AKI Follow-Up: Continuity of Care after Discharge

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Objectives:

- Definitions
- AKI Sequelae
- Ideal surveillance timeline and inclusion criteria
- Components of AKI follow-up
- Risk stratification and population enrichment
- Education
- Long-term follow-up and impact

Acute kidney injury (AKI): Why do we care?

- AKI is very common in hospitalized children
  - 30% of ICU admissions
  - 5% of non-ICU admits
- Research has shown that even one incidence of AKI can cause an increase in morbidity and mortality in hospitalized patients
  - ↑ risk of death in mechanically ventilated patients on CRRT (continuous renal replacement therapy)
  - ↑↑ higher risk of mortality in critically ill patients with nephrotoxic AKI
- AKI is recognized as an important risk factor for Chronic Kidney Disease (CKD), and accelerated progression to end-stage renal disease (ESRD)

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AKI: How do we define it?

- The sudden decrease in kidney function which may or may not be sustained. Defined by Kidney Disease Improving Global Outcomes (KDIGO) criteria.
  - 3 stages

- Measured by changes in the:
  - Serum
    - SCr (Serum Creatinine)
    - CysC (Cystatin C) (as it pertains to estimating GFR)
  - Urine
    - Output

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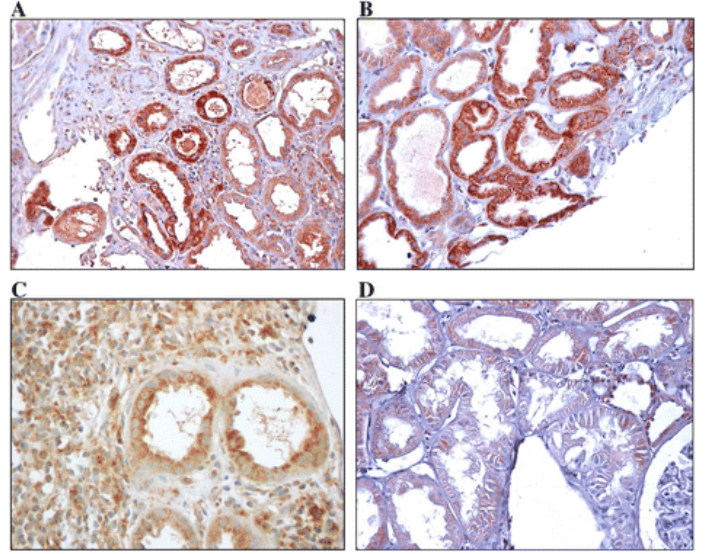
AKI stage	Increase in Creatinine	Urine Output	Other
Stage 1	≥0.3 mg/dL OR 1.5-1.9 times the baseline	<0.5 ml/kg/h for 6-12 hrs	
Stage 2	≥ 2.0-2.9 times the baseline	<0.5 ml/kg/ for >12 hrs	
Stage 3	GFR <35mL/min per 1.73m^2 OR ≥3 times the baseline	<0.3 ml/kg/h for ≥24 hrs OR anuria ≥12 hrs	Dialysis Initiation

Kidney Disease: Improving Global Outcomes (KDIGO) Acute Kidney Injury Work Group. KDIGO Clinical Practice Guideline for Acute Kidney Injury. Kidney inter., Suppl. 2012; 2 : 1–138.

Additional and novel biomarkers:



- **Cystatin C (CysC)-**
  - low molecular weight protease inhibitor
  - produced at a constant rate regardless of age, weight or muscle mass
- **Neutrophil-gelatinase associated lipocalin (NGAL)-**
  - released from tubular cells under stress as well as neutrophils during inflammation
  - Released by damaged nephrons prior to changes in other labs, and highly predictive of AKI
- **Kidney injury molecule-1(KIM-1)-**
  - Protein expressed by damaged kidney cells, functioning as a receptor of apoptotic cells and oxidized lipids (pictured above)

Follow-up:
A Structured Surveillance Timeline

- The awareness of the increased risk of CKD after AKI has necessitated follow-up for ***some*** period of time subsequent to injury

- KDIGO guidelines suggest AKI survivors be reevaluated at 3 months post injury, but specifications surrounding additional monitoring are sparse in the literature

AKI Sequelae and the risk of CKD: Why do we need follow-up?

