Intensive Care Unit Renal Support: In Search of New Directions

Balazs Szamosfalvi, MD
Monday, 08/30/2011 11:45-12:15
Presenter Disclosure Information

**I will** discuss off label (US/FDA) use and/or investigational use of citrate solutions for regional anticoagulation during renal replacement therapy in my presentation.

**I have** financial relationships to disclose:

**Employee of:** Henry Ford Health System, Detroit, MI
**Consultant for:** Baxter, Inc
**Stockholder in:**
**Research support from:** Fresenius-NA, Cytopherx, Inc (formerly Nephrion)
**Honoraria from:**
**Patent:** Automated RCA Systems
Objectives

1. Introduce ICU continuous renal replacement therapy (CRRT) equipment and terminology

2. Summarize current recommendations and future directions after the ATN and RENAL trials

3. Present our novel CRRT program integrating regional citrate anticoagulation (RCA) and 24-hour sustained low efficiency dialysis (SLED) with computerized prescription generation and internet-based telemetry
Select CRRT Machines in the USA

1. Gambro Prismaflex

2. Braun Diapact

3. NxStage System One
CRRT Machine: Basic Layout

- Blood Pump
- Filter Effluent Pump
- Replacement Fluid Warmer
- Replacement and/or Dialysis Fluid Pumps
- Heparin Syringe Pump
- Pressure Pod
- Scales x 2
CRRT Device in Europe

Fresenius Multifiltrate™ CRRT System — Integrated Citrate & Calcium Pumps
Continuous Renal Replacement Therapy (CRRT): Modalities

1. Continuous Arterio-Venous Hemofiltration: CAVH
   The earliest form of CRRT, it used arterial blood pressure to drive blood flow and ultrafiltration in the circuit

2. Continuous Veno-Venous Hemofiltration: CVVH
   It replaced CAVH with a blood pump added to the circuit;
   Pre-dilution CVVH: Replacement fluid infused pre-filter
   Post-dilution CVVH: Replacement fluid infused post-filter

3. Continuous Veno-Venous Hemodialysis: CVVHD
   Uses counter-current dialysis for solute removal; it is being replaced by less expensive sustained low efficiency dialysis (SLED) using online generated dialysis fluid

4. Continuous Veno-Venous Hemodiafiltration: CVVHDF
   The combination of CVVH and CVVHD on a single filter
RCA for 24-hour Post-Dilution CVVHDF

- Blood is Anticoagulated at this Point
- Anticoagulation Reversed Here
- Hemo-filter
- Data Screen
- Bicarbonate Post-Dilution and Dialysis Fluid 72 L/24h
- Dialysis fluid Pump
- Ultrafiltration Pump 78+ L/24h
- Blood Pump
- Hematocrit Sensor
- Post-Dilution Pump
- Citrate Infusion 5 L/24h
- Ca^{2+} Infusion 1 L/24h
- Vein Access Catheter
RCA for Simultaneous Pre- and Post-Dilution High Volume Hemofiltration for SIRS

- **Bicarbonate Pre-Dilution and Post-Dilution Fluid**: 80 L/10h
- **Post-Dilution Pump**: Data Screen
- **Hemofilter**: Blood Pump
- **Ultrafiltration Pump**: 85+ L/10h
- **Post-Dilution Pump**: Bicarbonate Pre-Dilution and Post-Dilution Fluid
- **Pre-Dilution Pump**: Ca^{2+} Infusion 1 L/10h
- **Blood Pump**: Citrate Infusion 4 L/10h
- **Vein Access Catheter**: Blood is Anticoagulated at this Point
- **Hematocrit Sensor**: Anticoagulation Reversed Here
- **Access Catheter**: Blood is Anticoagulated at this Point
1. Significance

- Large, randomized clinical outcomes study for intensity of CRTT and intermittent HD in acute renal failure
- Compared CRRT with 20 ml/kg/h versus 35 ml/kg/h filter effluent flow rate
- Compared intermittent HD 1.2-1.4 single-pool urea Kt/V per session 3x/week versus 6x/week

2. Conclusions

- “Intensive renal support in critically ill patients with acute kidney injury did not decrease mortality, improve recovery of kidney function, or reduce the rate of non-renal organ failure as compared with less-intensive therapy involving a defined dose of intermittent hemodialysis three times per week and continuous renal-replacement therapy at 20 ml per kilogram per hour.”

