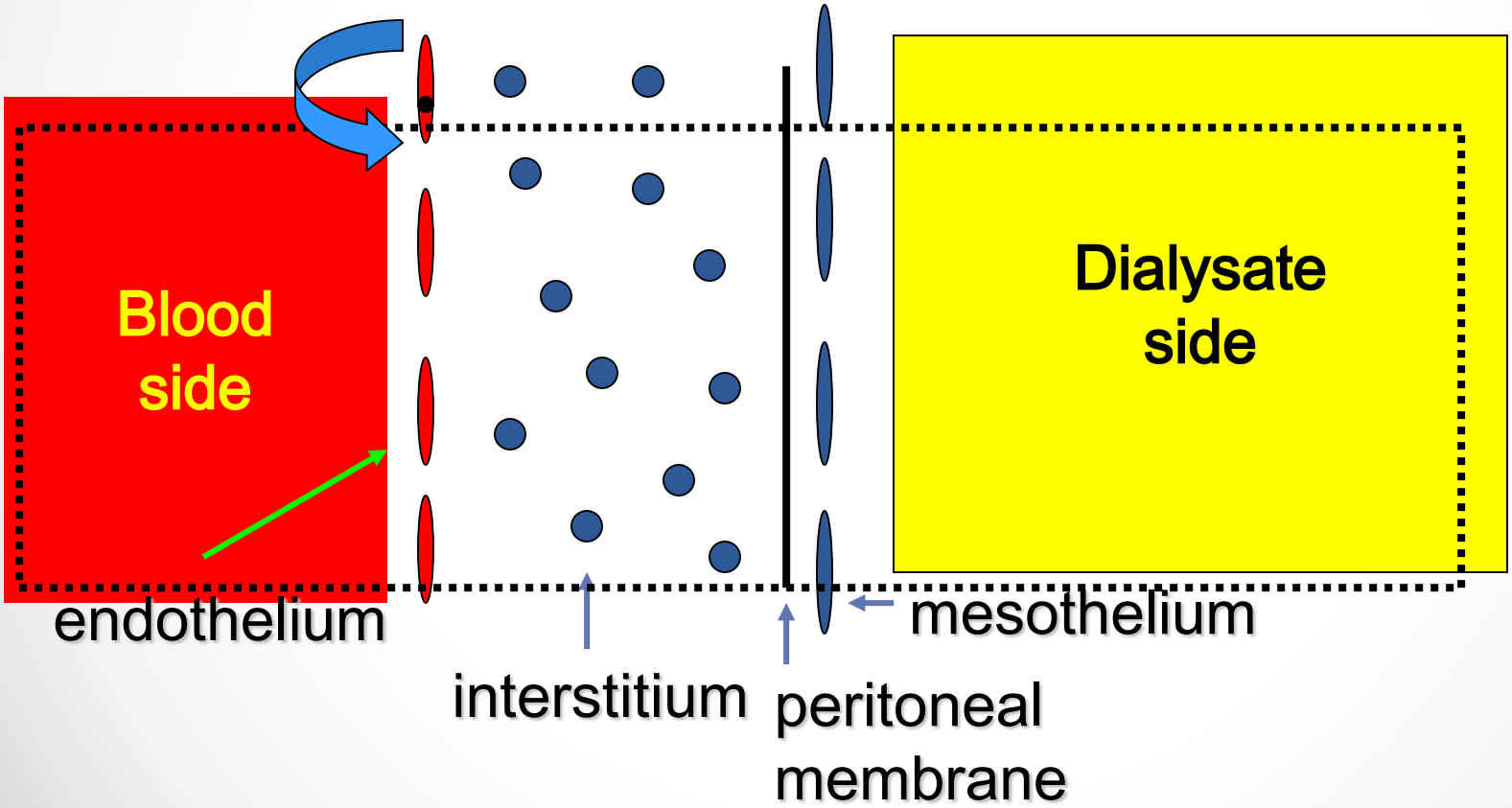


The Peritoneal-Vascular Interface



The Peritoneal-Vascular Interface

Important transport occurs here



Solute Transport in PD

How does solute enter peritoneal fluid?

I. Diffusion

II. Convection (during ultrafiltration)

Principles of Solute Transport

Convection

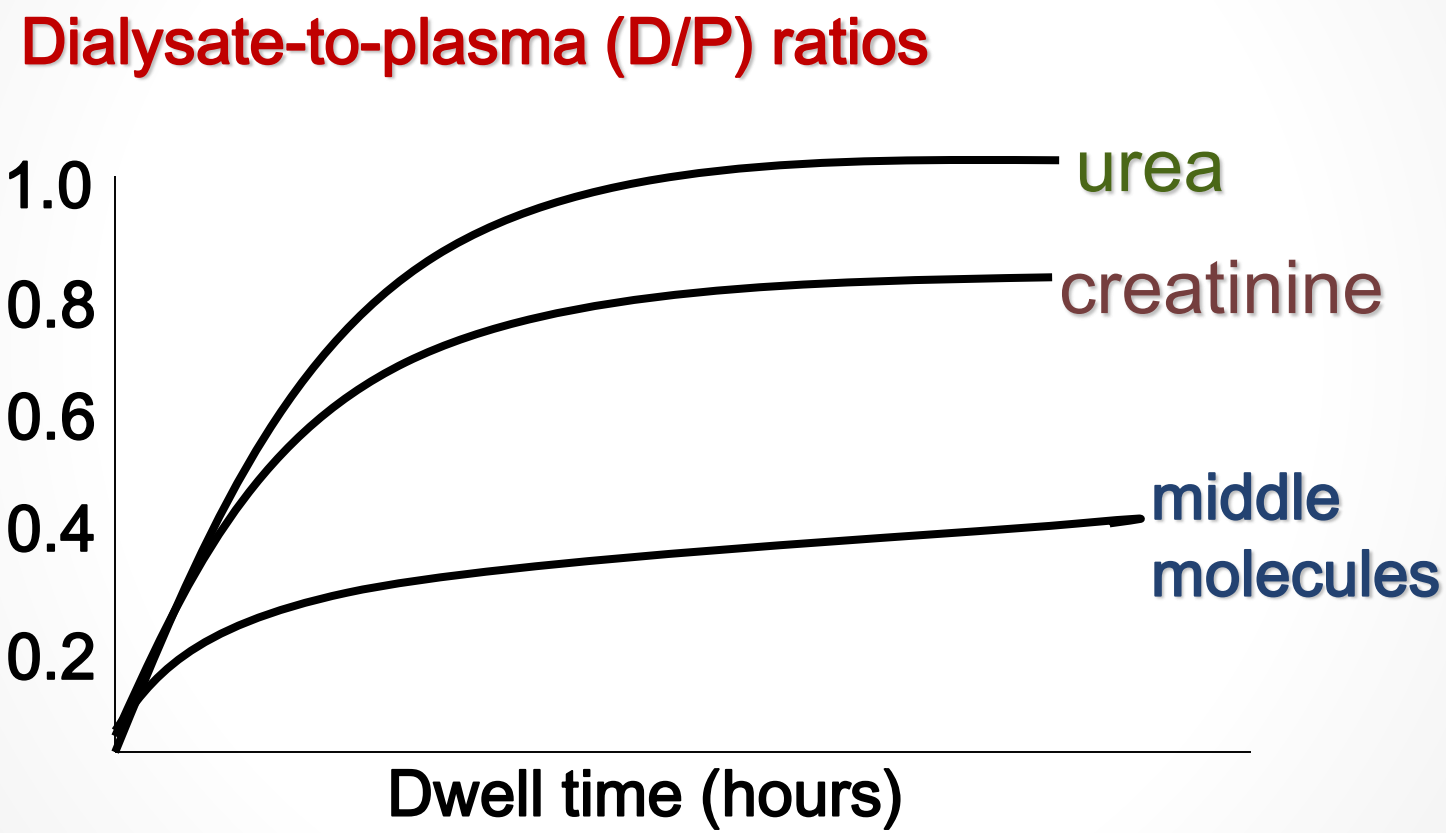
Diffusion

Slide courtesy of Dr. O. Heimburger

Diffusion Kinetics - *from blood to dialysate*

- diffusive flux is highest in first hour and lessens over time
- by 4 hours, urea is > 90% equilibrated, creatinine > 60% equilibrated
- further small solute removal is minimal after that
- long dwells more important for removal of *larger* MW solutes

Diffusion Curves – a Schema



Diffusion Kinetics - *from dialysate to blood*

What can you add to dialysate?

- antibiotics (not just for peritonitis)
- insulin
- KCl (up to 10 mEq/l)
- xylocaine, $NaHCO_3$ (infusion pain)
- metoclopramide, erythromycin (gastroparesis)
- erythropoietin

Ultrafiltration in PD

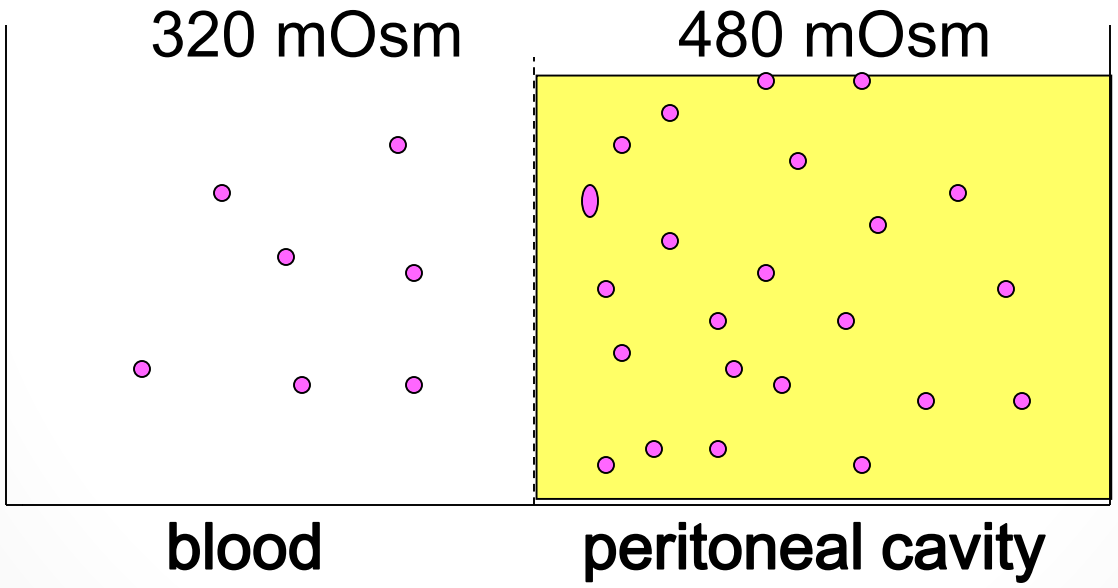
- done by *osmotic* pressure (compared to HD where done by *hydraulic* pressure)
- results of ultrafiltration:
  - fluid removal
  - convective removal of solutes, especially middle molecules

