COI

David Askenazi M.D.
• Speaker for AKI foundation

Geoffrey Fleming M.D.
• None

Amelia Allsteadt RN
• None
Overview

• Prescribing CRRT for Neonates – David
• Blood Prime for Neonatal CRRT - Amelia
• Infant with Hyperammonmonemia - Geoffrey
• CRRT and ECMO - Geoffrey and Amelia
• Future of CRRT in neonates - David
Case #1

- 2 week old term newborn HPI: Perinatal asphyxia associated with placental abruption and chorioamnionitis
- Na 132 mEq/L, K 5.1 mEq/L, HCO3⁻ 28 mEq/L, BUN 40 mg/dL, SCr 1.8 mg/dL
- UOP 0.3 to 0.5 ml/kg/hr
- Currently on ½ volume feedings with breast milk with ½ volume TPN
Case 1 Questions

• Does this patient have AKI?
• What was/is the etiology of AKI?
• What else would you want to know about this infant?
## Neonatal AKI Definition

<table>
<thead>
<tr>
<th>Stage</th>
<th>Serum Creatinine Criteria</th>
<th>UOP criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SCr rise by $\geq 0.3$ mg/dl w/in 48hrs or SCr rise by $\geq 1.5$ to $1.9 \times$ reference SCr within 7 days</td>
<td>UOP $&gt; 0.5$ cc/kg/hr and $\leq 1$ cc/kg/hr</td>
</tr>
<tr>
<td>2</td>
<td>SCr rise $\geq 2$ to $2.9 \times$ reference SCr</td>
<td>UOP $&gt; 0.1$ cc/kg/hr and $\leq 0.5$ cc/kg/hr</td>
</tr>
<tr>
<td>3</td>
<td>SCr rise $\geq 2$ to $2.9 \times$ reference SCr</td>
<td>UOP $\leq 0.1$ cc/kg/hr</td>
</tr>
<tr>
<td></td>
<td>SCr $\geq 2.5$ mg/dl or Receipt of dialysis</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Baseline SCr will be defined as the lowest previous SCr value</strong></td>
<td></td>
</tr>
</tbody>
</table>
Neonatal AKI

- Premature Neonate
- Infant with Perinatal Asphyxia
- Cardiopulmonary Bypass
- Sick Infant in NICU
- ECMO

What are the outcomes in those with AKI?

How often does it happen?

Risk Factors For Neonatal AKI?
# Neonatal AKI Incidence

<table>
<thead>
<tr>
<th>Population</th>
<th>Incidence</th>
<th>Mortality AKI v no AKI</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLBW</td>
<td>18%</td>
<td>55% vs. 5%</td>
<td>1</td>
</tr>
<tr>
<td>ELBW</td>
<td>12.5%</td>
<td>70% vs. 22%</td>
<td>2</td>
</tr>
<tr>
<td>Sick near term/term</td>
<td>18%</td>
<td>22% vs. 0%</td>
<td>3</td>
</tr>
<tr>
<td>Asphyxiated Newborn</td>
<td>38%</td>
<td>14% vs. 2%</td>
<td>4</td>
</tr>
<tr>
<td>CPB</td>
<td>25% - 62%</td>
<td>10% - 25% vs. 2% - 8%</td>
<td>5, 6, 7, 8</td>
</tr>
<tr>
<td>ECMO</td>
<td>54% at initiation</td>
<td>Outcomes in those with AKI not good... CRRT and PAS meeting...</td>
<td></td>
</tr>
</tbody>
</table>
References

1 Koralkar, Askenazi et al... Pediatric Research 2010
2 Viswanathan et al. Ped Nephrology 2012
3 Askenazi et. al. Pediatric Nephrology Dec 2012
6 Alabbaas A et al.. Pediatric Nephrology March 2013
7 Krawczeski CD et. al. Journal of Pediatrics (158) 6; June 2011
9 Fleming et al. CRRT Abstract 2014
Smaller children in ppCRRT have lower survival

Small children are dialyzed differently!

