ACUTE RENAL FAILURE

Acute renal failure (ARF), also termed acute renal insufficiency, is a clinical syndrome in which a sudden deterioration in renal function results in the inability of the kidneys to maintain fluid and electrolyte homeostasis.

ARF occurs in 2-3% of children admitted to pediatric tertiary care centers and in as many as 8% of infants in neonatal intensive care units.

Acute Kidney Injury Network categorizes severity by rise in serum creatinine.

Stage 1 >150%, stage II >200%, stage III >300%.

CAUSES

1. Prerenal causes: Dehydration, Hemorrhage, sepsis, Hypoalbuminemia, cardiac failure.

2.Intrinsic renal causes: Glomerulonephritis (Postinfectious /post streptococcal, Lupus erythematosus, Henoch-Schönlein purpura, Membranoproliferative) , Hemolytic-uremic syndrome, Acute tubular necrosis, Cortical necrosis, Renal vein thrombosis, Rhabdomyolysis, Acute interstitial nephritis, Tumor infiltration, Tumor lysis syndrome.

3. Postrenal causes: Posterior urethral valves, Ureteropelvic junction obstruction, Ureterovesicular junction obstruction, Ureterocele, Tumor, Urolithiasis, Hemorrhagic cystitis, neurogenic bladder.

Clinical Manifestations and Diagnosis

1) History include:

An infant with a 3-day history of vomiting and diarrhea most likely has prerenal ARF caused by volume depletion, but HUS must be a consideration.

A 6 yr old child with a recent pharyngitis who presents with periorbital edema, hypertension, and gross hematuria most likely has intrinsic ARF related to acute postinfectious glomerulonephritis.

A critically ill child with a history of protracted hypotension or with exposure to nephrotoxic medications most likely has ATN.

A neonate with a history of hydronephrosis on prenatal ultrasound and a palpable bladder and prostate most likely has congenital urinary tract obstruction, probably related to posterior urethral valves.

2) Physical examination include:

Careful attention to volume status. Tachycardia, dry mucous membranes, and poor peripheral perfusion suggest inadequate circulating volume and the possibility of prerenal ARF.

Peripheral edema, rales, and a cardiac gallop suggest volume overload and the possibility of intrinsic ARF from glomerulonephritis or ATN.

The presence of a rash and arthritis might suggest systemic lupus erythematosus (SLE) or Henoch-Schönlein purpura nephritis.

Palpable flank masses might suggest renal vein thrombosis, tumors, cystic disease, or urinary tract obstruction.

Laboratory Findings

1. CBP: include anemia (the anemia is usually dilutional or hemolytic, as in SLE, renal vein thrombosis, HUS); leukopenia (SLE, sepsis); thrombocytopenia (SLE, renal vein thrombosis, sepsis, HUS).

2. Renal function test: elevated serum concentrations of blood urea nitrogen, creatinine.

3. Electrolytes: hyponatremia (dilutional); metabolic acidosis; uric acid, potassium, and phosphate (diminished renal function); and hypocalcemia (hyperphosphatemia).

4. The serum C3 level may be depressed (postinfectious glomerulonephritis, SLE, or membranoproliferative glomerulonephritis).

5. Antibodies may be detected in the serum to streptococcal (poststreptococcal glomerulonephritis), nuclear (SLE), neutrophil cytoplasmic (Wegener granulomatosis, microscopic polyarteritis), or glomerular basement membrane (Goodpasture disease) antigens.

6. GUE: The presence of hematuria, proteinuria, and red blood cell or granular urinary casts suggests intrinsic ARF, in particular glomerular disease.

The presence of white blood cells and white blood cell casts, with low-grade hematuria and proteinuria, suggests tubulointerstitial disease.

Urinary eosinophils may be present in children with drug-induced tubulointerstitial nephritis.

7. Urinary indices may be useful in differentiating prerenal ARF from intrinsic ARF.

Patients whose urine shows an elevated specific gravity (>1.020), elevated urine osmolality (UOsm > 500 mOsm/kg), low urine sodium (UNa <20 mEq/L), and fractional excretion of sodium (FENa) <1% (<2.5% in neonates) most likely have prerenal ARF. Those with a specific gravity of<1.010, low urine osmolality (UOsm < 350 mOsm/kg), high urine sodium (UNa > 40 mEq/L), and FENa > 2% (>10% in neonates) most likely have intrinsic ARF.

