Dialysis Dose Prescription and Delivery

Rolando Claure-Del Granado, M.D.
CRRT, 2011
Dose in RRT: Key concepts

- Dose definition
- Quantifying dose
- Prescribed versus delivered
- Factors influencing clearance
- Practical Considerations
Dose in RRT: Key concepts

- Dose definition
- Quantifying dose
- Prescribed versus delivered
- Factors influencing clearance
- Practical Considerations
What defines dose?

- **Dose, noun:** A definite *quantity* of a medicine or drug given or prescribed to be given at one time.

- **Dose, verb:** To give or prescribe (medicine) in specified amounts.

- **In RRT:**
  - A *measure* of the *quantity* of a *representative marker solute* which is removed from a patient.
What Defines Dose?
“The representative marker”

**Biochemical parameters**
- Small-solute (Urea)
- Correction of electrolyte disturbances
- Adequate clearance of larger middle-molecules (β2-microglubulin)
- nPCR
- pH, HCO3, AG, SIG

**Clinical Parameters**
- Fluid balance
- Cardiovascular stability (↓ vasopressor, MAP, etc.)
- Improvement in respiratory function
- Nutritional needs
Dialysis dose in acute kidney injury and chronic dialysis

*Andrew Davenport, Ken Farrington
Centre for Nephrology, University College London Medical School, Royal Free Campus, London NW3 2PF, UK (AD); and Renal Unit, Lister Hospital, Stevenage, Hertfordshire, UK (KF)
Prospective observational study. 297 children from 13 centers across the United States.

Fluid overload from ICU admission to CRRT initiation, defined as a % equal to \( \frac{(\text{fluid in [L]} - \text{fluid out [L]})}{(\text{ICU admit weight [kg]})} \times 100\% \).

Patients who developed 20% fluid overload at CRRT initiation had significantly higher mortality.

Adjusted mortality OR was 1.03 (95% CI, 1.01-1.05)

Sutherland et al. AJKD; 2010
618 patients enrolled in a prospective multicenter observational study (PICARD).

Fluid overload was defined as more than a 10% increase in body weight relative to baseline.

\[(\sum \text{daily (fluid intake (L) – total output (L))} / \text{body weight (in kilograms)}) \times 100.\]

Dialyzed patients, survivors had significantly lower fluid accumulation when dialysis was initiated compared to non-survivors after adjustments for dialysis modality and severity score.

Non-dialyzed patients, survivors had significantly less fluid accumulation at the peak of their serum creatinine.

Bouchard et al. Kidney Int; 2009
Dose in RRT: Key concepts

- Dose definition
- Quantifying dose
  - Dose expressions
  - RRT modalities and modality switch
  - A unified dose expression
- Prescribed versus delivered
- Factors influencing clearance
- Practical Considerations
There are no well-established standard methods to assess the efficacy of dialysis treatments of AKI patients.

In AKI the assessment of dialysis dose across modalities has been limited:
- Effluent volume for delivered dose in CRRT
- Single pool (spKt/V), equilibrated (eKt/V), or days per week for IHD
- BUN levels
Clinical trials evaluating dialysis dose in AKI during the last decade