- HTN in the first-year post AKI significantly correlates with subsequent identification of CKD
- There is a higher risk of additional AKI during subsequent hospitalizations
- The pediatric ICU population may be a more important cohort for assessing CKD risk due to the presence/increased presence of:
  - Nephrotoxic antibiotics
  - NSAIDS
  - Use of vasopressors
  - Use of steroids
  - Mechanical ventilation

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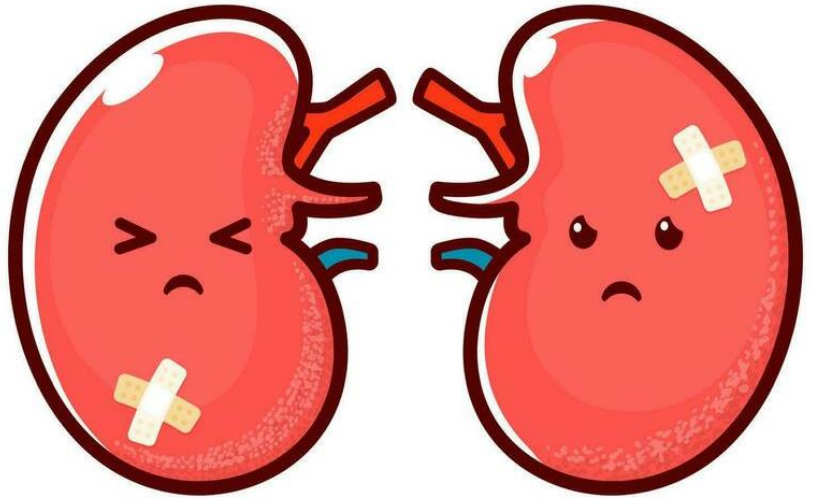
Major Adverse Kidney Event (MAKE) risk:

- AKI survivors are at a higher risk of MAKE throughout follow-up. Events consistent with the 3 D's:
  - Dysfunction
  - Dialysis
  - Death

- Increased risk in the first year, but with elevated risk up to 15+ years.



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Who do we want to follow? Inclusion criteria:

Severe AKI- sCr based 2012 KDIGO definition of stage 2/3
Subsequent severe AKI*
RRT needs during admission
HTN*
Adolescents- may extend monitoring if nearing puberty
Neonates- <28 wks gest, VLBW, cardiac disease
Excluded: ESRD, BMT

AKI Follow-Up:

- Surveillance
  - Stage II/III AKI: (serum and urine studies, BP measurement, +/- imaging, review medications, review growth chart)
    - 2 weeks post injury
    - 3 mos post injury
    - 6 mos post injury
    - Annually for 2-5 years

- Adolescents
  - Extend surveillance to assess renal functional reserve

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Assessing for CKD: Recommended Monitoring

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Standard labs at each surveillance time point:

- **Renal profile**
- **ACR**
- **CysC >age 2**
- **UPC**
- **+ /- NGAL**

BP measurement

Imaging

- Repeat RUS if prior abnormalities
- NMGFR only if concerning eGFR trend

Review patient medications

Review growth chart

Comprehensive kidney health assessment for neonatal population**

When are you escalating care in inpatient AKI?

- *Significant/refractory HTN*
- *Severe electrolyte derangements*
- *Fluid overload (approaching 10% or >)*

Risk Stratifying and Population Enrichment in AKI follow-up:

- Population enrichment is the selection of a subgroup of pts who are more likely to suffer an outcome of interest or respond to a given therapy (can be prognostic or predictive).
- Enriched population data allows for goal directed care and increased resource utilization post AKI.
- Enables the building of AKI registries with better predictors of CKD in different patient cohorts.

Variables	Population Cohorts
↑Fluid accumulation	Oncology, Cardiology, Neonatology
Younger age	Required RRT
Shock	Sepsis induced AKI
↓Serum Alb, platelets, Hgb	Incomplete recovery
↑WBC, INR, lactate, K	Low and middle income

Risk stratification for kidney monitoring and follow-up recommendations in NICU graduates

