Fluids and Electrolytes

INTRODUCTION: The requirements for fluids and electrolytes of the newborn infant are unique. At birth, there is an excess of extra-cellular water (ECW), and this decreases over the first few days after birth. Furthermore, ECW at birth and insensible water loss decrease as birth weight and gestational age increase. Several days after birth, fluid and electrolyte requirements increase as the infant starts to grow. Therefore, appropriate management of fluids and electrolytes in preterm infants must take into consideration the birth weight, gestational age and age after birth. Fluid and electrolyte requirements are also influenced by a variety of medical conditions that affect preterm infants (*e.g.*, RDS, patent ductus arteriosus, necrotizing enterocolitis).

BODY COMPOSITION at birth varies with gestational age and body weight. Examples are shown in the table below. (BW, body weight)

Gestation (weeks)	Body Weight (g)	Total Body Water (%BW)	ECW (%BW)	Body Fat (%BW)
24-27	<1,000	85-90	60-70	0.1-2.5
28-32	1,500	82-85	50-60	3.3-5.5
36-40	>2,500	71-76	~40	9-16

After birth, infants lose weight due to loss of ECW, and this is proportionately greater in smaller, less mature infants. Weight loss after birth reflects this difference in ECW; term infants normally lose up to 5% of their body weight, whereas very immature infants may lose up to 10-15%. Thus, fluid replacement must be adjusted accordingly.

INSENSIBLE WATER LOSS (IWL) is greatest in the smallest and least mature infants due to high surface area to body mass ratio and to immature, water-permeable skin. Estimated IWL in the first few days of life are:

Body	Insensible water loss (mL/kg/d)	
Weight (g)	In Radiant Warmer	In Incubator
<1,000	100-150	75-100
1,000-1,500	75-100	50
1,500-2,000	50	25-50
>2,000	50	25-50

Phototherapy can increase IWL by 25-50%. IWL may exceed urinary output in smaller infants but, unlike urine output, IWL cannot be measured directly. However, IWL must be estimated in order to plan appropriate fluid management. IWL can be estimated by:

IWL = Fluid intake - Urine output + weight loss (or – weight gain)
(*e.g.*, 24-hour totals = intake 90 mL, urine output 60 mL, and weight loss 55 g. Therefore, IWL = 90 - 60 + 55 = 85 mL)

Some SGA infants have increased IWL and, therefore, need increased fluid intake to compensate for this (see section on Intrauterine Growth Retardation, P. 69).

INITIAL FLUID ADMINISTRATION: Guidelines for the first few days of life are:

- For larger infants (*i.e.*, >1,250 g) start at **60 mL/kg/d of D10W**. If estimated ILW is high (*e.g.*, extreme prematurity, abdominal wall defect), start fluids at higher rate, 80-100 mL/kg/d.
- Normal glucose utilization rate in a newborn is 4-8 mg/kg/min. Initial glucose administration rate should be in that range.
- Extremely premature infants (23-26 weeks gestation) under radiant warmers may occasionally require more than 200 mL/kg/d during the first 2 to 3 days of life.
- Increase IV fluid rate if weight loss is >expected, urine output is low, urine specific gravity is rising, and/or serum sodium concentration [Na^+] is rising.
- Conversely, decrease IV fluid rate if serum [Na^+] is falling, weight did not decrease appropriately or actually increased.
- Proper fluid management requires accurate determination of urinary output in mL/kg/h. In the first 24h after birth, urine output may be very low (or even absent) in normal newborns. **After the first day, urine output should be >1 mL/kg/h**.
- If you make a major change in the rate of fluid infusion, you must also change the glucose concentration proportionately to maintain a constant rate of glucose delivery and prevent hyperglycemia (and osmotic diuresis) or hypoglycemia.
- Fluid requirements gradually decrease by day 5-6 as skin permeability decreases.

