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Fluid and Electrolyte Homeostasis in Newborn Baby

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Summary:

Assessment of fluid and electrolyte properly in neonate is very important but difficult. Fluid and electrolyte homeostasis during this period depends on some factors notably gestational age of baby, its postnatal age, pathological conditions and environmental situation. In fetus, water and electrolytes is constantly supplied from mother, which is cut-off by delivery of the baby. Extra-cellular fluid volume that is greater than intracellular fluid volume in fetus precipitously decreases after birth. Adaptation of fluid and electrolyte after birth is due to discontinuation of placental exchange, onset of insensible water loss, thermoregulation, autonomic renal regulation and intake of fluid and other nutrients. The adaptation course is divided into transition phase, intermediate phase and stable growth phase. Fluid and electrolyte therapy in neonate should be very judicious, because administration of minimum fluid and electrolyte may bring a maximum proportionate change of such environment. Fluid requirement in neonate after birth increases gradually by first few days. Preterm baby require more fluid than term baby during the first week of life due to high insensible water loss in the former. Electrolytes with intravenous fluid should be offered after ensuring initial diuresis, a decrease in sodium or at least 5-6% weight loss in neonates.

Key word: Fluid, electrolyte, homeostasis, newborn baby.

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Introduction:

Fluid and electrolyte assessment during neonatal period is very important and difficult. This is because the transition from fetal to neonatal period is associated with major changes in water and electrolyte homeostatic control. The fetus has a constant water and electrolyte supply from mother across the placenta. After birth, the newborn must acquire responsibility for its own. fluid and electrolyte homeostasis in an environment where fluid and electrolyte availability and losses fluctuate widely. Proportion of various constituents of such environment varies normally depending on gestational age of neonate and even on postnatal age of baby. It also varies during pathological situations and environmental conditions. Again, relative small absolute changes in body water and electrolyte represent as large proportionate change in a neonate due to its small body size[1]. So careful fluid and electrolyte management is essential for the well being of sick neonate. Inadequate administration of fluids can result in hypovolemia, hypersomolarity, metabolic abnol-111alities and renal failure in neonate whereas excess fluid administration may results generalized edema and abnormalities of pulmonary function. Excess fluid in newborn infant is also associated with patent ductus arteriosis, congestive heart failure, intraventricular hemorrhage, necrotizing enterocolitis and bronchopulmonary dysplasia (BPD)[2]. Electrolyte abnormality in neonatal period is quite undesirable. Sodium is a permissive factor for growth and depletion of sodium in this period is associated with poor weight gain along with other abnormalities[2]. Though both Hyponatranlia and hypernatramia contribute to neurological morbidity in sick neonate[2], prevalence of hypematramia (7.1/100 000 term baby[3] or 274/100 000 term baby[4]), fluid and other electrolyte abnormality is not less even in developed nations[2]. Minerals are essential for healthy life, but its administration within few hours of life is associated with adverse effect on neonatal health[2]. So, fluid and electrolyte management in neonatal period should be very judicious and thus is ever encountered in medicine. The goal is not to maintain fluid and electrolyte status after birth, rather to allow the changes to occur appropriately. Shortage of understanding of health clinicians regarding fluid and electrolyte homeostasis of newborn baby will make an adverse effect on newborn health. Unfortunately, understanding of many physicians remained incomplete regarding such vital pediatric issue. The review is written to orient and update health personals particularly the clinicians regarding some fundamental aspect of such important topic to help

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neonate through allowing such vital changes to occur appropriately.

Background:

Total body water (TBW) decreases markedly from intrauterine life to adulthood. Water contributes to 90% of body weight in the 24 weeks old fetus, 75% in term neonates, and 50% in adults'. During intrauterine life water content decreases along with relative increase of fat mass particularly during third trimester of gestation[6]. Water turnover is high in neonates and decreases with increasing age[7,8]. Body water is divided into two compartments: intracellular fluid (ICF) and extracellular fluid (ECF)[9]. In the fetus, the ECF volume is larger than ICF volume, and ECF decreases with age. The ECF volume drops precipitously after birth in large part because of postnatal dieresis. By 1 year of age both fluid compartments come close to adult levels (Fig-1)[10]. The major ion of ECF is sodium (Na+). Blood volume in neonates is 85-100 ml/kg body weigh compared to 60-70 ml/kg body weights in adolescents and adults[11].

