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1. Introduction

Fluid and electrolyte management in paediatric neurosurgical patients requires careful attention to correct intravenous fluid prescribing, along with close monitoring of fluid balance and assessment of clinical hydration status. This is due to the pathophysiological processes that occur in neurosurgical patients, for example excess ADH secretion – either appropriate or inappropriate, cerebral salt wasting or cranial diabetes insipidus.

Hyponatraemia (serum sodium <136mEq/L) is one the most frequently encountered electrolyte abnormalities in children, it has been shown to be an independent risk factor for mortality in adults. It is more common in the neurosurgical population & in adult neurosurgical patients prevalence has been reported to be as high as 50%. Due to cerebral effects of hyponatraemia, neurosurgical patients are at increased risk of complications including severe cerebral oedema, altered conscious level, seizures, vasospasm, and death. These complications may also arise from the inappropriate treatment of hyponatraemia. Neurosurgical patients who have recently undergone surgery particularly to the ventricles ie shunt insertion or those who have acute CNS infection – shunt infection or cerebral abscess may be at particular risk of hyponatraemia.

NB. Hypotonic saline solutions (ie 0.45% NaCl, 0.45% NaCl +5% Dextrose, 0.18% NaCl + 10% Dextrose, 0.18% NaCl + 4 % Dextrose and 10% dextrose solutions) are therefore viewed with extreme caution in neurosurgery and should only be used to treat a demonstrated hypernatraemia (Na >150 mmol/l), including in the neonatal population.
2. Objectives

1. To reduce incidence of Hyponatraemia in Neurosurgical patients in PICU, HDU and Neurosurgical Ward areas
2. To ensure patients on intravenous fluids have regular monitoring of electrolytes

3. Scope

This guideline is intended for all healthcare professionals caring for patients requiring intravenous fluids under the care of the Neurosurgical Team at the Royal Hospital for Sick Children, Glasgow.

4. Roles & Responsibilities

All medical, nursing and allied professionals caring for patients who are receiving intravenous fluids under the care of the Neurosurgical Team should be familiar with the guideline.

5. Evidence

The guidelines have been constructed after consultation with standard textbooks, Ovid and Google Scholar searches (fluid management, neurosurgery, paediatrics) and local expert opinion from the fields of neurosurgery, anaesthetics, renal medicine and intensive care. The best available levels of evidence were used to construct these guidelines.
6. Intravenous fluid management of Neurosurgical Patients

**Hypotonic saline solutions** (ie 0.45% NaCl, 0.45% NaCl + 5% Dextrose, 0.18% NaCl + 10% Dextrose, 0.18% NaCl + 4% Dextrose and 10% dextrose solutions) are viewed with extreme caution in neurosurgery and **should only be used** to treat a demonstrated hypernatraemia (Na >150 mmol/l), including in the neonatal population.

Initial fluid management should be with 0.9% NaCl + 5% dextrose +/- 10 mmol KCl per 500ml bag in all paediatric neurosurgical patients. In older children where the risk of hypoglycaemia with fasting is small and in patients with documented hyperglycaemia (Lab glucose >10) 0.9% NaCl without dextrose may be prescribed (see flow diagram below).

In the past there has been concern that children prescribed 0.9% NaCl may be at risk of hypernatraemia. This is unusual in patients with normal renal function and sodium handling. In any patient with known renal disease, fluid management should be decided on a case-by-case basis in discussion with the renal team, recognising that severe hyponatraemia may have severe neurological consequences.
Neurosurgical Patient requiring IV fluids

Check Baseline Electrolytes, Glucose and FBC

< 1 month of age
Prescribe 0.9% NaCl + 10% dextrose +/- 10mmol KCl per 500ml bag at a rate of 100ml/kg/day

> 1 month and <5 years of age
Prescribe 0.9% NaCl +5% Dextrose +/- 10mmol KCl per 500ml bag at a rate of 70% ‘Maintenance*’
See table 1

> 5 years of age
Prescribe 0.9% NaCl +/- 10 mmol KCl per 500ml bag at a rate of 70% ‘Maintenance*’
See table 1

Check Electrolytes at least 24 hourly and glucose 4 hourly if not on Dextrose containing fluid unless Na drops by 5 mmol/ 24 hours or <130 mmol/l in which case inform Neurosurgical Consultant or Senior Clinical Fellow AND Neurology or HaN Registrar

