# Peritoneal Dialysis Prescription and Adequacy Monitoring

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## Objectives

1. To describe the clinical factors that impact peritoneal dialysis (PD) prescription in children
2. Understand the role of dialysis adequacy to monitor the effectiveness of peritoneal dialysis

## Peritoneal Dialysis vs. Hemodialysis

Advantages:
- Vascular access not required
- Less anti-hypertensive medication
- Independence
- Relatively safe and simple
- Few dietary restrictions
- Better growth
- Better for infants

Disadvantages:
- Peritonitis
- Exit site and tunnel infections
- Hernias
- Need capable family
- Decreased appetite
- Body image disturbance

## Contraindications to PD

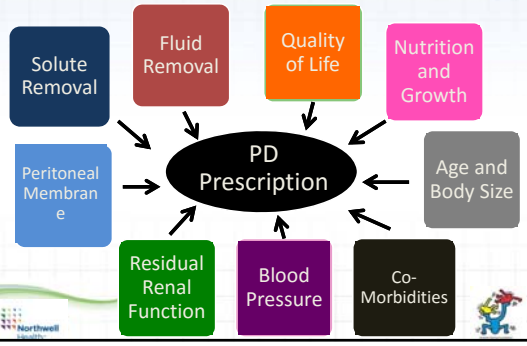
Absolute contraindications:
- Omphalocele
- Gastroschisis
- Bladder extrophy
- Diaphragmatic hernia
- Obliterated peritoneal cavity
- Peritoneal membrane failure

Relative contraindications:
- Inadequate living situation for home dialysis
- Lack of appropriate caregiver
- Impending/recent major abdominal surgery
- Imminent living-related donor transplantation

NKF KDOQI Guidelines AJKD 2006

## PD Prescription

## PD Prescription

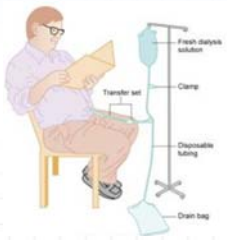


## PD Prescription

- Modality
- Solution
- Fill Volume
- Dwell Time
- Number of Exchanges

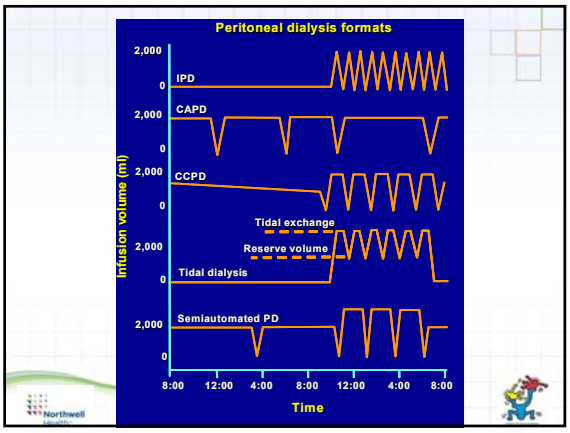
## PD Prescription: Modality

- Continuous Ambulatory Peritoneal Dialysis (CAPD)




## PD Prescription: Modality

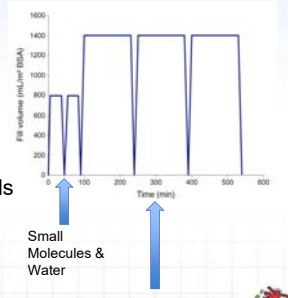
- Continuous Ambulatory Peritoneal Dialysis (CAPD)
- Automated Peritoneal Dialysis (APD)
  - Continuous Cycling (CCPD)
  - Nightly Intermittent (NIPD
  - Tidal (TPD)




## PD Prescription: Modality

Adaptive PD

- Initial fast exchanges with low volumes
  - Better UF
  - Small molecule clearance
- Followed by long dwells
  - Larger molecule clearance

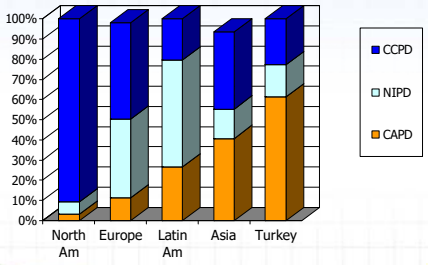



## PD Prescription: Modality

Determinants of Modality Choice:

- Financial
- Center preference
- Geography
- Lifestyle
- Peritoneal Membrane Transport Characteristics