8. Chest radiography may reveal cardiomegaly, pulmonary congestion (fluid overload) or pleural effusions.

9. Renal ultrasonography can reveal hydronephrosis and/or hydroureter, which suggest urinary tract obstruction, or nephromegaly, suggesting intrinsic renal disease.

10. Renal biopsy can ultimately be required to determine the precise cause of ARF in patients who do not have clearly defined prerenal or postrenal ARF.

11. Other biomarkers under investigation include changes in plasma neutrophil gelatinase-associated lipocalin (NGAL) and cystatin C levels and urinary changes in NGAL, interleukin-18 (IL-18), and kidney injury molecule-1 (KIM-1).

Treatment

Medical Management

1. In infants and children with urinary tract obstruction, such as in a newborn with suspected posterior ureteral valves, a bladder catheter should be placed immediately to ensure adequate drainage of the urinary tract. The placement of a bladder catheter may also be considered in nonambulatory older children and adolescents to accurately monitor urine output during ARF.

2. Determination of the volume status is of critical importance when initially evaluating a patient with ARF. If there is no evidence of volume overload or cardiac failure, intravascular volume should be expanded by intravenous administration of isotonic saline, 20 mL/kg over 30 min. In the absence of blood loss or hypoproteinemia, colloid-containing solutions are not required for volume expansion.

Severe hypovolemia may require additional fluid boluses. After volume resuscitation, hypovolemic patients generally void within 2 hr; failure to do so points to intrinsic or postrenal ARF. Hypotension due to sepsis requires vigorous fluid resuscitation followed by a continuous infusion of norepinephrine

3. Diuretic therapy should be considered only after the adequacy of the circulating blood volume has been established. Mannitol (0.5 g/kg) and furosemide (2-4 mg/kg) may be administered as a single IV dose.

Bumetanide (0.1 mg/kg) may be given as an alternative to furosemide. If urine output is not improved, then a continuous diuretic infusion may be considered. To increase renal cortical blood flow, many clinicians administer dopamine (2-3 mg/kg/min) in conjunction with diuretic therapy, although no controlled data support this practice. Mannitol may be effective in pigment (myoglobin, hemoglobin)-induced renal failure.

4. If there is no response to a diuretic challenge, diuretics should be discontinued and fluid restriction is essential. Patients with a relatively normal intravascular volume should initially be limited to 400 mL/m2/24 hr (insensible losses) plus an amount of fluid equal to the urine output for that day.

5. Markedly hypervolemic patients can require further fluid restriction, omitting the replacement of insensible fluid losses, urine output, and extrarenal losses to diminish the expanded intravascular volume. Fluid intake, urine and stool output, body weight, and serum chemistries should be monitored on a daily basis.

6. Hyperkalemia Serum potassium level >6 mEq/L can lead to cardiac arrhythmia, cardiac arrest, and death. The earliest electrocardiographic change seen in patients with developing hyperkalemia is the appearance of peaked T waves. This may be followed by widening of the QRS intervals, ST segment depression, ventricular arrhythmias, and cardiac arrest. Procedures to deplete body potassium stores should be initiated when the serum potassium value rises to>6.0 mEq/L. Exogenous sources of potassium (dietary, intravenous fluids, total parenteral nutrition) should be eliminated. Sodium polystyrene sulfonate resin (Kayexalate), 1 g/kg, should be given orally or by retention enema. This resin exchanges sodium for potassium and can take several hours to take effect. A single dose of 1 g/kg can be expected to lower the serum potassium level by about 1 mEq/L. Resin therapy may be repeated every 2 hr, the frequency being limited primarily by the risk of sodium overload.

More-severe elevations in serum potassium (>7 mEq/L), especially if accompanied by electrocardiographic changes, require emergency measures in addition to Kayexalate.

The following agents should be administered:

- Calcium gluconate 10% solution, 1.0 mL/kg IV, over 3-5 min
- Sodium bicarbonate, 1-2 mEq/kg IV, over 5-10 min
- Regular insulin, 0.1 U/kg, with glucose 50% solution, 1 mL/kg, over 1 hr

Calcium gluconate counteracts the potassium-induced increase in myocardial irritability but does not lower the serum potassium level. Administration of sodium bicarbonate, insulin, glucose lowers the serum potassium level by shifting potassium from the extracellular to the intracellular compartment. A similar effect has been reported with the acute administration of β-adrenergic agonists in adults, but there are no controlled data in pediatric patients.