Composition of Peritoneal Dialysate: Osmolality

- 1.5% dextrose - 347 mOsm/l (*isotonic*)
- 2.5% dextrose - 397 mOsm/l (*hypertonic*)
- 4.25% dextrose - 485 mOsm/l (*more hypertonic*)

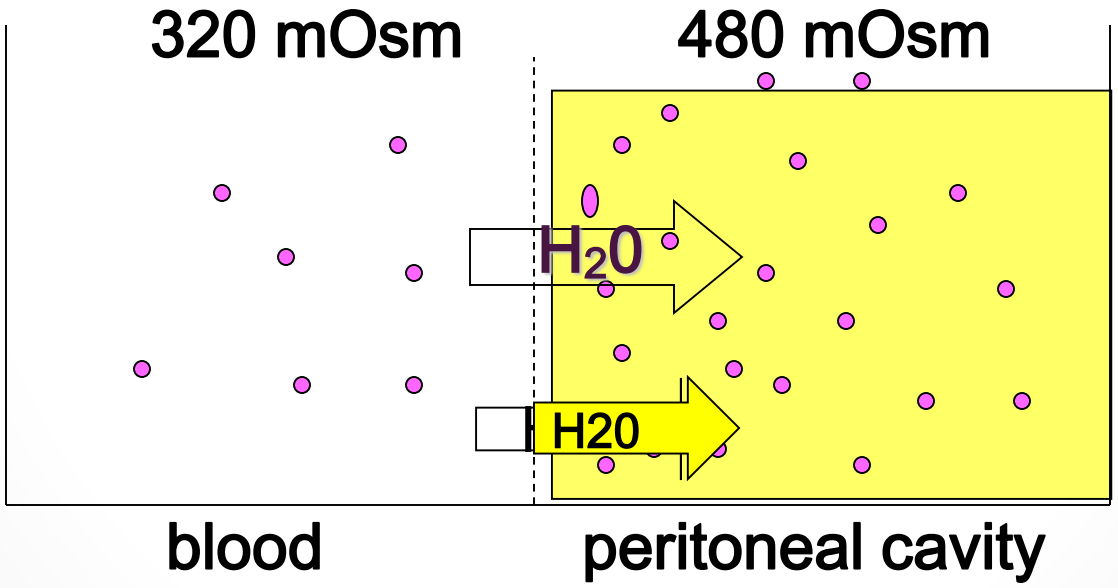
Ultrafiltration

Example: 4.25% dextrose dialysate



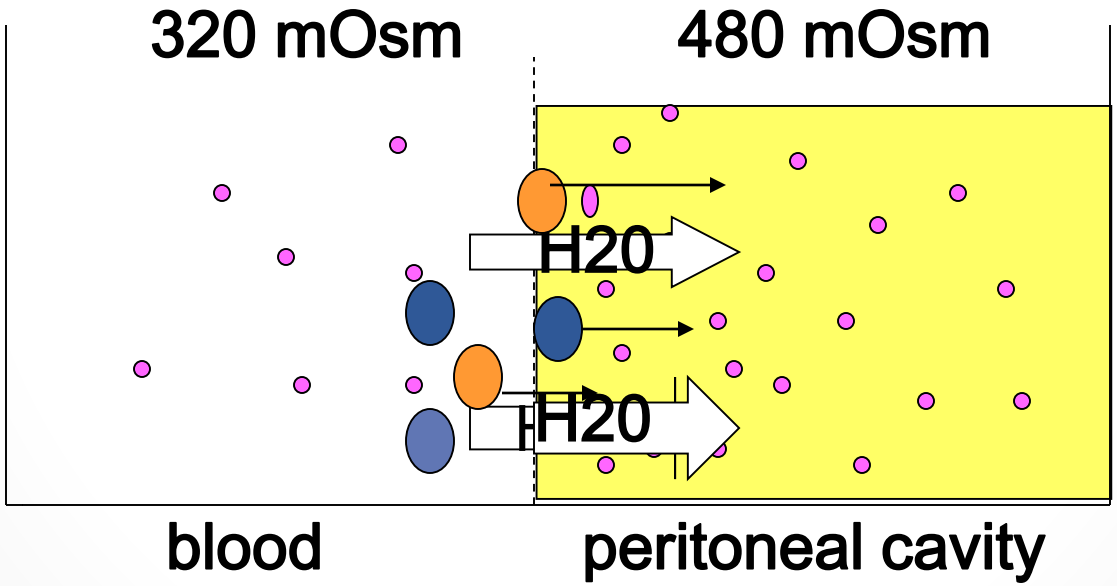
Ultrafiltration – Example of 4.25% Dialysate

Water will move from lower to higher osmolality



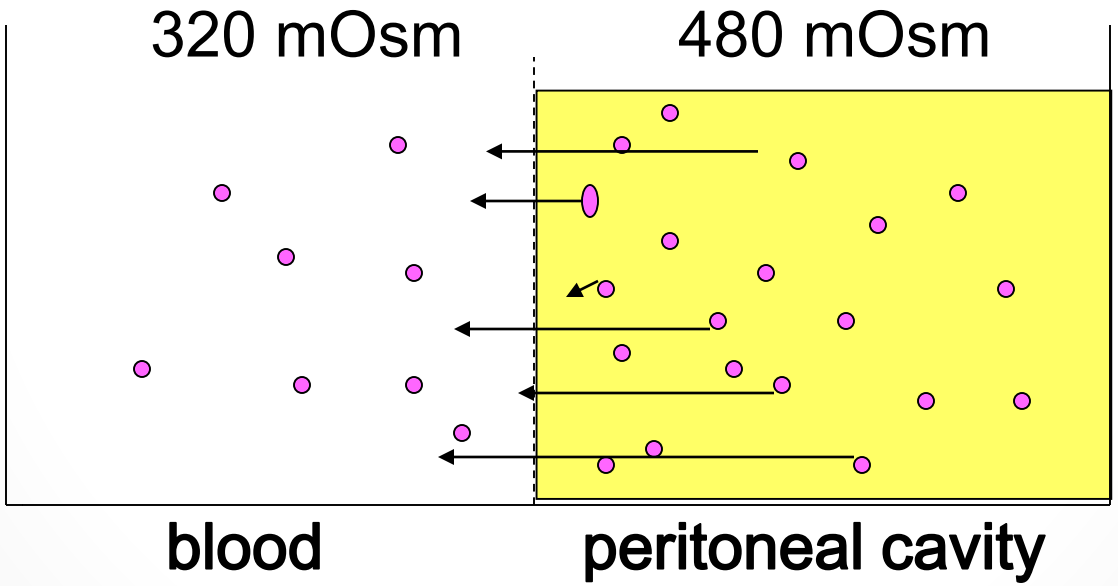
Ultrafiltration – Example of 4.25% Dialysate

Water will move from lower to higher osmolality and take solute along

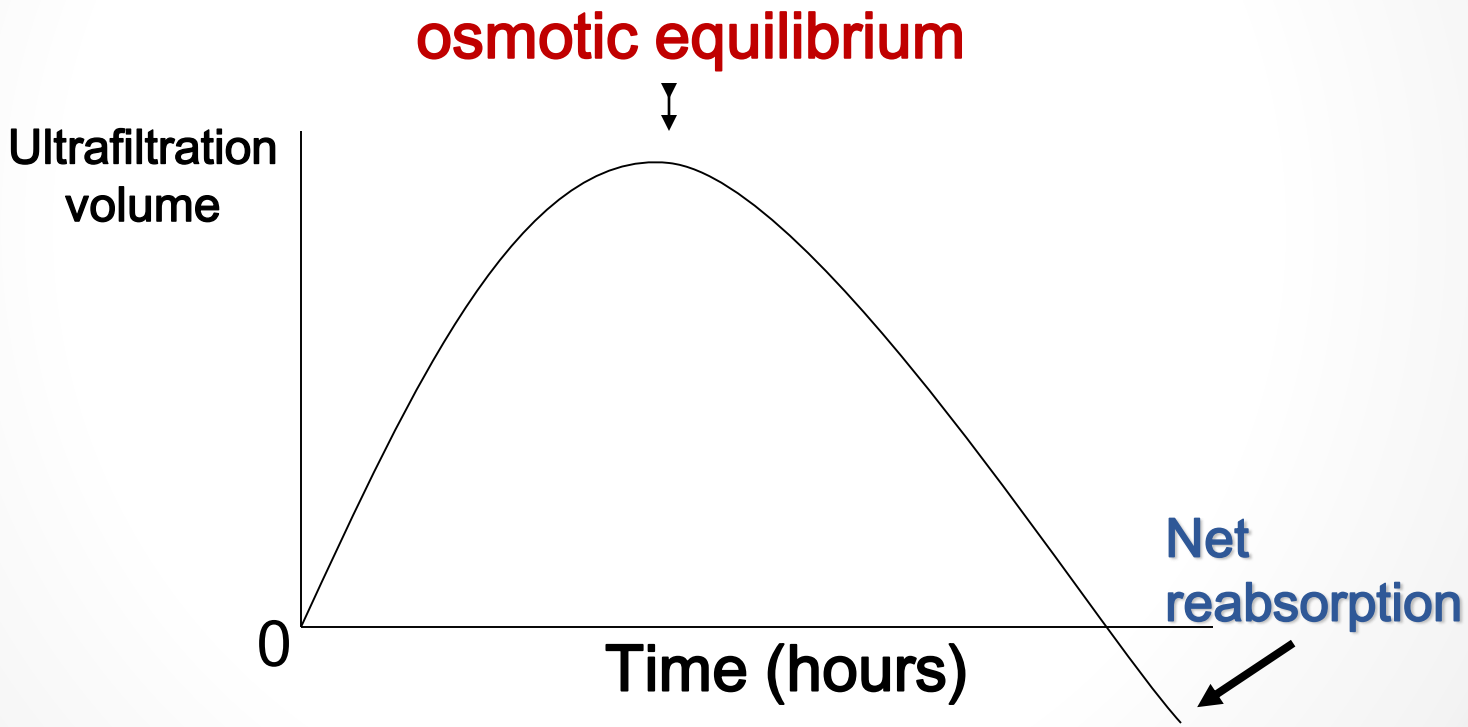


Ultrafiltration in PD

Glucose itself will diffuse out of peritoneal cavity along its own concentration gradient



