Acute Kidney Injury

Definition

Acute kidney injury (AKI) is the rapid decline in glomerular filtration rate resulting in impairment of excretion of nitrogenous waste products and loss of water, electrolyte and acid base regulation.

- All critically ill children should be stratified for risk of AKI according to their susceptibilities and exposures according to table 1.
- Evaluate patients at increased risk for AKI with **repeated measurements** of serum creatinine and urine output to detect AKI (see relevant sections of the guideline).
- Individualize frequency and duration of monitoring based on patient risk and clinical course.
- Evaluate patients with AKI promptly to determine the cause; pre-renal, intrinsic renal or post-renal, with special attention to reversible causes.
- Evaluate patients **3 months after** AKI for resolution, new onset or worsening of pre-existing CKD.

Staging of AKI for severity according to pRIFLE criteria (table 1)

Stage	Estimated creatinine clearance (eCCl)	Urine output
Risk	eCCl decrease by 25%	<0.5ml/kg/h for 8 hours
Injury	eCCl decrease by 50%	<0.5ml/kg/h for 16 hours
Failure	eCCl decrease by 75% or eCCl <35ml/min/ 1.73 m^2	<0.3ml/kg/h for 24 hours or Anuria for 12 hours
Loss	Persistent failure > 4 weeks	
End stage	Persistent failure for > 3 months	

Only one criterion needs to be fulfilled (eCCl or urine output)

*Calculation of eCCl = $\frac{\text{Ht (cm) x k}}{\text{Creatinine (µmol/l)}}$ (ml /min/1.73m^2)

(Consider k = 40 for all ages for the calculation of eCCl approximately)

Scenarios in which children can be at high risk of developing AKI

1. Sepsis
2. Hypoperfusion or dehydration
3. Hypoxic events
4. History of exposure to drugs (ACE/ARB, NSAIDS, aminoglycosides, calcineurin inhibitors) or toxins that may adversely affect renal functions
5. Underlying renal disease or urinary obstruction
6. Major surgery
7. Cardiac or liver disease
8. Malignancy and / or bone marrow transplant
9. Dependence on others for access to fluids

Evaluation

Important factors to consider during initial and daily assessment of the patient

- Fluid status – Body weight – Required daily or twice daily
  Hydration status
  Accurate fluid balance – fluid input, urine output, any other fluid loss (eg: drain, GI losses)
- Blood Pressure
- Evidence of pulmonary oedema – tachycardia, gallop rhythm, basal crepitations
- Neurological Examination - level of consciousness, reflexes, puplis for evidence of uraemia, papilloedema
- Evidence of infection

Investigations

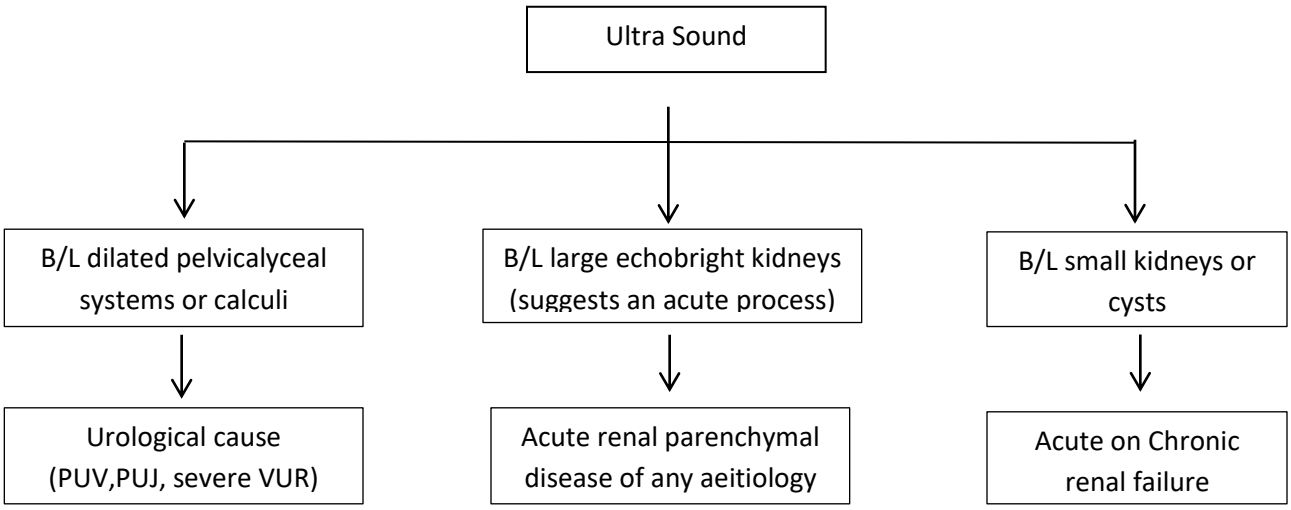
Basic Investigations – Table 2(*repeat daily or more frequently as determine by the clinical condition)

