Peritoneal Dialysis Prescription and Adequacy Monitoring

Annabelle N. Chua, MD
February 8, 2020
Disclosures

No financial disclosures relevant to this talk

Acknowledgment:
Some slides borrowed/modified from Dr. Christine Sethna
Overview

• Physiology of the peritoneal membrane
• Clinical factors that impact peritoneal dialysis (PD) prescription in the pediatric population
• Role of dialysis adequacy to monitor the effectiveness of peritoneal dialysis
# Why Peritoneal Dialysis?

## Advantages
- Vascular access not required
- Improved fluid balance; less antihypertensive medications
- Fewer dietary restrictions
- Relatively safe and simple
- Allows for regular school attendance
- Better growth
- Better for infants
- Less travel to dialysis unit

## Disadvantages
- Risk of infection (peritonitis, exit site and tunnel infections)
- Hernias
- Labor intensive; increased caregiver burden  
  - Risk of non-adherence
- Decreased appetite
- Body image disturbance
Contraindications to PD

ABSOLUTE
• Omphalocele
• Gastrochisis
• Bladder Exstrophy
• Diaphragmatic hernia
• Obliterated peritoneal cavity
• Peritoneal membrane failure

RELATIVE
• Impending abdominal surgery
• Impending (<6 months) living-donor kidney transplantation
• Lack of appropriate caregiver for home therapy; lack of appropriate home environment

NKF KDOQI Guidelines 2006
PD Prescription

- Age and body size
- Residual renal function
- Co-Morbidities
- Bone metabolism
- Nutrition and Growth
- Acid-base balance
- Peritoneal transport
- Primary renal disease
- Patient/Family Quality of Life
Physiology of Peritoneal Membrane

- Ultrasmall Pore (Transcellular Pore) Aquaporin I, $r = 3-5 \text{ Å}$
  - Molecules Transported: Water

- Small Pore, $r = 40-60 \text{ Å}$
  - Molecules Transported: Urea, Creatinine, Glucose, Water

- Large Pore, $r > 200 \text{ Å}$
  - Molecules Transported: Proteins/Macromolecules

Blood → Peritoneal cavity
PD Prescription Components

• Modality – CAPD vs APD
• Solution
• Fill volume
• Dwell Time
• Number of Exchanges
Modality – Continuous Ambulatory Peritoneal Dialysis (CAPD)

- Provides continuous solute and fluid removal throughout the day and night
- Daytime exchanges ~5 hours
- Nighttime exchange ~9 hours
- Ease of use
- Low cost of equipment
- Often used in developing countries with limited resources available
Modality – Automated Peritoneal Dialysis (APD)

• Continuous Cycling (CCPD)
• Nightly Intermittent (NIPD)
• Tidal (TPD)
Adapted APD

Water and small molecules

Sodium and large molecules (uremic toxins)

Fischbach et al Kidney International (2016) 89: 761-766
PD Rx: Modality

Determinants of Modality Choice

• Financial
• Center preference
• Geography
• Lifestyle
• Peritoneal membrane transport characteristics
PD Rx: 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

Duke Children’s
PD Rx: Solution

![Graph showing net UF (mL) over time (hours) for different solutions: icodextrin, 4.25% dextrose, 2.5% dextrose, and 1.5% dextrose.](image-url)
# Solutions

## Table 1: Selected peritoneal dialysis solutions currently available in Europe

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

*Deerfield, IL, USA. †Bad Homburg, Germany. Abbreviation: GDPs, glucose degradation products.*

Glucose degradation products

Delflex
Effects of 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

Progressive changes during long-term PD therapy

Effects of Conventional Solutions

- Normal peritoneal membrane
- Progressive changes during long-term PD therapy

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

Suboptimal patient and technique survival

Biocompatible Solutions

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

Normal peritoneal membrane

Progressive changes during long-term PD therapy

Effects of Biocompatible Solutions

- Normal peritoneal membrane
  - Improved systemic effects
    - Improved metabolic control
    - Improved body composition
    - Improved UF capacity
    - Improved fluid status
    - Preservation of RRF?
    - Reduced peritonitis rate?
    - Reduced systemic inflammation?
  - Improved patient and technique survival?