Ultrafiltration in PD



Typical Ultrafiltration in PD

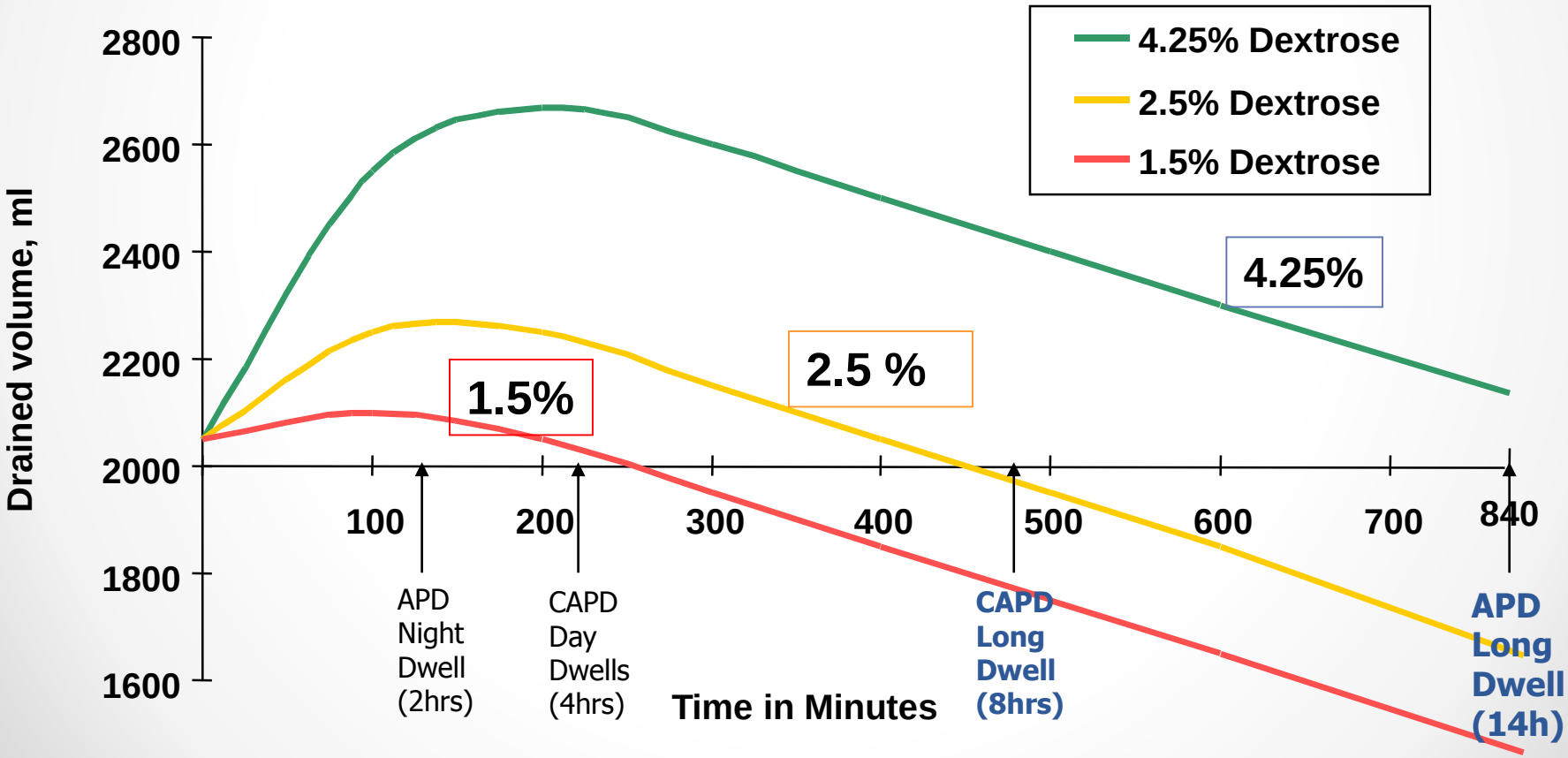
1.5 % Dialysate

- maximum UF 330 +/- 187 ml
- time to maximum UF 140 +/- 48 minutes

4.25 % Dialysate

- maximum UF 1028 +/- 258 ml
- time to maximum UF 247 +/- 61 minutes

Typical Ultrafiltration Curves for Each Strength of Dialysate



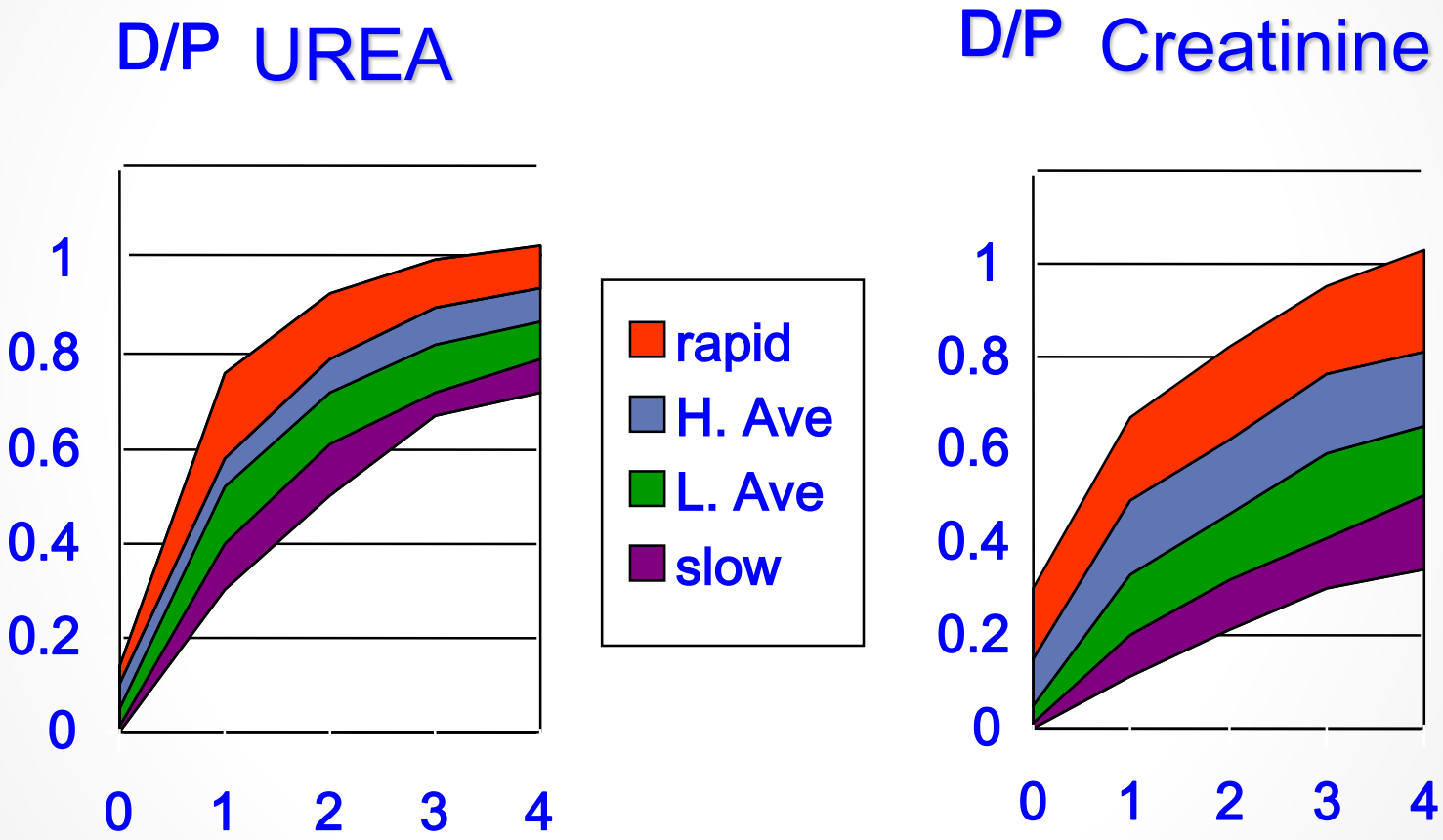
Rippe, et.al.,, 2000.

Summary of Ultrafiltration in PD

The amount of UF depends upon:

- tonicity of dialysate
  - **4.25% > 2.5% > 1.5%**
- duration of dialysate dwell
  - after osmotic equilibration, fluid starts to be absorbed
- permeability of peritoneal membrane to glucose
  - osmotic gradient dissipates faster across a more permeable membrane

Peritoneal Equilibration Test



Twardowski et al. Perit Dial Bull

Membrane Permeability and Ultrafiltration - *"rapid transporters"*

the "***leakier***" the peritoneal membrane (more vascular beds are open)

↓

the faster glucose will diffuse out of the peritoneal cavity

↓

the faster the osmotic gradient will dissipate

Why Might Someone Be a Rapid Transporter from the Start?