Because the duration of action of these emergency measures is just a few hours, persistent hyperkalemia should be managed by dialysis.

7. Mild metabolic acidosis is common in ARF because of retention of hydrogen ions, phosphate, and sulfate, but it rarely requires treatment. If acidosis is severe (arterial pH < 7.15; serum bicarbonate < 8 mEq/L) or contributes to hyperkalemia, treatment is required. The acidosis should be corrected partially by the intravenous route, generally giving enough bicarbonate to raise the arterial pH to 7.20 (which approximates a serum bicarbonate level of 12 mEq/L). The remainder of the correction may be accomplished by oral administration of sodium bicarbonate after normalization of the serum calcium and phosphorus levels. Correction of metabolic acidosis with intravenous bicarbonate can precipitate tetany in patients with renal failure as rapid correction of acidosis reduces the ionized calcium concentration.

8. Hypocalcemia is primarily treated by lowering the serum phosphorus level.

Calcium should not be given intravenously, except in cases of tetany, to avoid deposition of calcium salts into tissues. Patients should be instructed to follow a low-phosphorus diet, and phosphate binders should be orally administered to bind any ingested phosphate and increase GI phosphate excretion. Common agents include sevelamer (Renagel), calcium carbonate (Tums tablets or Titralac suspension), and calcium acetate (PhosLo). Aluminum-based binders, commonly employed in the past, should be avoided because of the established risk of aluminum toxicity.

9. Hyponatremia is most commonly a dilutional disturbance that must be corrected by fluid restriction rather than sodium chloride administration.

Administration of hypertonic (3%) saline should be limited to patients with symptomatic hyponatremia (seizures, lethargy) or those with a serum sodium level <120 mEq/L.

10. ARF patients are predisposed to GI bleeding because of uremic platelet dysfunction, increased stress, and heparin exposure if on hemodialysis or continuous renal replacement therapy. Oral or intravenous H2 blockers such as ranitidine are commonly administered to prevent this complication.

11. Hypertension can result from hyperreninemia associated with the primary disease process and/or expansion of the extracellular fluid volume and is most common in ARF patients with acute glomerulonephritis or HUS. Salt and water restriction is critical, and diuretic administration may be useful.

Isradipine (0.05-0.15 mg/kg/dose, maximum dose 5 mg qid) may be administered for relatively rapid reduction in blood pressure. Longer-acting agents such as calcium channel blockers (amlodipine, 0.1-0.6 mg/kg/24 hr qd or divided bid) or β-blockers (propranolol, 0.5-8 mg/kg/24 hr divided bid or tid; labetalol, 4-40 mg/kg/24 hr divided bid or tid) may be helpful in maintaining control of blood pressure. Children with severe symptomatic hypertension (hypertensive urgency or emergency) should be treated with continuous infusions of sodium nitroprusside (0.5-10?g/kg/min), labetalol (0.25-3.0 mg/kg/hr), or esmolol (150-300? g/kg/min) and converted to intermittently dosed antihypertensives when more stable.

12. Neurologic symptoms in ARF can include headache, seizures, lethargy, and confusion (encephalopathy). Potential etiologic factors include hyponatremia, hypocalcemia, hypertension, cerebral hemorrhage, cerebral vasculitis, and the uremic state.

Diazepam is the most effective agent in controlling seizures, and therapy should be directed toward the precipitating cause

13. The anemia of ARF is generally mild (hemoglobin 9-10 g/dL) and primarily results from volume expansion (hemodilution). Children with HUS, SLE, active bleeding, or prolonged ARF can require transfusion of packed red blood cells if their hemoglobin level falls below 7 g/dL. In hypervolemic patients, blood transfusion carries the risk of further volume expansion, which can precipitate hypertension, heart failure, and pulmonary edema. Slow (4-6 hr) transfusion with packed red blood cells (10 mL/kg) diminishes the risk of hypervolemia. The use of fresh washed red blood cells minimizes the risk of hyperkalemia. In the presence of severe hypervolemia or hyperkalemia, blood transfusions are most safely administered during dialysis or ultrafiltration

14. Nutrition is of critical importance in children who develop ARF. In most cases, sodium, potassium, and phosphorus should be restricted. Protein intake should be restricted moderately while maximizing caloric intake to minimize the accumulation of nitrogenous wastes.

