AKI and CRRT:
A PICU Nurse Perspective

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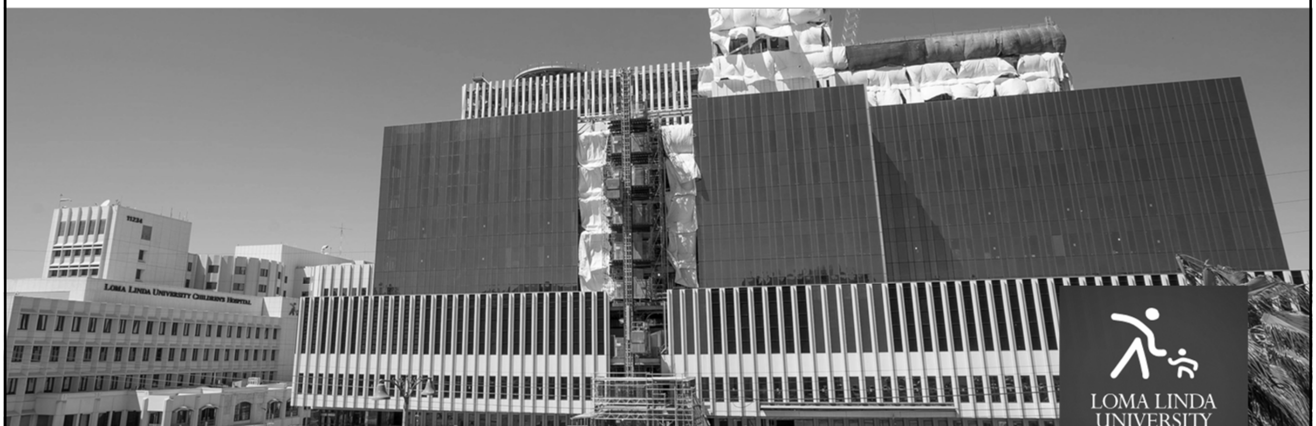

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Goals & Objectives:

» **Goal:** To provide a general overview to the participant of acute kidney injury, treatment with continuous renal replacement therapy, and the impact of these on the pediatric critically ill child.

» **Objectives:**

1. Discuss the pathophysiology and risk factors for acute kidney injury (AKI).
2. Identify the impact of fluid overload on patient outcomes.
3. Describe interventions for treatment of AKI in the PICU including continuous renal replacement therapy (CRRT).
4. Discuss the impact of the critical illness and the PICU environment on pediatric patients and their long term outcomes.

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Pediatric Acute Kidney Injury (AKI)

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Pediatric AKI

- » Abrupt decrease in kidney function leads to:
  - ~ Accumulation of creatinine, urea, and other waste products
  - ~ Impaired fluid & electrolyte balance
- » Terminology change from failure to injury – continuum of disease as even modest decreases of kidney function associated with worsened outcomes
- » Common cause of morbidity and mortality in children

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AKI Defined

» Varied definitions (RIFLE, PRIFLE, AKIN, KDIGO)

» Current consensus definition from 2012 Kidney Disease: Improving Global Outcomes (**KDIGO Criteria**)

~ AKI defined as *any of the following*

- Increase in SCr by $\geq$ 0.3 mg/dl ($\geq$26.5 μmol/l) with 48 hours; or
- Increase in SCr by $\geq$ 1.5 times baseline, which is known or presumed to have occurred within the prior 7 days; or
- Urine volume < 0.5 ml/kg/hr for 6 hours

Serum Creatinine

Urine Output

https://www.md-health.co/Normal-Urine-Output.html

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AKI Staging (Severity)

Stage	Serum Creatinine	Urine Output
1	1.5-1.9 x baseline OR $\geq$0.3 mg/dl ($\geq$26.5 μmol/l) increase	<0.5 ml/kg/h for 6-12 hrs
2	2.0-2.9 x baseline	<0.5 ml/kg/h for $\geq$12 hrs
3	3.0 x baseline OR Increase in serum Crea to $\geq$4.0 mg/dl ($\geq$353.6 μmol/l) OR Initiation of RRT OR In patients <18 yrs, decrease in eGFR to <35 ml/min per 1.73 m^2	<0.3 ml/kg/h for $\geq$24 hrs OR Anuria for $\geq$ 12 hrs

KDIGO Guidelines – Section 2

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Etiology

1. Pre-Renal Causes
2. Renal Causes
3. Post-Renal Causes

Pre-Renal

» Most common form of pediatric AKI = related to decreased renal perfusion.

