Pediatric AKI & CRRT: How Do I Care for my Patient and my Program?

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Zaccaria Ricci
Jordan Symons

23rd International Conference on Advances in Critical Care Nephrology
San Diego 2018
Introduction

• Pediatric AKI is no longer a “mystery” issue
  – Growing data on epidemiology and outcome
• Pediatric CRRT is no longer a “novel” therapy
  – Experience and literature to support our approach
• Each patient presents unique challenges
  – Adapting standards to clinical situations
  – Adjusting approach to address complications
• Each program faces its own issues
  – Technology, support, staffing, acuity, etc.
Format for the Session

- Present a clinical case or question
- Discuss as a group
- Review our perspective
  - Case resolution
  - Points illustrated
  - Data/literature review where available
- Build on clinical examples to discuss QI and program management
Pediatric AKI & CRRT Part I

HOW DO I CARE FOR MY PATIENT?
Case #1

OLIGURIA AND EDEMA
Case #1: Case Presentation

- 14 y/o F s/p stem cell transplant for high-risk ALL
- Sepsis/hypotension; multiple boluses of IV crystalloid
- Patient weight initially 38kg, now 44kg
- Serum creatinine
  - Initial 0.7mg/dL (62µmol/L)
  - Now 2.1mg/dL (186µmol/L)
- I/O last 24h: 9800ml in/1050ml out
  - "1ml/kg/hr" says the resident!
- BP 90s/50s on dopamine 15mcg/kg/min
- Mechanical ventilation
Case #1: Questions

• Does this patient have acute kidney injury?
• How do we define AKI in children?
• Can we “prove” that a patient has AKI?
• What’s your approach to determining if a patient with AKI needs renal replacement?
**AKI in Children: KDIGO Criteria**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Serum creatinine (SCr) criteria</th>
<th>Urine output criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SCr rise by $\geq 0.3, \text{mg/dl}$ w/in 48hrs, OR SCr rise by $\geq 1.5\times$ to $1.9\times$ reference SCr within 7 days</td>
<td>$&lt;0.5, \text{mL/kg/hr for } &gt; 6, \text{hrs}$</td>
</tr>
<tr>
<td>2</td>
<td>SCr rise $\geq 2\times$ to $2.9\times$ reference SCr</td>
<td>$&lt;0.5, \text{mL/kg/hr for } &gt; 12, \text{hrs}$</td>
</tr>
<tr>
<td>3</td>
<td>SCr rise $\geq 3\times$ reference SCr OR Increase $\geq 4.0, \text{mg/dl}$ OR Renal Replacement Therapy OR eGFR in children $&lt; 35, \text{ml/min/1.73m2}$</td>
<td>$&lt;0.3, \text{mL/kg/hr for } &gt; 24, \text{hrs}$ OR anuria for 12 hrs</td>
</tr>
</tbody>
</table>
AKI in Children: Epidemiology

AWARE

- Global study of AKI in critically ill children (3mo – 25y)
- 32 Pediatric ICUs
- >5000 patients enrolled

AWAKEN

- International study of AKI in neonates
- 24 Neonatal ICUs
- >2000 infants enrolled

Epidemiology of Acute Kidney Injury in Critically Ill Children and Young Adults

Ahmad Kaddourah, M.D., Rajit K. Basu, M.D., Sean M. Bagshaw, M.D., and Stuart L. Goldstein, M.D., for the AWARE Investigators

NEJM 2016

Incidence and outcomes of neonatal acute kidney injury (AWAKEN): a multicentre, multinational, observational cohort study

Jennifer G Jetton, Louis J Boohaker, Sidharth K Seth, Sanjay Waze, Smriti Rohatgi, Danielle E Soranno, Aftab S Chishti, Robert Wronacki, Cherry Mammen, Jonathan R Swanson, Shanthy Sridhar, Craig S Wong, Juan C Kupferman, Russell F Griffin, David J Askenazi, on behalf of the Neonatal Kidney Collaborative (NKC)*

Lancet Child and Adol Health 2017
AWARE: Prevalence of AKI in PICUs

N=4683

AKI: 26.9%

Severe AKI: 11.6%

Increased risk for ventilator support, RRT, mortality
AWAKEN: Prevalence of AKI in NICUs

N=2022

AKI: 25.2%

Severe AKI: 15.7%

Increased risk for mortality; increased length of stay
Can We Predict Pediatric AKI?