- Patients and Risk Factors:
- **At Risk:**
  - 28 to 33 6/7 wks gestation
  - >/=34 wks gestation and stage 1 AKI
  - Critical cardiac disease (i.e. acute myocarditis, idiopathic cardiomyopathy, genetic conditions)
- High-Risk:
  - <28 wks gestation
  - BW <1500 g
  - AKI with dialysis
  - Critically ill infants with history of AKI and: Stage 2/3 AKI or dialysis, recurrent AKI, AKI with severe nonkidney comorbidity (ECMO, CDH, HIE, NEC, CLD)
  - Infants with critical cardiac disease and: stage 2/3 AKI, single ventricle, heart transplant, HIE, <34 wks gestation/BW <1500 g, ECMO, daily nephrotoxins at DC

What do we teach our families? Education:

- Education
  - Counseling
    - Describing the initial insult: SCr graph, timing, source, “motivation interviewing”
  - Brochure
    - “AKI Knowing Note”
    - “AKI and CKD in Infants Knowing Note”
  - Nephrotoxic medication wallet-card
  - Continuity and rapport
    - *Dedicated* AKI F/U providers, niche area for APNs
  - “Graduating” to PCP surveillance after 2-5 years

Education (con't)

- In the follow-up time period patients/families want to know they're in the final stages of healing or getting better. Not feeling that way contributes to reluctance to follow-up. (Sean Bagshaw, MD)

- Utilize teach-back methodology and teach patients how to communicate AKI history and request kidney safe care going forward. (Leslie Meigs, Patient & Patient Advocate)

Educational materials:

Growing Through Knowing

Acute Kidney Injury (AKI)

Growing Through Knowing

Acute Kidney Injury and Chronic Kidney Disease in Infants

RED ZONE = AVOID

Do NOT use these medications unless directed by your Urologist/Nephrologist

- **Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)**
  - Ibuprofen (Advil®, Motrin®)
  - Naproxen (Aleve®, Naprosyn®)
  - Ketorolac (Toradol®)

YELLOW ZONE = CAUTION

These medications treat other health problems your child might have. Discuss with your provider.

- **Blood Pressure Lowering Drugs**
  - Captopril (Capoten®)
  - Enalapril (Vasotec®)
  - Lisinopril (Prinivil®. Zestril®)
  - Losartan (Cozaar®)
- **Decongestants** (In "Multi-Symptom" Cough, Cold and Flu Products)
  - Phenylephrine (Sudafed PE®, Triaminic Cough and Cold, most Dimetapp products)
  - Pseudoephedrine (Sudafed®, combination cough, cold, flu, and allergy products such as Claritin-D®)
- **Anti-Virals** (Drink plenty of fluids while taking these medications)
  - Acyclovir (Zovirax®)
  - ValACYclovir (Valtrex®)
  - ValGANcyclovir (Valcyte®)

Medications that May Harm Your Kidneys

Medication Tips for Safe Use:

Discuss your Chronic Kidney Disease (CKD) Status with the prescribing provider **before** starting any new medication(s), including oral or intravenous **contrast agents** used in imaging.

Always talk with your provider before trying **herbal products or nutritional supplements.** Some may have dangerous side effects or may interact with other medication you are taking.

Certain **antibiotics** (used to treat infections) may harm your kidneys. Choice and/or dose of an antibiotic may need to change based on your CKD status.

Ask your provider or pharmacist about safe doses or alternatives.

If you have questions about your medications and their risk of kidney harm please call:

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Educational materials (con't):

Important Facts about Acute Kidney Injury (AKI)

- AKI is a sudden decrease in the function of the kidney.
- Over time, without proper check-ups, this sudden change could lead to a permanent loss of kidney function (Chronic Kidney Disease or "CKD").
- Seeing the doctor on a regular ba for testing of the blood and urin how well your kidneys are worki

What Causes AKI?

There are many factors that may cau such as:

- Certain medications
  - Medicines used in im
  - Pain/fever reducers
  - Medicines used to co blood pressure
- Heart problems and/or surg correct them
- Infections in the blood
- Problems with the liver
- Dehydration, blood loss, bur

AKI has little to symptoms

Simply put, AKI does not hu notice any symptoms at all.

It is possible to lose up to 50 function before you notice ar body.

- This can be dangerous sir see a doctor before your considerably damaged.
- Getting regular follow – kidney doctor is importar permanent damage to yo

Routine care is very importar kidneys healthy and working

How can you tel child has AKI?

The doctor may order the fol

- Blood tests
- Urine tests
- Ultrasounds, X-rays

What is the Tre for AKI?