<table>
<thead>
<tr>
<th></th>
<th>≤ 5kg</th>
<th>&gt; 5kg</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N</strong></td>
<td>N = 170</td>
<td>N = 251</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Anticoagulation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protocol</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Citrate</td>
<td>76 (45%)</td>
<td>155 (62%)</td>
<td></td>
</tr>
<tr>
<td>Heparin</td>
<td>94 (55%)</td>
<td>96 (38%)</td>
<td></td>
</tr>
<tr>
<td><strong>Prime</strong></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Blood</td>
<td>164 (96.5%)</td>
<td>202 (80%)</td>
<td></td>
</tr>
<tr>
<td>Saline</td>
<td>5 (3%)</td>
<td>29 (12%)</td>
<td></td>
</tr>
<tr>
<td>Albumin</td>
<td>1 (0.5%)</td>
<td>20 (8%)</td>
<td></td>
</tr>
<tr>
<td><strong>Blood Flow</strong> *</td>
<td>12 (7.9-15.6)</td>
<td>6.6 (4.8-8.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>(ml/kg/min)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Daily Effluent Volume</strong> *</td>
<td>3328 (2325-4745)</td>
<td>2321 (1614-2895)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>(ml/hr/1.73m²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Circuit Life</strong></td>
<td>28 (11-67)</td>
<td>37 (16-67)</td>
<td>0.15</td>
</tr>
</tbody>
</table>

## CRRT Outcomes in Newborns

<table>
<thead>
<tr>
<th>Underlying Diagnosis</th>
<th>Survival (%) (n=84)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renal disease (n=5)</td>
<td>80%</td>
</tr>
<tr>
<td>Inborn error of Metabolism (n=13)</td>
<td>62%</td>
</tr>
<tr>
<td>Pulmonary disease (n=5)</td>
<td>60%</td>
</tr>
<tr>
<td>Oncologic disease (n=6)</td>
<td>50%</td>
</tr>
<tr>
<td>Cardiac disease (n=16)</td>
<td>38%</td>
</tr>
<tr>
<td>Sepsis (n=25)</td>
<td>36%</td>
</tr>
<tr>
<td>Hepatic disease (n=9)</td>
<td>0%</td>
</tr>
<tr>
<td>Other (n=5)</td>
<td>75%</td>
</tr>
</tbody>
</table>

#### Total cohort (n=84)

- If > 10kg = 64%

- Highest survival in:
  - Primary renal diseases
  - Inborn errors

- Lowest Survival in:
  - Liver failure
  - Sepsis
  - Cardiac disease

---

Case #1 Update

• The infant you have been following is now nearly 3 weeks old and the Serum Creatinine is now 3.2 mg/dL
• He has developed ~20% fluid overload with feeds/TPN and low UOP
• His electrolytes are now more problematic with Na 130, K 5.5, Phos 7.5 mg/dL
Case #1 Update

• Should you institute RST?
• What mode?
• IF CRRT, then what access?
• How do you perform the therapy?
Renal Support Options

• Hemodialysis, Peritoneal Dialysis, CRRT
  – Each has advantages & disadvantages
  – Choice is guided by
    • Patient Characteristics
      – Disease/Symptoms
      – Hemodynamic stability
    • Goals of therapy
      – Fluid removal
      – Electrolyte correction
      – Toxin removal
    • Availability, expertise and cost
    • ESRD? Toxin removal? AKI with likely recovery?
CRRT in babies

• Smallest infant in ppCRRT registry = 1.3 kg
Prescribing CRRT for small infants

- Prescription of CRRT for pediatric patients
  - Vascular access
  - Blood Prime
  - Blood flow rates
  - Fluids (CVVH vs. CVVHD vs. CVVHDF)
  - Ultrafiltration goals
  - Anticoagulation
  - Filter options
Neonatal CRRT Access

• Access size is Key to success
  – Frequent clotting and circuit down time is time without therapy

• Vessel size
  – French ~ 3 x diameter of vessel in mm
  – Beside ultrasound nearly universally available
  – SVC is bigger than femoral vein

• Low resistance
  – Resistance ~ $8\eta/2r^4$
  – So, the biggest and shortest catheter should be best
Access Considerations

• Internal Jugular
  – Very accessible
  – Large caliber (SVC)
  – Great flows
  – Low recirculation rate
  – Risk for Pneumothorax
  – Cardiac monitoring may take precedence.