• Urinary biomarkers in patients with high AKI risk
  • NGAL
    – Data in adults and children
    – Among 311 children undergoing cardiac surgery (5th quintile)
      • Sensitivity for severe AKI = 42%; specificity for severe AKI = 85%
  • TIMP2/IGFBP7
    – Data mostly in adults, but promising prediction for severe AKI
    – 12 children undergoing cardiac surgery (cutoff 0.7)
      • Sensitivity = 83%; specificity = 77%

• Other options?

Combining Functional and Tubular Damage Biomarkers Improves Diagnostic Precision for Acute Kidney Injury After Cardiac Surgery

Basu et al, JACC 2014

At 2 hours after CPB start:

- uNGAL/Ucr cut off 200 ng/mg
- pCysC: cut off 0.8 mg/L

VS

At first POD check:

- DeltasCr > 50%

DEVELOPMENT OF AKI (KDIGO stage 2 or 3) at any POD
sCr levels

0.0
0.5
1.0
1.5
mg/dl

baseline
POD0
POD1
POD2
discharge

* PERSISTENT AKI
* DELAYED AKI
* TRANSIENT AKI

NO AKI

BIOM
sCr
Combining Functional and Tubular Damage Biomarkers Improves Diagnostic Precision for Acute Kidney Injury After Cardiac Surgery

Basu et al, JACC 2014

<table>
<thead>
<tr>
<th>Marker</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>AUC</th>
</tr>
</thead>
<tbody>
<tr>
<td>△ SCr &gt; 45%</td>
<td>38%</td>
<td>91%</td>
<td>0.65</td>
</tr>
<tr>
<td>pCysC &gt; 0.8</td>
<td>93%</td>
<td>92%</td>
<td>0.95</td>
</tr>
<tr>
<td>uNGAL &gt; 200</td>
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<td></td>
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</tbody>
</table>

**ANY AKI**

**Development of KDIGO stage 2 or 3 at any POD**
Combining Functional and Tubular Damage Biomarkers Improves Diagnostic Precision for Acute Kidney Injury After Cardiac Surgery

Basu et al, JACC 2014
Can We Predict Pediatric AKI?

- Risk stratification of critically ill patients to develop AKI
- RAI ≥ 8
- If renal angina present on day of ICU admit:
  - Severe AKI likely on day 3 (AUC 0.8)
  - Adding NGAL to model improved prediction (AUC 0.97)

### AKI Risk Tranche

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Risk Tranche</th>
<th>Risk Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICU Admission</td>
<td>Medium</td>
<td>1</td>
</tr>
<tr>
<td>History of Transplantation (Solid Organ or Bone Marrow)</td>
<td>High</td>
<td>3</td>
</tr>
<tr>
<td>Vasoactive Support &amp; Mechanical Ventilation</td>
<td>Very High</td>
<td>5</td>
</tr>
</tbody>
</table>

\[ X = \text{Renal Angina Index} \]

(Range 1-40)

### AKI Injury Tranche

<table>
<thead>
<tr>
<th>Change in Creatinine</th>
<th>Fluid Overload %</th>
<th>Injury Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0</td>
<td>&lt; 0 - 5%</td>
<td>1</td>
</tr>
<tr>
<td>1.0 - 1.49x</td>
<td>5 - 9.99%</td>
<td>2</td>
</tr>
<tr>
<td>1.5 - 1.99x</td>
<td>10 - 14.99%</td>
<td>4</td>
</tr>
<tr>
<td>&gt; 2x</td>
<td>≥ 15%</td>
<td>8</td>
</tr>
</tbody>
</table>

Basu et al. Kidney Int. 2014
Menon et al. NDT 2016
Assessment of a renal angina index for prediction of severe acute kidney injury in critically ill children: a multicentre, multinational, prospective observational study