INITIAL ELECTROLYTE MANAGEMENT:

1. General guidelines:

- All infants receiving only IV fluids should have daily measurements of electrolytes for the first few days of life. The frequency can be reduced as condition stabilizes.
- For infants <750 g, measure electrolytes within 12h of birth to have a baseline, so that adjustments in fluid intake can be made as serum sodium changes. In these extremely preterm infants, significant hyperkalemia may develop in the first 48-72h.
- Measure BUN and creatinine initially and at least every other day until stable, then weekly until feedings are well established.
- Measure magnesium in first few hours after birth if mother had received magnesium.

Suggested frequency of measurements of electrolytes, including calcium for infants receiving only IV fluids:

<750 g	q8-12 h x 3-4d, then daily
750-1,500 g	q12 h x 3-4 days, then daily
>1,500 g	daily

2. Sodium:

- Do not add Na^+ to IV fluids on the first day; wait until day 3-4 when [Na^+] begins to fall. Na^+ is usually given as NaCl, but Na-acetate may be used to decrease metabolic acidosis from renal bicarbonate wasting in ELBW infants.
- Usual maintenance for Na^+ is 2-4 mEq/kg/d.

3. Potassium (K^+):
- Do not add K^+ to IV fluids for the first few days after birth, until urine output is well established and serum K^+ level starts to decline. K^+ may be given as KCl or K-acetate.
- Usual maintenance for K^+ is 1-3 mEq/kg/d.

4. Calcium (Ca^{++}):
- Ca^{++} should be started on the first day after birth especially in infants who are preterm, SGA, asphyxiated, septic, and post operative, and infants of a diabetic mother.
- **Ca^{++} may be added to the IV solution infusing through central catheters after the location of the catheter tip has been verified radiographically to be in proper position.** This includes umbilical arterial and venous catheters and central venous catheters (see section on Intravascular Catheters, P. 25).
- **Ca^{++} should not be added to IV solutions infusing in peripheral veins** because extravasation of Ca^{++} containing solutions may cause severe sloughing of skin. If peripheral IV access is being used, Ca^{++} should be given as an intermittent bolus over 5 to 15 minutes while watching the IV insertion site to ensure that fluid is not infiltrating into the tissues.
- Usual maintenance for Ca^{++} is calcium gluconate 200-400 mg/kg/d.
- Usual intermittent dose is calcium gluconate 50-100 mg/kg IV q6h.

ELECTROLYTE ABNORMALITIES:

1. Hyponatremia is defined as serum [Na^+] <130 mEq/L. Hyponatremia may cause hypotonia, apnea, and, if acute and severe, seizures. **In the first few days after birth, hyponatremia usually indicates fluid overload** (*i.e.*, dilutional hyponatremia). After the first week, it may be either dilutional or indicate a true deficit of total body Na^+.

A. Dilutional hyponatremia is usually accompanied by weight gain or absence of expected weight loss and may be secondary to:
- Renal dysfunction with ↓ urine output and usually a low urine specific gravity.
- Excessive water intake, often with high urine output and low specific gravity.
- Congestive heart failure with ↓ urine output and ↑ specific gravity.
- ↑ extracellular fluid volume (*e.g.*, water retention due to sepsis, prolonged use of muscle relaxants).
- Syndrome of inappropriate secretion of anti-diuretic hormone (SIADH) with low urine output and high urine specific gravity. This condition is rare.

Dilutional hyponatremia should be treated primarily **by fluid restriction**. However, if serum [Na^+] is <120 mEq/L, the baby may require additional Na^+ as well.

B. Sodium deficiency may be accompanied by weight loss and may be caused by:
- Diuretic administration
- Low Na^+ intake
- Gastrointestinal Na^+ losses
- Renal Na^+ losses
- Osmotic diuresis from hyperglycemia

Treat Na^+ deficiency by treating the underlying condition and increasing Na^+ intake. If hyponatremia is caused by diuretic treatment for chronic lung disease, consider decreasing the diuretic dose or giving the diuretic every other day instead of daily, and consider tolerating lower serum $[Na^+]$ (*e.g.*, 125-130 mEq/L). Total body deficit of Na^+ can be calculated by:

Na^+ deficit (mEq) = (desired $[Na^+]$ - current $[Na^+]$) x 0.8 x body weight (kg)

(0.8 x body weight is the volume of distribution for Na^+)

C. Symptomatic hyponatremia: (*e.g.*, seizures or $[Na^+]$ <120 mEq/L). Calculate Na^+ deficit to raise $[Na^+]$ to 125 mEq/L and **give as 3% NaCl (0.5 mEq/mL) over 3-6h.** Correct remaining deficit over next 24h.