In critically ill patients with ARF, parenteral hyperalimentation with essential amino acids should be considered.

Dialysis

1. Intermittent hemodialysis is useful in patients with relatively stable hemodynamic status.

2. Peritoneal dialysis is most commonly employed in neonates and infants with ARF.

Anticoagulation is not necessary. Peritoneal dialysis is contraindicated in patients with significant abdominal pathology.

3. Continuous renal replacement therapy (CRRT) is useful in patients with unstable hemodynamic status, concomitant sepsis, or multiorgan failure in the intensive care setting.

Indications for dialysis in ARF include the following:

• Volume overload with evidence of hypertension and/or pulmonary edema refractory to diuretic therapy

• Persistent hyperkalemia

• Severe metabolic acidosis unresponsive to medical management

• Neurologic symptoms (altered mental status, seizures)

• Blood urea nitrogen >100-150 mg/dL (or lower if rapidly rising)

• Calcium: phosphorus imbalance, with hypocalcemic tetany

An additional indication for dialysis is the inability to provide adequate nutritional intake because of the need for severe fluid restriction.

In patients with ARF, dialysis support may be necessary for days or for up to 12 wk.

Many patients with ARF require dialysis support for 1-3 wk.

Prognosis

Children with ARF caused by a renal-limited condition such as postinfectious glomerulonephritis have a very low mortality rate (<1%); those with ARF related to multiorgan failure have a very high mortality rate (>90%).

Recovery of renal function is likely after ARF resulting from prerenal causes, HUS, ATN, acute interstitial nephritis, or tumor lysis syndrome.

Recovery of renal function is unusual when ARF results from most types of rapidly progressive glomerulonephritis, bilateral renal vein thrombosis, or bilateral cortical necrosis.

Medical management may be necessary for a prolonged period to treat the sequelae of ARF, including chronic renal insufficiency, hypertension, renal tubular acidosis, and urinary concentrating defect.

Chronic Kidney Disease

Chronic kidney disease (CKD) is defined as renal injury (proteinuria) and/or a glomerular filtration rate <60 mL/min/1.73 m2 for >3 mo.

Etiology

CKD in children <5 yr old is most commonly a result of congenital abnormalities such as renal hypoplasia, dysplasia, or obstructive uropathy. Additional causes include congenital nephrotic syndrome, prune belly syndrome, cortical necrosis, focal segmental glomerulosclerosis, polycystic kidney disease, renal vein thrombosis, and hemolytic uremic syndrome.

After 5 yr of age, acquired diseases (various forms of glomerulonephritis including lupus nephritis) and inherited disorders (familial juvenile nephronophthisis, Alport syndrome) predominate. CKD related to metabolic disorders (cystinosis, hyperoxaluria) and certain inherited disorders (polycystic kidney disease) can occur throughout the childhood years

Pathogenesis

Hyperfiltration injury may be an important final common pathway of glomerular destruction, independent of the underlying cause of renal injury.

As nephrons are lost, the remaining nephrons undergo structural and functional hypertrophy characterized by an increase in glomerular blood flow. Proteinuria itself can contribute to renal functional decline, as evidenced by studies that have shown a beneficial effect of reduction in proteinuria. Proteins that traverse the glomerular capillary wall can exert a direct toxic effect on tubular cells and recruit monocytes and macrophages, enhancing the process of glomerular sclerosis and tubulointerstitial fibrosis.

Uncontrolled hypertension can exacerbate disease progression by causing arteriolar nephrosclerosis and by increasing the hyperfiltration injury.

Hyperphosphatemia can increase progression of disease by leading to calcium phosphate deposition in the renal interstitium and blood vessels.

Hyperlipidemia, a common condition in CKD patients, can adversely affect glomerular function through oxidant-mediated injury.

Pathophysiology of CKD

1. Accumulation of nitrogenous waste products: Decrease in glomerular filtration rate.

2. Acidosis: Decreased ammonia synthesis, impaired bicarbonate reabsorption, and decreased net acid excretion.

3. Sodium retention: Excessive renin production Oliguria.

4. Sodium wasting: Solute diuresis, Tubular damage.

5. Hyperkalemia: Decrease in glomerular filtration rate, metabolic acidosis, Excessive potassium intake, Hyporeninemic, hypoaldosteronism

6. Renal osteodystrophy: Impaired renal production of 1, 25-dihydroxycholecalciferol, Hyperphosphatemia, Hypocalcemia, Secondary hyperparathyroidism.