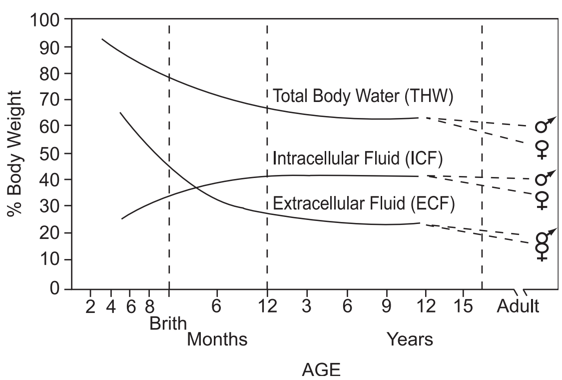

Fig-1: *Rearrangement of body fluid from intrauterine to extrauterine life.*

Immediate adaptation process after birth affects the metabolism of water and electrolytes as a result of discontinuation of placental exchange and the onset of considerable insensible water loss and thermoregulation. Subsequent adaptation includes the onset of autonomic renal regulation of fluids and electrolytes, and intake of fluids and other nutrients[12]. The time course of adaptation may be divided into three major phases[12].

*Phase-1 (Transition phase): The immediate postnatal phase is characterized by a relative oliguria[13] followed by a diuretic phase, during which body fluid compartments are rearranged by isotonic or hypertonic (i.e.hypernatraemic and hyperchloremic) contraction. Duration of this phase varies from hours to days. These changes are caused by considerable evaporative water loss via immature skin and by continuing natriuresis[14]. Phase 1 usually ends when maximum weight loss has occurred[12]. *Phase-II (Intermediate phase): This phase is characterized by diminished insensible water loss along with increasing cornification of epidermis, a fall in urine volume to less than 1-2 ml/kg per hour, and a low sodium excretion. Duration of this phase varies from 5 to 15 days[12]. *Phase-III (Stable growth phase): This is characterized by continuous weight gain with a positive net balance for water and sodium. Expected weight gain is 10-20gm/kg body weights per day[12].

The renal glomerular surface area available for filtration is small in neonates than that of in older infants and adults. In term neonate, glomerular filtration rate (GFR) increases significantly during the first week of life and continues to rise over the first two years of life[12]. Immaturity to the distal nephron with an anatomically shortened loop of Henle leads to reduced ability to concentrate urine[12]. Maximum urinary concentrations are up to 550 mosm/1 in preterm infants, and 700 mosm/1 in term infants, compared to 1200 mosm/1 in adults[15]. Neonates may be placed at risk for volume depletion when a high renal solute load cannot be compensated for by the ability to produce concentrated urine. Although hormonal factors i.e. renin-angiotensin-aldosterone system (RAAS), and arginin-vasopressin (AVP) is mature early in gestation, the effects are limited by renal immaturity[16]. A lower plasma oncotic pressure and higher permeability of the capillary wall in preterm infants compared to term infants and adults[12] enhances the shift of water from, intravascular to interstitial compartment, with an increased risk of edema especially under pathologic conditions[17].

Fluid and electrolyte assessment generally focuses on body water, serum sodium, potassium and calcium concentrations.

Body water and sodium: A weight loss of 5-10% in term[18] infants and 10-20% in preterm[19] infants is common during the first week of life. The net water and sodium loss is accepted as appropriate after birth[20]. Assessment of degree of this water loss is complicated by a relatively large and highly variable insensible water loss[1]. The more immature the infant, the more pronounced the contraction of the extra cellular space and higher the insensible water loss. Both of these factors predispose to hypernatremia in the first few days of life.

