



Basics of Fluid and Electrolyte Therapy in Newborn

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Outline

- Total Body Water Physiology in Neonates
- Fluid and Electrolyte Homeostasis in Neonate
- Smooth transition from aquatic in-utero to the dry ex-utero environment
 - Postnatal Fluid Changes
 - Renal Functional Changes
 - Insensible loss
- Fluid and Electrolyte Requirements
- Clinical assessment
- Water and Electrolyte abnormalities

Neonatal Fluid and Electrolyte Therapy is Challenging

- Premie with RDS ----
- VLBW baby from birth to full feeds ----
- Premie with NEC----
- IDM with hypoglycemia---
- Neonate with AKI -----
- Full term baby with hypoxic Ischemic Encephalopathy ---



Is Fluid Management different in Neonates?

- Physiology Immature - Different from adults and children.
- Disorders of fluid and electrolyte balance - commonest problem in preterm and critically sick neonates.
- All don't need the same IV fluids (either in quantity or composition).
- Wrong fluids given, neonatal physiology not well equipped to handle them.
- Serious morbidity from fluid and electrolyte imbalance.

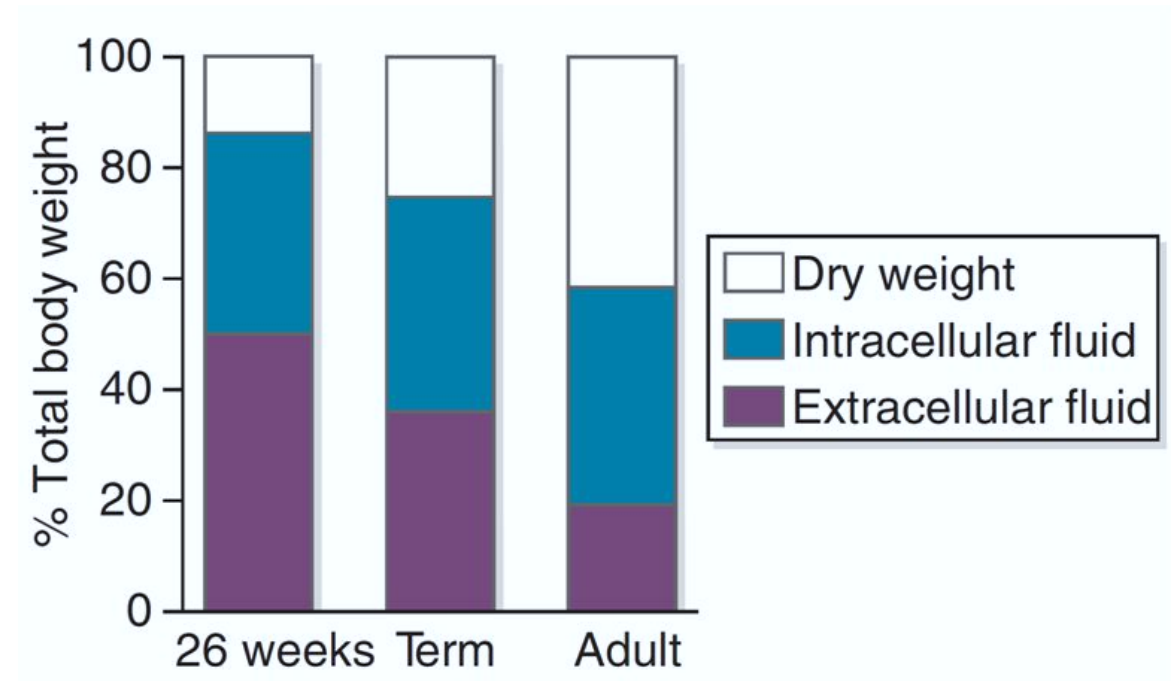
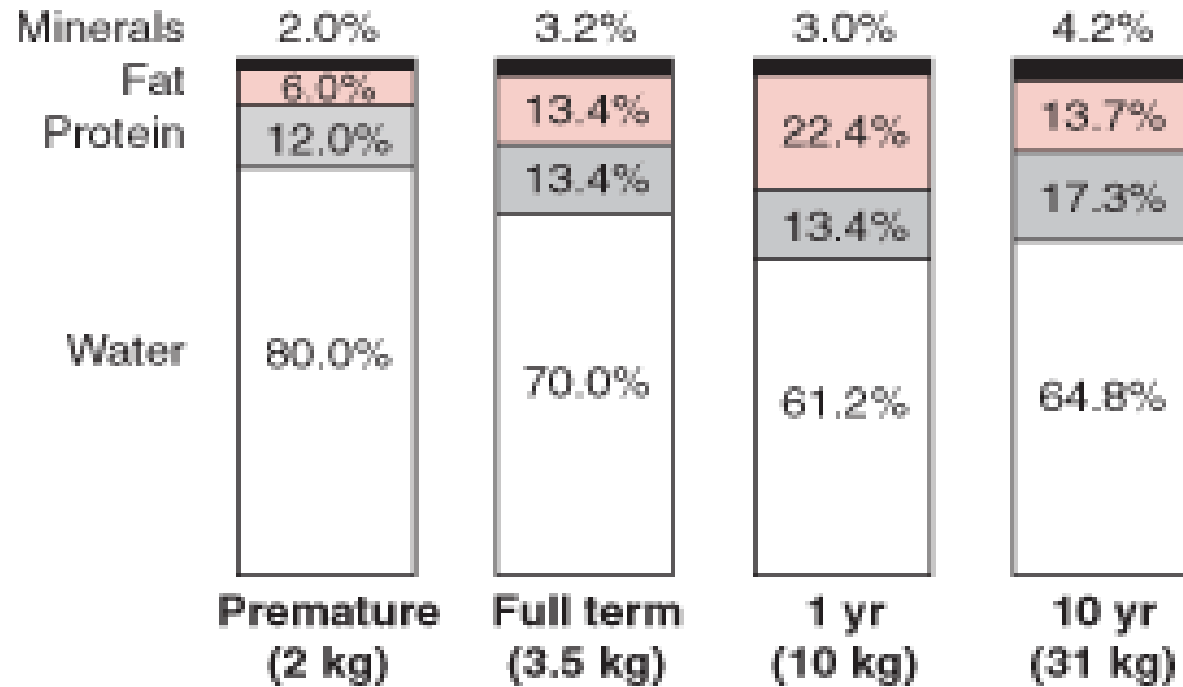
Why Fluid Management different in Neonates?