» Causes:

- ~ Shock states
  - Hypovolemic – hemorrhagic, GI losses (diarrhea, vomiting), burns
  - Cardiogenic – heart failure, cardiac surgery
  - Distributive – septic shock
- ~ Trauma
- ~ Multi-organ system dysfunction (MODS)
  - Children develop MODS earlier in ICU course than adults – highest number of organs fail within 72 hours of PICU admission (87%)

Renal

» Primary renal injury – damage to the nephrons
- ~ Interstitial
  - e.g. nephritis
- ~ Vascular
  - e.g. HUS (hemolytic uremic syndrome), thrombosis, vasculitis
- ~ Glomerular
  - e.g. post-streptococcal infection
- ~ Tubular
  - Ischemic - e.g. acute tubular necrosis
  - Toxic – poisons, metabolic disorders, nephrotoxic drugs (antibiotics, chemo, transplant, contrast)

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Post-renal

» Obstruction
- ~ Congenital or acquired anatomic urinary track obstructions
  - Obstructions can be related to traumatic injury, abdominal compartment syndrome, clots, stones, or tumor

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The Changing Epidemiology of Peds AKI

» Prevalence in early years related to:

- ~ Primary renal disease
- ~ HUS
- ~ Sepsis
- ~ Burns

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The Changing Epidemiology of Peds AKI

» Prevalence in last decade related to:
» Congenital heart disease surgery
» Acute Tubular Necrosis
» Sepsis
» Nephrotoxic drugs
» Complications of other systemic chronic diseases
» Bone Marrow Transplant
» Neonatal care/Inborn Errors of Metabolism

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Impact of Fluid Overload

Outcome in Children Receiving Continuous Venovenous Hemofiltration

Stuart L. Goldstein, MD*; Helen Currier, RN, CNN‡; Jeanine M. Graf, MD§; Carmen C. Cosio, MD§; Eileen D. Brewer, MD*; and Ramesh Sachdeva, MD§

Percent Fluid Overload Calculation

$$\% \text{ FO at CVVH initiation} = \frac{\text{Fluid In - Fluid Out}}{\text{ICU Admit Weight}} * 100\%$$

Fluid In = Total Input from ICU admit to CRRT initiation
Fluid Out = Total Output from ICU admit to CRRT initiation

Pediatrics 2001;107:1309-1312

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Fluid Overload Impact on Survival

Table 1 Fluid overload and outcome in pediatric continuous renal replacement therapy

Author	Cohort (*n*)	Outcome	*P*-value
Goldstein *et al.* [8]	Single center (22)	Survivors 16% FO Nonsurvivors 34% FO	0.03
Gillespie *et al.* [25]	Single center (77)	FO >10% with OR death 3.02	0.002
Foland *et al.* [9]	Single center (113)	3 organ MODS patients Survivors 9% FO nonsurvivors 16% FO 1.78 OR death for each 10% FO increase	0.01
Goldstein *et al.* [13]	Multicenter (116)	>2 organ MODS patients Survivors 14% FO; Nonsurvivors 25% FO <20% FO: 58% survival; >20% FO: 40% survival	0.002
Hayes *et al.* [24]	Single center (76)	Survivors 7% FO Nonsurvivors 22% FO OR death 6.1 >20% FO	0.001
Sutherland *et al.* [19••]	Multicenter (340)	<10% FO: 70.6% survival 10–20% FO: 56.9% survival >20% FO: 34.4% survival	0.001

FO, fluid overload; MODS, multiorgan dysfunction syndrome; OR, odds ratio.

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AKI and CRRT
(Continuous Renal Replacement Therapy)

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Renal Replacement Therapy (RRT)

» Purpose: temporarily replace kidney function
» Therapy selection may be based on:
  - ~ Underlying cause of AKI or failure
  - ~ Symptom severity
  - ~ General condition of patient
  - ~ Equipment/resources available

» 3 Types of dialysis available in PICU
  - ~ Peritoneal Dialysis (PD)
  - ~ Hemodialysis (HD)
  - ~ Continuous Renal Replacement Therapy

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What is Continuous Renal Replacement Therapy (CRRT)?

» CRRT closely mimics the kidneys
» Provides slow and continuous extracorporeal blood purification therapy
» Able to treat acute kidney injury and fluid overload
  ~ Removes fluid and waste products over time
  ~ Can provide slow and gentle therapy
  ~ More likely to be tolerated by hemodynamically unstable patients

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CRRT: Why use it?