- association with higher CRP, lower serum albumin, less residual renal function
- in some studies, more common in diabetics
- lower serum albumin seen *before* the start of PD

This suggests that rapid transporter status may be a marker of inflammation

Membrane Permeability and Ultrafiltration - *slow transporters*

the "***tighter***" the peritoneal membrane (fewer open vascular beds)

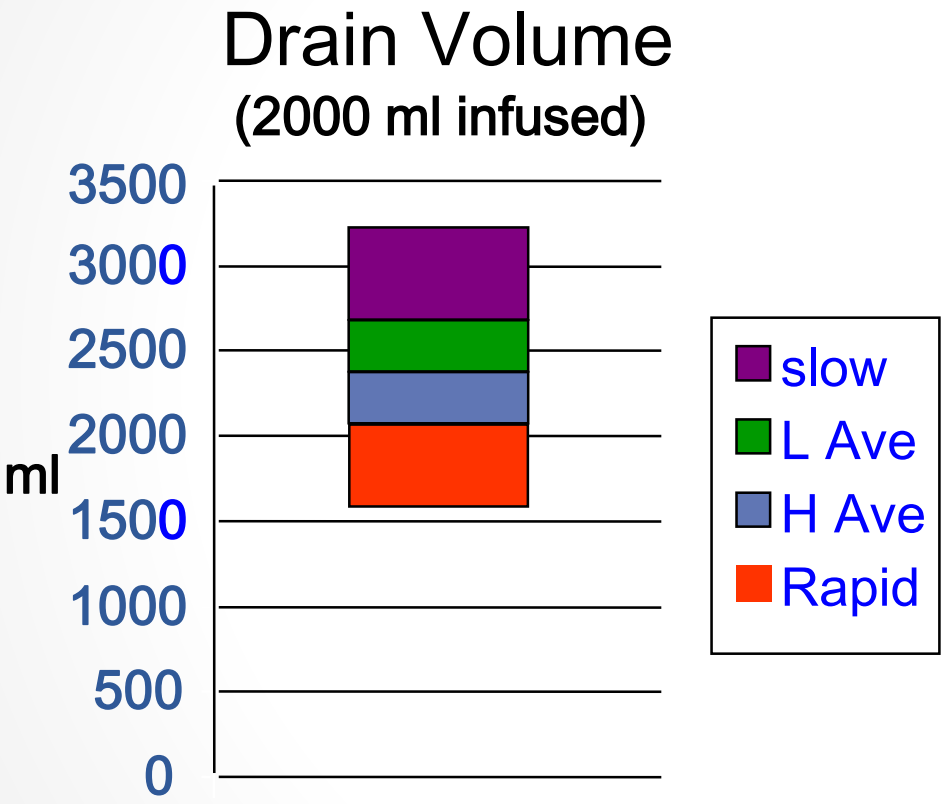
↓

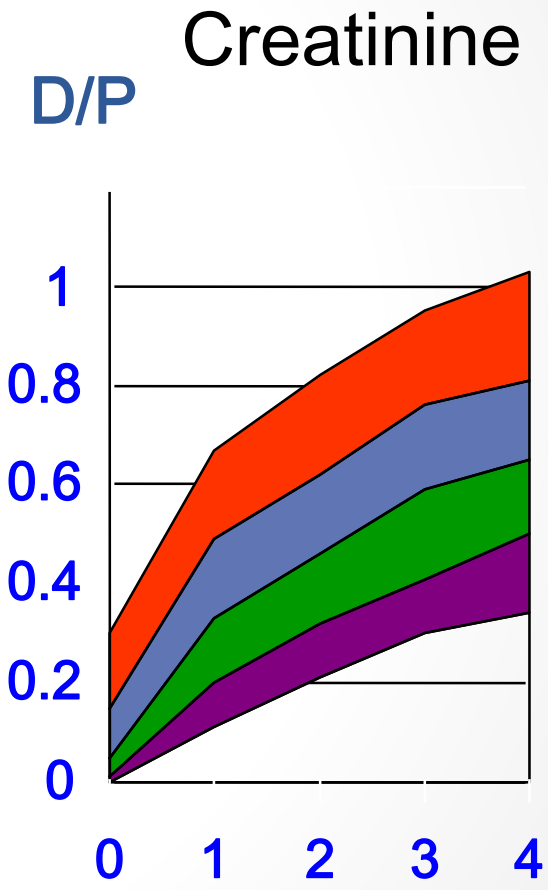
the slower glucose will diffuse out of the peritoneal cavity

↓

the osmotic gradient will be maintained longer

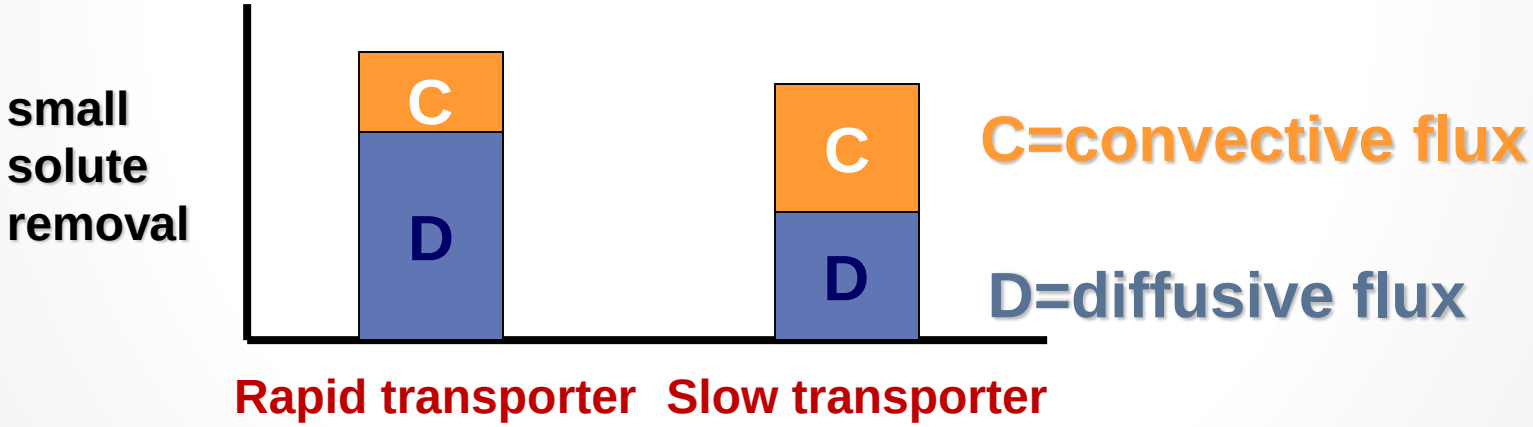
Transport Status – Implications for Ultrafiltration





Rapid vs Slow Transporters: Why Solute Removal Isn't that Different

the better UF in the slow transporters will increase solute removal through convective transport



Adequacy of Dialysis in PD

The strength of PD lies in

- continuous therapy 24/7
- preservation of RRF compared to HD
- good middle molecule clearance (by RRF and the peritoneal membrane)

None of these is adequately measured by Kt/V urea

Adequacy of Dialysis in PD

- randomized, controlled trials have not shown a survival benefit for any Kt/V urea > 1.5
- lower limit for Kt/V urea unknown

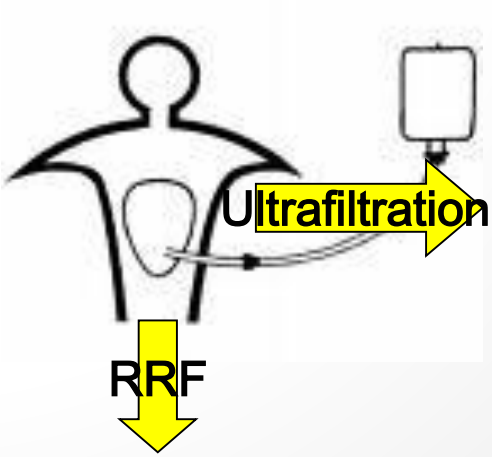
Adequacy of Dialysis in PD

The KDOQI Guidelines in a Nutshell

- minimum total (renal + peritoneal) Kt/V urea of 1.7
- monitor and protect RRF
- careful attention to volume status
- trial of increased dialysis is indicated if patient not doing well without another explanation

Fluid Balance in a Nutshell…

Intake		Output
Na+ and water	**=**	**Urine and UF**



Volume Overload

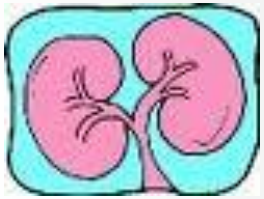
- Intake
  - excessive salt and water consumption
- Output
  - loss of residual renal function
  - use of the wrong dialysis fluid
  - failure of peritoneal membrane to respond (true ultrafiltration failure)
  - mechanical problems like leaks

Volume Overload

- **Intake** – excessive salt and water consumption
  - PD has often been "advertised" as allowing a more liberal dietary intake
  - patients with high salt intake are protected from volume overload while they have residual renal function (RRF)
    - *once urine volume diminishes, patient may develop fluid overload*

Volume Overload

- **Output: Loss of Residual Renal Function**
  - probably the commonest cause of progressive fluid overload
  - rate of loss of RRF is variable and unpredictable from patient to patient



