Fluid and electrolyte management in term and preterm neonates

Deepak Chawla, Ramesh Agarwal, Ashok Deorari, Vinod K Paul
Division of Neonatology, Department of Pediatrics
All India Institute of Medical Sciences
Ansari Nagar, New Delhi –110029

Address for correspondence:
Dr Ashok K Deorari
Professor
Department of Pediatrics
All India Institute of Medical Sciences
Ansari Nagar, New Delhi 110029
Email: ashokdeorari_56@hotmail.com

Abstract

Disorders of fluid and electrolyte are common in neonates and a proper understanding of the physiological changes in body water and solute after birth is essential to ensure a smooth transition from the aquatic in-utero environment. The newborn kidney has a limited capacity to excrete excess water and sodium and overload of fluid or sodium in the first week may result in morbidities like necrotizing enterocolitis, patent ductus arteriosus and chronic lung disease. Simple measures like use of transparent plastic barriers, coconut oil application, caps and socks are effective in reducing insensible water loss. Guidelines for the management of fluids according to birth weight, day of life and specific clinical conditions are provided in the protocol.

Disorders of fluid and electrolyte balance are among the commonest derangements encountered in preterm and critically sick neonates. The aim of fluid and electrolyte therapy is to ensure a smooth transition from the aquatic in-utero environment to the dry ex-utero environment.

Changes in body water and solute after parturition

After birth, there is efflux of fluid from the intracellular fluid (ICF) to the extracellular fluid (ECF) compartment. This increase in the ECF compartment floods the neonatal kidneys eventually resulting in a salt and water diuresis by 48-72 hours. Loss of this excess ECW results in physiological weight loss in the first week of life. Since the ECW compartment is larger in more preterm neonates, the weight loss is greater in preterm neonates. Term infants are expected to loose up to 10% of their birth weight as compared to 15% weight loss in premature neonates. Failure to loose this ECF may be associated with morbidities like patent ductus arteriosus (PDA), necrotizing enterocolitis (NEC) and chronic lung disease (CLD) in preterm neonates.

Renal function

Kidneys in the neonate have a limited capacity to excrete both concentrated and dilute urine. The physiological range for urine osmolality in neonates varies from a lower limit of 50 mmol/L to an upper limit of 600 mmol/L in preterms and 800 mmol/L in term infants[2]. An acceptable osmolality range of 300-400 mmol/L would correspond to a daily urine output of 2-3 ml/kg/hr.

The neonatal kidney has a 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. Therefore, sodium supplementation should be started after ensuring initial diuresis, a decrease in serum sodium or at least 5-6% weight loss[2-5]. Also, failure to supplement sodium after the first week of life would result in low body stores of sodium. Preterm neonates have a limited tubular capacity to reabsorb sodium and hence have increased urinary losses. Sodium requirement ranges from 3-5 mEq/kg/day in preterm neonates after the first week of life. Failure to provide this amount of sodium may be associated with poor weight gain[2,6,7,8]. Very low birth weight infants on exclusive breast-feeding may need sodium supplementation in addition to breast milk until 32-34 weeks corrected age[9-10].

Fluid losses

In addition to mandatory water loss by the kidneys and gastro-intestinal system (termed as sensible loss), additional water losses occur due to evaporation from the skin and respiratory tract. This water loss is termed as insensible water loss (IWL). Insensible water losses tend to be higher in preterm infants (see Table 1). Evaporation loss through the skin usually contributes to 70% of IWL[1]. The remaining 30% is contributed through losses from the respiratory tract. Various environmental and neonatal factors have been implicated in excessive insensible water losses through the skin and respiratory tract (see Table 2). *The emphasis in fluid and electrolyte therapy should be on prevention of excessive IWL rather than replacement of increased IWL.* Hence incubators, plastic barriers and heat shields should be used liberally in the management of extremely premature neonates.