D. Asymptomatic hyponatremia: Calculate total deficit of Na^+ and give ½ over 6-8h and the rest over the next 24h, as Na^+ added to IV fluids.

2. Hypernatremia (serum $[Na^+]$ >150 mEq/L) may cause hyperexcitability and hyperreflexia. Severe hypernatremia (serum $[Na^+]$ >160 mEq/L) may cause permanent CNS damage. Hypernatremia is usually secondary to excess Na^+ intake or negative water balance. Usually in a newborn, excessive Na^+ intake leads to excess total body water, and, thus, serum $[Na^+]$ is normal. When hypernatremia is due to excessive Na^+ intake, restrict Na^+ intake and consider administering diuretics. When due to water deficit, it is associated with weight loss and should be treated by increasing free water to correct negative water balance slowly. In babies with meningitis, hypoxic ischemic encephalopathy or severe intracranial hemorrhage, consider diabetes insipidus, which should be treated initially by increasing free water administration. Rapid correction of hypernatremia may cause seizures and permanent neurodevelopmental sequelae. **Therefore, do not lower serum $[Na^+]$ more rapidly than 10 mEq/L q12h.**

3. Hypokalemia (serum $[K^+]$ <3 mEq/L) may cause ileus, arrhythmia (unusual unless $[K^+]$ is <2.5 mEq/L), and altered renal function. Hypokalemia may be caused by:

- ↑ K^+ loss from diuretics, diarrhea, renal defect
- Inadequate K^+ intake
- ↓ extracellular K^+ secondary to metabolic alkalosis.

If the hypokalemia is secondary to metabolic alkalosis, correct alkalosis before considering increasing K^+ intake. For other causes of hypokalemia, increase K^+ in daily maintenance fluids. **K^+ must never be given as a push or bolus infusion because of the risk of serious cardiac arrhythmias.** In extreme emergencies, K^+ can be given as a rapid infusion, but give no more than **0.3 mEq/kg over 20 min**.

4. Hyperkalemia (serum $[K^+]$ >6 mEq/L) may cause lethal arrhythmias, especially ventricular fibrillation. Early EKG changes of hyperkalemia include peaked T waves and widening of the QRS complex. The most common cause of high serum $[K^+]$ is hemolysis of the specimen. When an abnormally elevated $[K^+]$ is reported by the Laboratory, send a repeat sample for **stat $[K^+]$** measurement before starting treatment unless the EKG indicates hyperkalemia.

Hyperkalemia is common in ELBW infants (*i.e.*, <1,000 g), especially in the first few days after birth. Newborns are more resistant to cardiac arrhythmias secondary to hyperkalemia than older children. Treatment is usually indicated when serum [K^+] is >7 mEq/L. If acidosis is present, it should be corrected to increase transfer of potassium from extracellular to the intracellular fluid compartment.

A. Causes of hyperkalemia include:
- •Oliguria and renal failure
- •Acidosis
- •"Sick cell" syndrome secondary to tissue hypoxia and marked prematurity
- •Excessive administration of K^+ in IV fluid or in old or hemolyzed blood
- •Congenital adrenal hyperplasia
- •Hemolysis of blood sample or, more rarely, laboratory error.