The RENAL Study (2009)

1. Significance

- Large, multicenter, randomized clinical study of the intensity of CRRT in acute kidney injury for 90-day mortality endpoint
- Compared CRRT with 25 ml/kg/hour versus 40 ml/kg/hour filter effluent flow rate

2. Conclusions¹

- “In critically ill patients with acute kidney injury, treatment with higher-intensity continuous renal-replacement therapy did not reduce mortality at 90 days.”

ICU Renal Support 2011

• Prescribe 25-30 ml/kg/h filter effluent rate
• 24-hour continuous therapy with early start
• Regional citrate anticoagulation\(^1,2\)
• (?) Plasma adsorption: protein-bound toxin, cytokine and endotoxin removal; liver support\(^3,4\)
• (?) Selective cytopheretic device: ameliorate severe inflammatory response syndrome\(^5\)
• (?) Online measured small solute clearance: for dosing of dialysis and medications

3. Cruz DN et al, Early Use of Polymyxin B Hemoperfusion...; JAMA. 2009;301(23):2445-2452
4. Intermittent Modular Plasma Adsorption of Cytokines and Toxins (IMPACT); Minntech Corp.
5. Humes HD et al, A Selective Cytopheretic Inhibitory Device... Blood Purif 2010;29:183-190
What is the biggest disadvantage of traditional CRRT?
1. Cumbersome despite improved machines:
   - Scale-based balancing of > 50 liters effluent
   - Frequent clotting complications
   - Cannot use fistula or graft access
2. Very expensive compared to dialysis:
   - Custom blood circuits and filters
   - Pre-packaged replacement fluid
   - Nurse time if 1:1 nurse: patient ratio is needed
3. Lack of consensus on best approach:
   - CVVH versus CVVHDF versus CVVHD
   - Optimal replacement fluid compositions
   - Optimal anticoagulation strategy
Principles of Our Near-Automated 24-hour SLED-RCA Protocol
Heparin versus Citrate

Scanning Electron Micrograph
Polysulfone Dialyzer Hollow Fiber

Heparin

Clotted Fiber

Citrate

Clean Fiber

# HFH Cost of 72 hours of CRRT ($)

<table>
<thead>
<tr>
<th></th>
<th>Traditional CRRT</th>
<th>24-hour SLED-RCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter &amp; Tubing</td>
<td>$300 (2 x $150)</td>
<td>$45 (1.5 x $30)</td>
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<tr>
<td>Fluid/Dialysate</td>
<td>$1000 (200L x $5)</td>
<td>$50</td>
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<tr>
<td>Citrate/Ca + Lab</td>
<td>$0</td>
<td>$150 (3 x $50)</td>
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<tr>
<td>Total Cost 72 h</td>
<td>$1300</td>
<td>$245</td>
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<td>Daily Savings</td>
<td>NA</td>
<td>≈ $350/day/pt</td>
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</table>

Savings due to alarm-free SLED-RCA with reduced CRRT technician and ICU nurse staffing costs are not considered
Dialysis with Automated RCA: QB 20-300 ml/min

1. SCD Device
2. Polymyxin B Column
3. Plasma adsorption

Optical Hematocrit and O₂ Saturation Sensor

Integrated Infusion Pumps With Air Detectors

Access Catheter

Optical Citrate and Calcium Sensor Array (0.1 mM accuracy)

To Drain

Effluent Analysis

Conductivity Sensors

Internal Balancing Chambers

Computer

Display

Dialyzer

Calcium Infusion

Citrate Infusion

Online Effluent
Citrate- and Calcium Sensor

**Citrate**

\[ y = 0.0219x + 0.2656 \]

\[ R^2 = 0.9990 \]

**Calcium**

\[ y = -0.0811x + 0.6052 \]

\[ R^2 = 0.9971 \]

New Dialyzer Designs Provide 24-hour SLED with the Middle-Molecule Transport Properties of CVVHDF
Middle-molecule clearance equal or greater in CVVHD than CVVH\(^2\)

1. Adapted from Depner T and Garred L: Solute transport mechanisms in dialysis; in Replacement of Renal Function by Dialysis, 5th edition; p85
ICU Extracorporeal Support 2011 → Future

- Near-automated RCA, reduced WBC, PLT and complement activation
- Ultrafiltration: blood volume and central venous $O_2$ saturation monitoring
- Biocompatibility: lower blood flow, ultrapure dialysate, no glucose degradation products