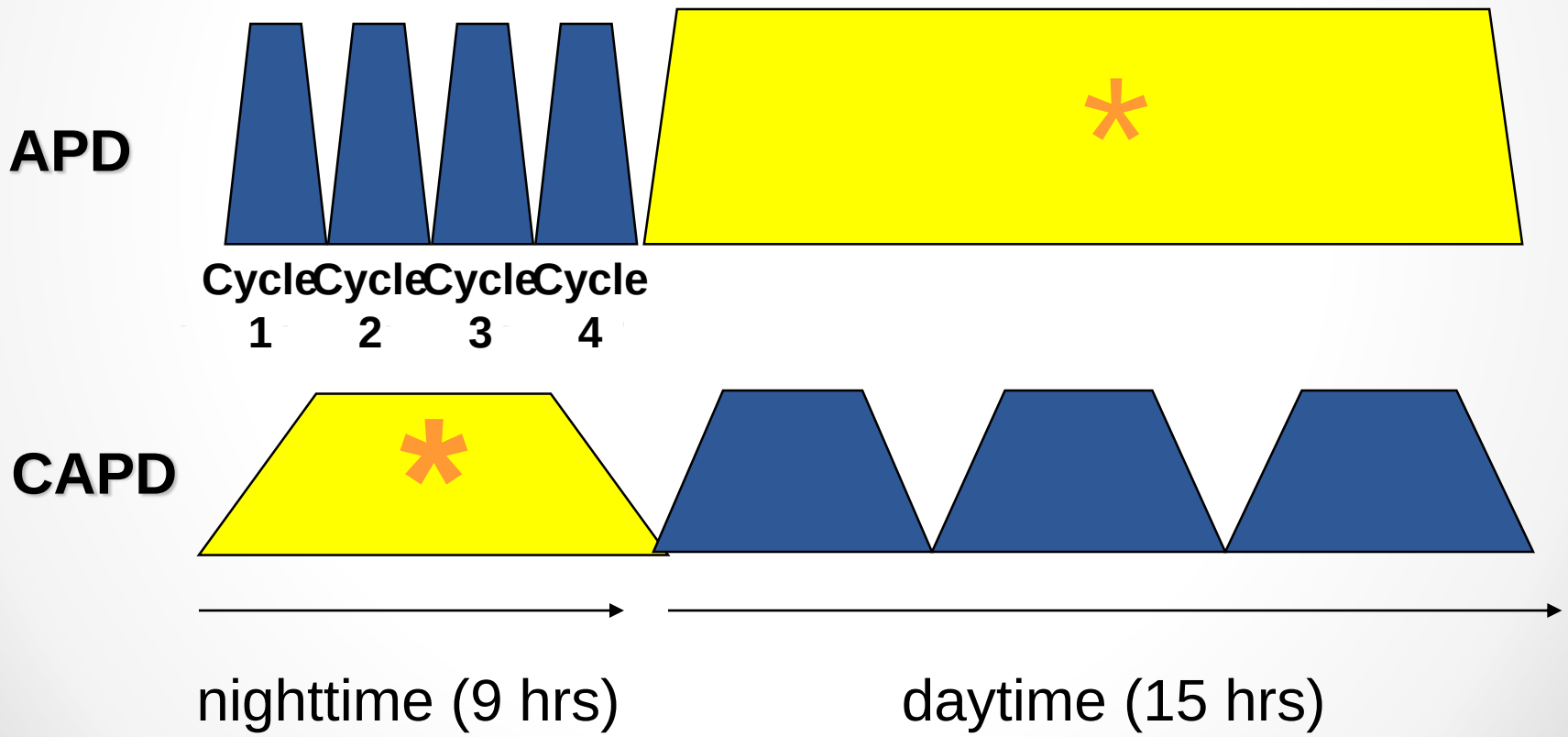
Volume Overload

- Loss of Residual Renal Function
  - protect RRF
    - avoid NSAID's, COX 2-inhibitors, dye studies, aminoglycosides, volume depletion
  - use diuretics to augment urine Na^+ & water output
    - eg furosemide, metolazone
  - continue immunosuppression for failed transplant kidneys that still have function

Volume Overload

- Use of the wrong type of PD fluid
  - usually this means failure to account for the long dwell

Temporal Profiles of APD and CAPD



Volume Overload

Tackling the long dwell:

1. use icodextrin or a more hypertonic dialysate (e.g. 2.5%)
2. break up the long dwell
   - day dry (only if there is a lot of RRF)
   - "mid-day" exchange in APD
   - drain out day exchange in APD after a few hours

Fluid Absorption During the Long Dwell

Or, it may not need any intervention

- if there is a lot of urine volume, may "forgive" fluid absorption
  - e.g. patient on APD
    - last fill 2L
    - initial drain 1.5 L (so .5L fluid absorption)
    - urine output 1.0 L
    - patient is clinically euvolemic

No Need to Change the Prescription

Volume Overload

- Output dependent
  - failure of the peritoneal membrane to respond to UF conditions (true UF failure)
  - mechanical failure of dialysis procedure

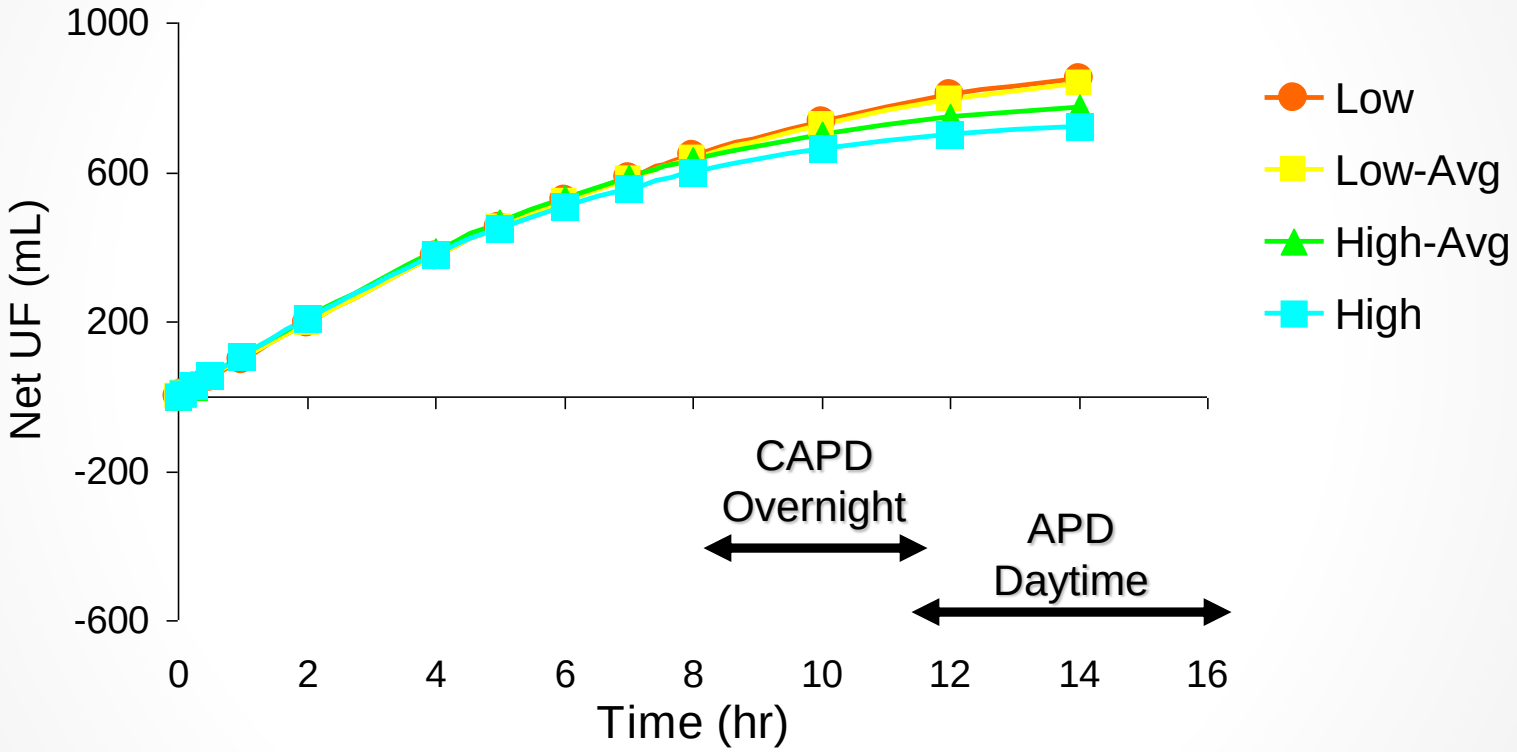
Ultrafiltration Failure

- on PET test, D/P creatinine is high
- these high transporters have rapid absorption of glucose across peritoneal membrane
- rapid dissipation of osmotic gradient
- poor ultrafiltration

Ultrafiltration Failure

- Management of rapid transporters (I):
  - reinforce salt and water restriction
  - use more hypertonic dialysate
  - icodextrin can be quite helpful here (*as effective in high transporters as other transport types*)

Icodextrin: Similar Ultrafiltration in All Transporter Types



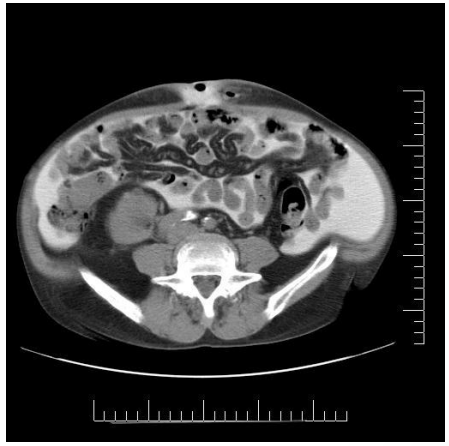
Mujais S, Vonesh E. *Kidney Int*. 2002;62(suppl 81):S17-S22.

Ultrafiltration Failure

- Management of rapid transporters(II):
  - "push" residual urine output (diuretics)
  - APD with dry day, or drain out last fill at lunch (if enough RRF)
  - once anuric, watch closely for volume overload
  - *consider transfer to hemodialysis if patient is chronically overloaded* ***(start talking about fistula placement with the patient)***

Volume Overload

- **Output dependent**
  - mechanical failure of dialysis procedure



Mrs. B.D. Karma

- 33 year old woman with postpartum renal failure
- no appropriate kidney donor
- attends dialysis education class and chooses home peritoneal dialysis
- PD catheter inserted by blind surgical technique

Mrs. B.D. Karma

- comes to peritoneal dialysis unit to begin training
- dialysate infuses easily, but very slow outflow
  - first 500 mls takes about 30 minutes, and then the flow stops

Catheter-Related Problems

Usually soon after implantation:

- 2-way obstruction
  - problem with inflow and outflow
- 1-way obstruction
  - good inflow, poor outflow
- painful inflow or outflow

What is *Not* Necessarily a Problem…

- First ever exchange:
  - 1 liter good inflow
  - 500 ml good outflow

WHY?
WHAT WOULD YOU NEXT?