• Femoral
  – Usually accessible
  – Smaller than SVC
  – Flows may be diminished by:
    • Abdominal Pressures
    • Patient movement
  – Risk for retroperitoneal hemorrhage
  – Higher recirculation rate

• Subclavian: Many feel current double lumen vas cath are too stiff to make the turn into the SVC and I don’t personally use them. Although they are used in some centers.
• Better for bigger kids likely.
Practical anatomic landmarks for determining the insertion depth of central venous catheter in paediatric patients

H. S. Na¹, J. T. Kim²*, H. S. Kim², J. H. Bahk², C. S. Kim² and S. D. Kim²

• For the IJ position
• (I to A) + (A to B) – 0.5cm
• Requires CXR confirmation

Fig 1 Method for determining the insertion depth of CVC. Two points are marked on the patient’s skin during the IJV catheterization. Point A is marked at the sternal head of the right clavicle, most prominent point. Point B is marked at the midpoint of the perpendicular line from Point A to the line connecting both nipples. Point I is the insertion point of the needle. Distance from Point I to Point A and from Point A to Point B is measured. The depth of CVC is determined by adding the two measurements and subtracting 0.5 cm from this.
In patients with cardiac lesions
- concerns re upper vessels needed for future heart transplant
- Femoral vessels may not be big enough for an 8F DLC
  - Risk for clots
  - Risk for future inability to perform catheterizations

Reported on 6 babies
- PD failed
- All had 2 single lumen catheters
  - Most ran for over 60 hours....
  - Average circuit life 55.2 hr (double circuit life for infants < 5 kg in ppCRRT registry)
CRRT Prescription

• Qb
  – Need a minimum of 30-50 ml/min
    • Some equipment will not allow Qb below 50 ml/min
CRRT Prescription

• Clearance
• Mode
  – No proven benefit of convection vs diffusion for small molecules
  – Some improved clearance of “middle molecules” in convection
  – Many may chose to use both in CVVHDF mode
  – It appears that > 20ml/kg/hr is beneficial, but no further proven dose response
  – For IEM, however, this may be pushed up dramatically to achieve rapid detoxification
  – Clearance is often more than adequate and needs attention to details such as
    • Phos, Medications, Protein Loss
  – When using citrate anticoagulation – remember that clearance of citrate is necessary for a given blood flow – thus many neonates end up on tons of clearance.
Neonatal CRRT: The Filter

- Depending upon equipment used different filters available.
  - We will not endorse specific products.
- Some of the smaller filters/filter sets have been associated with significant hemodynamic reactivity at initiation.
- Using larger filters/filter sets will increase risk of complications with blood priming circuits...
Circuit Priming for Neonatal CRRT
WHAT IS BLOOD PRIME?

- A METHOD OF REPLACING THE PRIME SALINE IN THE DISPOSABLE TUBING SET WITH DONOR RED CELLS
WHY CONSIDER A BLOOD PRIME?

• Changes in blood volume and reduction in circulating red cell mass during a procedure may be poorly tolerated by the patient. Adding Blood Prime can help maintain the patient’s hemodynamic stability
When Should a Blood Prime Be Considered?

- ECV: \( \geq 10\% \) of TBV
- Extracorporeal RBC volume:
  
  “If the drop of original RBC volume is greater than 30\% or the patient is hemodynamically unstable, anemic, or at risk of organ ischemia.”

