Electrolyte Maintenance & Replacement- Full Clinical Neonatal Guideline UHDB

Reference no.: NIC ME 01

1. Introduction

To provide a standardised approach to the maintenance of a normal electrolyte balance in the neonate. In particular, the maintenance of normal sodium, potassium, calcium and magnesium.

2. Aim and Purpose

The maintenance of normal electrolyte levels in the neonate may be challenging due to their physiology undergoing rapid changes and being poorly equipped to deal with electrolyte abnormalities. Both term and preterm neonates have poor renal electrolyte reabsorption and will undergo a physiological weight loss diuresis from being born with excess total body water, mostly as extracellular fluid. An additional challenge with the preterm neonate is the insensible fluid loss from their immature skin.

These can result in both fluid and electrolytes becoming rapidly depleted within the first week of life and serious morbidity.

This guideline will address the daily requirements for sodium, potassium, calcium and magnesium and their correction if their levels are low.

Daily Requirements and Normal Ranges

The daily requirements and normal ranges for sodium, potassium and magnesium are shown in the table below:

Electrolyte	Normal Range	Requirement
Sodium	135-145 mmol/L[1]	*Preterm:* 3-5 mmol/kg/day *Term:* 1-2 mmol/kg/day[2,3]
Potassium	3.5-4.5 mmol/L[1]	2 mmol/kg/day[2]
Calcium	*Adjusted calcium 2.0-2.5mmol/L[4]* *Ionised calcium 1.1-1.3[1]*	1 mmol/kg/day[2]
Magnesium	*≥ 0.7 mmol/L[5]*	0.5 mmol/kg/day[2]

If a neonate is requiring electrolytes supplementation or replacement, it is recommended to take daily U&E's to ensure correct levels.

3. Sodium

3.1 Hyponatraemia

Before correcting sodium, it is important to address the underlying cause. The causes may be split into *"dilutional"* and *"depletion"*:

Dilutional - SIADH or excess fluid intake (iatrogenic)

- Increased weight
- Low serum osmolality
- Normal / low urine sodium

Depletion - poor renal conservation or use of diuretics or poor sodium intake

- Loss of weight
- High serum osmolality
- High urine sodium

Management of hyponatraemia: preferable route of sodium supplementation is orally. Use if hyponatraemia is not as a result of dilutional causes (in which case fluid restriction is needed)

A) ***Plasma sodium ≥ 130mmol/L -*** give oral supplement of sodium chloride 30% (5mmol/ml) as per daily requirement in table above. Split requirement into 3-4 doses to be given with feeds

B) ***Plasma sodium 125 - 129mmol/L -*** give based upon deficit. Deficit calculated using: *(135 - plasma sodium) x 0.6 x weight(kg) = mmol/day. Given over 8-12 hours*

C) ***Plasma sodium 120 - 124 mmol/L -*** calculate deficit as above but underestimate loss and replace slowly over a 24-48 hour period, usually as a slow IV correction

D) ***Emergency management <120mmol/L with symptoms of irritability, apnoea or convulsions -*** start a bolus of 15/20ml/kg of 0.9% NaCl and check U&E 6-8 hourly. Aim for sodium correction over a 24-48 hour period.

Practical tips when treating hyponatraemia:

- Prescribe oral dose as mmols
- Consider if sufficient sodium may be given by changing fluids e.g. to a bag of sodium chloride 0.45% with glucose
- Can additional sodium be added in the next bag of TPN - See 'Total Parenteral Nutrition in Neonates' guideline on Net-i
- If needed, consider making a correct infusion of Sodium Chloride 1.8% - see 'Sodium Chloride 1.8 % (0.3mmol/mL) NICU' monograph on Net-i

- ***Monitoring*** - when the patient is unstable U&E's should be monitored 8 to 12 hourly until clinically stable. Once stable U&E's may then be monitored daily.

3.2 Hypernatraemia

Defined as a serum sodium >145 mmol/L. The causes are normally either dehydration (due to insufficient fluid replacement), however other causes to consider are:

- GI losses
- Diabetes insipidus – Hyperglycaemia resulting in osmotic urinary losses if blood sugar > 10mmol/L
- Iatrogenic (too much sodium in IV fluids)
- High output renal failure
- Transepidermal water loss – minimalized by ensuring adequate humidity in incubator

Management of hypernatraemia: it is essential to assess fluid status clinically and using lab tests including U&Es. After assessment treat the underlying cause and collect urine for urine osmolality and electrolytes.