There is no cure for AKI.

You will play an important your kidneys healthy. Chec kidney doctor before taking

- Pain/fever reducers/an medicines
- Blood pressure lowerin
- Decongestants
- Antibiotics
- Herbal products/nutriti supplements

You or your child will need doctor on a regular basis to kidneys healthy and preven

Important Facts abou premature kidneys:

- Kidney development is not cor 34 weeks gestation and does nc after babies are born.
- Compared to babies born at te weeks +), premature infants ha numbers of nephrons (which a that filter the blood) and are at risk of chronic kidney damage decreased kidney function in th
- Certain conditions which affec structure and function of the k beginning in utero may lead to Kidney Injury) or CKD (Chror Disease).
- Follow-up has been proven to slow further loss of kidney function as it helps with the earlier detection of changes that could lead to a permanent loss of kidney function.

Why is it important to monitor the kidneys if a baby is born preter

Babies born early may be at a n of kidney damage secondary to occurred in the hospital or mec had to be used that can be harc Routine care with a kidney doc important to watch your infant further signs of kidney problen

- It is possible to lose up to 5 function before any change detected
- Studies have shown that in acute kidney injury events (higher risk for developing c disease (CKD) in the future
- Follow up with a kidney do important to avoid and mo of more permanent damage kidneys, and to keep them working well.

What can I do to help protect my infant's kidneys?

You will play an important role in keeping your child's kidneys healthy. If your child has less than 4 wet diapers in 24 hours, it is important to let a doctor know. Additionally, if your child has a history of AKI, check with the kidney doctor before giving your child:

- Pain/fever reducers/anti-inflammatory medicines
- Blood pressure lowering drugs
- Decongestants
- Antibiotics
- Herbal products/nutritional supplements

Long-term Follow-up

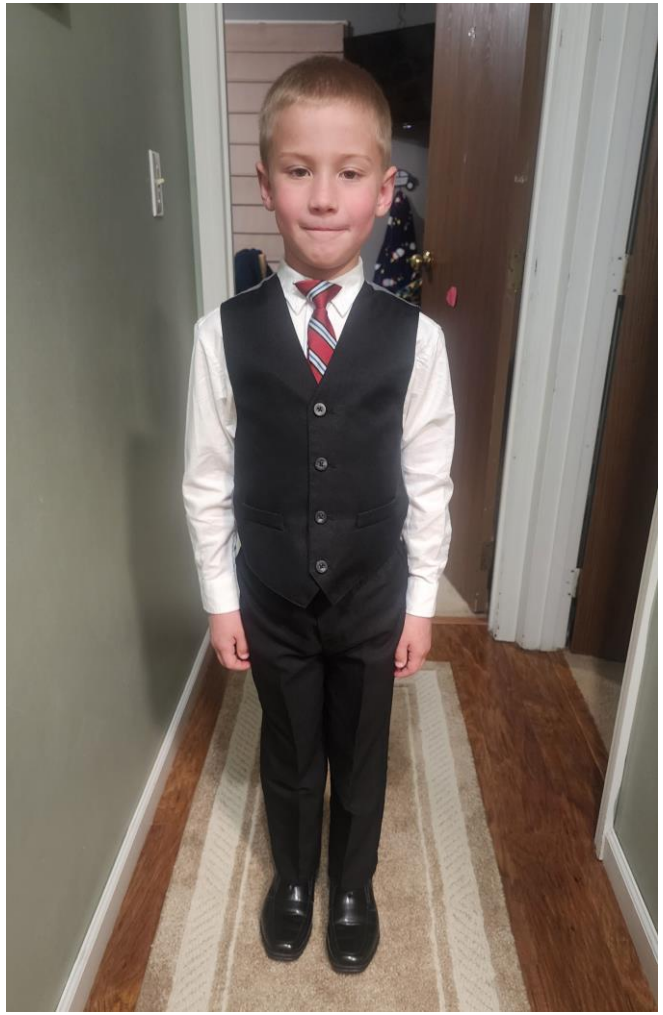
- CKD f/u pathway:
  - Frequency and depth of surveillance based on functional changes
    - Stage 2- Annual
    - Stage 3A- Q6 mos
    - Stage 3B- Q3-6 mos
    - Stage 4- Q3 mos
    - Stage 5- monthly
- Specialty diagnoses followed for CKD:
  - HTN Clinic
  - Tuberous sclerosis clinic
  - ACHD population
  - High risk NICU f/u clinic

What have we learned?