TBV Calculation

• TBV Calculation Examples

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Neonates</td>
<td>100 mL/kg</td>
</tr>
<tr>
<td>Infants and small children</td>
<td>80 mL/kg</td>
</tr>
<tr>
<td>Older children and adults</td>
<td>70 mL/kg</td>
</tr>
</tbody>
</table>

Note: MD or center protocol determines which TBV calculation to use.
EXTRACORPOREAL VOLUME (ECV)

Calculate ECV as the % of patient’s total blood volume (TBV)

If pt wt >10 kg, estimate TBV 70 ml/kg

\[
ECV\% = \frac{ECV \text{ (ml)}}{Wt \text{ (kg)} \times 70 \text{ (ml/kg)}} \times 100
\]

If pt wt < 10 kg, estimate TBV 80 ml/kg

\[
ECV\% = \frac{ECV \text{ (ml)}}{Wt \text{ (kg)} \times 70 \text{ (ml/kg)}} \times 100
\]

If using CRRT inline with ECMO, include the ECMO circuit volume as part of the patient’s total blood volume

\[
ECV\% = \frac{ECV \text{ (ml)}}{[Wt \text{ (kg)} \times 70 \text{ (ml/kg)}] + ECMO \text{ volume (ml)}} \times 100
\]
Blood Prime Considerations

• When calculating the ECV, aside from the volume in the disposable tubing set, consider the volume of blood samples drawn and the ECV of any additional inline devices (blood warmers).
Added Risk for PRBC prime

- Packed RBCs
  - HYPOCALCEMIC
    - Citrate
  - HYPERKALEMIC
    - LYSIS OF CELLS
  - ACIDIC

- There are no Plts in packed pRBC’s
  - Every prime you start CRRT you should expect for your plts count to drop
  - Example:
    - 4 kg infant (BV = 80 * kg = 320)
    - HF 1000 (ECV = 160)
    - Expect a drop in plts of 33%

- There are no coagulation factors in pRBC’s
  - Every prime you start CRRT you should expect for your coagulation factor to drop.
Added Risk for PRBC prime

- Anticipate the need for plts, ffp for those with high ECV
- Protocols for initiation of CRRT use need to keep in mind that blood is acidotic (pH 7.0) and hypocalcemic (iCa around 0.3)
  - Reconstitute the blood – like ECMO folks do and use it to prime
  - Dialyze the Blood before you start
  - Incorporate bicarbonate and calcium
  - Just do it and be ready to give calcium and bicarbonate
  - If you have a circuit running and need to change – USE THE BLOOD in the current circuit for the second circuit
Blood Prime Diagram

Patient blood lines connected after blood prime complete

Courtesy of Dr. Riley
How to Blood Prime in 10 Easy Steps

- Initiate CRRT without connecting patient as follows:
  1. Attach access line to PRBC bag via 3 way stopcock or recirculator
  2. Attach return line to saline prime waste bag (not the effluent bag)
  3. Start Qdial at 2000 mL/hr
  4. Start blood pump flow rate at 30 mL/hr
  5. Start with patient fluid removal rate at 0 ml/hr
  6. Once circuit is completely primed, change the Qdial to prescribed flow rate, connect the patient, and restart circuit
  7. Initiate ACD-A and CaCl2 regional anticoagulation at prescribed rates
  8. Increase blood pump rate gradually to prescribed rate
  9. Start replacement fluids (PBP, post filter) and patient fluid removal (UFR) at prescribed rates
  10. Send STAT patient and circuit iCa levels
Blood Prime

PRBC

10 ml / min

NaHCO3

10 ml / min

Calcium Gluconate

GO

Blood Flow = 20 ml / min

Waste NS Bag

Brophy et al. AJKD 2001
blood prime

PRBC -> NaHCO3

Waste NS Bag

Brophy et al. AJKD 2001
Blood Prime

Brophy et al. AJKD 2001
Blood Prime: Rinseback

- DO NOT RINSEBACK to maintain the patient in an isovolemic state and in cellular equilibrium, unless specified by MD
Case 2

• 2.8 kg infant male born at term who presents on DOL 4 to an outside hospital with lethargy and cardiovascular collapse.

• He is resuscitated with 60/kg normal saline and placed on dopamine for hypotension.

