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

Disadvantages of PD:
- 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

PD Prescription

Solute Removal
Fluid Removal
Quality of Life
Nutrition and Growth
Age and Body Size
Peritoneal Membrane
Residual Renal Function
Blood Pressure
Co-Morbidities
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)
- Automated Peritoneal Dialysis (APD)
  - Continuous Cycling (CCPD)
  - Nightly Intermittent (NIPD)
  - Tidal (TPD)

<table>
<thead>
<tr>
<th>Infusion Volume (ml)</th>
<th>2,000</th>
<th>2,000</th>
<th>00</th>
<th>IPD</th>
<th>CAPD</th>
<th>CCPD</th>
<th>Tidal exchange</th>
<th>Reserve volume</th>
<th>Tidal dialysis</th>
<th>Semiautomated PD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>8:00</td>
<td>12:12</td>
<td>12:00</td>
<td>12:00</td>
<td>12:00</td>
<td>12:00</td>
<td>12:00</td>
<td>12:00</td>
<td>12:00</td>
<td>12:00</td>
</tr>
</tbody>
</table>

Peritoneal dialysis formats

- IPD
- CAPD
- CCPD
- Tidal exchange
- Reserve volume
- Tidal dialysis
- Semiautomated PD

Time: 8:00, 12:12, 12:00, 12:00, 12:00, 12:00, 12:00, 12:00, 12:00, 12:00, 12:00
Adaptive APD
- Initial fast exchanges with low volumes
  - Better UF
  - Small molecule clearance
- Followed by long dwells
  - Larger molecule clearance

Determinants of Modality Choice:
- Financial
- Center preference
- Geography
- Lifestyle
- Peritoneal Membrane Transport Characteristics

PD Prescription: Modality

PD Prescription: Modality

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**

![Graph showing ultrafiltration response to dextrose and icodextrin](image)

**PD Prescription: Solution**

**Conventional Solutions**

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

![Image showing normal and progressive changes in peritoneal membranes](image)

*Garcia-Lopez et al., Nature Reviews 2012*
PD Prescription: Solution

Conventional vs. Biocompatible Solution

<table>
<thead>
<tr>
<th>Solution (Conventional)</th>
<th>pH</th>
<th>Glucose (Glu)</th>
<th>Buffer</th>
<th>Oncotic Pressure (OP)</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional 0.4% glucose</td>
<td>7.2</td>
<td>4.5</td>
<td>Single</td>
<td>Lactate</td>
<td>General High</td>
<td>Low pH, poor peritoneal membrane compatibility, reduced survival, increased peritonitis</td>
</tr>
<tr>
<td>Conventional 0.9% glucose</td>
<td>5.6</td>
<td>7.8</td>
<td>Single</td>
<td>Lactate</td>
<td>Low</td>
<td>Lactate, reduced survival, increased peritonitis</td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td>7.4</td>
<td>0.1</td>
<td>Single</td>
<td>Lactate</td>
<td>Normal</td>
<td>Normal survival, increased peritonitis</td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td>7.4</td>
<td>0.1</td>
<td>Single</td>
<td>Lactate</td>
<td>Normal</td>
<td>Normal survival, increased peritonitis</td>
</tr>
<tr>
<td>Icodextrin</td>
<td>7.1</td>
<td>0.05</td>
<td>Single</td>
<td>Lactate</td>
<td>Higher OP</td>
<td>Higher OP, reduced survival, increased peritonitis</td>
</tr>
</tbody>
</table>

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

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

Kidney International 2015

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

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

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 ambulatory PD</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: 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 40-90 minutes

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

**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: # of Exchanges**

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

**CAPD**
- 3-5 exchanges/day
- 4 hour dwell time during day
- Long nocturnal dwell
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
- Increase fill volume*

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**PD Adequacy**

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**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

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

Weekly Renal Kt/V

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

Daily Renal Urea Clearance

\[
\frac{\text{Volume of 24-Hr Urine in mL x Urine Urea Nitrogen Conc.}}{1440 \text{ min/day x Blood Urea Nitrogen Concentration}}
\]
Volume \(=\) Total Body Water

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

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

Morgenstern et al, JASN, 2006

The minimal delivered dose of total (peritoneal and kidney) small-solute clearance should be a Kt/V\(_{\text{urea}}\) of at least 1.8/wk.

NKF KDOQI Guidelines AJKD 2006

Residual Kidney Function

- Defined as urine Kt/V\(_{\text{urea}}\) > 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 and BP control

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

  – Chapter 11 Technical Aspects of Prescription of Peritoneal Dialysis in Children p169-203
  – Chapter 25 Adequacy of Peritoneal Dialysis p484-488
  – Chapter 26 Volume Status and Fluid Overload in Peritoneal Dialysis p483-489
  – Chapter 37 Dialysis in Infants and Children p693-712
Thank You!

Acknowledgment: Some figures provided by Dr. Brad Warady