7. Growth retardation: Inadequate caloric intake, renal osteodystrophy, metabolic acidosis, Anemia, Growth hormone resistance.

8. Anemia: decrease erythropoietin production, iron deficiency, folate deficiency, vitamin B12 deficiency, and decrease erythrocyte survival.

9. Bleeding tendency: defect platelet function.

10. Infection: Defective granulocyte function, impaired cellular immune functions, indwelling dialysis catheters.

11. Neurologic symptoms (fatigue, poor concentration, headache, drowsiness, memory loss, seizures, peripheral neuropathy): Uremic factor(s), Aluminum toxicity, Hypertension.

12. Gastrointestinal symptoms (feeding intolerance, abdominal pain): Gastroesophageal reflux, Decreased gastrointestinal motility.

13. Hypertension: Volume overload, Excessive renin production.

14. Hyperlipidemia: Decreased plasma lipoprotein lipase activity.

15. Pericarditis, cardiomyopathy: uremic factors, hypertension, fluid overload.

16. Glucose intolerance: Tissue insulin resistance.

Clinical Manifestations

Children and adolescents with CKD from chronic glomerulonephritis (membranoproliferative glomerulonephritis) can present with edema, hypertension, hematuria, and proteinuria.

Infants and children with congenital disorders such as renal dysplasia and obstructive uropathy can present in the neonatal period with failure to thrive, polyuria dehydration, urinary tract infection, or overt renal insufficiency.

Children with familial juvenile nephronophthisis can have a very subtle presentation with nonspecific complaints such as headache, fatigue, lethargy, anorexia, vomiting, polydipsia, polyuria, and growth failure over a number of years.

The physical examination in patients with CKD can reveal pallor and a sallow appearance. Patients with long-standing untreated CKD can have short stature and the bony abnormalities of renal osteodystrophy.

Children with CKD due to chronic glomerulonephritis (or children with advanced renal failure from any cause) can have edema, hypertension, and other signs of extracellular fluid volume overload.

Laboratory Findings

1. Renal function test: elevations in blood urea nitrogen and serum creatinine.

2. Electrolytes: hyperkalemia, hyponatremia (if volume overloaded), acidosis, hypocalcemia, hyperphosphatemia, and an elevation in uric acid. Patients with heavy proteinuria can have Hypoalbuminemia.

3. CBP: A complete blood cell count shows a normochromic, normocytic anemia.

4. Lipid profile: Serum cholesterol and triglyceride levels are often elevated

5. GUE: In children with CKD caused by glomerulonephritis, the urinalysis shows hematuria and proteinuria. In children with CKD from congenital lesions such as renal dysplasia, the urinalysis usually has a low specific gravity and minimal abnormalities by dipstick or microscopy.

6. Inulin clearance is the gold standard to determine GFR, but it is not easy to measure

7. In children, the degree of renal dysfunction may be determined by applying the following formula, which provides an estimation of the patient's GFR:

GFR (ml/min/1.73m2)= k* ht (cm)

S.cr. (mg/dl)

Where is 0.33 for LBW infants less than 1 yr , 0.45 for term infants less than 1yr whose wt. is appropriate for GA , 0.55 for children & adolescent girl , & 0.70 for adolescent boys.

STAGES OF CHRONIC KIDNEY DISEASE

STAGE	DESCRIPTION	GFR (mL/min/1.73 m^2)
1	Kidney damage with normal or increased GFR	>90
2	Kidney damage with mild decrease in GFR	60-89
3	Moderate decrease in GFR	30-59
4	Severe decrease in GFR	5-29
5	Kidney failure	<15 or on dialysis

Treatment

The treatment of CKD is aimed at replacing absent or diminished renal functions, which progressively deteriorate in parallel with the progressive loss of GFR, and slowing the progression of renal dysfunction.

The management of CKD requires close monitoring of a patient's clinical and laboratory status. Blood studies to be followed routinely include serum electrolytes, blood urea nitrogen, creatinine, calcium, phosphorus, albumin, alkaline phosphatase, and hemoglobin levels.

Periodic measurement of intact parathyroid hormone (PTH) levels and roentgenographic studies of bone may be of value in detecting early evidence of renal osteodystrophy.