Catheter-Related Problems

2-way obstruction

- kink or bend in catheter
- intraluminal obstruction (blood clot, fibrin)

- *treatment:*
  - radiologic insertion of trochar to straighten catheter
  - vigorous flush with heparinized saline, insertion

Fibrin Plug

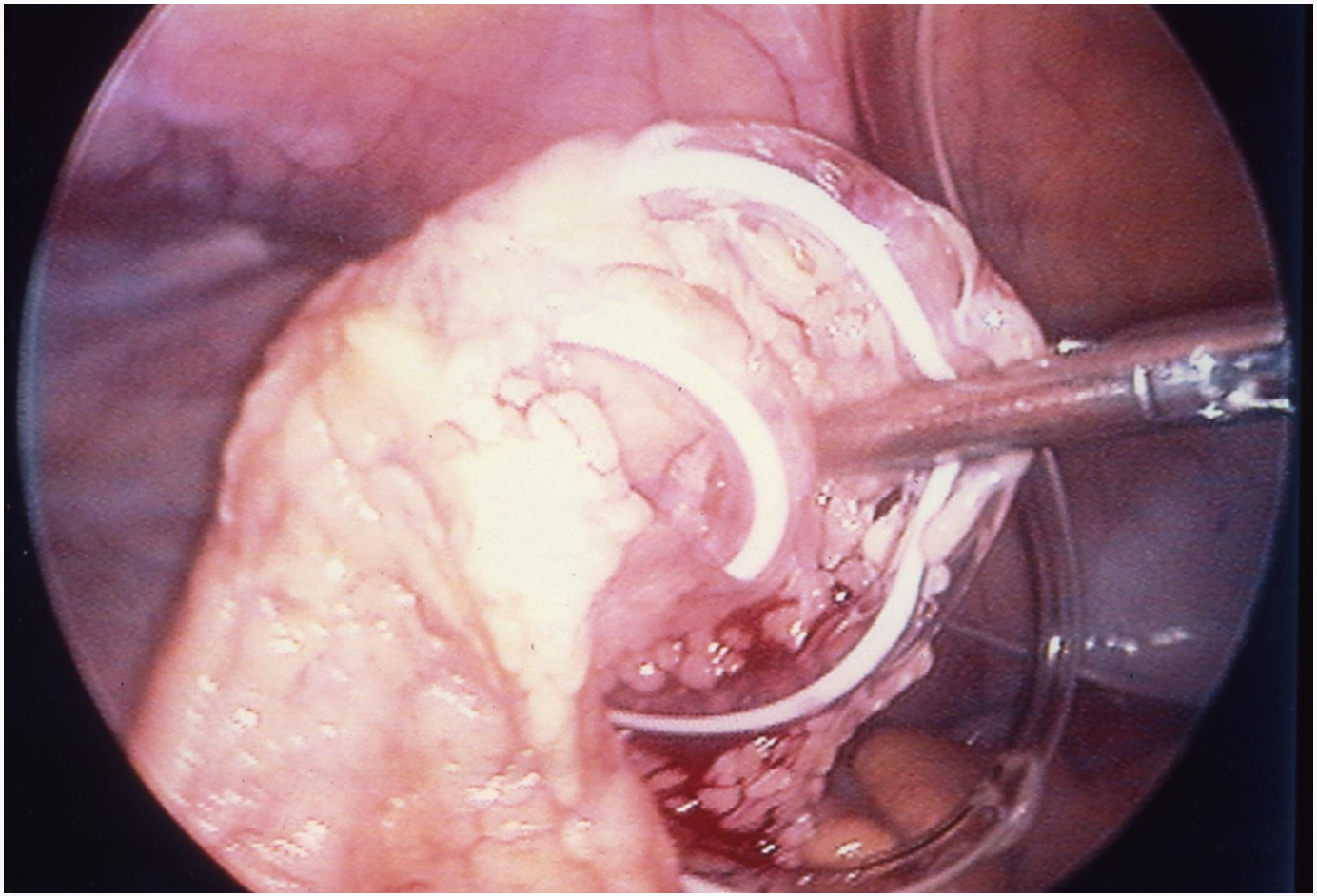
Catheter-Related Problems

1-way obstruction

- constipation ***
- catheter migration into upper quadrants or into a loculated pocket
- omental wrap

- *treatment*
  - careful attention to bowel cleanout ***
  - radiologic or laparoscopic manipulation of catheter
  - surgical removal of omentum or laparascopic omentopexy

Omental Wrap



Slide courtesy of Dr. J. Crabtree

Mrs. B.D. Karma

Her abdominal flat plate shows:

- tons of stool in the large bowel
- catheter tip in the left middle quadrant

Mrs. Karma

- she is sent home for the weekend with lactulose and senna
- over the weekend she has 8 more bowel movements
- still no improvement in outflow

Catheter-grams

- inject enough dye to fill catheter and spill into peritoneal cavity
- what you can diagnose:
  - kink in catheter
  - obstruction within lumen
  - omental wrap
  - peritoneal compartment problem

Catheter-gram: Compartment Problem

Courtesy Dr. Martin Simons

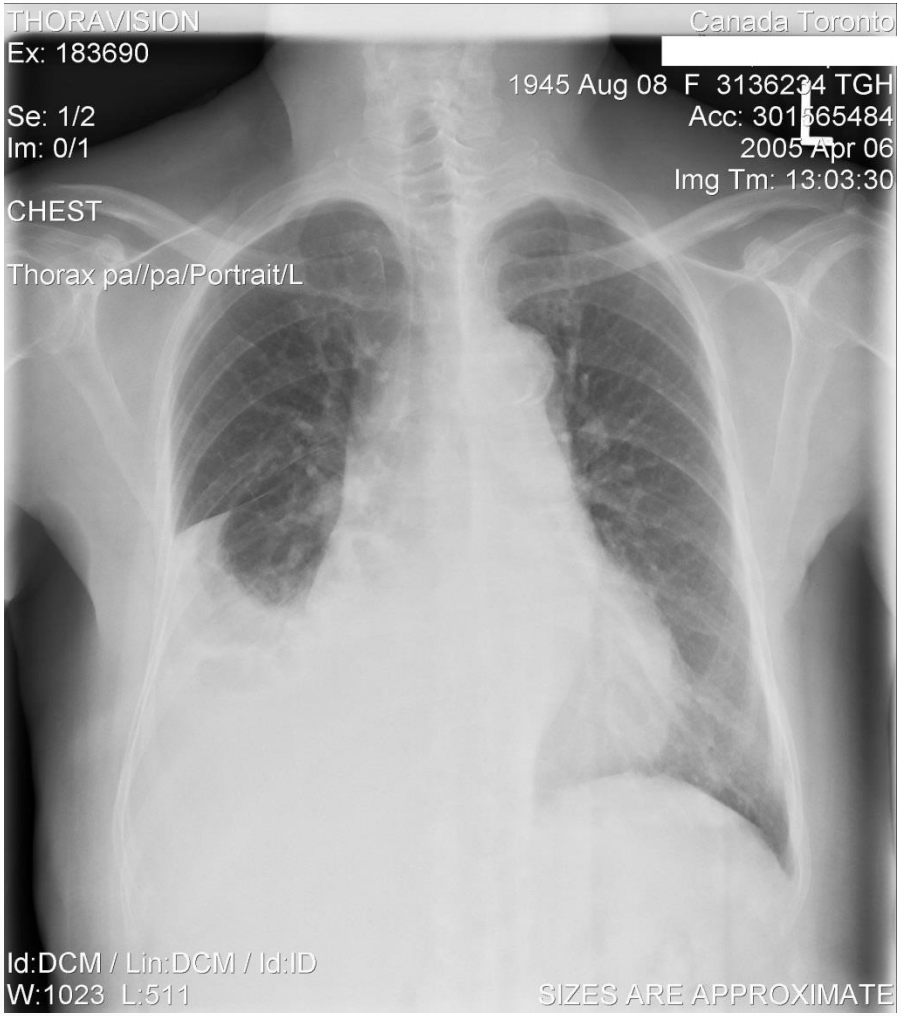
Mrs. B.D. Karma

- catheter-gram suggested omental wrap around catheter
- discussed with patient: patient chose to continue with PD
- laparoscopic removal of omentum from around catheter
- Finally: catheter outflow improved dramatically!

Mrs. Karma's Breathing Problems

- after her laparoscopic unwrap of omentum, she is trained and discharged on APD, 2L X 3 exchanges over 8 h, 1.5L last fill
- 3 days later, she calls the unit, complaining of progressive shortness of breath
  - mild cough, but no fever or sputum
  - weight is increased 1 kg, but no edema nor change in blood pressure
  - a chest x-ray is ordered

Mrs. Karma's CXR



Hydrothorax

Definition: The presence of peritoneal dialysis fluid in the pleural cavity

Incidence: Probably < 5%

Pathogenesis: Movement of dialysate, under increased intra-abdominal pressure, from peritoneal to pleural cavity through congenital or acquired defects in the diaphragm

Hydrothorax

Presentation:

- may be asymptomatic
- shortness of breath
- diminished effluent return
- right-sided pleural effusion on CXR

Hydrothorax

Diagnosis:

- thoracentesis for relief of symptoms and/or diagnosis
- pleural fluid analysis:

  -transudate

  -very high glucose concentration (*usually, but not always*)

  -cell count variable
- no intraperitoneal methylene blue !

Hydrothorax

Treatment:

- thoracentesis may be helpful if very SOB
- stop PD
- temporary hemodialysis, if dialysis necessary
- pleurodesis (talc, tetracycline, bleomycin, autologous blood)
- operative or pleuroscopic repair (diaphragmatic defects identified and patched or oversewn)

Peritonitis: Cloudy Effluent

Peritonitis - Diagnosis

- The diagnosis of peritonitis requires at least 2 of the following 3 features:
  - peritoneal fluid leukocytosis (>100/mm^3, and at least 50% polymorphonuclear cells)
    - the fluid should dwell 2 to 4 hours
  - abdominal pain
  - positive culture of the dialysis effluent

Hematogenous seeding

- bacteremia can cause peritoneal seeding and secondary peritonitis

but

- ***peritonitis hardly ever causes bacteremia***

(keep this in mind if you have a patient with a mechanical heart valve or prosthetic hip)

Hematogenous seeding

Use antibiotic prophylaxis at times of anticipated bacteremia

eg dental work, endoscopy (upper and lower), colposcopy or GU instrumentation (and drain effluent before the procedure!)

Peritonitis - Principles of Treatment

- start antibiotic treatment quickly
- cover for both gram positive and gram negative organisms until cultures available
- adjust antibiotics according to culture results
- re-evaluate the treatment if no improvement* in 36-48 hours
  - * less abdominal pain, falling peritoneal fluid WBC count

Peritonitis - Principles of Treatment

- consider removal of the PD catheter if little or no improvement in 4-5 days *(especially if staph. aureus or pseudomonas)*
- fungal peritonitis: catheter removal as soon as possible

don't let peritonitis drag on for days !