Rajit K Basu, Ahmad Kaddourah, Stuart L Goldstein on behalf of the AWARE study investigators

Lancet Child And Adolesc Health 2018

1500 children with complete data for days 0, 3, and 28

A positive RAI score (>8) within the first 12 h of admission showed association with:
1. a two-fold incidence of day 3 sAKI, which occurred in 121 (42%) patients RAI positive vs. 247 (19%) patients RAI negative (relative risk [RR] 2·23, 95% CI 1·87–2.66, p<0·0001)
2. prolonged mechanical ventilation,
3. increased need for renal replacement,
4. higher risk of mortality
Furosemide Stress Test

FST, 1mg/kg of furosemide in naive patients or 1.5 mg/kg in those with prior exposure

Chawla et al. Crit Care 2013
Furosemide Stress Test

• AUC for the urine output 2 hrs after FST to predict progression to AKIN3 in 77 patients was 0.87
• The ideal cutoff: urine volume of 200 ml (100 ml/hr) with a sensitivity of 87.1% and a specificity of 84.1%.
• FST outperformed any available biomarker
• In patients with increased biomarker levels, the AUC for progression to AKIN3 improved to 0.90 and the AUC for receipt of RRT improved to 0.91

Koyner, JASN 2015
Case #1: Continued

With evidence of AKI and concerns for worsening status for this patient, RRT is indicated

• What RRT options do you have at your institution?

• What would you do for this patient, and why?

• How do you determine the dose of CRRT for this patient?
Pediatric CRRT Dose

• A lot of confusion
• Suggestions, but no prospective study
• Some literature from the adults
• Potentially no benefit from higher doses
• Potential harm deriving from higher doses
Common Approaches to CRRT Dose in Pediatric Patients

• 2000 ml/h/1.73m²
• Based on paper describing nutritional issues in pediatric CRRT; later described with citrate anticoagulation for pediatric patients

• 25-35ml/kg/h
• Based on adult studies suggesting higher mortality with lower rates
Dialytic dose in pediatric continuous renal replacement therapy patients

Zaccaria RICCI 1 *, Francesco GUZZI 2, Germana TUCCINARDI 3, 4, Stefano ROMAGNOLI 4, 5

66 papers from the year 2000

4 retrospective papers only verified if delivered dialytic doses were significantly different in surviving and non surviving patients
Dialytic dose in pediatric continuous renal replacement therapy patients

Zaccaria RICCI 1 *, Francesco GUZZI 2, Germana TUCCINARDI 3, 4, Stefano ROMAGNOLI 4, 5

Dose ranged from 1000 to 4000 l/h/1.73 m² and from 20 to 150 mL/kg/h.

1 study systematically analyzed the effect of pCRRT dose over time on serum markers such as creatinine and urea, and it showed that even a relatively small dose (35 mL/kg/h) was effective in controlling such molecules blood levels.

1 study analyzed the significant loss of amino acids during PCRRT occurring at the standard prescription of 2L/h/1.73 m².
3 Kg neonate (BSA 0,2 m²)

**OPERATIONAL CONSEQUENCES**

- **35 ml/kg/h:** 100 ml/h CVVH (0,9 L/h*1.73m²)
- **2 L/h*1.73m²:** 230 ml/h CVVH (80 ml/kg/h)
No Standard Recommendation for Pediatric CRRT Dose

Daily $Kt/V=1$

Ricci et al, Minerva Pediatrica 2016
Kt/V: A Measure of Efficacy

It represents the K delivered by the dialytic system over time indexed on patient’s target solute volume of distribution

\[ K = \frac{\text{effluent flow rate (provided corrections for predilution hemofiltration)}}{\text{time of actual treatment provision}} \]

\[ V = \text{in the case of urea it corresponds to patients’ total body water (TBW)} \]

\[ Kt = 35 \text{ ml/kg/h in a 3 kg patient for 24 hours} = 35 \times 3 \times 24 = 2520 \]

\[ \text{TBW (} V_{\text{UREA}} \text{)} \text{ in a critically ill fluid overloaded patient can be approximated (in excess) to 80\% of body weight} = 2400 \text{ ml} \]

\[ Kt/V = \frac{2520}{2400} = 1.05 \]
Case #1: Further Questions

• Does your center have a formalized screening program or diagnostic plan for AKI?
• Which modalities of RRT do you use for AKI and how do you choose?
• How do you address the question of “dose” for CRRT?
Pediatric AKI and Dose of CRRT: Summary