## PD Prescription: Modality




International Pediatric Peritoneal Dialysis Network

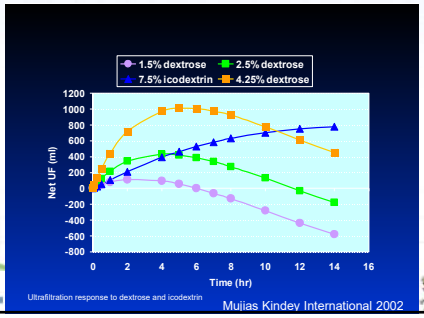
## PD Prescription: Solution

Composition:

- Water
- Osmotic agent:
  - Dextrose (1.5%, 2.5%, 4.25%)
  - Icodextrin
  - Amino Acids
- Buffer
  - Lactate
  - Bicarbonate
- Electrolytes
  - Sodium 132-134 mEq/L
  - Chloride 96-105 mEq/L
  - Magnesium 0.25-0.5 mEq/L
  - Calcium 2-3.5 mEq/L
  - No potassium
- Additives
  - Heparin
  - Antibiotics

## PD Prescription: Solution

Osmotic Agent



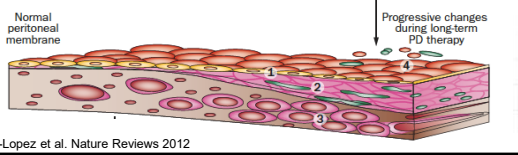

Ultrafiltration response to dextrose and icodextrin

Mujias Kindey International 2002

# PD Prescription: Solution

## Conventional Solutions

**Peritoneal membrane injury**
- Mesothelial denudation 1
- Interstitial fibrosis and peritoneal thickening 2
- Neoangiogenesis and vasculopathy 3
- AGE accumulation and inflammation 4
- Increased solute transport rate
- Loss of ultrafiltration capacity

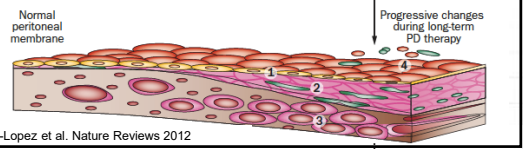



Garcia-Lopez et al. Nature Reviews 2012

# PD Prescription: Solution

## Conventional Solutions

**Harmful systemic effects**
- Fluid and sodium retention
- Left ventricular hypertrophy
- Hyperglycemia
- Hyperinsulinemia
- Hyperlipidemia
- Abdominal obesity

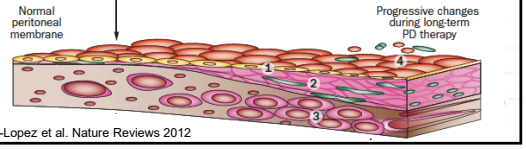



Garcia-Lopez et al. Nature Reviews 2012

# PD Prescription: Solution

## Biocompatible Solutions

**Improved peritoneal membrane viability**
- Attenuation of peritoneal fibrosis
- Preservation of peritoneal cell viability and function
- Less AGE accumulation
- Less inflammation

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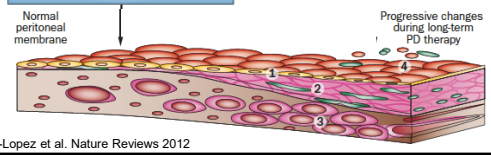
# PD Prescription: Solution

## Biocompatible Solutions

**Improved systemic effects**
- Improved metabolic control
- Improved body composition
- Improved UF capacity
- Improved fluid status
- Preservation of RRF?
- Reduced peritonitis rate?
- Reduced systemic inflammation?