Body Composition & Total Body water Distribution

Physiology Immature - Different from adults and children.

Body Composition & Total Body water Distribution



GA 23 weeks ,TBW 90% weight - 60% ECF and 30% ICF

Preterm SGA- Higher TBW

Lose 10-15% weight in first week

Primarily from an isotonic reduction in ECF

Flaherman VJ, Schaefer EW, Kuzniewicz MW, et al. Early weight loss nomograms for exclusively breastfed newborns.

Pediatrics 2015; 135:e16

Newborn

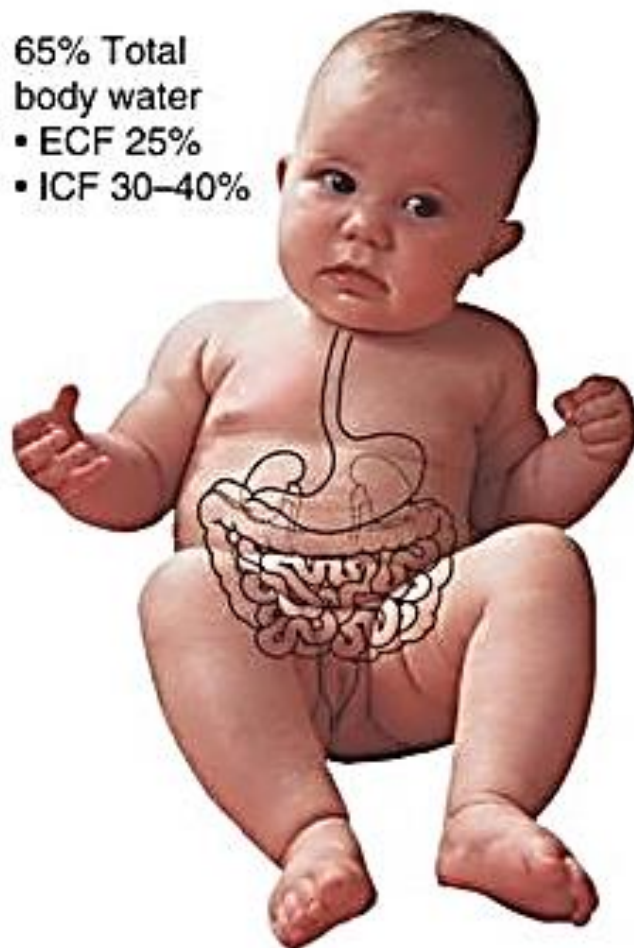
- 75% Total body water
- ECF 45%
 - ICF 30%



Brain and skin occupy a greater proportion of body weight and are high in interstitial fluid

Infant

- 65% Total body water
- ECF 25%
 - ICF 30–40%



High BSA promotes fluid loss

Little fluid reserve in intracellular fluid

5–6x greater fluid exchange daily

High metabolic rate requires generous fluid intake

Child/Adolescent

- 50% Total body water
- ECF 10–15%
 - ICF 40%



Kidneys are immature until 2 years and unable to conserve water and electrolytes or fully assist in acid–base balance

Fluid and Electrolyte Homeostasis in Neonate

Adaptation To Extra uterine Life

Smooth transition from aquatic in-utero to the dry ex-utero environment

Primarily dependent on renal function and fluid intake versus losses.