Urine	Blood	Radiological & other
Urinalysis – proteins, red cells, casts, epithelial cells	Full blood count* & blood picture	Renal ultrasound
Culture & ABST	ESR	CXR if respiratory or cardiac signs
Osmolality	CRP	ECG
Sodium, creatinine	Blood culture	
Urea	Urea & Electrolytes*	
	Creatinine*	
	VBG*	
	Ca, PO_4, Alkaline phosphatase	
	LFT	
	Group & cross match	
	Coagulation screen	

Consider the following investigations on clinical grounds (table 3)

Suspected clinical condition	Investigation
Urinary obstruction	MCUG, DTPA, IVU
Glomerulonephritis	Throat swab, ASOT, C3, C4, immunoglobulin A, ANA, dsDNA
HUS	Stool culture, blood film, direct Coomb's test, Lactate dehydrogenase (LDH)
Vasculitis	ANCA, anti-GBM, anti- cardiolipin antibodies
Acute on chronic renal failure	PTH, X ray left wrist
Rhabdomyolysis	Creatinine kinase & urine myoglobulin

Ultra sound scan in the diagnosis of the cause of AKI



Urinary Electrolytes and Urea excretion in AKI

- Urine osmolality, electrolytes and urea (done before starting diuretics) can be used to differentiate fluid responsive pre-renal AKI from acute tubular necrosis (ATN) due to structural damage. (Table 4)
- Calculate the fractional excretion of sodium (Fe Na%) from the formula as below: Fractional excretion of Urea (Fe urea %) is also similarly calculated.

$$\text{Fe Na\%} = \frac{\text{Urine Na} \times \text{Plasma creatinine} \times 100}{\text{Plasma Na} \quad \text{Urine creatinine}}$$

Table 4

	Pre - enal	ATN
Osmolality mosm/l	>400	<350
Urine Na mmol/l	<10	>40
Fe Na %	<1	>2
***Fe Urea %**	<35%	>35%

*may not be reliable in sepsis

Prevention of AKI in high risk patient

- It is possible to prevent **development of acute kidney injury** in the susceptible child by:
  - adequate fluid therapy +/- inotropic support to maintain renal perfusion
  - avoiding nephrotoxins.
- Children at risk of kidney injury can be prevented from **progressing into renal failure** by:
  - frequent monitoring of the urine output & creatinine
  - early intervention to restore the urine output

Monitor

- Regular monitoring of creatinine until stable.
- Record fluid balance **accurately** and review **6-12hourly**.
- Monitior PR, RR, BP frequently: 1-4hrly
- Daily / twice daily weight
- Any signs of sepsis should be urgently investigated and treated.