If dehydrated, give slow rehydration over 24-48 hours either orally or using isotonic solutions (e.g. 0.9% NaCl)

Serum sodium greater than 150mmol/L but <160mmol/L

- If possible reduce sodium intake by 2mmol/kg/day
- Increase fluids by 20-30ml/kg/day with a sodium free solution e.g. glucose 5%
- Recheck Sodium every 6-8 hours

Serum Sodium greater than 160 mmol/l

This is an emergency as the baby is at risk from intracerebral fluid changes
Sodium should be corrected slowly (reduction of no more than 10mmol/l every 12-24 hours)

- Minimise sodium intake by selecting a low sodium maintenance fluid
- Increase fluids by 20 - 30 mL/kg/day
- Recheck sodium after 4 hours
- Review prescription of diuretics
- Review fluid balance
- Review the diluents of all continuous infusions (e.g. morphine etc); consider switching the diluent to glucose - see BNFc, Medusa or 'Y-Site compatibility chart' found on Net-I for information about drug compatibility. Where unsure, contact pharmacy.

Practical tips when treating hypernatraemia:

- Do not allow serum sodium to drop by more than 10mmol/L per day to prevent cerebral oedema through fluid shift.

4. Potassium

4.1 Hypokalaemia

This is defined as a serum potassium level <3.5mmol/L. A low potassium is usually a late sign, as potassium is predominantly (90%) intracellular. The important causes for low potassium are:

- Inadequate intake
- Gastrointestinal losses from vomiting, diarrhoea, nasogastric or stoma
- Use of non-potassium sparing diuretics e.g. furosemide
- Metabolic alkalosis
- Hyperaldosteronism
- Hypomagnasaemia[3]

Management of hypokalaemia: perform urgent ECG to exclude arrhythmia and laboratory UE.

Aim is to increase potassium levels and this can be done through supplementation. You may consider oral potassium chloride 7.5% w/v syrup (Kay-Cee-L; equivalent to 1 millimole of potassium per ml) or consider addition to further TPN (contact pharmacist) or through adding to IV fluids.

Daily U&E's are required until normal potassium levels are achieved and supplementation stopped.

4.2 Hyperkalaemia

Defined as ***two*** successive serum potassium measurements >7.5mmol/L in a non-haemolysed venous or arterial blood sample.

Hyperkalaemia can cause cardiac arrhythmias, in particular SVT or sins bradycardia. This in turn can lead to cardiac arrest. The aims of treatment is to remove excess potassium, drive extracellular potassium into the cells and minimise the chance of arrhythmias.

Management of hyperkalaemia: repeat urgent, free flowing UE to ensure accurate measurement of potassium. Bring to NICU and start cardiac monitoring. Stop potassium containing fluids and start monitoring urine output. If there are any concerns of ECG changes including:

1. ***Tall tented T waves***
2. ***Prolonged PR***
3. ***Flattened P waves***
4. ***Widened QRS***

5. Arrhythmia

Call for senior help immediately

Treatment of life threatening arrhythmias:

A) ABC

B) Calcium gluconate 10% IV, 0.11mmol/kg (0.5ml/kg) over 5-10 minutes. Onset within 5 minutes, duration of 30-60 minutes. Ensure ECG monitoring in place. *See 'Calcium Gluconate - NICU' monograph on Net-i*

C) Salbutamol 4 micrograms/kg IV bolus over at least 5 minutes, may be repeat after 2 hours

D) Sodium bicarbonate to half correct acidosis. Onset within 15-30 minutes, duration of 60 minutes. *See 'Sodium Bicarbonate - NICU' monograph on Net-i*

E) Glucose and insulin infusion. **DISCUSS WITH SENIOR PRIOR TO INITIATING**

Prescribing Insulin:

5 units of Actrapid insulin to 50ml of 10% glucose, giving a solution of 1unit insulin/2g glucose.

Infuse at 0.1 units/kg/hr (1mL/kg/hr). Can increase up to 0.5 units/kg/hr in 0.1units/kg/hr increments. Monitor blood glucose every 30 minutes.

Note: Insulin monograph on Net-I is NOT to be followed, as not indicated for hyperkalaemia. Make as follows:

Draw up 100 units of Actrapid insulin (1ml) and dilute to 10mls with sodium chloride 0.9% (**NOT glucose** as prescription may occur).

This will provide a solution of 10 units Actrapid per 1ml of sodium chloride 0.9%

Take 0.5mls of this 10 units/mL solution and dilute to 50mL with glucose 10% to give 0.1units/ml.

Insulin binds to the syringe and giving set, therefore make up the insulin and prime the insulin giving set and leave for 10 minutes - then discard 10mLs of the infusion from your primed line **BEFORE** connecting infusion to the patient.