Challenges

- Gestational age
 - Redistribution of total body water
 - Functional immaturity of Neonatal kidney
 - Postnatal Renal physiological changes
 - Magnitude of postnatal diuresis
 - Altered response to hormones
- Increased insensible water losses (IWL)
(higher at lower GA- 24 weeks -as high as 200 mL/kg /d Vs. 20 mL/kg/d for a term)
 - Water loss due to environmental factors.
 - Inability to independently access water.

Three phases of Post Natal Fluid handling (Water & Sodium)

❖ **First Phase - Shrinkage of ECF Compartment: Maximum Weight Loss**

- Salt & Water Diuresis by 72 hours
- Evaporative Loss from Skin
- Physiologic weight Loss (Term 7-10%, Preterm -10-15%)

❖ **Second phase:**

- Diminished Insensible water loss as skin matures.
- Fall in Urine Output 1-2ml/kg/hour
- Low sodium Excretion

❖ **Third Phase :**

- Stable Growth & Weight gain
- Positive Net balance of water & salt.

Renal Functional Changes – 3 Phases of Salt & Water Handling

Low GFR 25 %

Limited Capacity for Dilution & Concentration

50mmol/L to 600 mmol/L
Pre terms & 800 mmol/L
in term infants

❖ Day 1- Pre Diuretic phase :

- Oliguria with low GFR and low FENa
- Birth associated renal nerve stimulation increases renal vascular resistance
- GFR and renal blood flow are suppressed.

❖ Days 2 to 3- Diuretic and Natriuretic phase:

- Absorption of Lung fluid resulting in increased ECF volume.
- Inhibition of sympathetic activity with subsequent reduced renal vascular resistance
- Increase in GFR and FENa
- Increased urine output and sodium losses by the increased GFR and high FENa.

❖ Days 4 to 5 – Post Diuretic phase :

- Urine output dependent upon fluid intake, with reduction of GFR and FENa compared to days 2 to 3.

Insensible Water Loss

Skin -70%

Respiratory Tract- 30%

Higher at lower GA- 24 weeks - 200 mL/kg /d
Term - 20 mL/kg/d

Increased insensible water loss (IWL)

Increased respiratory rate

Surgical malformations

Gastroschisis, Omphalocele, Neural tube defects

Increased body temperature: 30% increase/ °C

High ambient temperature: 30% increase/ °C

Radiant warmer & phototherapy: 50% increase

Decreased ambient humidity.

Increased motor activity

Crying: 50-70% increase in IWL

Decreased insensible water loss (IWL)

Use of incubators

Humidification (Head box & Ventilators)