<table>
<thead>
<tr>
<th>Reference</th>
<th>Dialysis Modality</th>
<th>Assessment of Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ronco et al 2000</td>
<td>Post-dilution CVVH</td>
<td>Ultrafiltration volume (mL/kg/h)</td>
</tr>
<tr>
<td>Schiff et al 2002</td>
<td>IHD</td>
<td>Frequency (3 per wk v.s.daily)</td>
</tr>
<tr>
<td>Bouman et al 2002</td>
<td>CVVH</td>
<td>Ultrafiltration volume (mL/kg/h)</td>
</tr>
<tr>
<td>Saudan et al 2006</td>
<td>CVVH vs. pre-dilution CVVHDF</td>
<td>Ultrafiltration volume (mL/kg/h)</td>
</tr>
<tr>
<td>Tolwani et al 2008</td>
<td>Pre-dilution CVVDHF</td>
<td>Ultrafiltration volume (mL/kg/h)</td>
</tr>
<tr>
<td>Palevsky et al 2008</td>
<td>IHD, SLED &amp; CRRT</td>
<td>Ultrafiltration volume (mL/kg/h) for CRRT and frequency of session &amp; Kt/V for IHD and SLED</td>
</tr>
<tr>
<td>Faulhaber-Walter et al 2009</td>
<td>Extended dialysis</td>
<td>BUN levels</td>
</tr>
<tr>
<td>Vescon et al 2009</td>
<td>IHD, CVVH, CVVHD, CVVHDF, HVHF &amp; couple plasma filtration and adsorption</td>
<td>Frequency of sessions per week for IHD and Ultrafiltration volume (mL/kg/h) for CRRT</td>
</tr>
<tr>
<td>Bellomo et al 2009</td>
<td>Post-dilution CVVHDF</td>
<td>Ultrafiltration volume (mL/kg/h)</td>
</tr>
</tbody>
</table>

Modified from Bouchard et al. AJKD; 2009.
Dose expression characteristics

- Any dose measurement must have the ability to be associated to:
  - Process of solute removal
  - Patient outcomes

- Measurement should also be simple to calculate without sacrificing accuracy

- Ideal measurement for RRT dose should be numerically comparable across all modalities and treatment schedules
Is $K_t/V$ a good dose expression?

$K_t/V$

- $K$ does not remain constant, it falls during dialysis.

- $K$ affected by weight changes and $G$ during dialysis

- $K_t/V$ is a measure of dialyzer performance, not reflects dialysis in patient
  - Access recirculation
  - Diffusion of urea within the patient

  $K_t/V$ depends on BUN “perturbation”, can’t be applied to CRRT or native kidney function

  Multiplying tx $K_t/V$ by $N$ per week overestimates contribution of intermittent therapy

Is $mL/kg/hr$ a good dose expression?

Dose in RRT: Key concepts

- Dose definition
- Quantifying dose
  - Dose expressions
  - RRT modalities and modality switch
  - A unified dose expression
- Prescribed versus delivered
- Factors influencing clearance
- Practical Considerations
Trends in Dialysis Modality for Individuals with Acute Kidney Injury

Areef Ishani
Department of Medicine, Minneapolis VA Medical Center, University of Minnesota, School of Medicine, Minneapolis, Minnesota, USA

![Graph showing trends in dialysis modality from 1998 to 2005. The graph compares the percentages of continuous, daily intermittent, intermittent HD, and peritoneal dialysis methods over the years.]
Table 4 Reasons for modality switch within first three RRT sessions, based on initial modality used

<table>
<thead>
<tr>
<th>Initial modality</th>
<th>Switched to SLED</th>
<th>Switched to CRRT</th>
<th>Switched to IHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLED</td>
<td>–</td>
<td>hemodynamic intolerance (n = 1)</td>
<td>improved hemodynamics (n = 3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>limited nursing availability (n = 1)</td>
<td></td>
</tr>
<tr>
<td>CRRT</td>
<td>none</td>
<td>–</td>
<td>improved hemodynamics (n = 4)</td>
</tr>
<tr>
<td>IHD</td>
<td>hemodynamic intolerance (n = 4)</td>
<td>hemodynamic intolerance (n = 1)</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>deteriorated clinical status (n = 1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fifteen patients switched RRT modality within the first 3 days of therapy
Dose in RRT: Key concepts

- Dose definition
- Quantifying dose
  - Dose expressions
  - RRT modalities and modality switch
  - A unified dose expression
- Prescribed versus delivered
- Factors influencing clearance
- Practical Considerations
Standard $Kt/V$