- Computerized SLED prescribing & telemetry monitoring
- Antibiotic dosing: according to online measured clearance
- Columns for removal of endotoxin, cytokines, inflammatory cells, protein-bound toxins
- FOCUS: EASE OF USE + LOW COST FOR EARLY START CRRT

OUTCOME:
- Improved Survival & Renal Recovery
- Reduced Complications & Cost
Citric Acid / Citrate
Fundamental Properties

- Only citrate$^{3-}$ in plasma
- Molecular weights:
  - Citrate$^{3-}$ 189 Da
  - Ca-Citrate$^{-}$ 229 Da
- No RBC entry
- Metabolized to $\text{HCO}_3^-$
- Anti-inflammatory: blocks WBC, PLT and complement activation

Crismon et al, J Appl Physiol 1961; 16(6):1103-1108
Citrate Effects on Plasma

- 90–95 % of Ca dialyzable
- $K_{Ca} = 0.95 \times K_{Citrate}$
- $K_{Ca} \approx D_{Mg}$
# Commercial Citrate Solutions

## ACD-A Solution

<table>
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<th>Component</th>
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<tr>
<td>Na⁺</td>
<td>225 mM</td>
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<tr>
<td>Citrate³⁻</td>
<td>75 mM</td>
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<tr>
<td>Citric acid</td>
<td>38 mM</td>
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<tr>
<td>Dextrose</td>
<td>124 mM</td>
</tr>
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</table>

**ACD-A — Acid**
- Used most often
- Provides acidic circuit pH
- Plasma ΔNa⁺ ≈ +3 mEq
- Plasma ΔHCO₃⁻ ≈ -3 mEq

## 4%-TSC Solution

<table>
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<th>concentration</th>
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<td>Na⁺</td>
<td>408 mM</td>
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<tr>
<td>Citrate³⁻</td>
<td>136 mM</td>
</tr>
<tr>
<td>Citric acid</td>
<td>0 mM</td>
</tr>
<tr>
<td>Dextrose</td>
<td>0 mM</td>
</tr>
</tbody>
</table>

**4%-TSC — Basic**
- Used rarely, briefly
- Acidemic patients (pH <7.1 or HCO₃⁻ <10)
- Plasma ΔNa⁺ ≈ +9 mEq
- Plasma ΔHCO₃⁻ ≈ 0 mEq

\[
Q_{cit} \text{ (ml/h)} = 2 \times QB \text{ (ml/min)} \text{ for 4%-TSC}
\]

\[
Q_{cit} \text{ (ml/h)} = 2.5 \times QB \text{ (ml/min)} \text{ for ACD-A}
\]

(Ex: \(QB \ 100 \text{ ml/min} \rightarrow Q_{cit} 200 \text{ ml/h if 4%-TSC is used}\)
“Truly Regional” Citrate Anticoagulation

- Calcium Infusion
  - iCa \approx 1.2 \text{ mM}
  - Cit: < 0.3 \text{ mM}
- Citrate Infusion
  - iCa < 0.2 \text{ mM}
  - Cit: < 0.3 \text{ mM}
- Calcium and Citrate Removal
  - \sim 98\% Removal of Calcium and Citrate!

- Dialyzer
  - Ca-free Dialysate
- Drain Circuit

Start RCA
- iCa < 0.2 \text{ mM}
- Cit: 7-10 \text{ mM}
End RCA
## Online-Generated Dialysate

<table>
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<th>Ion</th>
<th>Range (Min-Max)</th>
<th>Concentration</th>
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</thead>
<tbody>
<tr>
<td>Na⁺</td>
<td>140 (130-150)</td>
<td>mM</td>
</tr>
<tr>
<td>K⁺</td>
<td>1, 2, 3 or 4</td>
<td>mM</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>32 (20-40)</td>
<td>mM</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>0.5</td>
<td>mM</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>108</td>
<td>mM</td>
</tr>
<tr>
<td>Phosphate</td>
<td>1.0</td>
<td>mM</td>
</tr>
<tr>
<td>Acetate</td>
<td>4</td>
<td>mM</td>
</tr>
<tr>
<td>Dextrose</td>
<td>5.5</td>
<td>mM</td>
</tr>
</tbody>
</table>

- High Mg²⁺; IV Mg²⁺ supplementation not required
- Contains P; IV phosphate supplementation not required
Flexible Dialysate Na\(^+\)/HCO\(_3\)\(^-\) Selection