Potassium. Serum potassium concentration rise in the first 24 to 72 hours after birth in moderately to markedly premature infants, even in the absence of exogenous potassium intake and in the absence of renal dysfunction[21]. This increase seems to be the result of a shift of potassium from the intracellular to extracellular space. The magnitude of this shift roughly correlates with the degree of immaturity[21]. Potassium load is excreted by the kidneys[1].

Calcium. Total calcium concentration in cord plasma increases with increasing gestational age and is significantly higher than maternal values[1]. With delivery of baby, plasma calcium falls, reaching a nadir at age 24-48 hour[22]. Serum parathyroid hormones (PTH) increase postnatally in response to this fall in plasma calcium concentration. This increase in PTH mobilizes calcium from bone, and plasma calcium concentration rises and subsequently stabilizes even in the absence of exogenous calcium intake. Clinically significant hypocalcemia occurs in premature infants, asphyxiated newborns, and infants of diabetic mothers. The etiology in all these circumstances is a sluggish response in PTH secretion to the postnatal fall in plasma calcium concentration.

Approximately 50% of total plasma calcium is bound (predominantly to albumin) and 50% is ionized. Ionized calcium is the best indicator of physiologic blood calcium activity. Changes in plasma ionized calcium concentration parallel those described above for total plasma calcium concentration[23]. Lower serum albumin concentration and acidosis, not uncommonly found in premature infants, result in a lower total plasma calcium concentration for a given plasma ionized calcium concentration. Changes in ionized plasma calcium mirror to total plasma calcium concentration. Again, larger sample volume is required in many laboratories to determine ionized calcium. Hence, calcium status is routinely monitored with total plasma calcium concentration[23]. In neonates, faecal sodium loss depends on gestational age. The loss is 0.1 mmol/kg/day in preterm and 0.02 mmol/kg/day in term babies[12]. Faecal potassium losses are about twice as high as sodium loss, but show no relation with gestational age[12]. Under pathological conditions (e.g. bowel obstruction, ileostomy, pleural fluid aspiration etc.) electrolyte contents of lost fluids cannot be predicted precisely. Here, it is wise to measure at least once the sodium concentration of such lost fluid in order to replace them. Chloride loss usually correlates with sodium loss and potassium loss is usually much smaller[12].

Fluid and electrolyte management:

Management of fluid and electrolyte in neonate should be based on background of such issue. It depends on baby's age, weight, associated pathological situation, environmental conditions and on phase that the baby is passing.

Phase 1: Transition phase

The objectives for fluid and electrolyte administration during this period are:

- To allow contraction of ECF with negative water balance of not more than 10% without compromising intravascular fluid volume and cardiovascular function.
- To allow a negative net balance for sodium of 2-5 mmol/kg per day for the first postnatal days, to maintain normal serum electrolyte concentration.
- To secure a sufficient urinary output and avoid oliguria (<0.5-1.0 ml/kg per hour) for longer than twelve hours.
- To ensure regulation of body temperature by providing enough fluid for transepidermal evaporation.

During phase 1, administration of fluid and electrolytes needs very caution. Clinician is to be judicious enough regarding fluid and electrolytes at the onset of diuresis and in polyuric patient specially in ELBW infant[12]. Fluid load during this phase in healthy preterm neonate range from 96 to 200 ml/kg/day from the third day of life[24], but rarely exceed 130 ml/kg per day. The fluid intake dependent on birth weight and increases daily (Table-1) Electrolyte administration during the first 3-5 days also depends on maturity and birth weight[12]. Generally, sodium[25] and potassium[12] supplementation should be started after ensuring initial diuresis, a decrease of serum sodium or at least 5-6% weight loss in neonates[25].