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# PD Prescription: Solution

## Conventional vs. Biocompatible Solution

**Table 1** | Selected peritoneal dialysis solutions currently available in Europe

| Solution (manufacturer) | pH | Chambers | Buffer | Osmotic agent | GDPs | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|
| Dianeal® (Baxter*) | 5.2 | Single | Lactate | Glucose | High | Easy to manufacture; low cost | Low pH; poor peritoneal membrane biocompatibility; infusion pain; contains lactate |
| Extraneal® (Baxter*) | 5.6 | Single | Lactate | Icodextrin | Low | Sustained ultrafiltration; reduced hyperglycemia; improved metabolic profile and body composition | Contains lactate; low pH; single daily use only; hypersensitivity |
| Nutrineal® (Baxter*) | 5.5 | Single | Lactate | Amino acids | No | Avoids glucose exposure; peritoneal membrane protection; enhanced nutrition | Contains lactate; low pH; single daily use only |
| Physioneal® (Baxter*) | 7.4 | Double | Lactate/ bicarbonate | Glucose | Low | Improved biocompatibility; preserved membrane defense; reduced infusion pain | Local and systemic glucose exposure; reduced peritoneal lactate exposure |
| Stay-safe® (Fresenius#) | 5.5 | Single | Lactate | Glucose | High | Ease of manufacture; low cost | Low pH; poor peritoneal membrane biocompatibility; infusion pain; contains lactate |
| Balance® (Fresenius#) | 7.0 | Double | Lactate | Glucose | Low | Improved biocompatibility; preserved membrane defense; reduced risk of peritonitis? | Higher but not neutral pH; local and systemic glucose exposure; contains lactate |
| BicaVera® (Fresenius#) | 7.4 | Double | Bicarbonate | Glucose | Low | Improved biocompatibility; preserved membrane defense; improved correction of acidosis | Local and systemic glucose exposure |
| Gambrosol® Trio (Fresenius#) | 6.5 | Triple | Lactate | Glucose | Low | Improved biocompatibility; preserved membrane defense | Higher but not neutral pH; local and systemic glucose exposure; |

Garcia-Lopez et al. Nature Reviews 2012

# PD Prescription: Solution

**Risk factors for loss of residual renal function in children treated with chronic peritoneal dialysis**

Il-Soo Ha[1], Hui K. Yap[2], Reyner L. Munarriz[3], Pedro H. Zambrano[4], Joseph T. Flynn[5], Ilmay Bilge[6], Maria Szczepanska[7], Wai-Ming Lai[8], Zenaida L. Antonio[9], Ashima Gulati[10], Nakysa Hooman[11], Koen van Hoeck[12], Lina M.S. Higuita[13], Enrico Verrina[14], Günter Klaus[15], Michel Fischbach[16], Mohammed A. Riyami[17], Emilja Sahpazova[18], Anja Sander[19], Bradley A. Warady[20] and Franz Schaefer[21] for the International Pediatric Peritoneal Dialysis Network (IPPN) Registry[22]

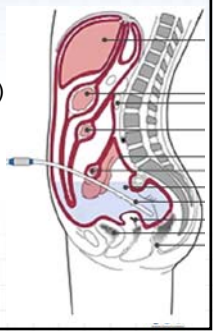
Kidney International 2015

- Icodextrin associated with increased risk of developing oligoanuria HR 2.38 (1.33- 4.2) and lower residual urine output (p=0.043)
- Biocompatible fluid associated with greater residual urine output (p=0.028)

## PD Prescription: Fill Volume

- Peritoneal membrane area is related to body size
- Use Body Surface Area to calculate fill volume (not weight)
- Fill volume affects peritoneal membrane recruitment and diffusion capacity

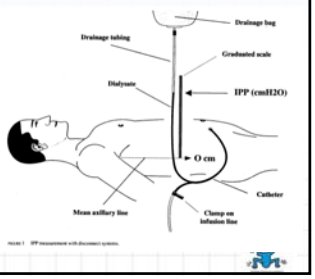
↑ Volume = ↑ Clearance



## PD Prescription: Fill Volume

Intra-peritoneal pressure maximum 18 cm $H_20$
Normal 7- 14 cm $H_20$

Excess Volume:
- Loss of UF
- Pain
- Risk of hernia
- Risk of hydrothorax
- Risk of breathing problems




## PD Prescription: Fill Volume

APD

Nocturnal Fill Volume:

>2 yrs: 1000-1200 mL/$m^2$

<2 yrs: 600-800 mL/$m^2$

Daytime Fill Volume:

50% of nocturnal fill volume

CAPD 600-800 ml/$m^2$ (day)
800-1,000 ml/$m^2$ (night)

## PD Prescription: Dwell Time

Short exchanges:

- Clearance of small solutes (urea)
- Better ultrafiltration

Long exchanges:

- Clearance of higher molecular weight (creatinine and phosphate)
- Less ultrafiltration