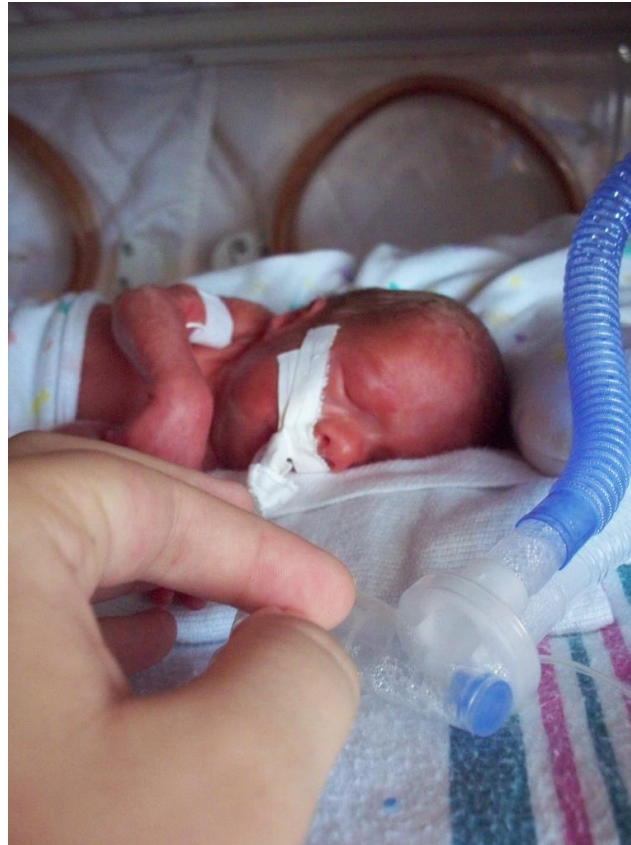
Use of Plexiglas heat shields

Increased ambient humidity

Thin transparent plastic barriers - 30%

reduction

Fluid and Electrolyte Requirements



Maintenance Fluid Requirement

- Neutral water balance –Replace obligatory loss(urine & stool) plus insensible loss
- Factors influencing fluid Balance:
 - Gestational age (GA)
 - Postnatal age
 - Environmental temperature and humidity
 - Renal function
 - Ventilator dependence (which affects respiratory losses).
 - Excessive loss-ileostomy or gastric drainage, polyuria(osmotic diuresis & diuretics) , thoracostomy
- Physiologic fluid loss in first few days
(2 to 3 % body weight/ day in term& 3 to 5 % /day in preterm infants)

Basic Principle of fluid management---

- Allow initial loss of ECF over first week (as reflected by weight loss)
- Maintain normal intravascular volume and tonicity (as reflected by HR, UO, Lytes, pH).
- Subsequently maintain water and electrolyte balance, including requirements for body growth.
- Individualize approach according to response of the child and age.

Maintenance Fluid in the First Week of Life

Birth weight	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
<1000g	80	100	120	130	140	150	160
1000 to 1500g	80	95	110	120	130	140	150
>1500g	60	75	90	105	120	135	150

- Term Baby with AKI restrict Fluid to 40-60 ml/Kg
- Phototherapy using Fluorescent Blue Light 10 % more Fluid (10-15ml/kg/day)
- Phototherapy with LED Light (High Intensity Gallium Nitride)-No additional fluid as no increase in IWL

Choice of Fluid for Maintenance Therapy

Term Babies & Birth Weight > 1500 Gm

- DAY 1

10% Dextrose - glucose infusion 4-6mg/kg/min

- DAY 2 TO 7

10% Dextrose

Na & K added after 48 hours

Requirement of Na& K -2-4 meq /kg/day

Preterm & Birth Weight 1000-1500 Gm

- DAY 1

10% Dextrose - glucose infusion 4-6mg/kg/min

- DAY 2-7

10% Dextrose

Na & K to be added after 48 hours

- AFTER DAY 7

Fluids given at 150-160 ml/kg/day

Na at 3-5 meq/kg till 32-34 Wks corrected GA.

Recapitulate-----

DAILY FLUID REQUIREMENTS DURING 1ST WEEK OF LIFE (ml/Kg/day)

Birth Weight	Day 1	Day 2 to Day 7	Day 7
>1500 gm	60	(+15-20)	150
1000-1500 gm	80	(+10-15)	150

GUIDELINES FOR FLUID THERAPY: TERM

Day 1 : Solutes Excreted → 15 mmol/Kg/day
Acceptable Urine Osmolarity → 300mmol/L
→ Minimum UOP required → 50ml/Kg/day
+ IWL → 20ml/Kg/day

Total → 60-70ml/Kg/day
→ 10% D @ 4-6mg/Kg/min

Day 2 : Solute load increased + Fecal Losses + Growth Requirement
→ +15-20ml/Kg/day
→ + Na⁺, K⁺ after 48 hrs

Day 7 : 150-160 ml/Kg/day



A quick formula to calculate glucose infusion :

$$= \frac{\% \text{ Dextrose} \times \text{rate (ml/hr)}}{6 \times \text{weight (kg)}} = \text{mg/kg/min}$$

Clinical Assessment



Clinical Assessment

- General assessment – GA & Postnatal age
- History & Physical examination
 - **Body weight most important Criterion**
 - Physiologic weight loss
(5-10 % in first week in term & 15% in pre terms.)
 - Weight reaches a nadir at 3-4 days
 - Birth weight regained by 7-10 days.
 - **Hydration status**
 - Skin turgor, Mucus membrane ,AF
 - Urine output
 - Presence or absence of oedema.

Severe Hypovolemia

- Cardiovascular stability (HR, BP,CFT)
- Tachycardia-
Too much ECF(excess in CHF) or too little ECF (hypovolemia)
 - Delayed capillary refill -Low cardiac output
 - Hepatomegaly - ECF excess
 - Blood pressure changes very late

Lab Evaluation of fluid and electrolyte status

○ Urine output, Specific gravity (SG) and osmolarity:

- Urine Volume: 1-3 ml/kg/hr
- Specific gravity :1.005 to 1.012
- Urine Osmolarity: 100-400 mOsm/L

○ Serum biochemistry:

- Serum sodium: 135-145 meq/L.