- $StdKt/V$ is a measure of clearance
- Define as: weekly continuous $K$ normalized by $V$ that achieves a given mean pretreatment urea concentration
- Based on: achieving equivalent average pre-dialysis BUN concentrations, regardless of how many dialysis sessions are given per week
- Two equations
  - Gotch
  - Leypoldt et al.
Standard Kt/V

Gotch

- Relationship between urea generation (nPCR) and mean pre-dialysis BUN
  
  \[
  \text{std}(Kt/V) = 7*1440[0.184(PCRn - 0.17)]/\text{Co weekly}
  \]

- Not simple to compute
- Steady state
- Is most often expressed only with respect to eKt/V

Leypoldt et al

- Requires only three variables (spKt/V, frequency, and duration of session)
- Requires only pre and post-treatment BUN measurements
- Underestimates urea StdKt/V
- Provides correction for urea rebound

\[
\text{stdKt/V} = 168 \times (1 - \exp[-Kt/V]) / t / [(1 - \exp[-Kt/V]) / (Kt/V) + 168 / (N \times t) - 1],
\] (3)
Calculated stdKt/V (Gotch’s and Leypoldt’s equations) using simulated cases (n = 10,000)

Comparison of Gotch’s and Leypoldt’s equations and they showed a good correlation between them.

Comparison of continuous and intermittent therapies.
- IHD (different frequencies)
- CAPD
- CRRT

Both equations could be use in clinical practice

A significant theoretic advantage was noted for CRRT over IHD

\[
\text{stdKt/V Gotch vs stdKt/V Leypoldt (b)} = 0.02109 + 0.97973 \times \text{stdKt/V Gotch} \\
r = 0.99978
\]
Use of Standard Kt/V for Comparison of Efficiency between Continuous Renal Replacement Therapies and Intermittent Hemodialysis in Acute Kidney Injury.

Rolando Claure-Del Granado, MD\textsuperscript{1}, Etienne Macedo, MD\textsuperscript{1}, Sharon Soroko, MS\textsuperscript{1}, Glenn M. Chertow, MD, MPH\textsuperscript{2}, Jonathan Himmelfarb, MD\textsuperscript{3}, T. Alp Ikizler, MD\textsuperscript{4}, Emil P. Paganini, MD\textsuperscript{5}, Ravindra L. Mehta, MD\textsuperscript{1}.

Program to Improve Care in Acute Renal Disease (PICARD) study

1,538 CRRT 24 hour sessions in 244 critically-ill patients with at least 48 hours on CRRT.

**CVVH, CVVHD, or CVVHDF**

- **CVVH postfilter dilution**
  
  \[
  Kt/V = QHF \times \frac{10.080}{(W \times 0.55)} \times S
  \]

- **CVVH prefiltter dilution**
  
  \[
  Kt/V = \frac{[Q_{in}\text{f} + Q_{out}\text{f}]}{Q_p + Q_{in}\text{f}} \times \frac{10.080}{(W \times 0.55)} \times S
  \]

- **CVVHD**
  
  \[
  Kt/V = \frac{Q_{dial} + Q_{in}\text{f}}{Q_p + Q_{in}\text{f}} \times \frac{10.080}{(W \times 0.55)} \times S
  \]

- **CVVHDF postfilter dilution**
  
  \[
  Kt/V = \frac{[Q_{in}\text{f} + Q_{dial} + Q_{out}\text{f}]}{Q_p + Q_{in}\text{f}} \times \frac{10.080}{(W \times 0.55)} \times S
  \]

- **CVVHDF prefiltter dilution**
  
  \[
  Kt/V = \frac{[Q_{in}\text{f} + Q_{dial} + Q_{out}\text{f}]}{Q_p \times (W \times 0.55)} \times 10.080
  \]

610 IHD sessions in 254 critically-ill patients.

\[
\text{stdKt/V} = 168 \times \frac{(1 - \exp[-Kt/V])}{Kt/V} \times \frac{1}{(1 - \exp[-Kt/V])} \times \frac{1}{(Kt/V) + 168/(N \times t) - 1}
\]