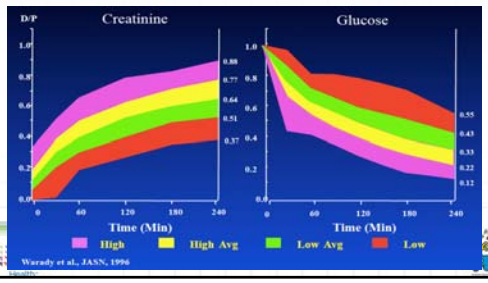
Dwell time should be determined by individual peritoneal membrane transport status

## Peritoneal Equilibration Test (PET)

- Test of peritoneal membrane transport
- Procedure:
  - 4 hour dwell
  - Volume: 1,100 ml/m$^2$ BSA
  - Solution: 2.5% Dextrose
  - Collect dialysate creatinine, urea, glucose at Time 0, 2 hr and 4 hr
  - Blood sample at 2 hr
- "Short" PET – 2 hours

## Peritoneal Equilibration Test (PET)

D/P = dialysate to plasma ratio for creatinine and urea
D/$D_0$ = dialysate glucose to initial glucose concentration



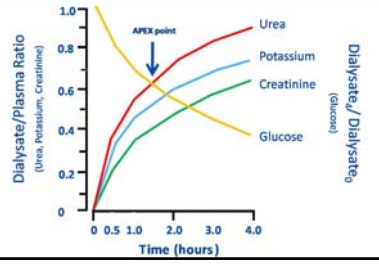
## PET: Transporter Type

| Transporter Type | Characteristics | Prescription |
|---|---|---|
| High | Highly permeable membrane<br>Rapid solute clearance<br>Loses osmotic gradient quickly (poor UF)<br>Higher protein loss – lower albumin | Short duration dwell<br>NIPD or daytime APD |
| High Average | Efficient membrane<br>Good solute clearance<br>Good UF | Any dialysis regimen |
| Low Average | Less efficient membrane<br>Slower solute clearance<br>Good UF | Any dialysis regimen with fewer cycles |
| Low | Low membrane permeability<br>Slow solute clearance<br>Very Good UF<br>Lower protein loss- higher albumin | High volume<br>Longer duration dwell<br>CAPD or CCPD |

## PD Prescription: Dwell Time

Accelerated Pertioneal Examination

APEX time indicates optimal dwell time for UF




## PD Prescription: # of Exchanges

APD

- 5-10 exchanges overnight
- 9-12 hours
- Daytime dwell

CAPD

- 3-5 exchanges/day
- 4 hour dwell time

## PD Prescription: Example

15 kg child BSA 0.6 $m^2$

**APD**

- Dianeal 1.5% dextrose
- Nocturnal fill 700 ml
- Daytime fill 350 ml
- 5 – 10 exchanges overnight
- 9 - 12 hours
- Fill/Drain time 10 minutes
- Dwell time 40-60 minutes

**CAPD**

- Dianeal 1.5% dextrose
- Daytime fill 480 ml
- Nocturnal fill 600 ml
- 3 daytime exchanges
- 1 nocturnal exchange
- 4 hour dwell time

## PD Prescription: Modeled Approach

Kinetic Modeling Software Based Programs

- PD-Adequest (Baxter)
  - Validated in children (Warady et al Ped Neph 2001)
- Patient Online (Fresenius)

## PD Prescription: Adjustment

**Inadequate Clearance**

- Introduce daytime dwell
- Increase fill volume
- Lengthen exchange time
- Increase number of exchanges
- Increase solution tonicity

**Inadequate UF**

- Increase solution tonicity
- Icodextrin
- Shorten exchange time

# PD Adequacy

## Adequacy of Dialysis

Delivered dose of dialysis is “adequate”:

- optimal growth
- blood pressure control
- optimal nutritional status
- avoidance of hypovolemia and sodium depletion
- psychomotor development

NKF KDOQI Guidelines AJKD 2006

## Adequacy: Measures of Clearance

- Solute Clearance Measures:
  - Weekly $Kt/V_{urea}$
  - Weekly Creatinine Clearance
- Current guidelines and consensus statements favor use of **$Kt/V_{urea}$** as the ‘standard’ measure to follow

## $Kt/V_{urea}$

- "K" is representative of CLEARANCE of UREA in the Kt/V formula
  - –Kd = clearance of dialysis delivered
  - –Kr = clearance of 'residual' renal function
- "t" is the time over which that dialysis is delivered
  - –In PD calculations t is normally considered 24 hours/ 1 day...ie the calculation is based on full day of dialysate/urine output (then scaled to 1 week)
- "V"urea is the volume of distribution for Urea in the patient, which is the patient's Total Body Water