Sodium intake should be restricted in very-low-birth-weight (VLBW) babies during the period of ECF contraction until a weight loss of approximately 6-10% has occured[26]. Fluid restriction reduces chance of patent ductus arteriosus, nacrotizing enterocolitis, death and tends to reduce the risk of bronchopulmonary dysplasia but increases risk of dehydration[27]. A restricted sodium intake has positive effects on oxygen requirements and the risk of later bronchopulmonary dysphasia[26]. Sodium restriction also induces higher risk of development hyponatraemia, and is associated with pontine (brain) myelinolyosis[12].

Phase lI: Intermediate phase

The objectives for fluid and electrolyte administration during phase ii are to:

- Replete the body for electrolyte losses, replaces actual water and electrolytes.
- Augmentation of oral feedings.

Phase lll: Stable growth phase -

The objectives for fluid and electrolyte administration during phase I I I are:

- To replace losses of water and electrolytes (maintaining water and electrolytes homeostasis).
- To provide extra water and electrolytes to build up new tissue at intrauterine growth rates.

The recommended fluid intakes in phase II (Table-2) are based on studies suggesting that a daily fluid intake equal to or higher than 170 ml/kg body weight per day is accompanied by high urinary excretion with negative sodium balance, even if Na+ intake is as high as 10 mmol/kg body weight per day[12]. Fluid therapy in extremely low birth weight (ELBW) in excess of 200/ml/kg/day does not maintain Na+ balance, regardless of the amount of NaCI provided. It is important to note that ELBW infants require more fluids than recommended during the first week of life for term infants, because of high insensible water loss[28]. Evaporation of water from upper respiratory passages accounts for approximately one third of net insensible water loss and reaches the level of 0.8-0.9 ml/kg-body weight per hour in premature infants and 0.5 ml/kg body weight per hour in term babies 12 Electrolytes requirements in preterm very low birth weight baby is less than that of preterm low birth-weight baby[12].

Fluid requirements during the phase III Table-3 re related to the expected weight gain[8]. Daily sodium requirement in term baby in this stage is -3 mmol/kg body weight in comparison to 3-5 mmol/kg body weight in preterm infant[12].

Urinary output may be as high as 6.0 ml/kg per hour of free water in the presence of a total urine production of 9.8 ml/kg per hour in preterm infants with birth weight 2000gm[28]. Water loss from stool is negligible in early life prior to establishing enteral feeding. When full enteral feeding is achieved, faecal losses of 5-10 ml/kg per day are usually assumed to balance metabolic water production[29]. Plasma Na+ concentrations are normal in infants with sodium intake of 1.1-3.0 mmol/kg body weight per day and

Table-I

Parenteral fluid and electrolyte intake during the first postnatal week.

Recommended fluid intake (ml/kg body weight per day)						
Days after birth	1stday	2ndday	3rdday	4thday	5thday	6thday
Term neonate	60-120	80-120	100-130	120-150	140-160	140-180
Preterm neonate >1500g	60-80	80-100	100-120	120-150	140-160	140-160
Preterm neonate <1500g	80-90	100-110	120-130	130-150	140-160	160-180
Recommended Na+, K+, Cl” supply (mmol/kg body weight per day)						

* Na+ = 0- 3 (5) ** K+ = 0- 3 Cl- = 0- 5

Vol. 26, No. 1, January 2008
48

Table-II

Parenteral fluid and electrolyte intake for newborn infants during the intermediate phase.

Gestational age Birth weight	Fluid intake (ml/ kg body weight/day)	Na+ intake (mmol/kg body weight/day)	K+ intake (mmol/kg body weight/day)	CI- intake (mmol/kg body weight/day)
Term neonate	140-170	2.0-5.0	1.0-3.0	2.0-3.0
Preterm neonate				
> 1500g	140-160	3.0-5.0	1.0-3.0	3.0-5.0
< 1500g	140-180	2.0-3.0(5)	1.0-2.0	2.0-3.0

Table-III

Potential fluid and electrolyte intake during the first month of life with stable growth