○ Blood gas:

Not routinely done . Useful in assessment of poor tissue perfusion and shock.

○ Fractional excretion of sodium (FeNa):

- Indicator of normal tubular function
- Limited value in preterm infants due to tubular immaturity

○ Serum Creatinine & BUN : Indicator of renal function.

Laboratory guidelines for fluid and electrolyte therapy

- **Increase Fluids**

- Increased weight loss ($>3\%$ /day or a cumulative loss $>20\%$)
- Increased serum sodium ($\text{Na} > 145$ meq/L)
- Increased urine specific gravity (>1.020) or urine osmolality >400 mosm/L
- Decreased urine output (<1 ml/kg/hr).

- **Restrict Fluids**

- Decreased weight loss ($<1\%$ /day or a cumulative loss $<5\%$)
- Decreased serum sodium in the presence of weight gain ($\text{Na} < 130$)
- Decreased urine specific gravity <1.005 or urine osmolality <100 mosm/L
- Increased urine output (>3 ml/kg/hr)

Commonly Used IV Fluids

	NS	RL	Iso lyte P	Plasmalyte A	5D	Album in 5%	Hetastarch 6%
Na	154	130	26	140		150	154
K		4	21	5		<2.5	
Cl	154	109	21	98		100	154
Ca		3					
Mg			3	3			
Acetate			24	27			
Lactate		28					
Glucose			5		5		
Phosphate			3				
Osmolality	308	274		295	252	330	310

Clinical Assessment of Dehydration

Clinical Sign	Mild dehydration (<3% wt loss)	Moderate (3-10%)	Severe >10%
General condition	Alert, restless	Thirsty ,lethargic	Cold , sweaty, limp
Pulse	Normal rate, volume	Rapid, weak	Rapid, feeble
respiration	Normal	Deep rapid	Deep
Systolic pressure	Normal	Normal or low	Low, Unrecordable
Reduced urine output	NO	YES	YES
Dry mouth	NO	YES	YES
Sunken eyes	NO	YES	YES
Ant. fontanellae	Normal	Sunken	Very sunken
Reduced skin turgor	NO (recoils instantly)	YES (1-2 secs)	YES (>2secs)
Prolonged capillary refill time	NO	May be slightly prolonged	YES (cool/mottled /pale peripheries)
drowsiness	NO	YES	Severe
Estimated deficit	30-50ml/kg	60-100ml/kg	>100ml/kg

Deficit Therapy- Correction of Hypovolemia

- For infants in shock, 10-20 ml/kg of normal saline is given immediately over 1-2 hours & repeat bolus in severe cases till hemodynamic stability achieved
- Moderate (10%) to severe (15%) dehydration, correct deficits gradually over 24 hours.
- Half correction of deficit over 8 hours followed by remaining deficit over next 16 hours.
- Assuming equal losses of fluid from the ECF and ICF, replacement fluid should consist of N/2 composition.
- The deficit should be administered in addition to maintenance fluid therapy.

Day 4 Neonate admitted with moderate dehydration

Weight : 3Kg

Assuming a deficit of 10% isotonic dehydration

Replacement Fluid /Deficit correction -300 ml N/2 saline over

24 hours (150 ml over 8 hours and 150 ml over 16 hours)

24 hour maintenance fluid: 100 ml/kg on day 4 = 300 ml of N/5 in 10% dextrose.

Neonatal Electrolyte Imbalance

Requirement of Lytes ----Sodium

- Neonatal kidney: Limited capacity both to excrete and to conserve sodium.
- Normally there is a salt and water diuresis in the first 48-72 hours of life.
- Sodium supplementation started after
 - Initial diuresis
 - Decrease in serum sodium
 - At least 5-6% weight loss.
- Failure to supplement sodium after first week of life result in low body sodium stores
- Preterm neonates: Limited tubular capacity to reabsorb sodium- increased urinary losses.
- Sodium requirements range from 3-5 mEq/kg/day in preterm children after first week of life.
- Failure to provide sufficient Sodium -Poor weight gain
- VLBW infants on exclusive breast-feeding - Should receive sodium supplements in addition to breast milk till 32-34 weeks corrected age.