- Progressive changes during long-term PD therapy

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

Il-Soo Ha¹, Hui K. Yap², Reyner L. Munarriz³, Pedro H. Zambrano⁴, Joseph T. Flynn⁵, Ilmay Bilge⁶, Maria Szczepanska⁷, Wai-Ming Lai⁸, Zenaida L. Antonio⁹, Ashima Gulati¹⁰, Nakysa Hooman¹¹, Koen van Hoeck¹², Lina M.S. Higuita¹³, Enrico Verrina¹⁴, Günter Klaus¹⁵, Michel Fischbach¹⁶, Mohammed A. Riyami¹⁷, Emilija Sahpazova¹⁸, Anja Sander¹⁹, Bradley A. Warady²⁰ and Franz Schaefer²¹ for the International Pediatric Peritoneal Dialysis Network (IPPN) Registry²²

• 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 Rx: Fill Volume

- Peritoneal membrane area is related to body size
- Use body surface area to calculate fill volume (as opposed to weight)
- Fill volume affects peritoneal membrane recruitment and diffusion capacity

\[
\text{Volume} = \text{Clearance}
\]
**PD Rx: Fill Volume**

**APD:**

- Nocturnal fill volume:
  - >2 years: 1000-1200 mL/m²
  - < 2 years: 600-800 mL/m²
- Daytime Fill volume:
  - 50% of nocturnal fill volume

**CAPD:**

- 600-800 mL/m² (day)
- 800-1000 mL/m² (night)
Measuring IPP

Intra-peritoneal pressure maximum 18 cm H$_2$O
Normal 7-14 cm H$_2$O

- Empty bladder
- Patient placed completely flat
- Connection made to peritoneal system
- Any fluid in abdominal cavity is drained and defined volume of PD fluid is instilled
- PD line is fixed vertically
- Zero level of column (on graduated scale) is set at center of abdominal cavity, on the medial axillary line
- Connection of line to patient is opened
- Level of column of dialysis fluid in the PD line is read with a scale graduated in cm after height of column stabilizes

Mean IPP = $\frac{IPP_{insp} + IPP_{exp}}{2}$

PD Rx: Excess Volume

Intra-peritoneal pressure maximum 18 cm H$_2$O
Normal 7-14 cm H$_2$O

Excess volume:
- Loss of UF
- Pain
- Risk of hernia
- Risk of hydrothorax
- Risk of breathing problems
PD Rx: 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
PD Rx: # Exchanges

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

CAPD
• 3-5 exchanges/day
• 4-5 hour dwell time, with longer overnight dwell
**PD Rx cheat sheet**

**Automated PD**

**Solution:**
1.5%, 2.5% or 4.25% dianeal

**Fill volume (nocturnal):**
- < 2 years old = 600-800 mL/m²
- > 2 years old = 1000-1200 mL/m²

**Last fill (daytime):**
1/2 the nocturnal fill volume

**#exchanges over #hours:**
5-10 exchanges overnight over 9-12 hrs

**Fill/Drain time:** 15 minutes

**Dwell time:** 40-60 minutes

**CAPD**

**Solution:**
1.5%, 2.5% or 4.25% dianeal

**Fill volume (daytime):**
600-800 mL/m²

**Long overnight dwell (nocturnal):**
800-1000 mL/m²

**# exchanges:**
3-5 exchanges/day with dwell time: 4 hours AND
1 nocturnal exchange with dwell time: ~9 hours
Peritoneal Equilibration Test (PET)

- Test of peritoneal membrane transport
- 4 hour dwell, 1,100 mL/m2 BSA, 2.5% Dextrose
- “Short” PET – 2 hours
## PET: Transporter Type

<table>
<thead>
<tr>
<th>Category of peritoneal transport</th>
<th>D/P urea&lt;sup&gt;a&lt;/sup&gt;</th>
<th>D/P creatinine&lt;sup&gt;a&lt;/sup&gt;</th>
<th>D/D0 glucose&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>0.91–0.94</td>
<td>0.77–0.88</td>
<td>0.12–0.21</td>
</tr>
<tr>
<td>High average</td>
<td>0.82–0.90</td>
<td>0.64–0.76</td>
<td>0.22–0.32</td>
</tr>
<tr>
<td>Low average</td>
<td>0.74–0.81</td>
<td>0.51–0.63</td>
<td>0.33–0.42</td>
</tr>
<tr>
<td>Low</td>
<td>0.54–0.73</td>
<td>0.37–0.50</td>
<td>0.43–0.55</td>
</tr>
</tbody>
</table>