- High prevalence of AKI in pediatric critical care
- More tools in toolbox to predict/clarify AKI
  - Biomarkers
  - Renal angina index
  - Furosemide stress test
- CRRT has become a common practice for AKI but there is minimal literature on dose
- $K_t/V$, a tool from chronic dialysis, may serve as a method to define dose in critical care
Case #2

RRT FOR THE NEONATE
Case #2: Case Presentation

• 3 week old term female with perinatal asphyxia (abruption) and chorioamnionitis; looks septic
• Cr has been rising (1mg/dL $\rightarrow$ 3.2mg/dL)
• Weight increased (BW 3.2kg $\rightarrow$ 4.1kg); edematous
• Increased ventilator support; urine 1.1ml/kg/hr
Case #2: Questions

• Does this patient require renal replacement?
• What modality would be best for support?
• What issues and complications must we watch for if we go forward with renal replacement?
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, cost
CRRT for Neonates: A Series of Challenges

• Small patient with small blood volume
• Equipment designed for bigger people
• No specific protocols
• Complications may be magnified
• No clear guidelines
• Limited outcome data
Prescribing CRRT:
Special Neonatal Considerations

• Vascular access
• Blood Prime
• Blood flow rates
• Fluids/Modality (CVVH vs. CVVHD vs. CVVHDF)
• Ultrafiltration goals
• Anticoagulation
• Filter/membrane
• Device
Neonatal CRRT Access

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

• Vessel size
  – Neonatal internal jugular vein ~3mm diameter
  – 1 Fr = 0.33mm
  – Get experienced individuals to place neonatal access

• Low resistance
  – Resistance ~$8\ln \eta/2r^4$
  – So, the biggest and shortest catheter should be best
Smallest HD Catheters in US

**Temporary Catheter**

Medcomp Soft-Line
7Fr – 10cm

**Medcomp Hemo-Cath LT**
8Fr – 18cm

**Tunneled Cuffed Catheter**

**Remember:**
- IJ diameter in a neonate is ~3mm
- 1Fr = 0.33mm
- Therefore . . .
  - 7Fr = 2.31mm
  - 8Fr = 2.65mm
• 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)
Blood Prime for Pediatric CRRT

• Blood prime supports BP, prevents hemodilution from saline prime
• Blood prime increases risk:
  – Blood product exposure, possibly repeated
  – HYPOCALCEMIA
    • Citrate anticoagulant in PRBCs
  – HYPERKALEMIA
    • K+ release from RBCs
  – ACIDEMIA
• Increases risk for bradykinin release syndrome
  – Acute hypotensive event
  – Associated with AN-69 membrane
Bypass System to Prevent Bradykinin Release Syndrome

Modified from Brophy, et al. AJKD, 2001
Recirculation System to Prevent Bradykinin Release Syndrome

Recirculation Plan:
- Qb 200ml/min
- Qd ~40ml/min
- Time 7.5 min

Normalize pH
Normalize K⁺

Circuit-to-Circuit Prime
Simple Systems to Limit Likelihood of Bradykinin Release Syndrome

• Don’t prime on with blood
• Don’t use the AN-69 membrane
Device Limitations for Infant CRRT
Infant-Specific/Adapted Devices

Cardio Renal Pediatric Dialysis Emergency Machine (CARPEDIEM)

Newcastle Infant Dialysis and Ultrafiltration System (NIDUS)

Aquadex FlexFlow
Case #2: Further Questions

• Do you perform CRRT for neonates at your center? What CRRT device do you use?
• What challenges and issues have you needed to address for these patients?
Neonatal CRRT: Summary