Relationship between urea volume of distribution, volume removal and StdKt/V

Dose in RRT: Key concepts

- Dose definition
- Quantifying dose
- Prescribed versus delivered
- Factors influencing clearance
- Practical Considerations
### Prescribed vs. Delivered

<table>
<thead>
<tr>
<th>Reference</th>
<th>Dialysis Modality</th>
<th>Prescribed</th>
<th>Delivered</th>
<th>% of Delivered Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evanson et al. 1998</td>
<td>IHD</td>
<td>Kt/V 1.25±0.47</td>
<td>Kt/V 1.04±0.49</td>
<td>83.5%</td>
</tr>
<tr>
<td>Evanson et al. 1999</td>
<td>IHD</td>
<td>Kt/V 1.11±0.32</td>
<td>spKt/V 0.9±0.33</td>
<td>86.4 – 75.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>eKt/V 0.8±0.28</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>dpKt/V 0.8±0.30</td>
<td></td>
</tr>
<tr>
<td>Venkataraman et al. 2002</td>
<td>CRRT</td>
<td>24.5±6.7 mL/Kg/h</td>
<td>16.6±5.4 mL/Kg/h</td>
<td>68%</td>
</tr>
<tr>
<td>Tolwani et al. 2008</td>
<td>CRRT</td>
<td>Standard 20 mL/Kg/h</td>
<td>17 mL/Kg/h</td>
<td>85%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High 35 mL/Kg/h</td>
<td>29 mL/Kg/h</td>
<td>82%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>27.1 mL/Kg/h</td>
<td></td>
</tr>
<tr>
<td>Vesconi 2009 et al.</td>
<td>CRRT</td>
<td>34.3 mL/Kg/h</td>
<td>27.1 mL/Kg/h</td>
<td>79%</td>
</tr>
</tbody>
</table>
Survey of 26 questions

7 questions for IHD and SLED that included:
- target dosage of therapy
- whether and how frequently delivered dose was assessed

9 questions for CRRT
- characterized dose mL/h vs. mL/kg/h
- no target dosage or assessment of delivered dose was evaluated.

Only 21% of practitioners assessed delivered dialysis dose (IHD).
< 20% of practitioners reported using weight-based dosing of CRRT.

Absence of a consistent standard for prescription and monitoring of RRT during AKI.