Most Recent Guidelines: Find them at www.ispd.org

ISPD GUIDELINES/RECOMMENDATIONS

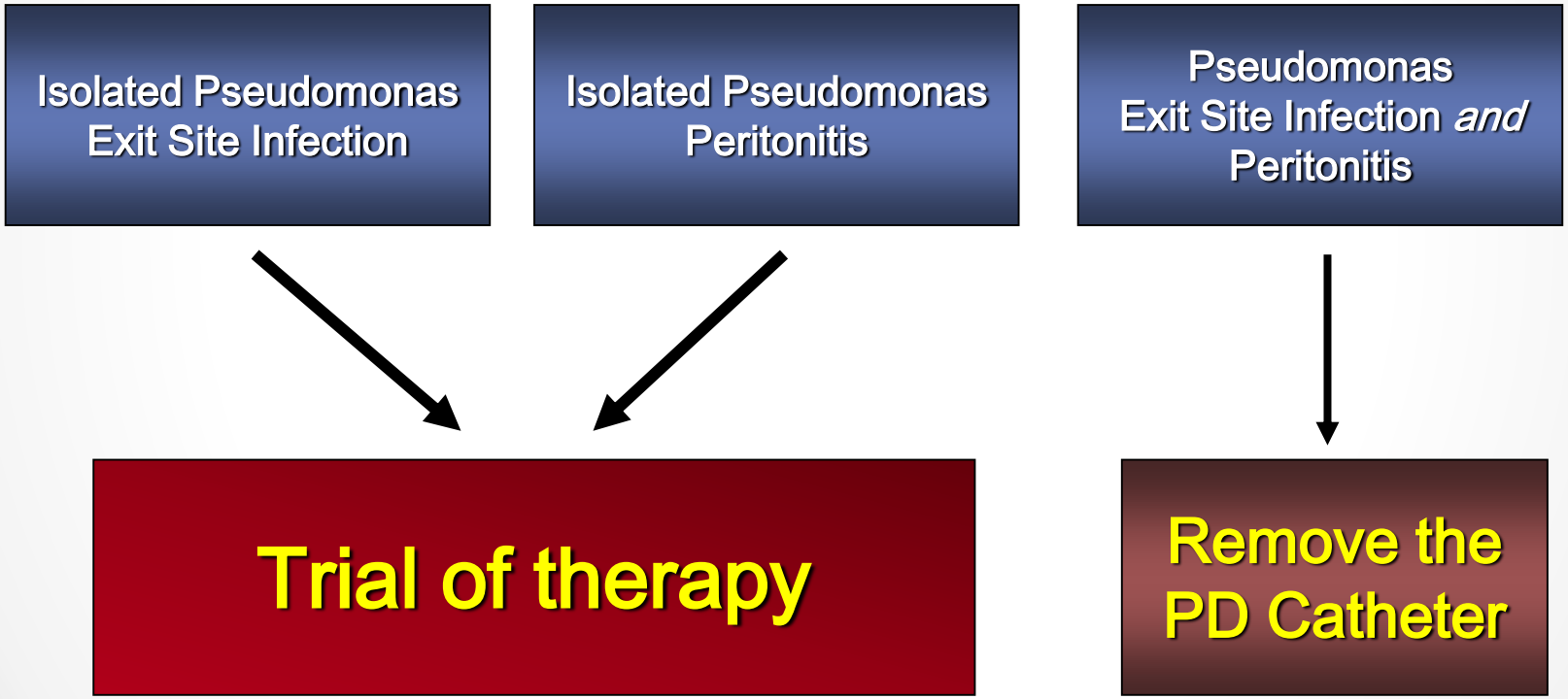
PERITONEAL DIALYSIS-RELATED INFECTIONS RECOMMENDATIONS: 2010 UPDATE

Philip Kam-Tao Li,[1] Cheuk Chun Szeto,[1] Beth Piraino,[2] Judith Bernardini,[2] Ana E. Figueiredo,[3] Amit Gupta,[4] David W. Johnson,[5] Ed J. Kuijper,[6] Wai-Choong Lye,[7] William Salzer,[8] Franz Schaefer,[9] and Dirk G. Struijk[10]

Special Cases: Pseudomonas Peritonitis

- combine 2 anti-pseudomonal antibiotics for 21 days
- if pseudomonas peritonitis is in association with pseudomonas exit site or tunnel infection, remove catheter

Pseudomonas Infection



Treatment of Other Special Cases

Multiple gram negative organisms imply a bowel leak

- add metronidazole 500 mg q 8 hrs. iv/ po/ per rectum - 21 days.
- get a surgical opinion

Mr. C the Building Superintendent

48 year old man with polycystic kidney disease is trained on cycler dialysis. Current prescription is 2.0 L X 4 exchanges over 8 hours at night, with 2.0 L day dwell

- one year later: he is doing well
- residual renal GFR is 8 ml/min
- his wife is almost finished being worked up as a kidney donor and is likely to be accepted

Mr C *(cont'd)*

- at clinic, he reports a new "lump" in his left groin. He had been bent over looking under a sink and felt a "pop" and some tenderness in the groin
- on physical exam, there is a left inguinal hernia

PD and Increased Intra-abdominal Pressure (IAP)

- instillation of dialysate into the peritoneal cavity leads to increased IAP
- the magnitude of the increase depends upon:

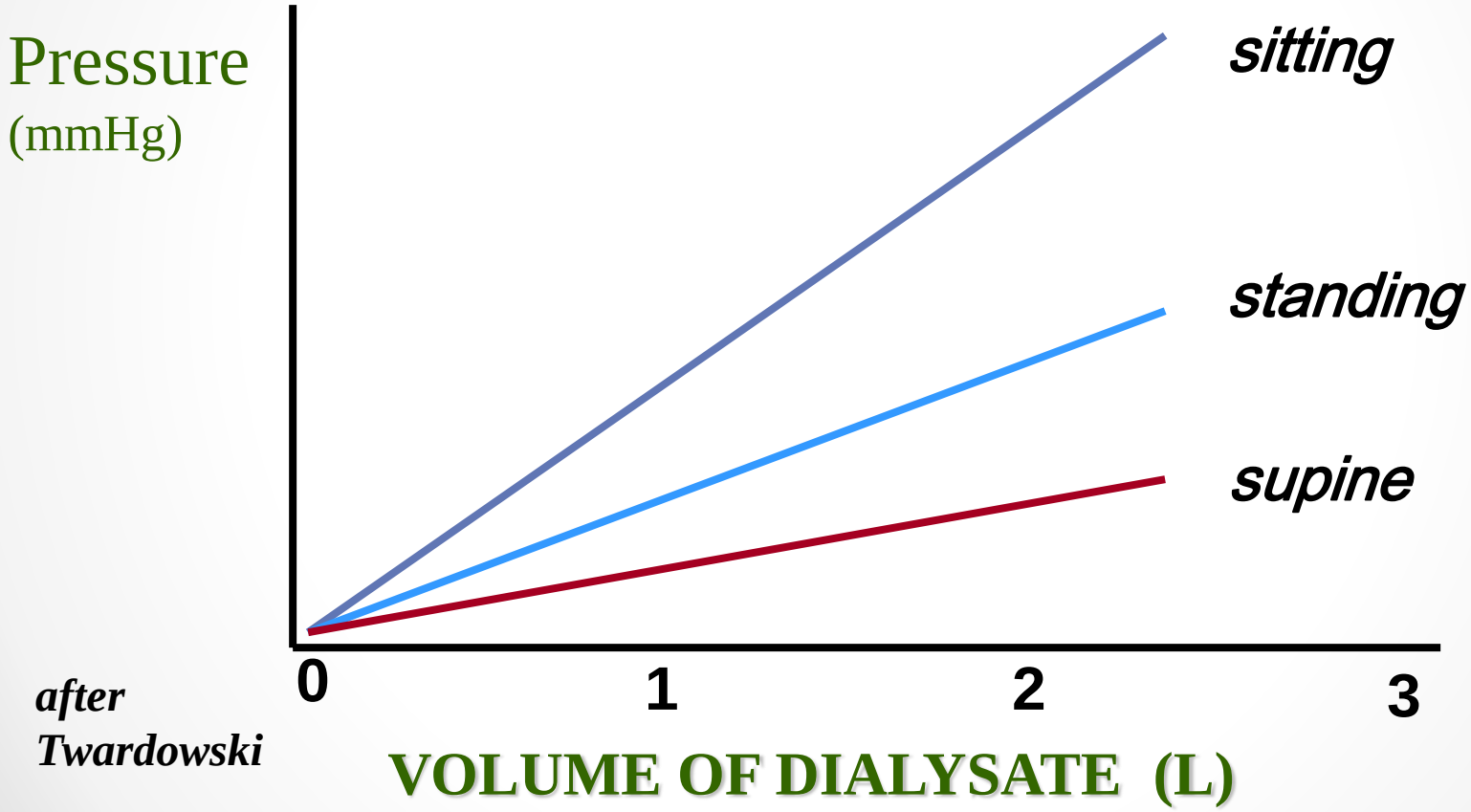
  -volume of dialysate instilled

  -position of the patient (*sitting>standing>supine*)

  -age, body mass index

  -coughing, lifting, straining at stool, aerobics class (!), chopping wood (!)