Guidelines for starting electrolytes

- After 48 hours Sodium and Potassium started in IV fluids
- Dose : 2-3 meq/kg/day.
- Calcium Gluconate –Dose:4 ml/kg/day (40 mg/kg/day) for the first 3 days
in high-risk situations

Sodium in Assessment of Fluid Balance in Sick Neonates & Pre terms

Sodium Imbalance is a Disorder of water balance

Extremely preterm infants with birth weights <1000 g are at risk for sodium disorders

Low S. Sodium- Weight Loss

- Water & Sodium depletion (Dehydration)

Low S. Sodium- Weight Gain

- Excess body water
- Decrease in effective circulation with third spacing (sepsis or ileus)- with oedema or ascites.

High S. Sodium- Weight Loss

- Inadequate fluid intake (Dehydration)
- Excessive weight loss, tachycardia, poor capillary refill
- Hypotension as a prelude to Neonatal shock in severe cases.

High S. Sodium- Weight Gain

- Salt & Water loading

Hyponatremia- Sodium \leq 128 mEq/L

Early New born Period (first 4-5 days)

Low S. Sodium- Weight Loss

- Water & Sodium depletion (Dehydration)

Treatment : Repletion of salt and water

Low S. Sodium- Weight Gain

- Excess body water (TBW) with normal total body sodium due to excessive fluid intake
- Decrease in effective circulation with third spacing (sepsis or ileus) - weight may be increased with evidence of oedema or ascites.
- Water retention(SIADH) may accompany pneumonia or meningitis, pneumothorax, or severe IVH.

Treatment

- Fluid restriction, which usually results in a slow return to normal levels.
- Adjustment of fluid intake is based on changes of Weight, S. Na and net fluid intake.

Hyponatremia- Sodium \leq 128 mEq/L

Late New born Period (> 4-5 days)

Negative sodium balance

- Inadequate replacement of large renal sodium losses in extreme preterm (EPT) infant (GA \leq 28 weeks) due to immature tubular function or diuretics.
- Repletion of the sodium deficit = Product of the total body volume times the sodium deficit per litre (i.e. 140 minus S. Sodium concentration).
- Volume of Distribution (Vd) - 60% is used to minimize likelihood of overly rapid correction.
- Sodium intake to provide maintenance sodium requirement.

Hyponatremia, Hyperkalemia, Metabolic acidosis & Shock in NB

- Congenital Adrenal Hyperplasia- 21 Hydroxylase Deficiency-
NS to correct hypovolemia , hyponatremia & Replacement steroids.

- Pseudo hypoaldosteronism Type 1

Autosomal recessive PHAI from mutations in the epithelial sodium channel (ENaC)

Autosomal dominant PHAI from mutations in the mineralocorticoid receptor.

Volume & Sodium Repletion and K binders

Neonatal hypernatremia

Sodium Imbalance is a Disorder of water balance

Extremely preterm infants with birth weights <1000 g are at risk for sodium disorders

Neonatal hypernatremia is serum sodium concentration ≥ 150 meq/L

High Serum Sodium- excessive fluid loss /inadequate intake/breastfeeding (Dehydration)

- Excessive weight loss >10 % weight loss, which exceeds normal weight loss after birth
- Tachycardia, poor capillary refill
- Hypotension as a prelude to shock in severe cases.

High Serum Sodium- Weight Gain/Excess Sodium

- Salt & Water loading
- Excessive sodium delivered through parenteral fluids, medication, or blood products
- Treatment –Stop excess sodium .Free water for correction

Too much Urine -- Too Little Water & Too much Sodium---

○ **Diabetes Insipidus**

- Polyuria and hypernatremia results due to excessive water loss

○ **Secondary DI**

- Hypoxic-ischemic encephalopathy or CNS malformations.

○ **Treatment :Free Water Correction**

- Rapid correction of hypernatremia (generally defined as more than 0.5 meq/L/hr) should be avoided - Risk of cerebral oedema and seizures.
- Adequacy of therapy based on serial sodium measurements.

Disorders of Kalium

Hypokalemia

- S.K <3 mEq/L
- Usually due to excessive loss.
- Contributing factors
 - Nasogastric tube
 - Diarrhoea
 - Ileostomy
 - Renal tubular defects
 - Chronic diuretic use

Symptoms

Usually asymptomatic
Weakness & paralysis,
ileus, urinary retention
Conduction defects ,
ST segment depression,
Low voltage T waves
U waves.