Transparent plastic barriers reduce IWL in preterm infants

Thin, transparent plastic barriers (e.g. cling-wrap) may be used to increase the local humidity and limit air movement. These transparent plastic films may be fixed to the supporting walls of the radiant warmer in order to create a micro-environment around the baby. These plastic barriers are effective in reducing IWL without interfering with the thermal regulation of the warmer. They have been found to reduce the IWL by 50-70% for infants under the radiant warmer[1]. We have found the use of these barriers to be quite effective in avoiding excessive IWL in preterm neonates being nursed under the radiant warmers.

Guidelines for fluid and electrolyte therapy

Day 1: Term babies and babies with birth weight > 1500 grams.

A full term infant on intravenous fluids would need to excrete a solute load of about 15 mosm/kg/day in the urine. To excrete this solute load at a urine osmolarity of 300 mosm/kg/day, the infant would have to pass a minimum of 50 ml/kg/day. Allowing for an additional IWL of 20 ml/kg, the initial fluids should be 60-70 ml/kg/day. The initial fluids should be 10% dextrose with no electrolytes in order to maintain a glucose infusion rate of 4-6 mg/kg/min. Hence total fluid therapy on day 1 would be 60 ml/kg/day. It is provided as 10% dextrose (see Table 3)

Day 1: Preterm baby with birth weight 1000-1500 grams. The urine output in a preterm baby would be similar to a term baby. However, the fluid requirement will be higher due to increased IWL and increased weight loss (extracellular fluid loss). We recommend the liberal use of caps, socks and plastic barriers to reduce the IWL under the radiant warmer. Using this method we have found 80 ml/kg/day of 10% dextrose to be adequate on day 1 of life (see table 2).

Day 2 - Day 7: Term babies and babies with birth weight >1500 grams. As the infant grows and receives enteral milk feeds, the solute load presented to the kidneys increases and the infant requires more fluid to excrete the solute load. Water is also required for fecal losses and for growth purposes. The fluid requirements increase by 15-20 ml/kg/day until a maximum of 150 ml/kg/day (table 3). Sodium and potassium should be added after 48 h of age and glucose infusion should be maintained at 4-6 mg/kg/min

Day 2 – Day 7: Preterm babies with birth weight 1000-1500 grams As the skin matures in a preterm baby, the IWL progressively decreases and becomes similar to a term baby by the end of the first week. Hence, the fluid requirement in a preterm baby, initially higher due to increased IWL, would become similar to a term baby by the end of the first week (Table 3). Plastic barriers, caps and socks are used throughout the first week in order to reduce IWL from the immature skin. Fluids need to be increased at 10-15 ml/kg/day until a maximum of 150 ml/kg/day. Sodium and potassium should be added after 48 hours and glucose infusion should be maintained at 4-6 mg/kg/min

>Day 7: Term babies and babies with birth weight >1500 grams Fluids should be given at 150-160 ml/kg/day.

>Day 7: Preterm babies with birth weight 1000-1500 grams Fluids should be given at 150-160 ml/kg/day and sodium supplementation at 3-5 mEq/kg should continue till 32-34 weeks corrected gestational age.

Monitoring of fluid and electrolyte status

Body weight: Serial weight measurements can be used as a guide to estimate the fluid deficit in newborns. Term neonates loose 1-3% of their birth weight daily with a cumulative loss of 5-10% in the first week of life. Preterm neonates loose 2-3% of their birth weight daily with a cumulative loss of 15-20% in the first week of life. Failure to loose weight in the first week of life should be an indicator for fluid restriction. However, excessive weight loss in the first 7 days or later would be non-physiological and would merit correction with fluid therapy.

Clinical examination: The usual physical signs of dehydration are unreliable in neonates. Infants with 10% (100 ml/kg) dehydration may have sunken eyes and fontanel, cold and clammy skin, poor skin turgor and oliguria. Infants with 15% (150ml/kg) or more dehydration would have signs of shock (hypotension, tachycardia and weak pulses) in addition to the above features. Dehydration would merit correction of fluid and electrolyte status gradually over the next 24 hours.