B. Treatment of hyperkalemia:
- •If [K^+] >7.0 mEq/L, obtain twelve lead EKG.
- •Discontinue K^+ administration
- •Increase pH with bicarbonate or THAM™
- •Give calcium gluconate (200 mg/kg IV over several minutes) to reach high-normal calcium range which stabilizes the myocardium but has no effect on serum [K^+]
- •If [K^+] >8, consider Kayexalate™, a cation exchange resin. Dose is 1 gm/kg q 4-6h per rectum, but it may be given q2h if [K^+] is rising. Kayexalate removes K^+ by exchanging it for Na^+; therefore, it will give the infant a Na^+ load.
- •↑ glucose administration rate IV and consider an insulin infusion.
- •Insulin infusion: add 2 units of soluble insulin to 60 mL of D12.5%, which gives a concentration of 1 unit of insulin per 30 mL D12.5% (or about 3.3 units of insulin/100mL). This will give glucose/insulin ratio of 3.75 /1, which is safe. Start <u>insulin infusion rate at 0.1 units/kg/h</u>.

5. <u>Hypocalcemia</u> is defined as ionized calcium (iCa^{++}) concentration <0.9 mmol/L. In preterm infants, total serum Ca may be low because serum albumin is low, but [iCa^{++}] may be perfectly normal. True hypocalcemia may cause jitteriness, irritability, high-pitched cry, hypocalcemic seizures, stridor, tetany as well as decreased myocardial contractility with hypotension and decreased cardiac output. EKG may show prolonged QT interval and flat T-wave. **Early onset** hypocalcemia is common in:
- •Preterm infants
- •SGA infants
- •Term infants with birth asphyxia
- •Infants of diabetic mothers

Late onset hypocalcemia may be associated with:
- •DiGeorge syndrome
- •Magnesium deficiency
- •Hyperphosphatemia
- •Renal failure
- •Hypoparathyroidism
  - -Transient neonatal hypoparathyroidism
  - -Secondary to maternal hyperparathyroidism
- •Diuretic therapy

Treatment of hypocalcemia: Slow infusion (over 5 min) of calcium gluconate 10% at a dose of 200 mg/kg (2 cc/kg). Rapid infusion may cause bradyarrhythmias. The infusion may be repeated if necessary and maintenance calcium dose can be increased. In

DiGeorge syndrome, may give oral calcium solution (Neo-Calglucon™). Calcium chloride infusion should be used only in emergencies.

6. Hypercalcemia is defined as total serum [Ca] >12 mg/dL or [ionized calcium] >1.5 mmol/L and is rare in newborns. Hypercalcemia may cause vomiting, hypotonia and encephalopathy.

Causes of hypercalcemia include:

- Low serum phosphorus with bone demineralization
- Congenital hyperparathyroidism (primary or secondary)
- William's syndrome
- Hypervitaminosis D
- Subcutaneous fat necrosis
- Adrenal insufficiency
- Thiazide diuretic therapy
- Hypophosphatasia
- Hyperthyroidism
- Blue diaper syndrome (abnormal tryptophan transport).

Treatment of hypercalcemia:

- Correct underlying cause, if possible
- Adequate hydration
- Obtain consult with Endocrine Service
- Furosemide to increase calcium excretion
- Glucocorticoids to inhibit intestinal absorption of calcium and ↓ bone resorption
- Increase inorganic phosphate by giving oral phosphate solution (Neutra-Phos™ 200 mg/mL) at a dose of 3-5 mg/kg. Avoid parenteral phosphate solution in severely hypercalcemic infants.

7. Hypomagnesemia is unusual and is associated with persistent hypocalcemia. Treatment is $MgSO_4$ 25-50 mg/kg/dose IV slowly over several minutes. This can be repeated.

8. Hypermagnesemia, defined as a serum magnesium concentration >3 mg/dL, usually occurs secondary to magnesium treatment of the mother as a tocolytic to stop preterm labor or in mothers with pre-eclampsia. Neonatal symptoms include hypotonia, hyporeflexia, hypotension and apnea, as well as vasodilatation with marked flushing. The treatment is usually symptomatic until magnesium level gradually falls secondary to renal excretion. With severe cases, administration of calcium IV (see above) may help. Infants with severe hypermagnesemia may require assisted ventilation and blood pressure support.