---

**Table 2. Management of IHD**

<table>
<thead>
<tr>
<th>Site</th>
<th>Respondents Using IHD</th>
<th>Treatment Frequency (%)</th>
<th>Median Treatment Duration (hr)</th>
<th>Median BFR (ml/min)</th>
<th>Monitoring of Delivered Dosage (No. of Practitioners)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2/wk</td>
<td>3/wk</td>
<td>Every Other Day</td>
<td>4/wk</td>
</tr>
<tr>
<td>VA sites</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>5</td>
<td>47.8</td>
<td>38.1</td>
<td>14.1</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>15.9</td>
<td>25.8</td>
<td>31.8</td>
<td>26.8</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>75.7</td>
<td>0.5</td>
<td>23.8</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>75.0</td>
<td>13.0</td>
<td>12.0</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>4</td>
<td>69.1</td>
<td>12.7</td>
<td>18.2</td>
<td></td>
</tr>
<tr>
<td>F^2</td>
<td>7</td>
<td>1.9</td>
<td>65.4</td>
<td>29.9</td>
<td>1.6</td>
</tr>
<tr>
<td>G</td>
<td>3</td>
<td>60.6</td>
<td>24.4</td>
<td>11.9</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>7</td>
<td>45.9</td>
<td>22.5</td>
<td>16.2</td>
<td>6.9</td>
</tr>
<tr>
<td>I</td>
<td>4</td>
<td>40.5</td>
<td>29.5</td>
<td>18.9</td>
<td>6.8</td>
</tr>
<tr>
<td>J</td>
<td>1</td>
<td>69.0</td>
<td>15.0</td>
<td>10.0</td>
<td>9.0</td>
</tr>
<tr>
<td>K</td>
<td>6</td>
<td>13.3</td>
<td>24.8</td>
<td>26.7</td>
<td>29.2</td>
</tr>
<tr>
<td>L</td>
<td>3</td>
<td>49.8</td>
<td>14.8</td>
<td>24.8</td>
<td>7.3</td>
</tr>
<tr>
<td>M</td>
<td>4</td>
<td>39.4</td>
<td>38.0</td>
<td>16.9</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>5</td>
<td>38.2</td>
<td>18.1</td>
<td>36.8</td>
<td>13.3</td>
</tr>
<tr>
<td>O</td>
<td>3</td>
<td>37.5</td>
<td>22.1</td>
<td>35.0</td>
<td>38.0</td>
</tr>
<tr>
<td>P</td>
<td>5</td>
<td>80.0</td>
<td></td>
<td>10.0</td>
<td></td>
</tr>
<tr>
<td>all VA</td>
<td>63</td>
<td>51.4</td>
<td>5.7</td>
<td>257.0</td>
<td>10.9</td>
</tr>
<tr>
<td>Non-VA sites</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td></td>
<td>88.9</td>
<td>11.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>4</td>
<td>56.8</td>
<td>12.7</td>
<td>13.7</td>
<td>6.7</td>
</tr>
<tr>
<td>S</td>
<td>6</td>
<td>72.2</td>
<td>2.8</td>
<td>23.1</td>
<td>18.4</td>
</tr>
<tr>
<td>T</td>
<td>7</td>
<td>23.1</td>
<td>2.5</td>
<td>34.4</td>
<td>15.0</td>
</tr>
<tr>
<td>U</td>
<td>13</td>
<td>16.5</td>
<td>11.6</td>
<td>35.2</td>
<td>8.0</td>
</tr>
<tr>
<td>V</td>
<td>5</td>
<td>81.5</td>
<td></td>
<td>14.8</td>
<td>3.7</td>
</tr>
<tr>
<td>W</td>
<td>11</td>
<td>77.2</td>
<td>1.8</td>
<td>13.8</td>
<td>3.9</td>
</tr>
<tr>
<td>all non-VA sites</td>
<td>46</td>
<td>47.8</td>
<td>8.3</td>
<td>367.0</td>
<td>6.8</td>
</tr>
<tr>
<td>Combined VA/non-VA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>7</td>
<td>12.9</td>
<td>2.2</td>
<td>17.9</td>
<td>41.2</td>
</tr>
<tr>
<td>Y</td>
<td>12</td>
<td>1.2</td>
<td>57.8</td>
<td>1.8</td>
<td>29.9</td>
</tr>
<tr>
<td>all combined</td>
<td>18</td>
<td>0.9</td>
<td>45.5</td>
<td>1.9</td>
<td>26.6</td>
</tr>
<tr>
<td>All sites</td>
<td>128</td>
<td>0.4</td>
<td>45.4</td>
<td>6.4</td>
<td>31.6</td>
</tr>
</tbody>
</table>

*BFR, blood flow rate; IHD, intermittent hemodialysis.