<sup>a</sup>At a 4 h dwell of an exchange performed with 1,100 ml/m<sup>2</sup> BSA of a 2.5% dextrose solution
## PET: Transporter Type

<table>
<thead>
<tr>
<th>Transporter Type</th>
<th>Characteristics</th>
<th>Prescription</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High</strong></td>
<td>- Highly permeable membrane</td>
<td>- Shorter dwell times</td>
</tr>
<tr>
<td></td>
<td>- Rapid solute clearance</td>
<td>- NIPD, or APD with icodextrin daytime fill</td>
</tr>
<tr>
<td></td>
<td>- Loss of osmotic gradient quickly (poor UF)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Higher protein loss (lower albumin)</td>
<td></td>
</tr>
<tr>
<td><strong>High Average</strong></td>
<td>- Efficient membrane</td>
<td>- Any dialysis regimen</td>
</tr>
<tr>
<td></td>
<td>- Good solute clearance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Good UF</td>
<td></td>
</tr>
<tr>
<td><strong>Low Average</strong></td>
<td>- Less efficient membrane</td>
<td>- Any dialysis regimen, but with fewer cycles</td>
</tr>
<tr>
<td></td>
<td>- Slower solute clearance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Good UF</td>
<td></td>
</tr>
<tr>
<td><strong>Low</strong></td>
<td>- Low membrane permeability</td>
<td>- Larger fill volumes</td>
</tr>
<tr>
<td></td>
<td>- Slow solute clearance</td>
<td>- Longer duration of dwell with less cycles</td>
</tr>
<tr>
<td></td>
<td>- Very good UF</td>
<td>- CAPD or CCPD</td>
</tr>
<tr>
<td></td>
<td>- Lower protein loss (higher albumin)</td>
<td></td>
</tr>
</tbody>
</table>
Kinetic Modeling Software Based Programs

• PD-Adequest 2.0 (Baxter)
  • Validated in children
• Patient Online (Fresenius)
**PD Rx: Adjustment**

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

**Inadequate Ultrafiltration**
- Increase solution tonicity
- Icodextrin
- Shorten exchange time
Delivered dose of dialysis is “adequate”:

• Optimal growth
• Blood pressure control
• Optimal nutritional status
• Avoidance of hypovolemia and sodium depletion
• Adequate psychomotor development
Adequacy: Measures of Clearance

• Solute Clearance Measures:
  - Weekly $\text{Kt/V}_{\text{urea}}$
  - Weekly Creatinine Clearance

• Current guidelines and consensus statements favor use of $\text{Kt/V}_{\text{urea}}$ as the ‘standard’ measure to follow
Kt/V

• “K” is representative of CLEARANCE of UREA
  -Kd = clearance of dialysis delivered
  -Kr = clearance of ‘residual’ renal function

• “t” is the time over which dialysis is delivered
  -In PD calculations, “t” is normally considered 24 hours/day (calculation is based on full day of dialysate/urine output, then scaled to 1 week)

• “V” is the volume of distribution for Urea in the patient, which is the patient’s TBW
Total $\frac{Kt}{V}_{\text{urea}} = \text{dialysis} + \text{renal clearance}$

**Weekly Peritoneal Dialysis $Kt/V$**

$24 \text{ Hr D/P urea} \times 24\text{-hr drained volume} \times 7 \left(\frac{\text{V}}{}\right)$

**Weekly Renal $Kt/V$**

$mL/\text{min Urea clearance} \times 1440 \text{ min/day} \times 7 \left(\frac{1000 \text{ mL}}{\text{V}}\right)$

**Daily Renal Urea Clearance**

$\text{Volume of 24-hr urine in mL} \times \text{Urine Urea Nitrogen Conc.}$

$1440 \text{ min/day} \times \text{BUN Concentration}$
Total Body Water Calculation