• His serum ammonia is 800 umol/L

• Serum Creatinine is 1.5 mg/dL
Case 2

- What threshold of ammonia level to start RST?
- What is the goal for ammonia clearance?
- What is the best method for achieving this goal?
- When a baby is on RST for hyperammonemia what should you do with the Sodium Benzoate and Sodium phenylacetate? (Ammonul®)
Inborn Errors of Metabolism (IEM)

• Most common indication for RST is Hyperammonemia
  – Urea Cycle Defects
  – Organic Acidemias

• Duration of hyperammonemia associated with neurodevelopmental outcome

• Goal is rapid detoxification
  – Get level below 200 umol/L
Toxin (NH4) Removal Procedures

• Extracorporeal therapies
  – Peritoneal dialysis
  – CRRT
  – Hemodialysis

• Current recommendations:
  – Bring down ammonia as quickly as possible
  – Keep it there until you get metabolic control
Original Article

Dialysis in neonates with inborn errors of metabolism

Franz Schaefer, Emine Straube, Jun Oh, Otto Mehls and Ertan Mayatepek

Results. Plasma ammonia or leucine levels were reduced by 50% within $7.1 \pm 4.1$ h by CVVHD and within $17.9 \pm 12.4$ h by PD ($P < 0.05$). Also, total dialysis time was shorter with CVVHD ($25 \pm 21$ h) than with PD ($73 \pm 35$ h, $P < 0.02$). A comparison of the CVVHD results with published literature confirmed superior metabolite removal compared to PD, and
CRRT vs IHD for IEM

• IHD has been a standard for some time.
  – Rapid detoxification due to high Qb and Qd
  – Problems
    • Hemodynamic stability
    • Small infant
    • Rebound after cessation

• CRRT has gained popularity
  – Detoxification can be as rapid if clearances increased
Nonrenal indications for continuous renal replacement therapy: A report from the Prospective Pediatric Continuous Renal Replacement Therapy Registry Group

Geoffrey M. Fleming, MD; Scott Walters, MD; Stuart L. Goldstein, MD; Steven R. Alexander, MD; Michelle A. Baum, MD; Douglas L. Blowey, MD; Timothy E. Bunchman, MD; Annabelle N. Chua, MD; Sarah A. Fletcher, MS; Francisco X. Flores, MD; James D. Fortenberry, MD; Richard Hackbarth, MD; Kevin McBryde, MD; Michael J. G. Somers, MD; Jordan M. Symons, MD; Patrick D. Brophy, MD

Table 2. Patient- and therapy-specific variables by subgroup and outcome

<table>
<thead>
<tr>
<th>Variable</th>
<th>Survivors</th>
<th>Nonsurvivors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inborn Errors of Metabolism</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survival</td>
<td>62% (n = 13)</td>
<td>38% (n = 8)</td>
</tr>
<tr>
<td>Dose delivered [IQR]</td>
<td>3140*</td>
<td>3659*</td>
</tr>
<tr>
<td>Continuous venovenous hemofiltration</td>
<td>8%</td>
<td>25%</td>
</tr>
<tr>
<td>Continuous venovenous hemodialysis</td>
<td>54%</td>
<td>50%</td>
</tr>
<tr>
<td>Continuous venovenous hemodiafiltration</td>
<td>38%</td>
<td>25%</td>
</tr>
<tr>
<td>Prior intermittent hemodialysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>69%</td>
<td>75%</td>
</tr>
<tr>
<td>Yes</td>
<td>31%</td>
<td>25%</td>
</tr>
<tr>
<td>Fluid overload at initiation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;10%</td>
<td>54%</td>
<td>0%</td>
</tr>
<tr>
<td>≥10%</td>
<td>46%</td>
<td>100%</td>
</tr>
</tbody>
</table>

- 21 infants with IEM
- Clearance was all > 2000 ml/1.73m²/min
- Prior IHD did not affect outcome
- 100% of the non-survivors were > 10% FO
High-dose continuous renal replacement therapy for neonatal hyperammonemia

Joann M. Spinale · Benjamin L. Laskin · Neal Sondheimer · Sarah J. Swartz · Stuart L. Goldstein

<table>
<thead>
<tr>
<th>Case 1</th>
<th>Case 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (hours)</td>
<td>Ammonia level (µmol/L)</td>
</tr>
<tr>
<td>0</td>
<td>1454</td>
</tr>
<tr>
<td>2</td>
<td>367</td>
</tr>
<tr>
<td>4</td>
<td>227</td>
</tr>
<tr>
<td>6</td>
<td>178</td>
</tr>
<tr>
<td>8</td>
<td>118</td>
</tr>
<tr>
<td>10</td>
<td>92</td>
</tr>
</tbody>
</table>

Case 1: (8,650 mL/h/1.73 m²).