Maintain adequate renal perfusion

- Assess circulatory volume status to ensure adequate perfusion pressure.
- Treat **hypoperfusion** and **hypoxia** urgently with protocol based crystalloid or colloid therapy, inotropic support and oxygen therapy (Refer relevant guideline).
- Achieve and maintain hemodynamic and oxygenation parameters.
  - CRFT < 2 s
  - Age appropriate systolic blood pressure
  - SPO2 > 94%

Minimize further injury to the kidneys

- Review, adjust dose and monitor medications that may adversely affect renal functions (aminoglycosides, ACE/ARB, NSAIDs, calcineurin inhibitors) -follow instruction in Paediatric BNF.
- Avoid IV contrast as far as possible.
- Avoid using aminoglycosides for the treatment of infections unless no suitable, less nephrotoxic, therapeutic alternatives are available.
- In patients with normal kidney function in steady state, administer aminoglycosides as a single dose daily rather than multiple-dose daily treatment regimens.
- Use topical or local preparations of aminoglycosides (e.g., respiratory aerosols), rather than IV application, when feasible

Management of confirmed AKI

- Recognize and treat the underlying cause.
- Patient should be assessed by a Consultant on an urgent basis.
- Patient management should be discussed with a PaediatrIc Nephrologist on an urgent basis.
- Catheterize the patient if urine output cannot be reliably measured on an hourly basis.

Fluid Management

- Fluid therapy depends on the strict assessment of the volume status.
- Aim is to maintain isovolaemia and prevent fluid overload of >10%, which is associated with high risk of mortality.

Hypovolaemic patient	Volume overloaded patient	Euvolaemic patient
• Boluses of normal saline 10-20ml/kg repeated till euvolaemic. • Reassess UOP in 1-2 hrs. • If it improves, give 100% of urine output+ insensible loss* + any ongoing losses over the next calculated hours.	• Give furosemide 2- 5mg/kg IV bolus over 15 mints or infusion of 0.1- 1mg/kg/hr. • If diuresis is established with furosemide, restrict fluids to 50-75% of UOP to allow a negative balance **till euvolaemic.** Thereafter, replace 100% of UOP & other losses • If no improve in UOP in 1-2hrs, ➢ restrict fluids to insensible loss* + 50%- 75% of UOP to create a negative balance ➢ stop further furosemide, ➢ consider RRT.	•Fluid challenge with 10-20ml/kg 0.9%saline •If no improvement in UOP in 1-2 hrs, ➢ restrict intake to insensible loss* + previous UOP + other losses. ➢ consider the need to start RRT on a daily basis.

*Insensible loss – 400ml/m^2/day, UOP- Urine output

Monitoring

- Hourly BP, PR, RR
- Body weight - twice daily
- Hourly input , output recording
- Neurological observation with frequency determined by clinical picture
- U&E, creatinine, VBG, Ca, PO_4, FBC - up to 6hourly until the onset of recovery
- Calculate % fluid overload daily, using the following equation and adjust the fluid regime accordingly.

$$\% \text{ Fluid Overload} = \frac{\text{Total fluid in (l)} - \text{Total fluid out (l)} \times 100}{\text{Body weight on admission (kg)}}$$

Minimize further injury

- Review, adjust and monitor medications especially aminoglycosides, ACEs, ARBs, NSAIDs, calcineurin inhibitors (Refer Paediatric BNF) .
- Avoid radio contrast
- Treat infection vigorously

Manage electrolyte and acid base disturbances

- Treat any K^+ and Na^+ disturbances (commonly hyperkalaemia and hyponatraemia) and acid base disturbance (commonly metabolic acidosis) according to relevant guideline.
- Treatment of hyperkalaemia includes stopping exogenous K intake (diet, medication).