Dialysate Composition

- **TCD**: 13.7 ms/cm
- **K\(^+\)**: 4.0 mEq/l
- **Ca\(^++\)**: 0.0 mEq/l
- **Mg\(^++\)**: 1.0 mEq/l
- **Ac.**: 3.0 mEq/l
- **Dex.**: 99 mg/dl

**Base Na\(^+\)**: 138 mEq/l

**Bicarbonate**: 36 mEq/l

Conductivity Limits

- **Conductivity**: 13.4 mS/cm

Alarm Settings

- **Alarm Position**: 13.9
- **Alarm Width**: 12.9

SVS Profile: None
136 mM Calcium Solution

<table>
<thead>
<tr>
<th>For ACD-A or 4%-TSC</th>
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<tbody>
<tr>
<td>Ca$^{2+}$</td>
</tr>
<tr>
<td>Mg$^{2+}$</td>
</tr>
<tr>
<td>Na$^{+}$</td>
</tr>
<tr>
<td>Cl$^{-}$</td>
</tr>
</tbody>
</table>

- Ca$^{2+}$ infusion restores Ca$^{2+}$ mass balance
- Na$^{+}$ mass balance is restored by the dialysis fluid
- Dextrose mass balance set by dialysis fluid dextrose
- At QB of 200 ml/min, QCa = 100–140 (120) ml/hour
Albumin Defines Plasma Total Calcium Goal

More Albumin $\Rightarrow$ More Bound Ca $\Rightarrow$ More Ca Needed
Hematocrit Defines Circuit Plasma Flow

More red cells $\Rightarrow$ Less plasma $\Rightarrow$ Less Ca Needed
Optical Hematocrit Monitor

Online Optical Hemoglobin

Sup. Vena Cava O₂ Saturation

HCT 18.5
HGB 6.3
TIME 15:59

BV ▲ 13.8
SAT 76
## Ca-Infusion Rate for 24-h SLED (ml/hr)

Ca/Mg solution (10 gm CaCl2 + 2 gm MgCl2 in 0.5 L 0.9% saline)

<table>
<thead>
<tr>
<th>Hgb g/dL</th>
<th>ALB g/dL</th>
<th>6-6.9</th>
<th>7-7.9</th>
<th>8-8.9</th>
<th>9-9.9</th>
<th>10-10.9</th>
<th>11-11.9</th>
<th>12-12.9</th>
<th>13-13.9</th>
<th>14-14.9</th>
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<td>42</td>
<td>40</td>
<td>37</td>
<td>35</td>
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</table>

**Starting Value**

**New Value**

- **Ca** Infusion Rate for 24-h SLED (ml/hr)
Simple, Predictive Ca-Infusion Dosing

• The blood flow rate is fixed
• Hematocrit sensor determines plasma flow rate
• The systemic albumin level is known
• The Ca-infusion rate is easily calculated
SLED-RCA *in vitro* Testing

- Calcium Infusion
- Citrate Infusion
- Venous Post Calcium
- Venous Pre Calcium
- Arterial Pre Citrate
- Arterial Post Citrate

Blood Container 0.5 Liter

RCA Circuit Chemistry Data [n=6] Anhepatic Sham Dialysis

Hct 30% (repeated at Hct = 21-45%)

Safe SLED-RCA Operation

Obtain Patient Labs

Start RCA

Body Ca$^{2+}$ fluxes: less impact with large Kt/V

SLED only Normalizes Labs

Citrate Metabolism Irrelevant

Check Ca$^{2+}$, Na$^+$, HCO$_3^-$ (ABG)

Stable Patient Chemistry
24-hour SLED-RCA Program
Clinical Performance
Uniform 24-hour SLED-RCA Prescription

1. SLED Prescription with high-flux filter
   - QB = 60 ml/min
   - QD = 400 ml/min (Ca-free)
   - QCit = 150 ml/h (ACD-A) (fixed)
   - QCa = 30-50 ml/h (from table)
   - QNetUF = 0-500 ml/h
   - 24-hour (continuous)

2. Other Features w iHD mode 9h 59m
   - Online measured delivered dose of dialysis
   - Continuous online display of the hematocrit and central venous O₂ saturation
Blood Flow = 60 ml/min

High Flux Dialyzer

Hematocrit Chamber on Arterial Blood Line

SLED 24 hr.
Dialyzer after 43 hours

Dialyzer New
Low blood flow (60ml/min) allows the use of smaller access catheters
Catheter connections can only be reversed for low blood flow at these points.