Males: TBW = 0.010
• (height • weight)\(^{0.68}\)
  − 0.37 • weight

Females: TBW = 0.14
• (height • weight)\(^{0.64}\)
  − 0.35 • weight
### Table 17. Male Total Body Water (L) Nomograms

| Height (cm) | 50  | 54  | 58  | 62  | 66  | 70  | 74  | 78  | 82  | 86  | 90  | 94  | 98  | 102 | 106 | 110 | 114 |
|------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 2          | 1.6 | 1.7 | 1.8 | 1.9 |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 3          | 1.9 | 2.1 | 2.2 | 2.4 |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 4          | 2.2 | 2.4 | 2.6 | 2.8 |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 5          | 2.4 | 2.7 | 2.9 | 3.1 |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 6          | 2.6 | 2.9 | 3.1 | 3.4 |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 7          | 2.8 | 3.1 | 3.4 | 3.6 |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 8          | 3.0 | 3.2 | 3.5 | 3.9 |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 9          | 4.0 | 4.4 | 4.7 | 5.0 | 5.3 | 5.6 | 5.9 | 6.2 | 6.5 | 6.7 |     |     |     |     |     |     |     |
| 10         | 4.2 | 4.6 | 4.9 | 5.2 | 5.6 | 5.9 | 6.2 | 6.5 | 6.8 | 7.1 | 7.4 | 7.7 |     |     |     |     |     |
| 11         | 4.4 | 4.8 | 5.1 | 5.5 | 5.8 | 6.2 | 6.5 | 6.8 | 7.1 | 7.5 | 7.8 | 8.1 | 8.4 |     |     |     |     |
| 12         | 4.5 | 4.9 | 5.3 | 5.7 | 6.0 | 6.4 | 6.8 | 7.1 | 7.5 | 7.8 | 8.1 | 8.5 | 8.8 | 9.1 |     |     |     |
| 13         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 14         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 15         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 16         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 17         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 18         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 19         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 20         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

### Table 17 (cont’d). Male Total Body Water (L) Nomograms

<table>
<thead>
<tr>
<th>Height (cm)</th>
<th>106</th>
<th>110</th>
<th>114</th>
<th>118</th>
<th>122</th>
<th>126</th>
<th>130</th>
<th>134</th>
<th>138</th>
<th>142</th>
<th>146</th>
<th>150</th>
<th>154</th>
<th>158</th>
<th>162</th>
<th>166</th>
<th>170</th>
<th>174</th>
<th>178</th>
<th>182</th>
<th>186</th>
<th>190</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>16.9</td>
<td>17.3</td>
<td>17.8</td>
<td>18.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>17.4</td>
<td>17.8</td>
<td>18.3</td>
<td>18.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>17.9</td>
<td>18.3</td>
<td>18.8</td>
<td>19.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>18.5</td>
<td>18.9</td>
<td>19.4</td>
<td>19.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>19.0</td>
<td>19.4</td>
<td>19.9</td>
<td>20.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>19.5</td>
<td>19.9</td>
<td>20.4</td>
<td>20.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>20.0</td>
<td>20.5</td>
<td>21.0</td>
<td>21.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>20.5</td>
<td>21.0</td>
<td>21.5</td>
<td>22.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>21.0</td>
<td>21.5</td>
<td>22.0</td>
<td>22.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>21.5</td>
<td>22.0</td>
<td>22.5</td>
<td>23.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>22.0</td>
<td>22.5</td>
<td>23.0</td>
<td>23.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>22.5</td>
<td>23.0</td>
<td>23.5</td>
<td>24.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>23.0</td>
<td>23.5</td>
<td>24.0</td>
<td>24.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>23.5</td>
<td>24.0</td>
<td>24.5</td>
<td>25.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>24.0</td>
<td>24.5</td>
<td>25.0</td>
<td>25.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>24.5</td>
<td>25.0</td>
<td>25.5</td>
<td>26.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>25.0</td>
<td>25.5</td>
<td>26.0</td>
<td>26.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>25.5</td>
<td>26.0</td>
<td>26.5</td>
<td>27.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>26.0</td>
<td>26.5</td>
<td>27.0</td>
<td>27.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>26.5</td>
<td>27.0</td>
<td>27.5</td>
<td>28.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NKF KDOQI Guidelines 2006
### Table 18. Female Total Body Water (L) Nomograms