Management of hypocalcaemia and hyperphosphataemia

- If hypocalcaemia is associated with hyperkalaemia, connect patient to ECG monitor to look for changes of acute hyperkalaemia (refer to guideline on hyperkalaemia).
- If, ECG changes of hyperkalemia are present, give 10% Calcium gluconate 0.5 -1ml/kg IV over 10-15 mints with ECG monitoring for arrhythmias.
- Hypocalcaemia will improve if hyperphosphataemia is treated.
- If serum PO_4 is high for the age(see below) , restrict dietary phosphates and use a calcium based phosphate binder provided the serum Ca is low or normal: eg calcium carbonate.
  - 0 – 6 years > 2.1 mmol/l
  - 6 -12 years > 1.8 mmol/l
  - Above 12 years > 1.4 mmol/l

Management of hypertension

- Often due to fluid overload.
- Use diuretics – furosemide , if responsive.
- Vasodilators can also be used- Ca channel blockers (Nifedipine), α blockers (Prazosine).
- Avoid ACEs/ ARBs as they reduce the glomerular filtration resulting in an increase in creatinine and worsening of hyperkalemia.
- Follow relevant guideline on hypertension.
- Consider RRT if there is severe hypertension that is refractory to management with antihypertensives.

Nutrition

- Adequate nutrition will prevent catabolism, control metabolic abnormalities and help recovery.
- Consider nasogastric or parenteral feeding if unable to meet nutritional requirements enterally.
- Caloric requirement

Body wt (kg)	Daily caloric requirement (kcal/day)
3-10	100 kcal/kg
10-20	1000 + 50kcal/kg for each kg > 10kg
>20	1500 + 20 kcal/kg for each kg > 20kg

- Protein requirement

Blood urea level (mmol/l)	Protein intake
>40	Protein free
30-40	0.5 g/kg/day
20-30	1g/kg/day
<20	2g/kg/day

- Restrict potassium and phosphates depending on blood values
- Replace vitamins and micronutrients

Drug therapy

- Correct drug doses according to GFR by following instructions in Paediatric BNF.
- Revise the drug doses regularly with changes in the GFR.
- Many drugs require either dose reduction or increase in dosing interval.
- Avoid nephrotoxic medications at all times.

Acute Renal Replacement Therapy

- After the initial management, an assessment has to be made whether to continue conservative management or to start renal replacement therapy
- Review this decision on a daily basis.
- An euvolaemic child can be managed conservatively for a few days even in the presence of oliguria with adequate nutrition and fluid restriction.
- All patients with established renal failure should be discussed with a Paediatric Nephrologist **on a daily basis** for further management.

- Available options
  - Peritoneal dialysis
  - Hemodialysis
  - Continuous Renal Replacement Therapy

- **Traditional Indications for commencing dialysis**
  1. Hyperkalaemia > 6.5 mmol/l
  2. ECG changes irrespective of K^+ value
  3. Severe fluid over load with hypertension, pulmonary oedema and cardiac failure
  4. Urea > 40 mmol/l (>30 mmol/l in neonate)
  5. Severe acidosis pH <7.2 refractory to HCO_3 therapy
  6. Multi-organ failure
  7. Severe hypo/hypernatraemia with oliguria
  8. Anticipation of prolonged anuria: eg HUS
  9. To create space for nutritional intake, administration of fluids and IV drug infusions and blood products due to fluid restriction.

- Consider early institution of dialysis in the critically ill child with AKI in order to maintain homeostasis and create enough volume space to allow nutritional and therapeutic needs as above.

Management during recovery phase

- Polyuria may develop in the recovery phase.
- Monitoring – twice daily weight
  Hourly input- output
  Hourly observations of vital signs
  U & E, creatinine, VBG twice daily
- Fluid therapy
  - Replace 100% of UOP and insensible loss with normal saline for 24 – 48hrs
  - If renal functions continue to improve, a slight fluid restriction is recommended until polyuria settles.
  - In the absence of polyuria with decline in creatinine, can proceed to normal maintenance fluid.

- Dialysis can be stopped when the urine output is sufficient to allow an adequate nutritional intake and the creatinine continues to decline.

Follow up

- Children with AKI are at risk of developing CKD subsequently
- Therefore, they should be followed up for development of hypertension, proteinuria and CKD. Patients with pre-renal ARF are and exception.
- Monitor GFR, BP and urine protein: urine creatinine ratio 3months and 12 months after ARF.
- Annual BP & urine for protein thereafter.
- Refer to a Paediatric nephrologist if any abnormality is detected.

References

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