Treatment

Increase daily intake by 1 to 2 mEq/kg.
Severe /Symptomatic
KCl 0.5 to 1 mEq/kg IV infusion over 1
hour continuous ECG monitoring

Disorders of Kalium

Hyperkalemia - S.K >6 mEq/L

- Higher normal range of potassium in Neonates
 - Reduced urinary excretion -Aldosterone insensitivity
 - Low expression of mineralocorticoid receptors
 - Decreased (GFR)
- Preterm normally higher serum potassium levels than term

Causes

- **Decreased clearance**
 - Renal failure
 - Congenital adrenal hyperplasia
- **Increased release**
 - Bleeding or tissue destruction
 - Intra-Ventricular haemorrhage
 - Cephalohematoma
 - Hemolysis
 - Bowel infarction
- **Excessive administration**
 - K Supplementation

Hyper K frequent in ELBW infants

Exaggerated K shift from ICF to ECF after birth.

Antenatal glucocorticoids may be protective .

Hyper kalemia -Manifestations

Asymptomatic or so severe as to constitute a medical emergency.

Signs: Arrhythmias and cardiovascular instability

ECG Changes:

Tall peaked T waves

Flattened P waves

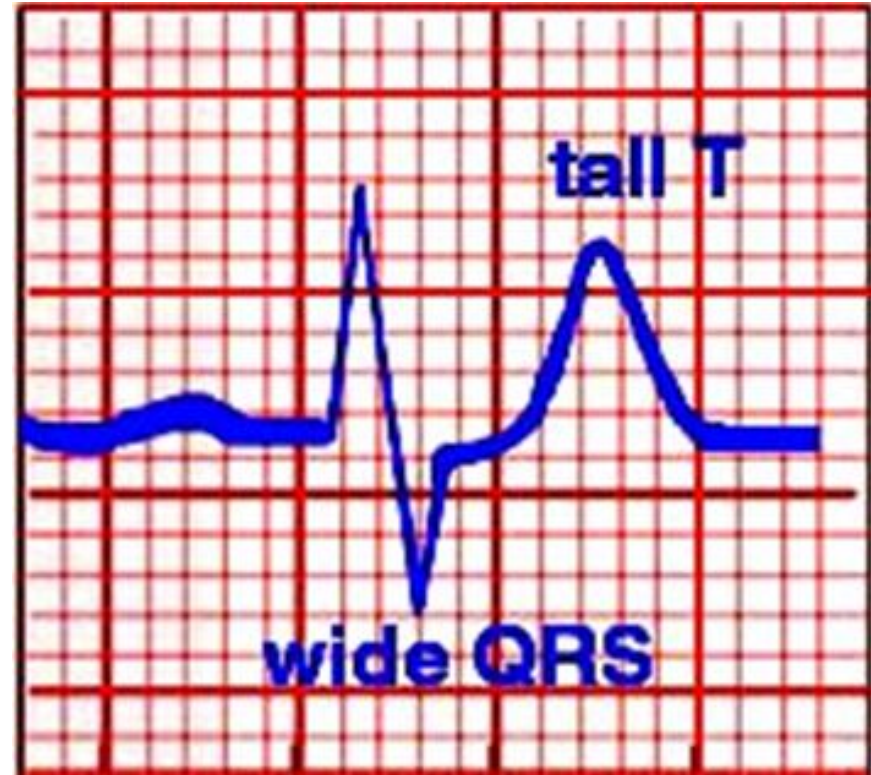
Increased PR interval

Widening of the QRS complex.

Bradycardia

Supraventricular or ventricular tachycardia

Ventricular fibrillation



Treatment of Hyperkalemia

Stop K in fluids ,Feeds & Drugs

Treatment is aimed at three factors

Reversal of effect of hyper kalemia on the cell membrane

Infusion of 10% calcium gluconate (0.5 mL/kg) or calcium chloride (dose of 20 mg/kg or 0.2 mL/kg) over five minutes.