<table>
<thead>
<tr>
<th>Height (cm)</th>
<th>50</th>
<th>54</th>
<th>58</th>
<th>62</th>
<th>66</th>
<th>70</th>
<th>74</th>
<th>78</th>
<th>82</th>
<th>86</th>
<th>90</th>
<th>94</th>
<th>98</th>
<th>102</th>
<th>106</th>
<th>110</th>
<th>114</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2.0</td>
<td>2.1</td>
<td>2.2</td>
<td>2.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2.4</td>
<td>2.6</td>
<td>2.8</td>
<td>2.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2.8</td>
<td>3.0</td>
<td>3.2</td>
<td>3.4</td>
<td>3.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>3.1</td>
<td>3.3</td>
<td>3.5</td>
<td>3.8</td>
<td>4.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3.3</td>
<td>3.6</td>
<td>3.8</td>
<td>4.1</td>
<td>4.3</td>
<td>4.6</td>
<td>4.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>3.5</td>
<td>3.8</td>
<td>4.1</td>
<td>4.4</td>
<td>4.8</td>
<td>4.9</td>
<td>5.2</td>
<td>5.5</td>
<td>5.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>3.7</td>
<td>4.0</td>
<td>4.3</td>
<td>4.6</td>
<td>4.9</td>
<td>5.2</td>
<td>5.5</td>
<td>5.8</td>
<td>6.1</td>
<td>6.4</td>
<td>6.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>3.9</td>
<td>4.3</td>
<td>4.6</td>
<td>4.9</td>
<td>5.2</td>
<td>5.5</td>
<td>5.8</td>
<td>6.1</td>
<td>6.4</td>
<td>6.7</td>
<td>7.0</td>
<td>7.3</td>
<td>7.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>4.1</td>
<td>4.4</td>
<td>4.7</td>
<td>5.0</td>
<td>5.3</td>
<td>5.6</td>
<td>5.9</td>
<td>6.2</td>
<td>6.5</td>
<td>6.8</td>
<td>7.1</td>
<td>7.4</td>
<td>7.7</td>
<td>8.0</td>
<td>8.3</td>
<td>8.6</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>4.3</td>
<td>4.6</td>
<td>4.9</td>
<td>5.2</td>
<td>5.5</td>
<td>5.8</td>
<td>6.1</td>
<td>6.4</td>
<td>6.7</td>
<td>7.0</td>
<td>7.3</td>
<td>7.6</td>
<td>7.9</td>
<td>8.2</td>
<td>8.5</td>
<td>8.8</td>
<td>9.1</td>
</tr>
<tr>
<td>12</td>
<td>4.5</td>
<td>4.8</td>
<td>5.1</td>
<td>5.4</td>
<td>5.7</td>
<td>6.0</td>
<td>6.3</td>
<td>6.6</td>
<td>6.9</td>
<td>7.2</td>
<td>7.5</td>
<td>7.8</td>