Case 2*: (7,700 mL/h/1.73 m²).
Phenylacetate and benzoate clearance in a hyperammononemic infant on sequential hemodialysis and hemofiltration

Timothy E. Bunchman · Gina-Marie Barletta · John W. Winters · John J. Gardner · Teri L. Crumb · Kevin D. McBryde

Table 1 Ammonia and metabolic clearance on hemodialysis (HD) and hemofiltration (HF) at the time of analysis

<table>
<thead>
<tr>
<th></th>
<th>Ammonia (µmol/l)</th>
<th>Sodium phenylacetate (µmol/l)</th>
<th>Sodium benzoate (µmol/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD: Prefilter</td>
<td>369</td>
<td>1,260</td>
<td>1,310</td>
</tr>
<tr>
<td>HD: Postfilter</td>
<td>71</td>
<td>571</td>
<td>614</td>
</tr>
<tr>
<td>HF: Prefilter</td>
<td>161</td>
<td>673</td>
<td>526</td>
</tr>
<tr>
<td>HF: Postfilter</td>
<td>73</td>
<td>349</td>
<td>278</td>
</tr>
</tbody>
</table>

- NaPheynylacetate and NaBenzoate are cleared
- However Plasma levels may remain sufficiently elevated to provide further NH4 management
Case 3

- Neonate born at 38 weeks gestation via C/S
- Pre-natal diagnosis of congenital diaphragmatic hernia
- Cannulated onto ECMO on DOL 1 because of severe hypoxic respiratory failure and pulmonary hypoplasia
- Scr is 1.5 on DOL 2 and rising with low UOP and increasing fluid overload
Neonatal CRRT and ECMO

- Who does some form of renal clearance on ECMO?
  - What do you do?
  - How do you do it?
Neonatal CRRT and ECMO

• An old concept
  – Early days of ECMO included a hemodiafilter in-line to provide clearance.

• Two main methods
  – In-line hemodiafilter
  – Using a standard CRRT machine connected to the circuit
In-Line Hemodiafilter

- Shunt off main filter
  - Post Pump Inlet
  - Pre pump Outlet
- Unregulated Qb
- High TMP
  - High potential Quf
- Quf Regulation
  - Using IV pumps
- CVVHD reported in this set up

Renal Replacement Therapy in Critically Ill Patients Receiving Extracorporeal Membrane Oxygenation

David J. Andrus, 
David T. Sadowski, 
Matthew L. Rubin, 
David S. Cooper, 
Brian G. Bridges, 
Michael Zappella, 
and Geoffrey A.M. Herrington

CRRT Machine + ECMO

• Connection will depend upon ECMO pump
  – Centrifugal preferably post pump
  – Roller Head can be pre or post pump

• Very Positive access pressures may require changing alarm profile in the machine to work

![Diagram of CRRT device within ECMO circuit](image)

**Fig. 3.** Schematic of the inclusion of a CRRT device into an ECMO circuit with a centrifugal pump. Reprinted with permission from Santiago et al. [63].