Calcium IV always attached to **BLUE** return blood line.

Citrate IV always attached to **RED** intake blood line.
Systemic Ionized Calcium
Individual patients during 24-h SLED-RCA

Ionized Ca (mM)

Days of Therapy

13.5 Days of Citrate Anticoagulation

N = 269
Severe Liver Failure Patient
Treated with 24-hour SLED-RCA

INR 3-4 on FFP
Lactate 15-20 mM
Total Bilirubin 29 mg/dL

- Ca Ratio
  - Total / Ionized
- Total Ca
- Ionized Ca

Ca (mM)

Time (hours)

- $f(x) = -0.00683x + 2.29 \quad R^2 = 0.303$
- $f(x) = 0.00124x + 2.06 \quad R^2 = 0.293$
- $f(x) = 0.00334x + 0.905 \quad R^2 = 0.344$
Calcium infusion rate
Individual patients during 24-h SLED-RCA

Ca/Mg Infusion Rate (ml/hr)

Days of Therapy

N = 1638

Patient #
1
2
3
4
5
6
7
8
9
10
11

0 2 4 6 8 10 12 14
Online Dialyzer Clearance

QB = 60 ml/min:
Kecn = 45 to 55 ml/min
(≈effective urea clearance)

Gotch, FA; Panlilio, FM; Buyaki, RA; Wang, EX; Folden TI; Levin, NW. Mechanisms determining the ratio of conductivity clearance to urea clearance. Kidney International (2004) 66, SS3–SS24
Online Ionic Dialysance (Kecn)

Individual patients during 24-h SLED-RCA

KECN (ml/min)

N = 855

80% Recirculating Catheter

Patient #
1
2
3
4
5
6
7
8
9
10
11
Individual patient mean data and overall mean of treatment data recorded every hour during 24-hr SLED-RCA

<table>
<thead>
<tr>
<th>Patient #</th>
<th>Total Dialysis Time (hrs)</th>
<th>Total Dialysis Time (Days)</th>
<th>Hb (g/dL)</th>
<th>O2 Saturati (ml/hour)</th>
<th>Ca/Mg Infusion (ml/hour)</th>
<th>Hourly Net Fluid Removal (ml/hour)</th>
<th>Total Fluid Removed (Liters)</th>
<th>KECN (ml/min)</th>
<th>ICA (mM/L)</th>
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<td>Total Hrs/Days</td>
<td>1638  / 68.3</td>
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</table>
Summary 24-h SLED-RCA

1. Main Performance Features
   - SLED-RCA is easy to perform & safe
   - Online clearance measurement
   - Costs are very low

2. Additional Benefits
   - Hct and central venous $O_2$ saturation sensing
   - Small dialysis catheter with blood flow 60 ml/min
   - Ready to integrate second cartridge
Scaling Up SLED-RCA: “In The Cloud” Electronic Prescription Generation and Database Archival
Inpatient Rounding List

Search: Nephrology Rounding Results

<table>
<thead>
<tr>
<th>Name</th>
<th>Mrn</th>
<th>Date of Entry</th>
<th>Pri Res.</th>
<th>Room</th>
<th>Round Active</th>
<th>Reason</th>
<th>Update Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test1, Patient</td>
<td>11111111</td>
<td>07/02/2009</td>
<td>-</td>
<td>H201</td>
<td>Y</td>
<td>SLED-Ready, ARF: Order...</td>
<td>04/23/2010 14:54:53</td>
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<td>Patient Test</td>
<td>15184704</td>
<td>02/02/2009</td>
<td>-</td>
<td>H1000</td>
<td>Y</td>
<td>DAILY TEST...NEW</td>
<td>04/09/2010 10:03:04</td>
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<tr>
<td>Test, Patient 3</td>
<td>33345678</td>
<td>02/02/2009</td>
<td>-</td>
<td>H2100</td>
<td>Y</td>
<td>Order Form...NEW</td>
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</tr>
</tbody>
</table>

Copyright © 2010 Henry Ford Health System: Confidential Data: Signed SALINE HEMO CCVHDF CITRATE
**24 HR SLED WITH CITRATE ANTICOAGULATION ORDER/NOTE**