<td>8.1</td>
<td>8.4</td>
<td>8.7</td>
<td>9.0</td>
<td>9.3</td>
</tr>
<tr>
<td>13</td>
<td>4.7</td>
<td>5.0</td>
<td>5.3</td>
<td>5.6</td>
<td>5.9</td>
<td>6.2</td>
<td>6.5</td>
<td>6.8</td>
<td>7.1</td>
<td>7.4</td>
<td>7.7</td>
<td>8.0</td>
<td>8.3</td>
<td>8.6</td>
<td>8.9</td>
<td>9.2</td>
<td>9.5</td>
</tr>
<tr>
<td>14</td>
<td>4.9</td>
<td>5.2</td>
<td>5.5</td>
<td>5.8</td>
<td>6.1</td>
<td>6.4</td>
<td>6.7</td>
<td>7.0</td>
<td>7.3</td>
<td>7.6</td>
<td>7.9</td>
<td>8.2</td>
<td>8.5</td>
<td>8.8</td>
<td>9.1</td>
<td>9.4</td>
<td>9.7</td>
</tr>
<tr>
<td>15</td>
<td>5.1</td>
<td>5.4</td>
<td>5.7</td>
<td>6.0</td>
<td>6.3</td>
<td>6.6</td>
<td>6.9</td>
<td>7.2</td>
<td>7.5</td>
<td>7.8</td>
<td>8.1</td>
<td>8.4</td>
<td>8.7</td>
<td>9.0</td>
<td>9.3</td>
<td>9.6</td>
<td>9.9</td>
</tr>
<tr>
<td>16</td>
<td>5.3</td>
<td>5.6</td>
<td>5.9</td>
<td>6.2</td>
<td>6.5</td>
<td>6.8</td>
<td>7.1</td>
<td>7.4</td>
<td>7.7</td>
<td>8.0</td>
<td>8.3</td>
<td>8.6</td>
<td>8.9</td>
<td>9.2</td>
<td>9.5</td>
<td>9.8</td>
<td>10.1</td>
</tr>
<tr>
<td>17</td>
<td>5.5</td>
<td>5.8</td>
<td>6.1</td>
<td>6.4</td>
<td>6.7</td>
<td>7.0</td>
<td>7.3</td>
<td>7.6</td>
<td>7.9</td>
<td>8.2</td>
<td>8.5</td>
<td>8.8</td>
<td>9.1</td>
<td>9.4</td>
<td>9.7</td>
<td>10.0</td>
<td>10.4</td>
</tr>
<tr>
<td>18</td>
<td>5.7</td>
<td>6.0</td>
<td>6.3</td>
<td>6.6</td>
<td>6.9</td>
<td>7.2</td>
<td>7.5</td>
<td>7.8</td>
<td>8.1</td>
<td>8.4</td>
<td>8.7</td>
<td>9.0</td>
<td>9.3</td>
<td>9.6</td>
<td>9.9</td>
<td>10.2</td>
<td>10.6</td>
</tr>
<tr>
<td>19</td>
<td>5.9</td>
<td>6.2</td>
<td>6.5</td>
<td>6.8</td>
<td>7.1</td>
<td>7.4</td>
<td>7.7</td>
<td>8.0</td>
<td>8.3</td>
<td>8.6</td>
<td>8.9</td>
<td>9.2</td>
<td>9.5</td>
<td>9.8</td>
<td>10.1</td>
<td>10.4</td>
<td>10.8</td>
</tr>
<tr>
<td>20</td>
<td>6.1</td>
<td>6.4</td>
<td>6.7</td>
<td>7.0</td>
<td>7.3</td>
<td>7.6</td>
<td>7.9</td>
<td>8.2</td>
<td>8.5</td>
<td>8.8</td>
<td>9.1</td>
<td>9.4</td>
<td>9.7</td>
<td>10.0</td>
<td>10.3</td>
<td>10.7</td>
<td>11.1</td>
</tr>
</tbody>
</table>