The use of continuous renal replacement therapy in series with extracorporeal membrane oxygenation

Maria J. Santiago, Amelia Sánchez, Jesús López-Herce, Rosario Pérez, Jimena del Castillo, Javier Urbano, and Angel Carrillo

*Kidney International* (2009) 76, 1289–1292
Future of CRRT in neonates

Toilet of the Future
What we are doing here......? 4 kg infant

- Blood volume = 80 * kg ≈ 320 ml
- Blood flow = 50 ml/min = (12 ml/kg)
- Clearance flow rates = 3500 ml/1.73m²/hr = 400 ml/hr
- System – HF 1000
  - BSA 1.1 m² (5 times infant’s BSA)
  - Extracorporeal volume (ECV) = 165 ml
- % ECV = 165/320 ≈ 50%
What if we did that to me ...... 70 kg

- Blood volume = 70 * kg ≈ 5000 ml = 5 L
- Blood flow = 840 ml/min = (12 ml/kg)
- Clearance flow rates 7000 ml/hr = 100/kg/hr
- System MEGA-25,000
  - BSA 8.6 m2 (5 times BSA)
  - Extracorporeal volume (ECV) = 2.5 L
- % ECV = 2.5 L / 5 L ≈ 50%
We must then acknowledge

• Its amazing we do CRRT in babies....
• Even with the best practices....this approach exposes the smallest children to added risk

Benefit ≠ RISK

Benefit

RISK
We must then acknowledge

• Its amazing we do CRRT in babies....
• Even with the best practices....this approach exposes the smallest children to added risk
• You have reason to be nervous...
• What about the 1-2 kg baby?
  Do we just ignore him/her....?
• If we believe that critically ill patients do better with renal support...we must strive to do better?
How do we improve our ability to support neonates with AKI?

- Timing of RST?
- Type of RST?
- How do we prime circuit?
- Current technology not designed for neonates
  - Should we be doing superdialysis?
  - Do we have alternatives?
Let's use a new filter....

• HF-20 filter (0.2m² surface area)
  – Optimized tubing diameters for improved hemodynamic properties

• Currently Available in Europe

• United States
  – Pre-clinical FDA approval (Dec 2013)
  – Study begins in Summer 2014
Lets use a new machine...

- CARPEDIEM: Ronco 2012
- About 10 kiddos in Europe
  - Smallest 1.1 kg
- Dedicated rather than adapted machine
- 3 sets:
  - 27.2, 33.5, 41.5 ml ECV

Courtesy and communication from Stefano Picca MD.
Adapt a smaller filter?

- HF-20 filter (0.2m² surface area)
  - Optimized tubing diameters for improved hemodynamic properties
- Currently Available in Europe
- United States
  - Study begins in 2015
Let's use a new machine...

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Courtesy and communication from Stefano Picca MD.
Newcastle Infant Dialysis and Ultrafiltration System (NIDUS)

Coulthard et al. Pediatric Nephrology 2014 29 (1873-1881)
Newcastle Infant Dialysis and Ultrafiltration System (NIDUS)

• Novel system
  – Single Catheter
  – 9 cc extracorporeal volume
  – Driven by syringes and uncoupled the babys blood flow capacity from requirement of dialysis filter

• Promising results
  – Improved clearance in piglets (compared to PD)
  – Description of 10 babies
The Aquadex™ Pureflow

- FDA approved for adults with Heart failure – resistant to diuretics
- Tubing and filter make up about 30 ml
  - Smaller vascular lines
  - Portable
  - Less complexity, risk, and nursing time
Let's adapt a machine

- **Aquadex** –
  - FDA -- 2007
  - Indication
    - fluid overload not responsive to diuretics
  - 33 cc circuit volume
  - HCT line optional
Let’s adapt a machine

Figure 2: Pre-Filter CVVH
Children’s of Alabama (Abstract CRRT 2015)

- 10 subjects (5 UF; 5 CVVH)
- 51 circuits
- No drops in blood pressure, plts or hct
- We like it
  - Babies like it
  - Nurses like it
  - Intensivists like it
  - Nephrologist like it.
- Full control of fluid / electrolytes/ waste products
- No major complications
State of the Art for Infant CRRT: Summary

- CRRT can be an effective therapy for even the smallest patients
- Overall survival comparable to larger children - skewed to selected diagnoses
- Neonates with metabolic disorders or intoxications may benefit from CRRT vs IHD
- Multiple challenges remain on several fronts
- The possibility of a better devices for neonates may open further options
Tell us about your experience?

• Do you do CRRT on neonates?
• Do you have a weight cut off?
• Where is the therapy done? NICU? PICU?
• Who is on your team?