Echocardiography should be performed periodically to identify left ventricular hypertrophy and cardiac dysfunction that can occur as a consequence of the complications of CKD.

1. Fluid and Electrolyte Management

Most children with CKD maintain normal sodium and water balance, with the sodium intake derived from an appropriate diet.

Infants and children whose CKD is a consequence of renal dysplasia may be polyuric, with significant urinary sodium losses. These children can benefit from high-volume, low-caloric-density feedings with sodium supplementation.

Children with high blood pressure, edema, or heart failure can require sodium restriction and diuretic therapy.

Fluid restriction is rarely necessary in children with CKD until the development of end-stage renal disease (ESRD) requires the initiation of dialysis.

In most children with CKD, potassium balance is maintained until renal function deteriorates to the level at which dialysis is initiated.

Hyperkalemia may be treated by restriction of dietary potassium intake, administration of oral alkalinizing agents, and/or treatment with Kayexalate

2. Acidosis

Metabolic acidosis develops in almost all children with CKD as a result of decreased net acid excretion by the failing kidneys.

Either Bicitra (1 mEq sodium citrate/mL) or sodium bicarbonate tablets (650 mg = 8 mEq of base) may be used to maintain the serum bicarbonate level >22 mEq/L.

3. Nutrition

Dietary phosphorus, potassium, and sodium should be restricted according to the individual patient's laboratory studies and fluid balance.

In infants with CKD, formulas containing a reduced amount of phosphate (Similac PM 60/40) are commonly employed.

The optimal caloric intake in patients with CKD is unknown, but it is recommended to provide at least the recommended dietary allowance of caloric intake for age. Protein intake should be 2.5 g/kg/24 hr.

Children with CKD can become deficient in water-soluble vitamins, these should be routinely supplied.

Zinc and iron supplements should be added only if deficiencies are confirmed.

Supplementation with fat-soluble vitamins A, E, and K is usually not required.

4. Growth

Children with CKD who remain less than −2 SD for height despite optimal medical support (adequate caloric intake and effective treatment of renal osteodystrophy, anemia, and metabolic acidosis) might benefit from treatment with pharmacologic doses of recombinant human GH (rHuGH).

Treatment may be initiated with rHuGH (0.05 mg/kg/24 hr) subcutaneously, with periodic adjustment in the dose to achieve a goal of normal height velocity for age.

Treatment with rHuGH continues until the patient reaches the 50th percentile for midparental height or achieves a final adult height or undergoes kidney transplantation.

Long-term rHuGH treatment significantly improves final adult height and induces persistent catch-up growth; some patients achieve normal adult height.

5. Renal Osteodystrophy

The skeletal pathologic finding in this condition is osteitis fibrosa cystica.

when the GFR declines to approximately 50% of normal, the decrease in functional kidney mass leads to a decline in renal 1α-hydroxylase activity, with decreased production of activated vitamin D (1,25-dihydroxycholecalciferol).

Clinical manifestations of renal osteodystrophy include muscle weakness, bone pain, and fractures with minor trauma. In growing children, rachitic changes, varus and valgus deformities of the long bones, and slipped capital femoral epiphyses may be seen.

Laboratory studies can demonstrate a decreased serum calcium level, increased serum phosphorus level, increased alkaline phosphatase, and a normal PTH level. Radiographs of the hands, wrists, and knees show subperiosteal resorption of bone with widening of the metaphyses

Treatment is by restrict phosphorus intake with phosphate binders e.g. calcium carbonate (or acetate) or by non–calcium-based binders (when there is hypercalcemia).Vit D is the cornerstone of Rx; 1st measure serum level of 25-hydroxy-vitamin D, if low, give ergocalciferol, whereas if it normal, give activated vit D, i.e, 1, 25-vitD e.g. Calcitriol 0.01–0.05 μg/kg/day, Paracalcitol or Doxecalciferol.

Note: maintain calcium/phosphorus product (Ca × PO4) below 55 to minimize the risk of tissue deposition of calcium phosphorus salts.

Adynamic (low-turnover) Bone Disease can cause osteomalacia due to oversuppression of PTH by excessive intake of Ca salt & vit D.

6. Anemia

Erythropoietin is usually initiated when the patient's hemoglobin concentration falls below 10 g/dL, at a dose of 50-150 mg/kg/dose subcutaneously 1-3 times weekly. The dose is adjusted to maintain the hemoglobin concentration between 11 and 12 g/dL, not more than 13 g/dL.