**ADD IPD DIALYSIS ORDER**

**Entry Date:** 10/27/2010 02:26:24 PM  
**User Log:** bszamos1: Add 10/27/10

<table>
<thead>
<tr>
<th>Treatment Type: 24 HOUR SLED WITH CITRATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Set machine in Hemodialysis Mode for 9 hours 59 minutes (Re-setup every 10 hours for continuous treatment)</td>
</tr>
</tbody>
</table>

**Contact Isolation:**
- NO
- YES Cause: [Blank]

**Fluid Flow Rates & Dialyzer**
- **Rexeed 15-SX FILTER**
- 60 Blood Flow (ml/min)
- 400 Dialysate Flow (ml/min)

**Dialysate Bath**
- Potassium: 2 mEq/L
- Calcium: 0 mEq/L
- Phosphorus: 3.2 mg/dL
- Sodium: 142 mEq/L
- Bicarbonate: 32 mEq/L

**Citrate Dextrose (ACD-A) at 150 ml/hr**

**136 mL Ca in 0.9% saline (10 gm CaCl₂ + 2 gm MgCl₂/500 mL)**

**Special Orders**
- Age: 69
- Sex: Male
- Height: 180 cm
- Weight: 90 kg

**Calculate Volume**
- Vol.: 45 L

**Ultrafiltration CALCULATOR**

- **Desired NET UltraFiltration Goal:** 200 ml/hr as tolerated
- **Effective NET UltraFiltration Goal:** 200 ml/hr

**TOTAL goal in 10 hours:** 3870 ml (Net goal + remove Citrate 1200 or 1500 + Ca/Mg ~400 ml infused in 10 hours)

**Dialysate temperature 36.5 C Sodium Program:** No

**Labs Date:** 10/26/2010

<table>
<thead>
<tr>
<th>Test</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>8.6 mg/dL</td>
</tr>
<tr>
<td>Ionized Calcium</td>
<td>1.12 mmol/L</td>
</tr>
<tr>
<td>Magnesium</td>
<td>2.1 mg/dL</td>
</tr>
<tr>
<td>Ionized Calcium</td>
<td>3.6 mg/dL</td>
</tr>
<tr>
<td>Na</td>
<td>137 mEq/L</td>
</tr>
<tr>
<td>K</td>
<td>4.3 mEq/L</td>
</tr>
<tr>
<td>Cl</td>
<td>105 mEq/L</td>
</tr>
<tr>
<td>PROTEIN</td>
<td>6.2 mg/dL</td>
</tr>
<tr>
<td>BUN</td>
<td>57 mg/dL</td>
</tr>
<tr>
<td>Cr</td>
<td>3 mg/dL</td>
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</table>

**TESTS & MEDICATIONS**

1. [Blank]
SUSTAINED LOW EFFICIENCY DIALYSIS (SLED) WITH REGIONAL CITRATE ANTICOAGULATION (RCA) ORDER/NOTE

Room Number: 1000c

Treatment Type: 24 HOUR SLED WITH CITRATE

☑ Set machine in Hemodialysis Mode for 9 hours 59 minutes (Re-setup every 10 hours for continuous treatment)

Isolation: ☑ NO ☐ YES Cause:

Citrate and Calcium infusion rates during RCA
☑ Citrate Dextrose (ACD-A) at 150 ml/hr
☑ Calcium/Magnesium (Ca/Mg) in 0.9% saline (10 gm CaCl₂ + 2 gm MgCl₂ /500 mL)

Ca/Mg Infusion RATE: 37 mL/Hour
(Select initial Ca/Mg infusion rate from 24-hour SLED-RCA Table 1. Adjust the Ca/Mg infusion rate per 24-hour RCA protocol.)

Ultrafiltration CALCULATION: UF RATE 387 ml/hr
Patient NET Goal PER HOUR 200 ml/hr (as tolerated)
TOTAL goal in 10 hours 3870 ml (Net goal + remove Citrate 1200 or 1500 ml + Ca/Mg ~400 ml infused in 10 hours)

Dialysate temperature 36.5 C Sodium Program: No
TESTS & MEDICATIONS
1.
2.
3.

Patient Evaluation: History:
80 y.o male status post CABG 10/12/2010; course complicated by HAP, VDRF and anuric AKI. CRRT was started 10/20/2010.