Serum biochemistry: Serum sodium and plasma osmolarity would be helpful in the assessment of the hydration status in an infant. Serum sodium values should be maintained between 135-145 meq/L. Hyponatremia with weight loss suggests sodium depletion and would merit sodium replacement. Hyponatremia with weight gain suggests water excess and necessitates fluid restriction. Hypernatremia with weight loss suggests dehydration and would require fluid correction over 48 hours. Hypernatremia with weight gain suggests salt and water load and would be an indication of fluid and sodium restriction.

Urine output, specific gravity (SG) and osmolarity: The capacity of the newborn kidney to either concentrate or dilute urine is limited and estimation of urine SG would be useful to guide fluid therapy. The acceptable range for urine output would be 1-3 ml/kg/hr, for specific gravity between 1.005 to 1.012 and for osmolarity between 100-400 mosm/L. Specific gravity can be checked by dipstick or by a hand held refractometer. Osmolarity is estimated by freezing point osmometer.

Blood gas: Blood gases are not needed routinely for fluid management. However, they are useful in the acid base management of patients with poor tissue perfusion and shock. Hypo-perfusion is associated with metabolic acidosis.

Fractional excretion of sodium (FENa): FENa is an indicator of normal tubular function but is of limited value in preterm infants due to developmental tubular immaturity.

Serum blood urea nitrogen (BUN), creatinine: Serum creatinine is a useful indicator of renal function. There is an exponential fall in serum creatinine levels in the first week of life as maternally derived creatinine is excreted. Failure to observe this normal decline in serial samples is a better indicator of renal failure as compared to a single value of creatinine in the first week of life.

Laboratory guidelines for fluid and electrolyte therapy

Intravenous fluids should be increased in the presence of (a) Increased weight loss (>3%/day or a cumulative loss >20%), (b) Increased serum sodium (Na>145 mEq/L) (c) Increased urine specific gravity (>1.020) or urine osmolality (>400 mosm/L), (d) Decreased urine output (<1 ml/kg/hr). Similarly fluids should be restricted in the presence of (a) Decreased weight loss (<1%/day or a cumulative loss <5%), (b)

Decreased serum sodium in the presence of weight gain (Na<130 mEq/L), (c) Decreased urine specific gravity (<1.005) or urine osmolality (<100 mosm/L), (d) Increased urine output (>3 ml/kg/hr)

Guidelines for starting electrolytes in fluid therapy

Sodium and potassium should be started in the IV fluids after 48 hours, each in a dose of 2-3 meq/kg/day. Calcium may be used in a dose of 4 ml/kg/day (40 mg/kg/day) of calcium gluconate for the first 3 days in certain high-risk situations (see protocol on hypocalcemia). Dextrose infusion should be maintained at 4-6 mg/kg/min. 10% dextrose may be used in babies ≥1250 grams and 5% dextrose in babies with birth weight <1250 grams.

Replacement of fluid deficit therapy

Moderate (10%) to severe (15%) dehydration fluid deficits are corrected gradually over 24 hours. For infants in shock, 10-20 ml/kg of normal saline is given immediately over 1-2 hours followed by half correction over 8 hours. The remaining deficit is administered over 16 hours. Assuming equal losses of fluid from the ECW and ICW, the replacement fluid after correction of shock, should consist of N/2 composition. This fluid and electrolyte solution should be administered in addition to the maintenance fluid therapy. Assuming a deficit of 10% isotonic dehydration in a 3 kg child on day 4, the fluid calculation would be as follows (a) Dehydration replacement: 300 ml of N/2 saline over 24 hours (150 ml over 8 hours and 150 ml over 16 hours) (b) Maintenance fluids: 300 ml (100 ml/kg/day on day 4) of N/5 in 10% dextrose over 24 hours.

Specific clinical conditions

Extreme prematurity (gestation <28 weeks, birth weight <1000 grams)[11]: These babies have large insensible water losses due to thin, immature skin barrier. The stratum corneum matures rapidly in 1-2 weeks and therefore fluid requirements become comparable to larger infants by the end of the second week. Fluid requirement in the first week may be decreased substantially by reducing the IWL with the use of plastic transparent barriers, coconut oil application or using double walled incubators.[12-13] The initial fluids on day 1 should be electrolyte free and should be made using 5% dextrose solutions to prevent risks of hyperglycemia. Sodium and potassium should be added after 48 h of life.