- What the literature/studies tell us:
  - RRT requiring, and subsequent severe AKI demonstrates higher rates of CKD and ESRD
  - CKD may not manifest until after a pubertal growth spurt
  - Stage 2/3 and ICU occurring AKI increases CKD and HTN risk in the first 5-6 years post DC
- What anecdotal evidence tells us:
  - It is hard to get pee from babies, but it does not hurt to try
  - Parents are terrified of OTC NSAIDS
  - Streamlined follow-up is best
  - There will still be LTFU despite diligent recruitment methods

This really works! Meet JP, an AKI Survivor:

- 2 yr old admitted x5 days for STEC-HUS with stage 2 AKI (no RRT) in 2019
- Full 5 years of AKI survivor clinic care
- Completed **all** surveillance timepoints
- Pt lived in rural area but had no transportation issues
- Family had the ability to navigate the EMR and competently schedule appointments at correct timepoints
- Diligently avoided NSAIDS, and emphasized good hydration at home, school, sports and during periods of viral illness



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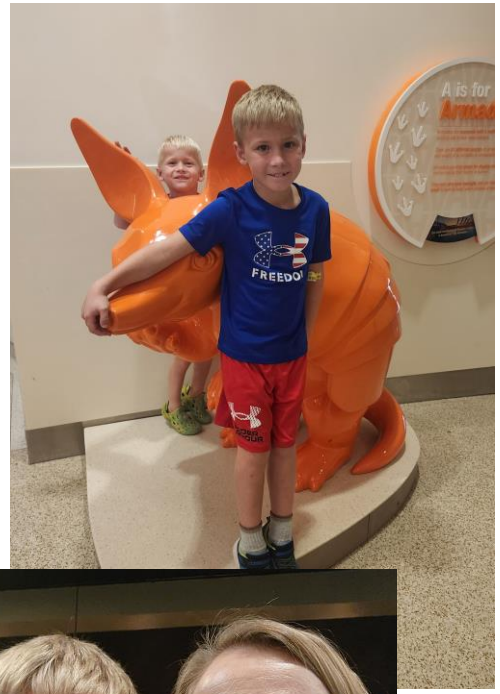
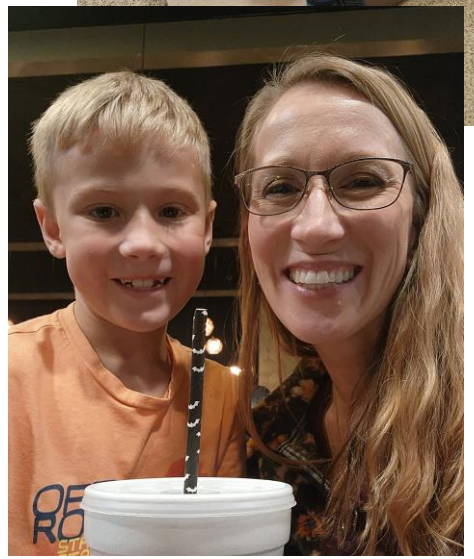
Surveillance Timepoint	Surveillance Completed?	Normal labs/testing?	Hypertension?
2 weeks post AKI (8/2019)	✓	Yes	No
~3 mos (12/2019)	✓	Yes	No
~6 mos (3/2020)	✓	Mild elevation in eGFR and UPC	Yes (89%ile)
1 year (8/2020)	✓	Yes	Yes (90%ile)
2 years (8/2021)	✓	Yes	No
3 years (8/2022)	✓	Yes	No
~4 years (10/2023)	✓	Yes	No
~5 years (10/2024)	✓	Yes	No





JP can now proudly declare he has been deemed an AKI Survivor!

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CCHMC AKI Survivor Cohort

(Ceschia et al, Pediatric Research, 2025)

In our CCHMC cohort, *every* patient with CKD at 3-5 years post AKI had evidence of it in at least one of their first-year follow-up visits.

Where do we go from here? Impact:

- Monitoring for HTN, use of nephrotoxins and eGFR changes mitigate progression to CKD. Modifiable risk factors substantially impact healthcare resource utilization.
- Early detection and management can improve long-term kidney health and survival.

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