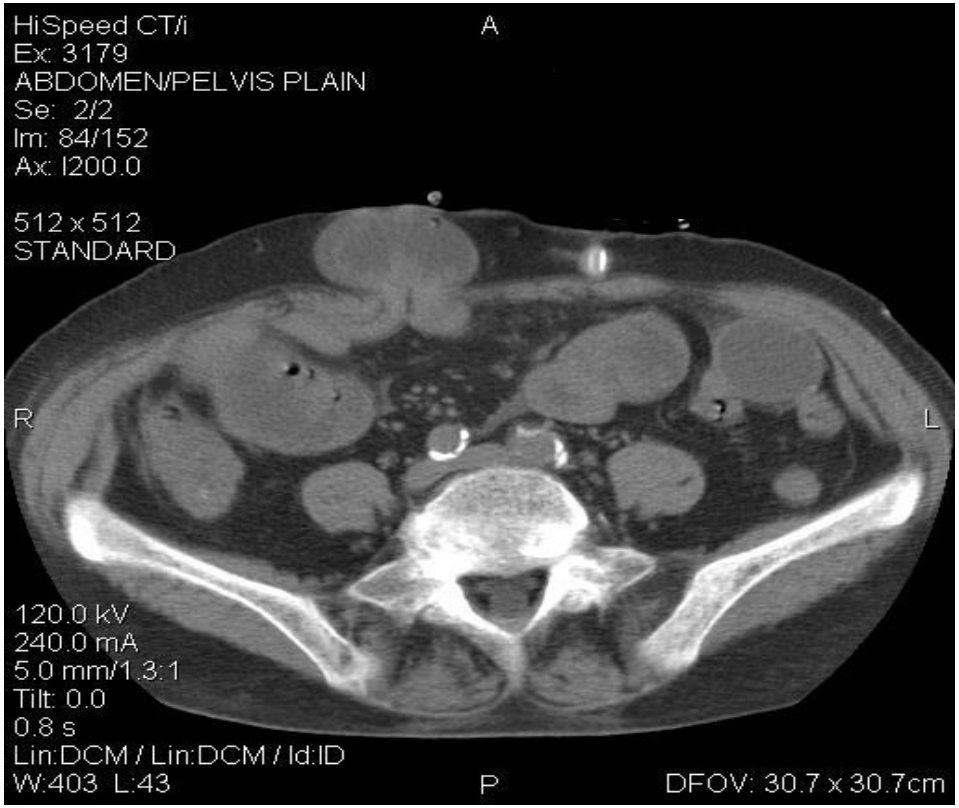
Relationship among Intra-Abdominal Pressure (IAP), Position & Dialysate Volume



after Twardowski

Ventral Hernias

60 year old woman on PD presents with localized abdominal pain



Hernias

Treatment:

- warn patient about signs of incarceration
- surgical repair:

  -dialysis around repair depends on renal function and condition of the patient

  -don't usually have to put them on HD !

  -reintroduce PD with low volumes, supine posture, increase volume over 2 weeks

So What Happened to Mr C?

- continued night cycler dialysis
- dry during day (RRF 8 ml/min)
- elective hernia repair
- no PD for 2 days
- back to night cycler 1.5L volume X 2 weeks, 2Lvolume X 2 weeks, then 2.5 L volume
- day dwell re-introduced 2 months later

Abdominal Wall and Genital Edema

Presentation:

- abdominal swelling or bogginess, scrotal or labial edema
- diminished effluent return
- weight gain without peripheral edema
- pericatheter leak: wetness or swelling at exit site

Abdominal Wall & Genital Edema

Diagnosis:

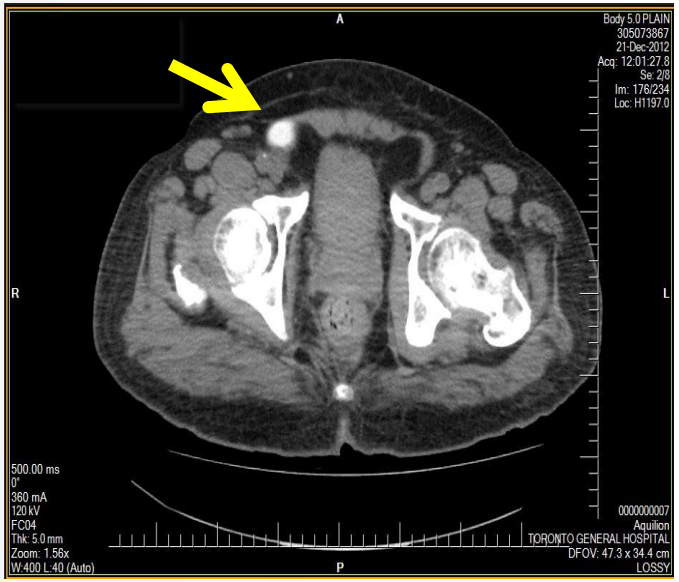
- physical exam (have patient stand in front of you)
- if decreased UF: unchanged PET results
- CT scan with IP dye

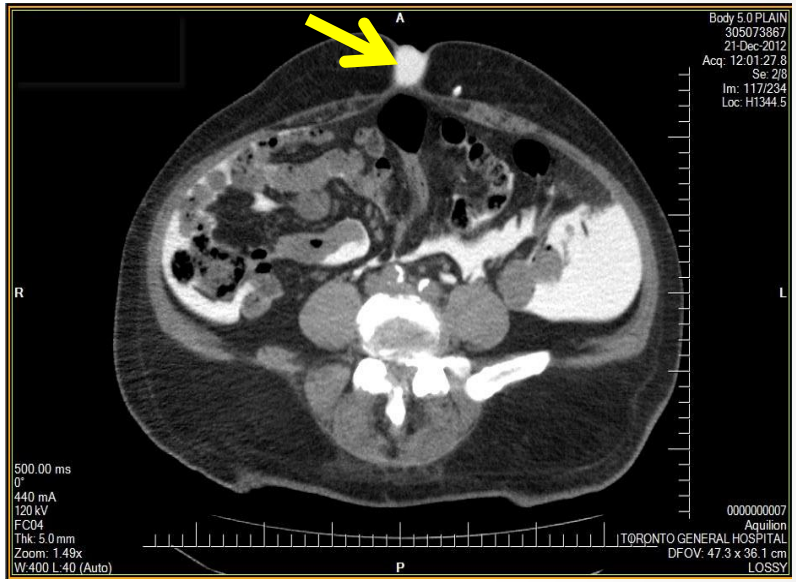
Abdominal Wall and Genital Edema

Diagnosis by CT Scanning:

- add 100-150 ml Omnipaque to dialysis bag
- infuse dialysate into patient
- have patient ambulatory for 30 to 60 minutes to increase intra-abdominal pressure
- send for CT scan - discuss with the radiologist !

Patent Processus Vaginalis and Umbilical Hernia





Abdominal Wall & Genital Edema

Management:

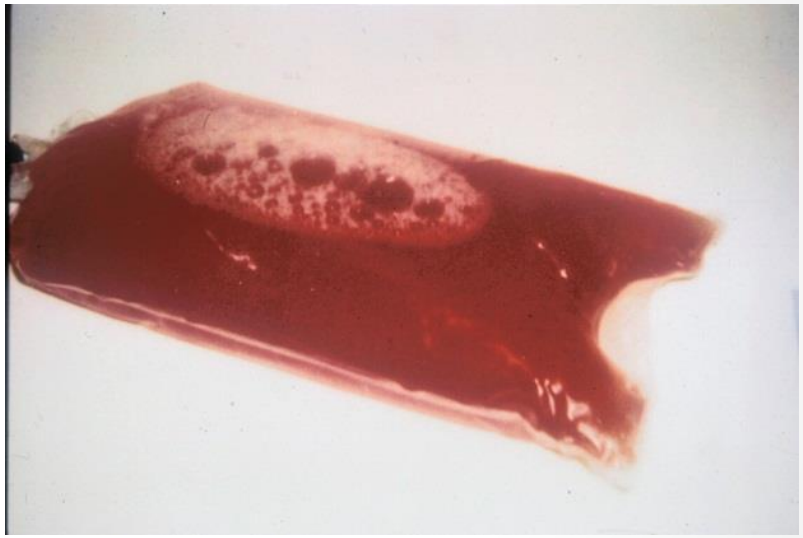
- reintroduce low pressure PD (eg APD with low volumes)
- temporary HD to allow healing
- abdominal wall: CT scan for occult hernia
- genital: CT scan for patent processus vaginalis, which is easily repaired

SV and Her Scary Episode

- 28 year old woman, CKD of unknown etiology
- predialysis education: chooses and starts on PD

SV and Her Scary Episode

- doing great on PD
- menses resume
- with 2nd menses: painless bloody dialysate effluent
- to ER: hemodynamically stable, but urgent CBC, PTT, cross and type



Hemoperitoneum

Definition:

- Bloody peritoneal effluent

Presentation:

- scary ! (*not as bad as it looks*)
- must consider "benign" and "serious" causes

Hemoperitoneum

"Benign" Causes:

- menstruation (retrograde menses or endometriosis)
- ovulation
- ruptured renal or ovarian cysts
- trauma
- coagulopathy

Hemoperitoneum

Serious Causes:

- ischemic bowel
- hepatic or colon cancer
- pancreatitis
- encapsulating peritoneal sclerosis
- kidney cancer

Hemoperitoneum

Treatment:

- IP heparin to avoid clotting of catheter
- flushes
- dialysate at room temperature
- investigations depend on whether benign or serious type of presentation

And What Do You Think About This?

So What Have We Learned? (1)

Peritoneal Equilibration Test

- "rapid transporter" has increased peritoneal vascularity and transports small solutes quickly; but loses glucose osmotic gradient quickly and has problems with ultrafiltration
- "slow transporter" has slower removal of small solutes but better ultrafiltration
- PD peritonitis can lead to transient "rapid transporter" state because of inflammation

So What Have We Learned? (2)

- short PD dwells leads to removal of more water than sodium
  - avoid short dwells except in rapid transporters
- residual renal function is a more important predictor of outcome than dose of PD measured by small solute kinetics
  - try to protect residual function
  - don't obsess about Kt/V – get at least to minimum target and obsess about RRF and volume status

So What Have We Learned? (3)

- constipation is the #1 cause of outflow obstruction in new catheters
  - having one bowel movement doesn't necessarily mean it's cured
- think of hydrothorax if a PD patient gets short of breath early on

So What Have We Learned? (4)

- long-term antibiotics are a risk for fungal peritonitis
  - fungal prophylaxis may or may not work, but it's low-risk therapy
- staph aureus or pseudomonas infection of BOTH exit site and PD fluid won't get better with antibiotics – remove catheter

So What Have We Learned? (5)

- commonest cause of hemoperitoneum is menstruation and needs no further investigation *in that setting*

So What Have We Learned? (6)

- Hernias are common
  - try to prescribe day dry or small day volumes in at-risk patients
  - they can be repaired operatively without switching to hemodialysis
  - they may lead to secondary bowel incarceration and even strangulation
  - they can be a source of leak of PD fluid into surrounding tissues