All patients receiving rHuEPO therapy should be provided with either oral or intravenous iron supplementation.

Benefit of erythropoietin: avoid and minimization of blood transfusion, improved appetite, improved sleep and wellbeing, and enhanced exercise tolerance.

Complication of erythropoietin: iron deficiency, seizure, hypertension, clotting of vascular access, and pure red aplasia due to erythropoietin antibodies.

Patients who appear to be resistant to rHuEPO should be evaluated for iron deficiency, occult blood loss, chronic infection or inflammatory state, vitamin B12 or folate deficiency, and bone marrow fibrosis related to secondary hyperparathyroidism.

An alternative option is darbepoetin alfa (Aranesp), a longer-acting agent administered at a dose of 0.45mg/kg/wk. The chief advantage of this agent is that it may be dosed once weekly to once monthly because of its extended duration of action.

7. Hypertension

Hypertensive children with suspected volume overload should follow a salt restricted diet (2-3 g/24 hr) and can benefit from diuretic therapy. Thiazide diuretics (hydrochlorothiazide 2 mg/kg/24 hr divided bid) are the initial diuretic class of choice for children with mild renal dysfunction (CKD stages1-3).

However, when a patient's estimated GFR falls into stage 4 CKD, thiazides are less effective and loop diuretics (furosemide 1-2 mg/kg/dose bid or tid) become the diuretic class of choice.

Angiotensin-converting enzyme (ACE) inhibitors (enalapril, lisinopril) and angiotensin II blockers (losartan) are the antihypertensive medications of choice in all children with proteinuric renal disease because of their potential ability to slow the progression to ESRD.

Calcium channel blockers (amlodipine), β-blockers (propranolol, atenolol), and centrally acting agents (clonidine) may be useful as adjunctive agents in children with CKD whose blood pressure cannot be controlled using dietary sodium restriction, diuretics, and ACE inhibitors.

8. Immunizations

Children with CKD should receive all standard immunizations according to the schedule used for healthy children.

An exception must be made in withholding live vaccines from children with CKD related to glomerulonephritis during treatment with immunosuppressive medications.

All children with CKD should receive a yearly influenza vaccine

9. Adjustment in Drug Dose

Because many drugs are excreted by the kidneys, their dosing might need to be adjusted in patients with CKD to maximize effectiveness and minimize the risk of toxicity.

Strategies in dosage adjustment include lengthening of the interval between doses, decreasing the absolute dose, or both.

10. Dialysis

Either peritoneal dialysis which should be done daily or hemodialysis require vascular access and done only at hospital by 3 session /week.

Indication of dialysis: refractory (fluid overload, electrolytes disturbance, and acidosis), uremic symptoms, and growth failure.

11. Renal transplantation.

Progression of Disease

Although there are no definitive treatments to improve renal function in children or adults with CKD.

There are several strategies that may be effective in slowing the rate of progression of renal dysfunction

1. Optimal control of hypertension (maintaining the blood pressure at lower than the 75th percentile and perhaps even lower) is critical in all patients with CKD.

2. Serum phosphorus should be maintained within the normal range for age and the calcium-phosphorus product <55 to minimize renal calcium phosphorus deposition.

3. Prompt treatment of infectious complications and episodes of dehydration can minimize additional loss of renal parenchyma

4. Correction of anemia, control of hyperlipidemia, avoidance of cigarette smoking, prevention of obesity, and minimization of use of nonsteroidal anti-inflammatory medications.

5. Although dietary protein restriction has been shown to be useful in adults, this recommendation is generally not suggested for children with CKD because of the concern of adverse effects on growth and development.

End stage renal failure

ESRD represents the state in which patients renal dysfunction has progressed to the point at which homeostasis and survival can no longer be sustained with native kidney function and maximal medical treatment unless by renal replacement therapy I,e dialysis or renal transplantation

Indication for long _term dialysis

In patient with CRF are similar to those of ARF e.g refractory fluid overload, electrolyte imbalance, acidosis, uremic symptoms, and growth failure

Dialysis in CRF can be done either by,

1- Daily peritoneal dialysis: it's easy &can be done at home, it's also suitable for infants.

2-hemodialysis: it's require vascular access by A-V shunt or fistula, it only done in hospital at 3 sessions /wk.