Site provided aggregate data for all practitioners.
Dose in RRT: Key concepts

- Dose definition
- Quantifying dose
- Prescribed versus delivered
- Factors influencing clearance
- Practical Considerations
Factors Influencing RRT Clearances in the ICU

- Patient factors
- Treatment factors
Patient Related Factors

- Generation of uremic toxins ($G$)
- Pool of uremic toxins ($V$)
Patient Related Factors

- Generation of uremic toxins (G)
  - Higher in general than for ESRD (nPCR often > 1.5 g/kg/day)
  - Variable

- Pool of uremic toxins (V)
Patient Related Factors

- Generation of uremic toxins ($G$)
- Pool of uremic toxins ($V$)
  - $V$ is higher in AKI compared to ESRD patients, often $>0.65\text{L/kg}$
  - $V$ does not equate to TBW in AKI as assessed BIA
  - $V$ is up to 50% or even 100% greater than anthropometrically calculated values

Patient Related Factors

- **Generation of uremic toxins (G)**

- **Pool of uremic toxins (V)**
  - Increased from $\text{Na}^+ / H_2O$ overload combined with loss of lean body mass during ARF and critical illness
  - Increased by a 20% $H_2O$ redistribution from intracellular to extracellular space in critical illness — *cellular dehydration*
  - $V$ is a *virtual* rather than literal anatomical parameter in critical illness

Factors influencing clearance:

- Effective treatment time
- Variable across days
- Protein catabolic rate

Treatment Related Factors

- Catheter
- Filter
- Compartmentalization
Treatment Related Factors

- Catheter
- Filter
- Compartmentalization
Pre-dilution CVVHDF
Filter 0.9 m² AN69
Anticoagulation LMW Heparin
Filter change each 72 hrs. or if clotted

Randomized
15 patients (46 treatments) PNT catheter
15 patients (46 treatments) ST catheter

Prescribed and delivered clearance was assessed

No difference in Qb

No difference in recirculation rate

ST catheters less catheter related thrombosis and infection

Klouche K et al. Am J Kidney Dis, 2007
Treatment Related Factors

- Catheter

- Filter
  - Down time due to *filter clotting* is the major reason for reduced RRT dose
  - *Concentration polarization* reduces ultrafiltration rate and the filtrate concentrations of various medium / large sized proteins
  - *Convection – Diffusion interactions*
  - *Pre-dilution* versus post-dilution

- Compartmentalization
Treatment Related Factors

Small solutes (Urea)  Plasma protein  Clotting

Prescribed K ≠ Delivered K

Data from 52 critically ill patients, AKI requiring dialysis (Pre-dilution CVVHDF)

Regional citrate anticoagulation.

Filter efficacy was assessed by calculating FUN/BUN ratios q12 hr.

Prescribed urea clearance (K, ml/min)
- Effluent volume rate = Qd (ml/min) + Qr (ml/min) + Qnet (ml/min)

K Estimated = Effluent volume adjusted for effective time of treatment

K delivered = FUN (mg/dl)/BUN (mg/dl)] x effluent volume rate (ml/min)

Claure-Del Granado et al. CJASN, 2011
Prescribed, Estimated, and Delivered Dose
Unadjusted and Adjusted for Pre-dilution

Claure-Del Granado et al. CJASN, 2011
# Reasons for Discontinuing CRRT and Filter Efficacy