• Added technical challenges with small infants
• Careful consideration about risks/benefits for vascular access choices
• Most CRRT devices to date designed for adults but neonatal-specific devices becoming available
• PD remains an excellent option!
Case #3

CRRT AND ECMO
Case #3: Case Presentation

- 14 years old, previously healthy with h/o URI for 4-5 days, to PICU with hypoxic respiratory failure, sepsis, necrotizing pneumonia
- Intubated and then cannulated for VA-ECMO
- Weight (actual) 61.2kg
- Urine output dropping, serum creatinine rising
  - 0.7mg/dL → 1.3mg/dL
- Worsening edema on exam
- PICU team contacts you regarding AKI and possible need for RRT
Case #3: Questions

• How do you address the need for RRT when a patient is on ECMO?
• What technical challenges must you anticipate?
• How do you coordinate care between teams?
RRT options during ECMO include peritoneal dialysis, intermittent hemodialysis, and continuous RRT (CRRT). Each has its own advantages and disadvantages (48–50). Patient factors, treatment goals, and center experience play a role in the RRT selected. RRT on ECMO is usually provided as a continuous modality because of hemodynamic instability. Continuous peritoneal dialysis may achieve the desired fluid management goals but provide less efficient management of electrolyte imbalance and clearance. CRRT is the most common modality because it offers the ability of making rapid changes to targeted fluid balance and provides excellent solute clearance.

The two most common methods to provide CRRT are via the use of an in-line hemofilter or via a traditional CRRT device connected to the extracorporeal circuit. A recent international survey of 65 ECMO centers showed that 50.8% of centers exclusively use CRRT, 21.5% exclusively use an in-line hemofilter, and 23% use no RRT during ECMO (21).

RRT Using an In-Line Hemofilter

One method to provide CRRT is by incorporating an in-line hemofilter into the ECMO circuit. The hemofilter is typically placed after the pump (to provide forward blood flow through the hemofilter) and before the oxygenator (to maintain the oxygenator's use as a clot and air trap in case of complications) (Figure 1). After passing through the hemofilter, the blood is returned to the prepump limb of the circuit. In this configuration, the shunt creates a disparity between the pump measured flow and the flow being delivered to the patient. An ultrasonic flow probe on the arterial return line is needed to determine the actual flow delivered to the patient. The hemofilter blood flow rate can be derived by subtracting the flow delivered to the patient from the total ECMO blood flow rate. The hemofilter blood flow rate can be adjusted via the use of a stopcock or other flow-restricting device; however, the potential for hemolysis and thrombus formation due to turbulent flow limit this practice.

Some centers use this technique to provide only slow continuous ultrafiltration. Other centers provide continuous convective clearance with replacement fluids delivered to the patient directly or through the ECMO circuit. Diffusive clearance can be achieved running countercurrent fluid using standard infusion pumps. Because these hemofilters are designed for use with high pressure systems, the fiber characteristics make diffusive clearance less effective than conventional membranes. In addition, the amount of ultrafiltration made is limited by the infusion pumps that maximize at approximately 1 L/h.

The hemofilter has the potential to generate large amounts of ultrafiltrate that can be regulated using a standard intravenous infusion device connected to the effluent port of the hemofilter. There are several methods to determine the amount of fluid being removed. The most precise method is to measure the actual volume of ultrafiltration removed using weight or a volumetric measuring device (such as a collection kit used when documenting urine output with a Foley catheter).

Figure 1. 