» Why?
  ~ Achieves goals of RRT – uremic toxin removal & effective control of electrolyte imbalances & acidosis
  ~ Decreases hemodynamic instability
  ~ Fluid removal control fairly precise and able to adapt when needed
  ~ Nutrition support
  ~ Possibly helps in management of inflammatory mediators (sepsis)
  ~ Fluid balance
    • Don't need to restrict fluids
    • Decreases excess fluid accumulation
» When????

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Goals in CRRT

- »Restore/maintain – fluid, electrolyte & acid-base balance
- »Prevent further kidney tissue damage
- »Promote renal healing & recovery
- »Allow other supportive measures – e.g. optimize nutrition

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Modes of CRRT

- »SCUF – Slow Continuous Ultrafiltration
  - ~ Goal: fluid removal
- »CVVH- Continuous Veno-Venous Hemofiltration
  - ~ Goal: solute & fluid removal
- »CVVHD – Continuous Veno-Venous HemoDialysis
- »CVVHDF – Continuous Veno-Venous HemoDiaFiltration

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Transport Mechanisms in CRRT

- Ultrafiltration: movement of fluid through semi-permeable membrane driven by a pressure gradient (hydrostatic pressure)
  - Provides fluid transport
  - +/- & osmotic pressures from non-permeable solutes
- Diffusion: movement of solutes only from an area of higher concentration to an area of lower concentration
  - Provides solute transport (removal of small solutes)
- Convection: forced movement of fluid with dissolved solutes (solute drag)
  - Solute transport
  - Facilitates removal of small, middle, & large solutes
- Adsorption: molecular adherence to surface or interior of membrane
  - Solute transport

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Comparison HD & CRRT

Therapy	Hemodialysis	CRRT
Duration	3-4 hours	24 hour
Blood Flow	300-400 mL/min	50-250 mL/min
Fluids Used	Dialysate only	Dialysate & Replacement
Fluid Rates	500-800 mL/min	34-68 ml/min
Dialysate Rates	mL/min	mL/hr
	Non-sterile dialysate	Sterile solutions
Typical Net Removal Rates	0-1000 mL/hr	0-100 mL/hr

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CRRT Dosing

- Current minimum delivered dose adult recommendation = 25 ml/kg/hr
- Goldstein recommendations for Pediatrics
  - 20-60 ml/kg/hr
  - 2000 – 3000 ml/1.73 m2/hr
  - BFR - minimum 5 ml/kg/min
  - CVVHDF – minimum 2000 ml/hr/1.73m2
    - Divide dialysis & replacement fluid equally
- Circuit – should not exceed 10% of patient calculated blood volume
  - If >10%, blood prime of circuit needed

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Pediatric Issues

- Large variability in age & size
  - 0 days – 25 years old
  - 2 kg – 150+ kg
- Challenges
  - Catheter size & access issues
  - Less frequent than in adult population
  - Equipment designed for adults
  - Volume of circuit
    - Blood prime
    - Temperature management

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Vascular Access

» Often the biggest limitation to therapy
» Vessel & catheter sizes
» Sites
  ~ IJ
  ~ Femoral
  ~ Subclavian

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Anticoagulation

» Key for successful delivery of therapy in pediatrics
» Critically ill patients at risk for both increased and decreased clot formation
» Options
  ~ Heparin
    • Systemic, risk of bleeding, risk of HIT
  ~ Citrate
    • Regional
    • Fewer bleeding complications
    • Risks for hypocalcemia, alkalosis, hypernatremia

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Indications for Pediatric RRT

» Fluid overload
» Electrolyte imbalance
» Uremia
» Kidney Injury
» Inborn Errors of Metabolism
» Toxins

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CRRT Teams

» Intensivist
» Nephrologist
» Pharmacy
» ICU nurses
» Dialysis nurses

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Factors Identifies As Impacting Outcomes

» Timing of CRRT initiation
» Hemodynamic instability
» Number & dose of vasopressors
» Underlying disease
» Low body weight
» Young age
» Mechanical ventilation
» MODS
» High central venous pressure (CVP)
» Fluid Overload

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Post-ICU Considerations

» Deconditioning
» Medication Impact
» Delirium
» PICS/PTSD
» ICU Rehab
» Long term impact of AKI

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