Prescribing Glucose:

Glucose should be run through the same line as the insulin/glucose (above) to ensure both infusions start and stop at the same time. (Note: maximum peripheral glucose concentration is 12.5%). If baby is currently receiving TPN, this should be held and switched to glucose only infusion. Ideally, the glucose should be 20% and given centrally.

Central line available – 20% glucose at initial min rate of 2.5ml/kg/hr (60ml/kg/day) - *this is instead of previously running fluids/PN*

Peripheral line – 10% or 12.5% glucose at min rate of 5ml/kg/hr (120ml/kg/day) - *this is instead of previously running fluids/PN*

Regular monitoring of blood glucose.

Stop PN or maintenance fluids whilst glucose and insulin running.

Guide to adjusting infusion rates - **use in combination with clinical judgement**:
Monitor blood glucose before starting infusion.
After 30 minutes check blood glucose and potassium levels and make changes as per table below.
Continue to monitor after stopping infusion due to the prolonged effects of insulin.

Blood Glucose Levels	Potassium Levels			
	Where K+ <6	Decreasing	Static	Increasing
Low <4mmol/L *(If BG <2.5mmol/L STOP the insulin infusion - contact consultant/and review glucose infusion)*	**Insulin:** STOP	**Insulin:** No change	**Insulin:** No change	**Insulin:** Consider increasing insulin by 0.1unit/kg/hr*
	Glucose: Review fluid and electrolyte management	**Glucose:** Increase rate or concentration *(Note: 12.5% max peripheral concentration)*	**Glucose:** Increase rate or concentration *(Note: 12.5% max peripheral concentration)*	**Glucose:** Increase rate or concentration *(Note: 12.5% max peripheral concentration)*
Within range: 4-7mmol/L	**Insulin:** STOP	**Insulin:** No change	**Insulin:** Consider increasing insulin by 0.1unit/kg/hr*	**Insulin:** Increase insulin by 0.1unit/kg/hr*
	Glucose: Review fluid and electrolyte management	**Glucose:** No change	**Glucose:** If insulin is increased then increase rate or concentration *(Note: 12.5% max peripheral concentration)*	**Glucose:** Increase rate or concentration *(Note: 12.5% max peripheral concentration)*
High >7mmol/L	**Insulin:** STOP and consider insulin for hyperglycaemia (see relevant drug monograph)	**Insulin:** No change	**Insulin:** Consider increasing insulin by 0.1unit/kg/hr*	**Insulin:** Increase insulin by 0.1unit/kg/hr*
	Glucose: Review fluid and electrolyte management	**Glucose:** Consider reducing glucose rate or concentration	**Glucose:** If insulin is not changed then reduce glucose rate or concentration.	**Glucose:** consider reducing glucose rate or concentration.
*insulin can be given to a maximum of 0.5units/kg/hour				

F) Consider calcium resonium 125-250 mg/kg PR every 6 hours. Irrigate the colon to remove resin after 8-12 hours.

Practical tips for treating hyperkalaemia:

- Must be confirmed with 2 free flowing venous or arterial samples
- Stop potassium containing fluids and supplements
- Get senior support early if any concern of hyperkalaemia causing cardiac arrhythmia

5. Calcium

5.1 Hypocalcaemia

There are multiple causes of hypocalcaemia including:

- Low albumin levels*
- Severe illness
- Renal failure - leading to excess calcium loss
- Magnesium dependent hypocalcaemia
- Maternal hypercalcaemia
- Hypoparathyroidism
- High phosphate cow's milk
- Low oral intake
- Low maternal Vitamin D levels
- Di George syndrome
- Maternal diabetes mellitus

In neonate there is a normal physiological fall in calcium levels on the first day of life which will then rise on the second day. Therefore replacement within the first 2 days is not required unless symptomatic or severely unwell.

** Serum calcium levels will fall by 0.1mmol/L for every 4g fall in serum albumin.*

Management of hypocalcaemia: treatment is started once certain threshold are met and investigate for underlying causes:

A) ***Plasma calcium <1.8mmol/L and symptomatic*** **-** seizures, PPHN, jitteriness, inotropes

B) Plasma calcium <1.5mmol/L or ionised calcium <0.8 and asymptomatic

If the above criteria are met, then it is important to discuss treatment options which may include:

Oral supplementation in the form of Calcium Carbonate 250mg/5mL oral liquid

OR, if also symptomatic

0.11mmol/kg (0.5ml/kg) of 10% calcium gluconate over 5-10 minutes into a central/large vein - *See 'Calcium Gluconate - NICU' monograph on Net-i*

If an infusion is required – please also refer to the calcium gluconate monograph above

Practical tips when treating hypocalcaemia:

- 10% calcium gluconate = 0.22mmol/ml of calcium

- Risk of IV burn during injection of calcium gluconate
- May reduce the half life of some IV drugs - check interactions
- Monitor ECG when giving IV correction

5.2 Hypercalcaemia

This is not commonly seen in the neonatal period and is defined as an ionised calcium >1.4mmol/L (for serum calcium, sources vary from >2.5 to >2.7). Discussion with seniors is advised.

