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
- Hemias
- 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

PD Prescription

NKF KDOQI Guidelines AJKD 2006
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)

PD Prescription: **Modality**

• Continuous Ambulatory Peritoneal Dialysis (CAPD)

• Automated Peritoneal Dialysis (APD)
  - Continuous Cycling (CCPD)
  - Nightly Intermittent (NIPD)
  - Tidal (TPD)
### Peritoneal Dialysis Formats

<table>
<thead>
<tr>
<th>Infusion Volume (ml)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,000</td>
<td>8:00</td>
</tr>
<tr>
<td>2,000</td>
<td>12:00</td>
</tr>
<tr>
<td>2,000</td>
<td>4:00</td>
</tr>
<tr>
<td>2,000</td>
<td>8:00</td>
</tr>
<tr>
<td>2,000</td>
<td>12:00</td>
</tr>
<tr>
<td>2,000</td>
<td>4:00</td>
</tr>
<tr>
<td>2,000</td>
<td>8:00</td>
</tr>
</tbody>
</table>

### 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

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

Garcia-Lopez et al. *Nature Reviews* 2012

- Peritoneal membrane injury
- Mesothelial denudation
- Intestinal fibrosis and peritoneal thickening
- Neovascularization and vasculopathy
- AGE accumulation and inflammation
- Increased solute transport rate
- Loss of ultrafiltration capacity

Biocompatible Solutions

Garcia-Lopez et al. *Nature Reviews* 2012

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

Progressive changes during long-term PD therapy
PD Prescription: Solution

**Biocompatible Solutions**

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

Garcia-Lopez et al. Nature Reviews 2012

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**PD Prescription: Solution**

**Conventional vs. Biocompatible Solution**

<table>
<thead>
<tr>
<th>Solution (gallons)</th>
<th>pH</th>
<th>Osmolarity</th>
<th>Calorie content</th>
<th>Glucose</th>
<th>Sodium</th>
<th>Protein</th>
<th>Taurine</th>
<th>Other amino acids</th>
<th>Other factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>4.5</td>
<td>Low</td>
<td>Low</td>
<td>Glucose</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Biocompatible</td>
<td>7.3</td>
<td>High</td>
<td>High</td>
<td>Glucose</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

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)

Garcia-Lopez et al. Nature Reviews 2012
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

\[ \text{Volume} = \frac{\text{Clearance}}{} \]

PD Prescription: Fill Volume

Intra-peritoneal pressure maximum 18 cm H₂O
Normal 7-14 cm H₂O

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/m²
<2 yrs: 600-800 mL/m²
Daytime Fill Volume:
50% of nocturnal fill volume

CAPD
600-800 mL/m² (day)
800-1,000 mL/m² (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/m² 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/D₀ = dialysate glucose to initial glucose concentration

---
**PET: Transporter Type**

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

**PD Prescription: Dwell Time**

**Accelerated Peritoneal 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 m²

**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/Vurea = dialysis + renal clearance

Weekly Peritoneal Dialysis Kt/V

\[
24 \text{ Hr D/P Urea} \times 24\text{-Hr Drained Volume} \times \frac{7}{V}
\]

Weekly Renal Kt/V

\[
\text{mL/min Urea clearance} \times 1440 \text{ min/day} \times 7
\]

\[
\frac{1000 \text{ mL} \times V}{1000 \text{ mL} \times V}
\]

Daily Renal Urea Clearance

\[
\text{Volume of 24-Hr Urine in mL} \times \text{Urine Urea Nitrogen Conc.}
\]

\[
1440 \text{ min/day} \times \text{Blood Urea Nitrogen Concentration}
\]

Volume = Total Body Water

Boys TBW = 0.10 x (HtWt)^{0.68} – 0.37 x weight

Girls TBW = 0.14 x (HtWt)^{0.65} – 0.35 x weight

Morgenstern et al, JASN, 2006
The minimal delivered dose of total (peritoneal and kidney) small-solute clearance should be a Kt/V urea of at least 1.8/wk.

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.

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.
  – Chapter 11 Technical Aspects of Prescription of Peritoneal Dialysis in Children p169-203
  – Chapter 25 Adequacy of Peritoneal Dialysis p464-462
  – Chapter 26 Volume Status and Fluid Overload in Peritoneal Dialysis p483-489
  – Chapter 37 Dialysis in Infants and Children p663-712
• www.Openpediatrics.org

REGISTRATION IS FREE
MANY RESOURCES
WORKING ON HD SIMULATOR TOO
Thank You!

Acknowledgment: Some figures provided by Dr. Alicia Neu