## Table 3. Reasons for stopping CRRT

<table>
<thead>
<tr>
<th>Reasons</th>
<th>Number of Filters</th>
<th>Percentage (%)</th>
<th>FUN/BUN Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factors affecting treatment time without affecting filter function</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D/C for surgical procedures</td>
<td>10</td>
<td>6.3</td>
<td>0.93 (0.92 to 0.99)</td>
</tr>
<tr>
<td>D/C for medical procedures</td>
<td>9</td>
<td>5.7</td>
<td>1.0 (0.95 to 1)</td>
</tr>
<tr>
<td>Routine filter changes</td>
<td>16</td>
<td>10.1</td>
<td>0.95 (0.84 to 1.0)</td>
</tr>
<tr>
<td>Machine problems</td>
<td>8</td>
<td>5.0</td>
<td>0.97 (0.85 to 1.0)</td>
</tr>
<tr>
<td>Transition to IHD</td>
<td>17</td>
<td>10.7</td>
<td>0.96 (0.82 to 0.97)</td>
</tr>
<tr>
<td>Venous access clot</td>
<td>6</td>
<td>3.8</td>
<td>0.97 (0.96 to 0.98)</td>
</tr>
<tr>
<td>Physician decision</td>
<td>10</td>
<td>6.3</td>
<td>0.98 (0.94 to 1)</td>
</tr>
<tr>
<td>Patient or family decision</td>
<td>11</td>
<td>6.9</td>
<td>0.96 (0.94 to 1)</td>
</tr>
<tr>
<td>Patient recovery</td>
<td>6</td>
<td>3.8</td>
<td>0.95 (0.92 to 0.99)</td>
</tr>
<tr>
<td>Death</td>
<td>3</td>
<td>1.9</td>
<td>0.98 (0.87 to 1.0)</td>
</tr>
<tr>
<td>Access change</td>
<td>9</td>
<td>5.7</td>
<td>0.9 (0.87 to 0.95)</td>
</tr>
<tr>
<td>Factors affecting filter function</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filter clotted</td>
<td>41</td>
<td>25.8</td>
<td>0.89 (0.83 to 0.94)</td>
</tr>
<tr>
<td>Filter leak</td>
<td>1</td>
<td>0.63</td>
<td>0.745</td>
</tr>
<tr>
<td>Low-sieving concentration polarization</td>
<td>12</td>
<td>7.5</td>
<td>0.86 (0.79 to 1.0)</td>
</tr>
</tbody>
</table>

Claure-Del Granado et al. CJASN, 2011
Treatment Related Factors

- Catheter
- Filter
- Compartmentalization
A diffusion-adjusted regional blood flow model to predict solute kinetics during haemodialysis

Daniel Schneditz¹, Dieter Platzer² and John T. Daugirdas³
Dose in CRRT: Practical considerations

- Clearances should be measured as part of routine care delivery as estimated clearances do not equate delivered.

- Optimizing RRT clearances requires constant assessment and adjustment for operational characteristics and treatment factors.

- Delivered Dose is less than Prescribed and consequently prescribed dose should compensate for the anticipated reduction (approximately 15-25%).

- Solute Clearances are not the sole measure of dialysis adequacy. Fluid removal and fluid balance are equally if not more important parameters to be monitored.
Dialysis or Blood side Measurements for Dialysis Dose Determination in Continuous Renal Replacement Therapies?

Rolando Claure-Del Granado, MD\textsuperscript{1}, Etienne Macedo, MD\textsuperscript{1}, Sharon Soroko, MS\textsuperscript{1}, Glenn M. Chertow, MD, MPH\textsuperscript{2}, Jonathan Himmelfarb, MD\textsuperscript{3}, T. Alp Ikizler, MD\textsuperscript{4}, Emil P. Paganini, MD\textsuperscript{5}, Ravindra L Mehta, MD\textsuperscript{1}.

Program to Improve Care in Acute Renal Disease (PICARD) study

Prescribed, Estimated, and Delivered

Filter Efficacy and Delivered Dose
## Proposed parameters for Dose Assessment

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Measurement</th>
<th>Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solute</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very small</td>
<td>( K^+ ), ( Na^+ ), Phosphate ( H^- )</td>
<td>Blood levels of ( K^+ ), ( Na^+ ), ( PO_4 ) Phosphate clearance pH, ( HCO_3^- ), ( SID_{eff} ), ( SID_{app} ), SIG Delta gap, Delta ratio.</td>
</tr>
<tr>
<td>Small waste products</td>
<td>Urea</td>
<td>Clearance (mL/min) EKR (mL/min) StdKt/V</td>
</tr>
<tr>
<td>Middle sized molecules</td>
<td>Serum ( \beta_2 ) Microglobulin</td>
<td>Clearance</td>
</tr>
<tr>
<td>Fluid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td></td>
<td>Weight changes Fluid accumulation Fluid overload BIVA BNP profile</td>
</tr>
<tr>
<td>Inputs-Outputs BIA BNP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>