A few causes include:

- Iatrogenic
- Endocrine causes - hypophosphatemia, severe hyperparathyroidism, thyrotoxicosis
- Metabolic causes
- Idiopathic

Management of hypercalcaemia: perform serum calcium, phosphate and magnesium, PTH, Vitamin D levels, ALP. ECG, renal ultrasound and skeletal survey may be considered.

Discuss treatment with senior, options include:

- Rehydration (orally or IV) if dehydrated
- Avoid excessive calcium in TPN
- Medications - loop diuretics, bisphosphonates, steroids

6. Magnesium

6.1 Hypomagnesemia

Hypomagnesaemia is now rare in neonates but should be thought of in a case of a fitting infant. It is linked to calcium levels and should always be given after treating hypocalcaemia because:

- Calcium increases the renal excretion of magnesium
- Occasionally giving calcium may correct both a hypocalcaemia and a hypomagnesemia

Management of hypomagnesaemia: to be given if serum levels are low and to be monitored if hypocalcaemia is present or suspected.

The normal range is: ***≥ 0.7 mmol/L***
If the above criteria are met, then the treatment is:

100mg/kg (0.4mmol/kg or 0.2ml/kg) of 50% Magnesium sulphate via slow IV over (see below for rate) or IM every 6-12 hours[5]

Magnesium Sulphate 50% = 500mg/ml i.e. 2mmol/ml
Magnesium sulphate must always be diluted with before administration.

Directions for dilution:

For peripheral administration a maximum concentration of magnesium sulphate 5% is recommended. Concentrations over 5% have a high osmolarity and may cause venous irritation and tissue damage in cases of extravasation.
If a central venous access device is unavailable, administer via a large peripheral vein monitoring insertion site closely using a recognised phlebitis scoring tool. Re- site cannula at first signs of inflammation.
Where central access is available, dilute to 10%.

- **To prepare a 5% solution** (50mg/mL) solution dilute each 1mL of magnesium sulphate 50% with 9mL of diluent.
- **To prepare a 10% solution** (100mg/mL) solution dilute each 1mL of magnesium sulphate 50% with 4mL of diluent.
- **To prepare a 20% solution** dilute each 1mL of magnesium sulphate 50% with 1.5mL of diluent. *NOTE - only for fluid restriction*

Suitable diluents: Glucose 5% or 10%, Sodium Chloride 0.45% or 0.9% or Glucose and Sodium Chloride combinations.

Rate of administration **should not exceed 10 mg/kg/minute** (0.04 mmol/kg/minute Mg^{2+}) of magnesium sulphate heptahydrate.

Practical tips when treating hypomagnesaemia:

- Usually 2 doses of magnesium sulphate is sufficient to correct levels
- If given rapidly magnesium sulphate may cause hypotension

3. References (including any links to NICE Guidance etc.)

1. Fox G, Hoque N, Watts T. *Oxford handbook of Neonatology 2nd Edition.* Oxford University Press, 2017
2. Millard K, Wardle S, Lee AM. *Management of Fluid and Electrolytes in Neonates D2*. Nottingham Children's Hospital, Nottingham Neonatal Service, Version 3, 2017
3. Bustani P, Smith C. *Fluid and electrolytes management in neonates.* North Trent Neonatal Network, 2011
4. Nottingham Children's Hospital; Guidelijne for the management of hyperkalaemia in neonates (D20); accessed 09.06.2023
5. Nottingham Children's Hospital; Management of fluid and electrolytes in Neonate (D2); accessed 09.06.2023
6. Leeds Teaching Hospitals NHS trust; Intravenous fluids and how to prescribe them on the Neonatal unit; accessed 21.1.2021
7. cBNF; accessed online 09.06.2023
8. Medusa; online IV drug monograph; accessed online 09.06.2023

Documentation Controls

<table>
<tr><td>Reference Number

From Library and Knowledge Service Manager</td><td colspan="2">Version:

V001</td><td>Status

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<tr><td rowspan="2">Version / Amendment History</td><td>Version</td><td>Date</td><td>Author</td><td>Reason</td></tr>
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Linked Documents: (Nice guidance/Current national guidelines)	
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Review Date	July 2026
Contact for Review	Dr Bala Subramaniam