Gestational age	Fluid intake (ml/ kg body weight/day)	Na+ intake (mmol/kg body weight /day)	K+ intake (mmol/kg body wt/day)
Term neonate	140-160	2.0-3.0	1.5-3.0
Preterm neonate	140-160	3.0-5.0(7.0)	2.0-5.0

fluid intakes of 140-170 ml/kg body weight per day[12,30]. There is evidence that fluid intake lower than 140 ml/kg body weight/day, together with Nay intake of about 1 mmol/kg body weight per day, is adequate to maintain sodium balance in ELBW neonates[31,32]. There is no increase in morbidity among infants given less Na+ and less fluid[33]. A non-significant trend to higher incidence of patent ductus arteriosus and bronchopulmonary dysplasia is observed in infants given more Na+ and more fluid intake[12]. Breast-fed term babies need as little as 0.35 to 0.7 mmol/kg body weight per day of Na during the first 4 months of life to achieve adequate growth. A recommendation to provide 1.0 to 2.0 mmol /kg per day of NaCI should counter-balance incidental losses from skin or gastrointestinal tract. In preterm infants, a higher growth rate explains a higher sodium requirement[12].

Preterm infants retain about 1.0 to 1.5 mmol/kg body weights per day K+, which is about the same as foetal accretion. About 2 to 3 mmol/kg/day of potassium, which is similar to the amount provided in human milk, is usually recommended for young infant[12].

During fluid and electrolyte management the clinician has to consider about some important environmental factors, which can potentially influence, such vital issues notably insensible water loss.

* A double wall incubator reduce insensible water loss in VLBW neonate by about 30% when a humidity of 90% is used at thereto-neutral temperature. With maturation of the epidermal barrier it is possible to reduce ambient humidity step by step commonly after first 5 days of life[12]. * Use of waterproof coverings (such as plastic films, plastic blankets, bubble blankets) in addition to treatment in a double wall incubator leads to further reduction of insensible water loss by 30-60% [12]. * Use of radiant warmers or single wall incubators for VLBW care may increase water loss and impair thermoregulation[34]. * Use of emollient ointments decreases insensible water loss of up to 50% in open care conditions[35,36]. * Endotracheal intubations and mechanical ventilation using warmed and humidified air significantly reduces insensible respiratory water loss by 20 mm/kg body weights per day[12].

Messages:

- During delivery of baby the extracellular fluid volume is larger than the intracellular volume.
- Extracellular volume drops precipitously after birth mainly due to postnatal diuresis.
- Adaptation of fluid and electrolytes is due to discontinuation of placental exchange, onset of insensible water loss, thermoregulation, renal regulation and intake of fluid and nutrients.
- Adaptation course is divided into three phases-namely, transition phase, intermediate phase and stable growth phase.
- Electrolytes generally should be supplemented after ensuring initial diuresis.
- Some environmental factors e.g. incubator care, waterproof coverings, radiant warmers, use of emollient etc potentially influences fluid and electrolyte management.

Conclusion:

Fluid and electrolyte homeostasis in neonatal period is an important issue. Proportion of various constituents of this environment in neonate is very different from older children. Even in same neonate, this environment changes depending on some factors including postnatal age. A relative small absolute pathological change in any of the constituent of this environment may bring a deleterious effect on neonatal health. During delivery extracellular fluid volume is larger than the intracellular volume which drops precipitously thereafter. Adaptation of fluid and electrolytes is divided into three phases and is due to discontinuation of placental exchange, insensible water loss, thermoreguilation, renal regulation and intake of fluid and nutrients by neonate. After birth if needed, fluid without minerals is supplemented and minerals are added when initial diuresis has occurred. The objective of management of this environment is not to maintain the status after birth but to allow the changes to occur appropriately. Clinician is to be updated enough regarding this change. Proper understanding of fluid and electrolyte homeostasis of newborn baby will make problem related to such environment preventable with a favorable change in neonatal health.

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Vol. 26, No. 1, January 2008
50

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