## Total $Kt/V_{urea}$ = dialysis + renal clearance

### Weekly Peritoneal Dialysis Kt/V

$$\frac{\text{24 Hr D/P Urea x 24-Hr Drained Volume x7}}{\text{V}}$$

### Weekly Renal Kt/V

$$\frac{\text{mL/min Urea clearance x 1440 min/day x 7}}{\text{1000 mL x V}}$$

### Daily Renal Urea Clearance

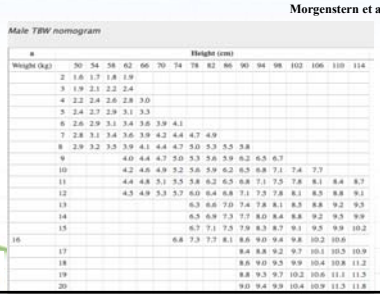
$$\frac{\text{Volume of 24-Hr Urine in mL x Urine Urea Nitrogen Conc.}}{\text{1440 min/day x Blood Urea Nitrogen Concentration}}$$

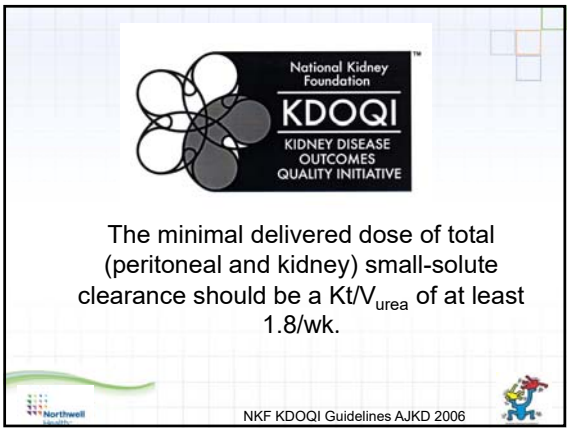
## Volume = Total Body Water

Boys TBW = $0.10 \times (HtWt)^{0.68} - 0.37 \times$ weight

Girls TBW = $0.14 \times (HtWt)^{0.65} - 0.35 \times$ weight

Morgenstern et al, JASN, 2006






## Residual Kidney Function

- Defined as urine $Kt/V_{urea}$ > 0.1/wk
- If the patient has RKF and residual kidney clearance is being considered as part of the patient's total weekly solute clearance goal, a 24-hour urine collection for urine volume and solute clearance determinations should be obtained at a minimum of every 3 months.

NKF KDOQI Guidelines AJKD 2006

## Ultrafiltration Adequacy: Euvolemia

Causes of Fluid Overload:

- Inappropriate solution selection
- Inappropriate prescription for membrane transport status
- Noncompliance with PD or diet
- Peritoneal membrane dysfunction
- Loss of residual renal function
- Poor blood glucose control

## Management

- The pediatric patient's clinical status should be reviewed at least monthly, and delivery of the prescribed solute clearance should render the patient free of signs and symptoms of uremia
- Measure KT/V 1 month after starting dialysis, when clinically needed and *at least* every 6 months
- PD effluent UF should be reviewed every month

## Useful Resources

- Warady et al Optimal Care of the Infant, Child and Adolescent on Dialysis: 2014 Update. AJKD 2014 July, 64(1); 128-142.
- Pediatric Dialysis, 2nd Edition. Warady, Schaefer, Alexander.
  - Chapter 11 Technical Aspects of Prescription of Peritoneal Dialysis in Children p169-203
- Handbook of Dialysis, 5th Edition. Daugirdas, Blake and Ing.
  - Chapter 25 Adequacy of Peritoneal Dialysis p464-482
  - Chapter 26 Volume Status and Fluid Overload in Peritoneal Dialysis p483-489
  - Chapter 37 Dialysis in Infants and Children p693-712
- KDOQI Clinical Practice Guidelines and Clinical Practice Recommendations for 2006 Updates. Hemodialysis Adequacy, Peritoneal Dialysis Adequacy and Vascular Access. *Am J Kidney Dis. 2006;28(suppl 1):S1*

REGISTRATION IS FREE

MANY RESOURCES

WORKING ON HD SIMULATOR TOO


www.Openpediatrics.org

**Harvard University**

# Thank You!

Acknowledgment: Some figures provided by Dr. Alicia Neu