4. Appendices

HYPERNATRAEMIA SUMMARY:

HYPERNATRAEMIA

PLASMA SODIUM >145 MMOL/L

MONITOR U&E'S DAILY

ASSESS FLUID BALANCE

IF DEHYDRATED GIVE SLOW REHYRDATION OVER 24-48 HOURS

REHYDRATION MAY BE ORALLY OR SLOW IV

DO NOT ALLOW SERUM SODIUM TO DROP BY >10MMOL/L PER 24 HOURS

HYPONATRAEMIA SUMMARY:

HYPONATRAEMIA **PLASMA SODIUM ≥130 MMOL/L**	***ORAL SUPPLEMENT*** ***30% SODIUM CHLORIDE (5MMOL/ML)*** ***DIVIDE TOTAL DAILY DOSE FOR TOLERANCE*** ***GIVE 3 - 4 TIMES A DAY***
HYPONATRAEMIA **PLASMA SODIUM 125 - 129 MMOL/L**	***SUPPLEMENT - USING:*** ***(135 - PLASMA SODIUM) X 0.6 X WEIGHT (KG) = MMOL/DAY***
HYPONATRAEMIA **PLASMA SODIUM 121 - 124 MMOL/L**	***SUPPLEMENT - USING:*** ***(135 - PLASMA SODIUM) X 0.6 X WEIGHT (KG) = MMOL/DAY***
HYPONATRAEMIA **PLASMA SODIUM ≤120 MMOL/L**	***BOLUS:*** ***15-20ML/KG 0.9% SODIUM CHLORIDE*** ***CHECK LEVELS 6-8 HOURLY***

MONITORING U&E'S:

- **WHEN UNSTABLE MONITOR 8-12 HOURLY**
- **ONCE STABLE MONITOR DAILY**

HYPOKALAEMIA SUMMARY:

HYPOKALAEMIA

PLASMA POTASSIUM <3.5MMOL/L

INCREASE THROUGH SUPPLEMENTATION. CONSIDER ADDING:

POTASSIUM CHLORIDE 1MMOL/ML ORAL SUSPENSION (KAY-CEE-L)

OR

ADD POTASSIUM TO INTRAVENOUS FLUIDS OR

ADD POTASSIUM TO NEXT BAG OF TPN

MONITOR U&E'S DAILY

HYPERKALAEMIA SUMMARY:

HYPERKALAEMIA

PLASMA POTASSIUM >7.5MMOL/L ON X2 FREE FLOWING VENOUS OR ARTERIAL SAMPLES

STOP ALL POTASSIUM CONTAINING MEDICINES

START URINE OUTPUT MONITORING

START CARDIAC MONITORING

IF EGG SHOWS: TALL TENTED T WAVES, PROLONGED PR, FLAT P WAVES, WIDE QRS OR ARRHYTHMIA

START ABC AND CALL FOR SENIOR

CALCIUM GLUCONATE 10% IV (0.5ML/KG OR 0.11MMOL/KG OVER 5-10 MINUTES)

SODIUM BICARBONATE TO HALF CORRECT ACIDOSIS

SALBUTAMOL 4 MICROGRAMS/KG IV BOLUS OVER AT LEAST 5 MINUTES

MUST DISCUSS WITH SENIOR PRIOR TO STARTING:

GLUCOSE/ INSULIN INFUSION (5 UNITS ACTRAPID TO 50ML OF 10% GLUCOSE. START AT 0.1 UNITS/KG/HR)

CALCIUM RESONIUM 125-250MG/KG PR EVERY 6 HOURS

HYPERCALCAEMIA SUMMARY:

HYPERCALCAEMIA

IONISED CALCIUM >1.4MMOL/L

ASSESS FLUID STATUS AND MEDICATIONS

PERFORM CALCIUM, MAGNESIUM, PHOSPHATE, VIT D, ALP, ECG.

CONSIDER RENAL USS

GIVE REHYDRATION IF DEHYDRATED

CONSIDER LOOP DIURETICS, BISPHOPHONATES AND STEROIDS

(DISCUSS WITH SENIOR)

Appendix D - Magnesium

HYPOMAGNESAEMIA SUMMARY:

HYPOMAGNESAEMIA

INVESTIGATE IF HYPOCALCAEMIA OR HAS BEEN TREATED FOR HYPOCALCAEMIA.

TREAT IF LEVELS ARE LESS THAN:

<0.7 MMOL/L

TREATMENT:

100MG/KG / 0.4MMOL/KG / 0.2ML/KG OF 50% MAGNESIUM SULFATE VIA SLOW IV OR IM INJECTION EVERY 6-12 HOURS.