Renal replacement therapy using an in-line hemofilter during ECMO

Askenazi, CJASN 2012
CRRT Device with ECMO

Figure 2 | Inclusion of the continuous renal replacement therapy (CRRT) device in the extracorporeal membrane oxygenation (ECMO) circuit.
Continuous Renal Replacement Therapy With an Automated Monitor Is Superior to a Free-Flow System During Extracorporeal Life Support*

Jordan Matthew Symons, MD1; Marcus Wayne McMahon, BS2; Tara Karamlou, MD, MSc3; Andrea Rae Parrish, MIP; David Michael McMullan, MD2

Figure 3. Continuous renal replacement therapy (CRRT) error over time. Integrated CRRT patients had significantly lower normalized CRRT error over the study interval compared with the free-flow patients. Solid light black lines represent individual patient measurements (n = 458) over time; horizontal lines display integrated mean values over time stratified by CRRT type (solid line = free-flow CRRT; interrupted line = integrated CRRT). Vertical axis is the CRRT error (desired fluid loss – actual fluid loss) normalized to body weight (kg) divided by 10 for scale. The horizontal axis represents patient-days on CRRT.
CRRT and ECMO: Issues with the ECMO Circuit

• Negative Pressure
  – CRRT circuit standard pressure mode
  – Lower pressures, likely less pressure alarms
  – Danger of **AIR** if disconnected

• Positive Pressure
  – CRRT circuit positive pressure mode
  – High ECMO pressures will influence CRRT pressures, likely more pressure alarms
  – Danger of **Exsanguination** if disconnected
Case #3: Further Questions

- Do you perform ECMO and CRRT at your center?
- What challenges and issues have you needed to address when considering RRT for patients receiving ECMO?
CRRT and ECMO: Summary

• Increased complexity when combining extracorporeal therapies (CRRT and ECMO)
• CRRT monitor connected to ECMO appears to give more accurate ultrafiltration control than free-flow systems
Case #4

CRRT IN PEDIATRIC LIVER FAILURE
Case #4: Case Presentation

- 2 y/o F to PICU with fulminant hepatic failure
  - Fever, altered mental status, seizures, hypotension
  - INR, ammonia, lactate, transaminases all elevated
- Resuscitated, intubated, massive blood product requirement
  - Developed 10% FO within first 24 hours of admission
  - BUN 30mg/dL, Creatinine 1mg/dL
- CRRT initiated
Case #4: Questions

• What prescription/clearance challenges are posed by this patient?
• What are our options for anticoagulation?
Better survival with better ammonia control
- For every 10% decrease in NH3 from baseline at 48hrs, likelihood of survival increased by 50%
- For every 1hr delay initiating CRRT, likelihood of mortality increased by 4%
High-Volume Hemofiltration in Children With Acute Liver Failure*

*HVHF: >80ml/kg/hr led to improved hemodynamic stability and neurological status
Anticoagulation for Pediatric CRRT

• Heparin
  – Decades of experience
  – Systemic anticoagulation
  – Risk of bleeding, HIT
  – Variations in monitoring
    • ACT, aPTT, Xa

• Citrate
  – Regional anticoagulation
  – Risk of calcium or acid-base abnormalities, accumulation of citrate
  – Somewhat more complex than heparin

• Other things?
  – Direct thrombin inhibitors
  – Prostacyclin
  – Nothing?
Case #4: Further Questions

• Do you make changes to your CRRT prescription for patient with liver failure?
• Do you individualize prescription/dose depending on the clinical situation?
CRRT in Liver Failure: Summary

• Pediatric acute liver failure patients are at high risk for complications
• Indications for CRRT may go beyond fluid and electrolyte balance
• Discussion with hepatology/transplant teams can help to clarify protocols
Case #5

CRRT IN THE OPERATING ROOM
Case #5 (a continuation of #4): Clinical Scenario

- 48 hours later – our patient receives offer for liver transplant
- Surgeons request CRRT support in OR
  - Fluid management
  - Hyperkalemia
Case #5: Questions

• What technical considerations are posed?
• How are prescription and dosing choices affected by OR location?
Intraoperative CRRT: Goals

• Maximize circuit life
• Address/mitigate surgeon concerns
  – Hyperkalemia
  – Fluid Overload
• Avoid complexity
  – Coordination with anesthesiologists
• Permit successful surgery and reasonable start to recovery
CRRT in the OR: Technical Discussion

• Staffing
  – Dedicate RN for CRRT management
  – MD for CRRT present at initiation; remains available