Respiratory distress syndrome (RDS)[11]: The renal function in preterm babies may be further compromised in the presence of hypoxia and acidosis due to RDS. Positive pressure ventilation may lead to increased secretion of aldosterone and ADH, leading to water retention. Symptomatic patent ductus arteriosus (PDA) is more likely to occur in the presence of RDS. Results from various studies have shown that restricted water intake has a beneficial effect on the incidence of PDA, CLD, NEC and death. Hence fluid therapy in sick preterm infants should be monitored strictly using the above mentioned clinical and laboratory criteria.

Perinatal asphyxia and brain injury: Perinatal asphyxia may be associated with syndrome of inappropriate ADH (SIADH) secretion. Fluid restriction in this condition should be done only in the presence of hyponatremia. The intake should be restricted to two-thirds maintenance fluids till serum sodium values return to normal. Once urine production increases by the third postnatal day, fluids may be gradually restored to normal levels. Renal parenchyma injury from perinatal asphyxia may result in acute tubular necrosis (ATN), which is commonly accompanied by oliguria or anuria In case of oliguric renal failure, fluid intake should be restricted to replenishment of IWL and metabolic water requirement (400 mL/m^2 or 40 mL/kg) and any other losses (urine output, gastric secretions etc.) During the recovery phase of ATN, there can be large urinary sodium and potassium losses, which should be calculated and replaced.

Diarrhea: The correction of fluid deficit is done over 24 hours. Ongoing losses need to be assessed and corrected 6-8 hourly.

Fluid restriction

There has been a lot of interest in the amount of fluid therapy and outcome of preterm neonates in terms of mortality and morbidity. The Cochrane meta-analysis on this topic could identify four eligible studies[14]. Their findings state that, although restricted fluid therapy may lead to greater weight loss and dehydration, it is associated with a decreased incidence of death, PDA and NEC. There also seems to be a beneficial effect of restricted fluid therapy on the incidence of BPD. The volume of fluids used in the restricted groups differs from the above-described fluid therapy by 20-50 ml/kg/day in the initial 3-4 days. Based on their meta-analysis, the investigators had concluded that fluid therapy needs to be balanced enough to meet the normal physiological needs without allowing significant dehydration.

Conclusion

In conclusion, the normal maintenance fluid required on the first day would range from 2.5-3.5ml/kg/hr in newborns. This volume would increase to 5-6 ml/kg/hr by the end of the first week and 7-8 ml/kg/hr thereafter. Sodium and potassium should be added to IV fluids after 48 hours of post-natal life. Frequent clinical and laboratory monitoring are essential to ensure correct fluid therapy in neonates. Infusion pumps with precise infusion rates would be required to deliver these small volumes to sick newborns.

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Table 1. Insensible water loss according to birth weight on day 1[1].

Birth weight	Insensible water loss (ml/kg/day)
<1000 g	60-80
1000 – 1500 g	40-60
>1500 g	20

Table 2. Factors affecting insensible water loss in neonates

Increased insensible water loss (IWL)
Increased respiratory rate Conditions with skin injury (removal of adhesive tapes) Surgical malformations (gastroschisis, omphalocele, neural tube defects) Increased body temperature: 30% increase in IWL per °C rise in temperature High ambient temperature: 30% increase in IWL per °C rise in temperature Use of radiant warmer and phototherapy: 50% increase in IWL Decreased ambient humidity. Increased motor activity, crying: 50-70% increase in IWL
Decreased insensible water loss (IWL)
Use of incubators Humidification of inspired gases in head box and ventilators Use of plexiglas heat shields Increased ambient humidity Thin transparent plastic barriers

Table 3. Daily fluid requirements during first week of life (ml/kg/day).

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