Fluid Management of Paediatric Neurosurgical Patients

Table 1: ‘Maintenance’ Intravenous Fluids: Standard Calculations

<table>
<thead>
<tr>
<th>Weight (Kg)</th>
<th>‘Maintenance’ fluids</th>
</tr>
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<tbody>
<tr>
<td>2-10kg</td>
<td>100ml/kg/day</td>
</tr>
<tr>
<td>10-20kg</td>
<td>1000ml plus 50ml/kg/day for each kg over 10kg</td>
</tr>
<tr>
<td>&gt;20kg</td>
<td>1500ml plus 20ml/kg/day for each kg over 20kg</td>
</tr>
</tbody>
</table>

NB if on Enteral feeds this should be included in total fluid volume

Fluid Management of Neurosurgical Patients
Author: Dr Anne McGettrick, Miss Jennifer Brown, Dr J Beattie
Issue Date: February 2014
Date of review: February 2016
Q pulse reference: YOR-PICU-062
6a. Stock of Solutions

- Pre-made 0.9% NaCl+5% Dextrose and 0.9% NaCl solutions are stocked on all medical and surgical wards in RHSC.
- Pre-made 1.8% NaCl solutions are available on PICU & 7A. To make a 500ml bag of 1.8% saline solution take 500ml bag of 0.9% saline solution and add 77mmol NaCl (15.4ml of 30% Sodium Chloride concentrate – available from PICU)
- Premade 2.7% NaCl solutions are available only on PICU as PICU team should be aware if using this in the hospital

7. Monitoring of Electrolytes

- All hospitalised patients receiving intravenous fluids should have electrolytes checked daily.
- Sampling may be by capillary sampling and where sodium is being checked frequently, capillary or venous gas samples should be taken at the same time to clarify result.
- In patients who have SIADH or cerebral salt wasting Na may fall very rapidly and treatment of this is a clinical emergency.
- Any patient with a Na <135 on routine bloods should be reviewed urgently with accurate fluid balance, ensuring they are receiving appropriate intravenous/enteral fluids and replacement of Na losses – eg. CSF losses.
- In any neurosurgical patient with a drop in Na of >4 mmol since last measurement or a Na <131 should immediately have repeat electrolytes and a blood gas to confirm hyponatraemia and institute urgent treatment.
- All patients with an EVD in situ should have twice weekly monitoring of electrolytes even if well and feeding enterally#

# #
8. Hyponatraemia in Neurosurgical Patients

Differentiating causes of Hyponatraemia in Neurosurgical Patients & Why is this Important? (See Table 2)

Extracellular Fluid Volume Depletion: ADH Secretion

Pathophysiology: Appropriate ADH secretion occurs in patients with high plasma osmolality and decreased effective blood volume (ie. lacking in total body water or dehydrated). Osmoreceptors in the hypothalamus detect this increased osmolality and baroreceptors in the aortic arch, carotid sinus and left atrium detect decreased circulating blood volume, stimulating release of ADH which acts on the distal convoluted tubule and collecting ducts in the kidney in order to reabsorb water without reabsorbing solute. Surgical patients may therefore be susceptible to appropriate ADH secretion due to peri-operative fluid loss and pre-operative fasting.

Clinical Features: Patients with appropriate ADH secretion therefore have clinical features of euvolaemia / hypovolaemia with hyponatraemia

Treatment: Replacement of Sodium +/- fluid restriction appropriate.

Syndrome of (In)appropriate ADH Secretion

Inappropriate ADH secretion occurs when this process occurs in response to non-osmotic stimuli such as CNS infection, changes to cerebral blood flow mechanical ventilation, pain, stress, pyrexia, nausea, vomiting, hypoxia, hypoglycaemia and a number of drugs including inhalational anaesthetic agents, opiates, NSAIDs, carbamazepine, sodium valproate and vincristine. Therefore hospitalised neurosurgical patients may have many reasons to develop SIADH.

Clinical Features: Patients with Inappropriate ADH secretion are therefore clinically hypervolaemic / euvolaemic with hyponatraemia – which can be difficult to assess.

Treatment: Fluid Restriction is appropriate, they may also need sodium administration and diuretics if clinically fluid overloaded.
**Cerebral Salt Wasting**

**Pathophysiology:** Uncertain, but it is likely that in CSW there is inappropriate and excessive release of natriuretic peptides, which leads to a primary natriuresis and volume depletion with a secondary neurohormonal response with an increase in the renin-angiotensin system and in ADH production.

**Clinical Features:** Hypovolaemia with hyponatraemia

**Treatment:** Mainstay of treatment is Sodium replacement, often requiring Sodium Chloride solutions > 0.9%. In these patients fluid restriction without sodium replacement may be dangerous and diuretic use is contra-indicated.

**Why is this important?**
SIADH and cerebral salt wasting are clinically different entities where different fluid management regimes are required. However, the two entities may be clinically very difficult to differentiate and in all cases of acute hyponatraemia sodium should be administered and consideration given to change in fluid management plan.