Exam: T : 36.5 BP: 100 / 50 HR: 110 RR: 18 W: 90 kg

Fluid Flow Rates & Dialyzer
FILTER: REXEED15-SX
BLOOD FLOW: 60 ml/min
DIALYSATE FLOW: 400 ml/min

Dialysate Bath
Potassium  ☐ 2 mEq/L ☑ 0 mEq/L
☐ 3 mEq/L
☐ 4 mEq/L Sodium: 142 mEq/L
Phosphorus ☐ 0 mg/dL ☑ 3.2 mg/dL
Bicarb: 32 mEq/L

Special Orders
Volume: 45 Liters
☑ 1. Document DELIVERED Kt/V
☑ 2. Document Average Kecn (Ionic dialysance)

Lab Date: 10/26/2010
Albumin: 2.6 g/dL
Calcium: 8.6 mg/dL
Magnesium: 2.1 mg/dL
Phosphorus: 3.6 mg/dL
Na: 137 mEq/L
K: 4.3 mEq/L
Cl: 105 mEq/L
Hepatitis BsAg : 10/25/2010 NEGATIVE
C.difficile toxin : 10/22/2010 NEGATIVE

Attending Physician Attestation:

1. Patient Seen on Dialysis Init: ____ hr: ____ min: ____
Scaling Up SLED-RCA: Treatment Telemetry and Database Archival
# Telemetry: Machine Status

![Telemetry Interface](image)

**Stations**

<table>
<thead>
<tr>
<th>Blood</th>
<th>Vitals</th>
<th>Dialysate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensed: ✓</td>
<td>Blood Pressure: 0/0</td>
<td>Flow Rate: 400</td>
</tr>
<tr>
<td>Flow Rate: 60.00</td>
<td>MAP: 0</td>
<td>Temp: 36.60</td>
</tr>
<tr>
<td>Volume: 235.00</td>
<td>Pulse: 0</td>
<td></td>
</tr>
</tbody>
</table>

**Pressure**

- Arterial: 4.00
- Venous: 34.00
- TMP: 97.00
- Conductivity: 13.50

**Ultrafiltration**

- Active: ✓
- Rate: 280
- Goal: 2,820
- Removed: 174

**BTM**

- Tart: 34.4
- Tven: 34.6
- Tbody: 0
- Engy: 0

**OLC**

- Keu: 0.00
- KTAV: 0.00
- Plasma Na: 0.00
- VSA: 0.00

**Alarms**

- Arterial: □
- Venous: □
- TMP: □
- BP: □
- Air: □
- Bl Alm: □
- Con Alm: □
- Temp: □

**Reading Date/Time:** 22-JUN-2010 15:09

**Remaining Time:** 562
# Telemetry: Flowsheet Data

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<th>Sys/Dia</th>
<th>MAP</th>
<th>Pls</th>
<th>BFL</th>
<th>Art</th>
<th>Ven</th>
<th>UFR</th>
<th>Cond</th>
<th>Tart</th>
<th>Tven</th>
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16:27 NAME ON DIALYZER (Y / N)=n
16:27 VERIFY DISINFECTION (Y / N)=y
16:27 STRILANT NEG. (Y / N)=y
16:27 VEN.LINE DETECTOR ARMED (Y / N)=y

PATIENT, TEST 1(UNIT) / 1

Exit
# 24-hr SLED-RCA is CRRT and More!

<table>
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<th>Feature</th>
<th>24-hr SLED-RCA</th>
<th>Traditional CRRT</th>
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<tr>
<td>Continuous</td>
<td>Yes; QB = 60 ml/min</td>
<td>Yes; QB ≥ 100 ml/min</td>
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<tr>
<td>Clearance</td>
<td>3 L/hr (fixed)</td>
<td>1-4 L/hr</td>
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<tr>
<td>Convection</td>
<td>≈ 10-30% (hidden)</td>
<td>0-100%</td>
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<tr>
<td>Automated RCA</td>
<td>Coming soon!</td>
<td>Not Implemented</td>
</tr>
<tr>
<td>Online Clearance</td>
<td>Standard</td>
<td>Not Available</td>
</tr>
<tr>
<td>Telemetry</td>
<td>Available</td>
<td>Available Soon?</td>
</tr>
<tr>
<td>Diagnostic Use Of CRRT</td>
<td>Hct sensing; VO₂ saturation</td>
<td>Not Implemented</td>
</tr>
</tbody>
</table>
HFH “Citrate Group”

- Balazs Szamosfalvi, MD
- Stanley Frinak, MSEE
- Jerry Yee, MD
- Tom Lubkowskki
- Gary Zasuwa
- CRRT Technician Team
- ICU Teams
- Greenfield Health System