• Preparation
  – IJ catheter is preferable
    • Easier access if circuit is lost, troubleshooting
    • Not affected by intraabdominal clamping and procedure
  – Second circuit primed and ready outside OR
CRRT in the OR: Prescription and Anticoagulation

- **Prescription**
  - Optimize Qb to prevent clotting
  - Clearance: coordinate goals with anesthesiologists
  - UF: consider fixed output for simplicity

- **Anticoagulation**
  - Heparin vs. citrate anticoagulation
  - Could consider no anticoagulation with NS flushes (50-250mL q30min)
Case #5: Further Questions

• Does your program provide RRT in the OR? What approach do you use?
• What challenges have you encountered with intraoperative RRT?
Case #5 – Summary

• CRRT in the OR presents unique challenges
• Careful planning and coordination ahead of time is essential
Pediatric AKI & CRRT Part II

HOW DO I CARE FOR MY PROGRAM?
Questions

• How do you train your team to perform CRRT effectively?
• How do you know you are being successful?
## Your CRRT Program

<table>
<thead>
<tr>
<th>Standardization of Practice</th>
<th>Quality of Care</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Guidelines</td>
<td>• Prescribed</td>
</tr>
<tr>
<td>• Procedures</td>
<td>• Delivered</td>
</tr>
<tr>
<td>• Education</td>
<td></td>
</tr>
</tbody>
</table>
Standardization of Practice

• Indications for therapy
• Initiation Procedures
• Circuit Changes
• Fluid Removal Calculation
• Documentation
CPR Process Measures
Fluid Status

- At Initiation
- Degree of Fluid Overload at Initiation associated with patient outcomes
- Benchmark w/literature

- Formula
  - Fluid In = Intake (since ICU Adm to CRRT initiation)
  - Fluid Out = Output (since ICU Adm to CRRT initiation)

\[
\text{\% FO at CRRT initiation} = \left[ \frac{\text{Fluid In} - \text{Fluid Out}}{\text{ICU Admit Weight}} \right] \times 100\%
\]
Filter Life

• Multifactorial
  – Anticoagulation
  – Prescription
  – Modality
  – Staff proficiency
  – Vascular access
Filter Life

• Analyze
  – Filter Life
    • Follow trend
    • Benchmark w/literature
      – ppCRRT registry data (Brophy et al, 2005)

– Unintended Changes (Mottes et al, 2013)
  • Specifically pressure related events & weight related events

Treatment Hours

• Analyze
  – Time therapy delivered
    • Alarms
    • Interventions
  – Narrowing the gap
    • Reflects aptitude
    • Increase delivered therapy

<table>
<thead>
<tr>
<th>AVERAGE FILTER HOURS</th>
<th>65.4</th>
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</thead>
<tbody>
<tr>
<td>AVERAGE TREATMENT HOURS</td>
<td>62.6</td>
</tr>
<tr>
<td>ACHIEVE 95% OF FILTER HOURS</td>
<td>98 %</td>
</tr>
</tbody>
</table>
Daily Fluid Goal

- Complex Measure
  - Communication
  - Teamwork
  - Patient Condition
  - Downtime

Infusion Pumps acceptable error ± 5%
Daily Fluid Goal

• Establishing Goal
• ± 10% of Goal

Goal = Intake - Goal
Dialysis Dose

• Prescribed vs Delivered
• Two-fold
  – Prescribing to our Standard of Care
  – Achieving dose
• Considerations
  – Definition
    • Filter vs Treatment
  – Anticoagulation
Other – CRRT Quality Indicators

• Compliance with Standard of Care Guidelines
• Time – Ordered to Start
• Anticoagulation
  – Samples outside of range
  – Complications
• Treatment Interruptions
• Catheter Events
• Education

Rewa et al, Systematic Reviews (2015) 4:102, 1-6
CRRT Quality of Care

- Metrics and measures reflect your program
- Not all programs are the same
- Metrics and measures remain debated in literature

HIGH QUALITY, SAFE, EFFECTIVE CARE SHOULD NOT BE CONTROVERSIAL
Any Other Comments or Questions?
Thanks for Your Participation!