**Table 2 Differentiating SIADH and CSW**

<table>
<thead>
<tr>
<th>Features</th>
<th>SIADH</th>
<th>CSW</th>
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<tbody>
<tr>
<td>Extracellular fluid volume</td>
<td>Normal to High</td>
<td>Low</td>
</tr>
<tr>
<td>Fluid Balance</td>
<td>Neutral or Positive</td>
<td>Negative</td>
</tr>
<tr>
<td>Urine Volume</td>
<td>Normal or Decreased</td>
<td>Normal or Increased</td>
</tr>
<tr>
<td>Central Venous Pressure</td>
<td>Normal to High</td>
<td>Low</td>
</tr>
<tr>
<td>Urine Na</td>
<td>High (&gt;40 mmol/l)</td>
<td>High (&gt; 40mmol/l)</td>
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</tbody>
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9. External Ventricular Drains (EVD)

CSF is continuously secreted by the choroid plexus of the lateral ventricles at a rate of approx. 20-25ml/hr in an adult (or 500ml/day). At any one time, approx. 100-150ml of CSF is contained within the cerebral ventricles and the spinal cord.

Cerebrospinal fluid contains a similar level of Na to plasma (138mmol/l) and has a higher Cl content (119mmol/l). It has a lower K content (2.8mmol/l) than plasma. Patients with EVDs in situ may be more prone to hyponatraemia due to sodium loss in CSF. Patients producing large volumes of CSF into the EVD (>10ml/hr) should have replacement of losses CSF losses with 0.9% NaCl and careful monitoring of sodium levels.
10. Management of Hyponatraemia in Neurosurgical Patients

- Documented hyponatraemia <130 mmol/l should always be discussed with Neurosurgical Consultant or Senior Clinical Fellow on Call in conjunction with on site Senior Medical Registrar (HaN / Neurology team).

- Careful assessment of fluid volume status should be made in order to attempt to differentiate between SIADH & cerebral salt wasting, though recognising that this may be extremely difficult. Careful review and monitoring of fluid inputs and outputs are extremely important.

- Administration of NaCl is the mainstay of treatment in either case, either alone or in conjunction with fluid restriction where SIADH is suspected

- 3ml/kg boluses of 2.7% NaCl over 1 hour should be given to increase plasma Na by 1-2 mmol/l/hour until Na >130. However if patient is clinically seizing this may be given over 15 mins. Na should be rechecked at the end of the infusion.

- If 2.7% NaCl boluses are required, PICU should be contacted and asked to review patient

- 2.7% NaCl should be given via large (preferably central) vein but do not delay Na administration for insertion of Central Venous Line.

- While Na <130 and during correction of Na patient should be monitored for signs of rising intracranial pressure – 1 hourly neuro obs including non-invasive BP and continuous ECG and SpO2 monitoring.

- Maintenance fluid may then include a continuous infusion of 1.8% NaCl or a combination of 1.8% and 0.9% NaCl depending on the preference of the Neurosurgical consultant.

- Electrolytes should be rechecked 4 hourly until Na >130 and at least twice daily for 48 hours following acute hyponatraemic episode

- These patients should be flagged as ‘Watchers’ at hospital Huddle
11. Cranial Diabetes Insipidus

These children are managed via a separate guideline and are under shared care with endocrinology: See Clinical Guideline - Diabetes Insipidus: Diagnosis and Management

YOR-PICU-036 Diabetes Insipidus Diagnosis and Management March 2012.pdf

Patients with suprasellar tumours are vulnerable to a triphasic response. The principles are that in the acute post operative period, Diabetes Insipidus is the most common disturbance but if the posterior pituitary has been disturbed or devascularised by the procedure, a period of SIADH may follow as the gland necroses releasing anti diuretic hormone. A period of more stable DI will inevitably follow but until this point is reached, DDAVP and its analogues must be given cautiously, in small single doses. Infusions of DDAVP are strongly contraindicated. Discussion with the Consultant Endocrinologist should take place before any major change in fluid or electrolyte management.

12. Review

This guideline should be reviewed every 2 years from date of approval

13. Monitoring

An audit of hyponatraemia will be performed following introduction of the guidelines

14. Implementation plan

1. Education and training for ward medical staff
2. Dissemination to Hospital at Night Team
3. Education for PICU trainees
4. Guideline to be put on Scotland’s Health on the Web Clinical Guidelines page
15. References

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Wang, J; Xu E; Xiao, Y: Isotonic Versus Hypotonic Maintenance IV Fluids in Hospitalized Children: A Meta-Analysis; Paediatrics 2014: 133 (1):105-113