Promotion of K movement from ECF compartment into the cells

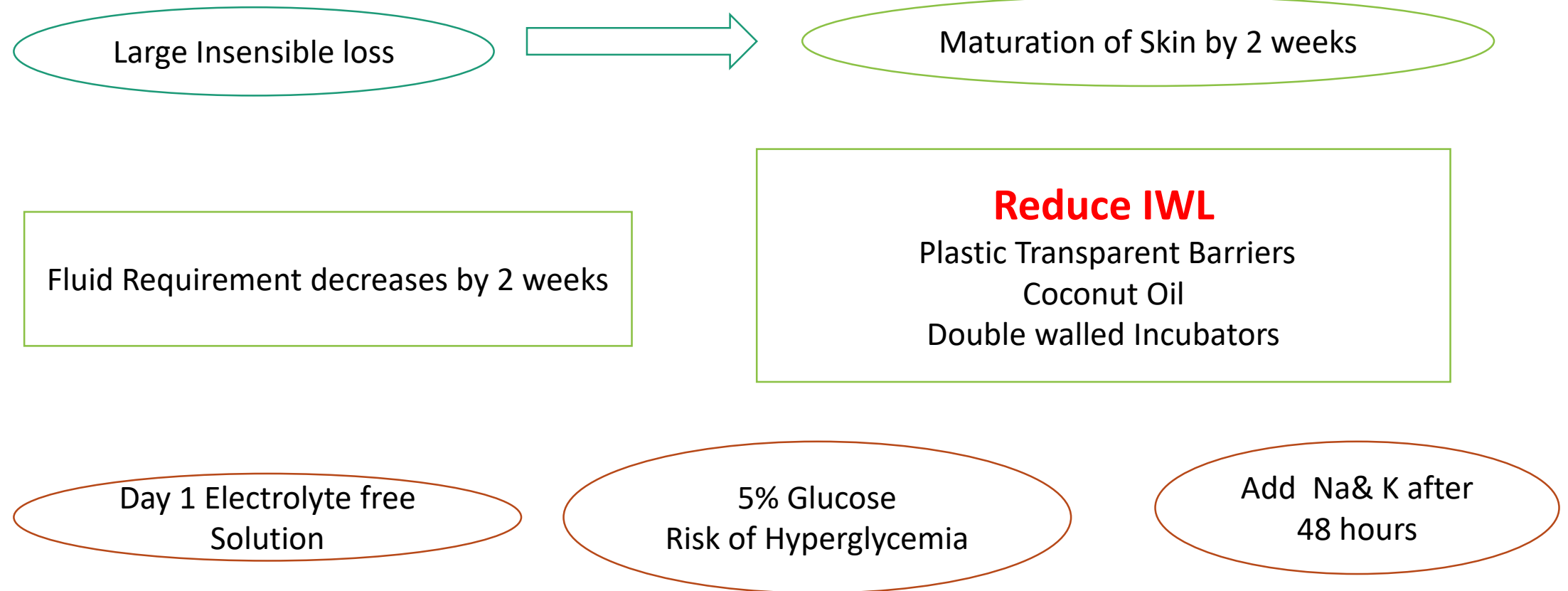
- IV glucose - insulin (0.05 units/kg human regular insulin with 2 mL/kg 10 % dextrose followed by a continuous infusion of insulin (0.1 units/kg per hour with 4 mL/kg/hr 10 % dextrose
- IV NaHCO₃ if acidosis (in a dose of 1 to 2 mEq /kg over 30 to 60 minutes).
- Salbutamol nebulization.

Increasing excretion

IV Furosemide (1 mg/kg per dose) in infants with adequate renal function
Dialysis can be considered in infants with oliguria or anuria.

Special Situations

Extreme Preterm (<28 weeks ,<1000 Gram



Sick Critically Ill Neonate ----

- Renal function compromise due to hypoxia and acidosis
- Positive pressure ventilation increases aldosterone and ADH
- Water retention.
- Symptomatic PDA more likely to occur in Premie with RDS.
- Restrict Fluid in Premie to reduce risk of PDA, BPD, NEC and death.
- Monitor strictly by clinical and lab criteria

Summary

- Neonatal Fluid-Electrolyte Balance is delicate
- GA, Weight and Postnatal Age - TBW distribution, Renal function and IWL on homeostasis
- Maintaining fluid and electrolyte balance of in the neonate demands
 - Physical examination to assess GA ,weight, integrity of skin and systemic diseases
 - Sequential examination to assess fluid status, daily weight and cardiovascular stability.
 - Weight loss over first 3-5 days should be expected.
 - Monitoring fluid intake and output of urine and stool.
 - For infants receiving parenteral fluids, serial measurement of S. Sodium.
 - Inadequate weight loss in 1st week or excessive weight gain, oedema,& high BP suggests volume overload.
 - Inadequate fluid administration - Excessive weight loss, tachycardia, poor capillary refill, and, in severe cases, hypotension.
- Frequency of monitoring is dependent on the infant's clinical condition and GA.

Summary

- Electrolyte imbalance constitute a common problem in preterm & critically sick neonates.
- Changes in sodium primarily reflect changes in water balance.
 - Hypo natremia is associated with excess water gain (hypervolemia) or salt & water loss
 - Hyponatremia with excessive water loss (hypovolemia) or salt gain
- Higher normal range of potassium in Neonates
 - Preterm normally higher S. Potassium levels than term
 - Hypokalemia is due to excessive loss of Potassium.
 - Hyperkalemia results decreased clearance, increased release or excessive administration
- **Prompt recognition & management is associated with good outcome.**