### Table 18 (cont'd). Female Total Body Water (L) Nomograms

| Height (cm) | 106 | 110 | 114 | 118 | 122 | 126 | 130 | 134 | 138 | 142 | 146 | 150 | 154 | 158 | 162 | 166 | 170 | 174 | 178 | 182 | 186 | 190 |
|------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 21         | 6.3 | 6.5 | 6.7 | 6.9 | 7.1 | 7.3 | 7.5 | 7.7 | 7.9 | 8.1 | 8.3 | 8.5 | 8.7 | 8.9 | 9.1 | 9.3 | 9.5 | 9.7 | 9.9 | 10.1| 10.3| 10.5|
| 22         | 6.5 | 6.7 | 6.9 | 7.1 | 7.3 | 7.5 | 7.7 | 7.9 | 8.1 | 8.3 | 8.5 | 8.7 | 8.9 | 9.1 | 9.3 | 9.5 | 9.7 | 9.9 | 10.1| 10.3| 10.5| 10.8|
| 23         | 6.7 | 6.9 | 7.1 | 7.3 | 7.5 | 7.7 | 7.9 | 8.1 | 8.3 | 8.5 | 8.7 | 8.9 | 9.1 | 9.3 | 9.5 | 9.7 | 9.9 | 10.1| 10.3| 10.5| 10.8| 11.1|
| 24         | 6.9 | 7.1 | 7.3 | 7.5 | 7.7 | 7.9 | 8.1 | 8.3 | 8.5 | 8.7 | 8.9 | 9.1 | 9.3 | 9.5 | 9.7 | 9.9 | 10.1| 10.3| 10.5| 10.8| 11.1| 11.4|
| 25         | 7.1 | 7.3 | 7.5 | 7.7 | 7.9 | 8.1 | 8.3 | 8.5 | 8.7 | 8.9 | 9.1 | 9.3 | 9.5 | 9.7 | 9.9 | 10.1| 10.3| 10.5| 10.8| 11.1| 11.4| 11.8|
| 26         | 7.3 | 7.5 | 7.7 | 7.9 | 8.1 | 8.3 | 8.5 | 8.7 | 8.9 | 9.1 | 9.3 | 9.5 | 9.7 | 9.9 | 10.1| 10.3| 10.5| 10.8| 11.1| 11.4| 11.8| 12.2|
| 27         | 7.5 | 7.7 | 7.9 | 8.1 | 8.3 | 8.5 | 8.7 | 8.9 | 9.1 | 9.3 | 9.5 | 9.7 | 9.9 | 10.1| 10.3| 10.5| 10.8| 11.1| 11.4| 11.8| 12.2| 12.5|
| 28         | 7.7 | 7.9 | 8.1 | 8.3 | 8.5 | 8.7 | 8.9 | 9.1 | 9.3 | 9.5 | 9.7 | 9.9 | 10.1| 10.3| 10.5| 10.8| 11.1| 11.4| 11.8| 12.2| 12.5| 12.8|

NKF KDOQI Guidelines 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/week.
Residual Kidney Function

• Should be measured when UOP > 100 mL/day
• Defined as urine $K_t/V_{\text{urea}} > 0.1$/week
• 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 2006
Residual Kidney Function

• May have a significant impact on patient outcome
• Efforts should be made to preserve RKF
  • Minimize nephrotoxic insults
  • Promptly treat UTIs
  • Diuretics to maximize salt and water excretion
  • Use of ACE/ARBs
Ultrafiltration Adequacy: Euvolemia

Causes of Fluid Overload

• Inappropriate solution selection
• Inappropriate prescription for membrane transport status
• Non-adherence to 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 prescribed solute clearance should render the patient free of signs and symptoms of uremia.
• Measure Kt/V one month after starting dialysis, when clinically needed and at least every 6 months.
• PD effluent UF should be reviewed every month.
Summary

• PD prescription must be individualized and optimized, and continually re-assessed
• While recommended minimal “delivered” dose of solute clearance should be a \( \frac{Kt}{V_{\text{urea}}} \geq 1.8/\text{week} \), adequacy is also determined by clinical outcomes of the patient
  • BP control, fluid management, growth, nutrition, bone disease, development
Useful Resources


• Care of the Pediatric Patient on Chronic Dialysis. *Adv Chronic Kidney Dis* 2017; 24(6): 388-397

  • Chapter 11 Technical Aspects of Prescription of Peritoneal Dialysis in Children, p 169-203

  • 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

Peritoneal Dialysis Simulator

www.Openpediatrics.org

Harvard University

Screenshots of the various components of the peritoneal dialysis simulator. (A) The knowledge guide. (B) The tactics. (C) The case studies. (D) Learner-controlled feedback.
Thank you!
PD Rx: Modality
**Effect of PD**

**PD fluid**
- Glucose (1380-4250 mg/dl)
- GDP
- Lactate, bicarbonate (34-40 mmol/l)
- pH 5.5 – 7.4
- Electrolytes

**Systemic PD effects**
- GDP-, AGE accumulation
- Inflammation (IL-6, complement)
- Insufficient toxin removal
- Fluid, salt overload

**Local PD effects**
- Healthy peritoneum
- Membrane transformation

**PD effluent**
- Water, salts, toxins
- Proteins, cytokines

**Uremia Peritonitis**
PD Rx: Dwell Time

Accelerated Peritoneal Examination (APEX) time indicates optimal dwell time for UF.