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THE UNIVERSITY OF BRITISH COLUMBIA

BC CHILDREN'S HOSPITAL
An agency of the Provincial Health Services Authority

Fluid Management in Hospitalized Children

Preventing Hospital Acquired Hyponatremia

This guideline was developed in collaboration with Pediatric Anaesthesia, Pediatric Endocrinology, Pediatric Nephrology, General Pediatrics, Pediatric Surgery and Pediatric Critical Care at the BC Children's Hospital

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Hospital Acquired Hyponatremia: General Introductory Statements

Key Points:

- Symptomatic hyponatraemia is a medical emergency.
- Hospital acquired hyponatraemia (HAH) may result from inappropriate fluid (IV or enteral) administration in acutely ill hospitalized children.
- HAH is preventable.

Preventing Hospital Acquired Hyponatremia (HAH) in Acutely Ill Children

There are over 50 published cases of death and long-term disability from hyponatraemia in hospitalized children (hospital acquired hyponatraemia). In 2009, a press release from ISMP Canada highlighted the dangers of hypotonic fluid administration to hospitalized children. Administration of hypotonic intravenous maintenance/replacement fluids or commercial enteral formula (all are hypotonic) may be associated with hyponatraemia (serum Na^+ < 135mmols/L). The use of isotonic fluids for both maintenance and replacement reduces the risk of iatrogenic hyponatremia, with little evidence of other complications.

Intravenous fluids are often required in hospitalized children. Standard replacement fluid volumes have traditionally been based upon the 4-2-1 rule, originally conceived by Holliday and Segar. This simple rule of thumb was based upon caloric requirements rather than weight in healthy otherwise normal children. Healthy children are able to monitor their own intakes based upon thirst and hunger.

Hyponatremia occurs in 15-30% of hospitalized children. Today's hospitalized child is generally sicker and more complex than when the 4-2-1 rule was formulated, many have elevated levels of circulating ADH due to pain, nausea, medications etc, as well as underlying chronic disease and are prone to free water retention. Consequently, the 4-2-1 rule may over-estimate fluid requirements. Hospitalized children are often administered fluids either intravenously or through an NG or NJ tube as they are unable to tolerate a normal diet as a consequence of their acute illness. A physician prescribes a fluid rate and solution type, without the safety of the patient's own thirst and hunger mechanisms to guide intake. An exact fluid requirement in an individual hospitalized child is difficult to determine. Using a catch all formula (4-2-1) could be anticipated to create problems for the junior resident unless taught otherwise.

Any intravenous hypotonic fluid can potentially cause or worsen hyponatraemia. A hypotonic solution has a tonicity less than plasma – generally less than 285mmoles/litre. It is important not to get confused between tonicity and osmolarity. Tonicity refers to the osmotic pressure exerted across a semi-permeable membrane and is influenced only by those osmoles that cannot cross the membrane. For example, 5% glucose has an osmolality of 252 mosmol/L but a tonicity of zero once the glucose is metabolized or taken up by cells – it is a source of pure water.

IV solutions are not the only contributors to HAH. All enteral feeds are hypotonic. They have been designed for normal children with an appropriate normal daily allowance of electrolytes and other nutritional supplements. Sick children will retain the extra free water

administered, resulting in hyponatremia. Sodium and potassium supplementation over and above normal requirements are often required in acutely ill hospitalized children. Daily electrolytes should be performed in these children until serum electrolytes and supplemental additives have stabilized.

Body Fluid Losses

Fluid losses are most commonly from the GI tract, but also from chest drainage/chylothorax, "third spacing", or renal losses. Failure to understand the electrolyte composition of body fluid losses is another preventable cause of hyponatraemia. It is important to replace losses from a body cavity with a solution containing like electrolyte composition.

Body Fluid Composition

Secretion	Na^+ (mmol/L)	K^+ (mmol/L)	Cl^- (mmol/L)	HCO_3^- (mmol/L)
Saliva	40	20	40	0
Gastric juice	70-120	10-30	100	0
Bile	140	5-10	100	30-40
Pancreatic juice	140	5-10	75	70-110
Small intestine	120-140	5-10	100	30-40
Normal stool	20-30	55-75	15-25	0
Diarrhea	50-140	15-60	50-150	10-75
Sweat	30-70	0-5	30-70	0

Intravenous Fluid Choices

Type of Fluid	Na^+(mmol/L)	K^+ (mmol/L)	Cl^- (mmol/L)	HCO_3^- (mmol/L)
Ab"Normal" saline	154	0	154	0
½ normal saline	77	0	77	0
Ringer's Lactate	130	4	109	Lactate 28
Plasmalyte	140	5	98	Acetate 27
D5W	0	0	0	0
5% albumin	140	0	108	0
PRBC	130-150	4-10	90-100	10-25
Frozen plasma	15-180	4	100	25

Intravenous Fluid Tonicity

Type of Fluid	Osmolality	Tonicity
Normal plasma	285-295	
Un"Normal" saline	308	hypertonic
½ normal saline	154	hypotonic
Ringer's Lactate	273	isotonic
Plasmalyte	294	isotonic
D5W	250	hypotonic
5% albumin	310	isotonic

Replacement Fluids:

Options are:
Isotonic crystalloids – 0.9%NaCl; Ringer's lactate; Plasmalyte

Ringer's Lactate contains Calcium, and there may be compatibility issues during slow infusion of Packed red blood cells.

Colloids – 5% albumin.

Starch products (HES) have recently been shown to increase the risk of acute kidney injury in adults and have been withdrawn from the market in Canada.

Blood Products – packed red blood cells (suspended in SAGM – 0.9%NaCl, adenine, glucose, mannitol); FP (frozen plasma (suspended in ACD3 solution – citrate); platelets (as for plasma)

Generally, children should initially be prescribed 0.9% NaCl or Ringer's lactate solution if a replacement fluid is required.

Maintenance Fluids:

Options are (dextrose can be added to all these solutions):
Isotonic crystalloids – 0.9%NaCl; Ringer's lactate (slightly hypotonic to normal plasma); Plasmalyte

Hypotonic solutions – 0.45% NaCl. There is rarely any indication for more hypotonic solutions and should only be prescribed if electrolytes are known and after careful discussion with senior medical staff. D5W should only be prescribed with a salt solution.

For routine maintenance, the initial prescription should be either 0.9% NaCl or Ringer's Lactate (with added 10% dextrose for children under 5kg and 5% dextrose for children over 5 Kg as a general rule of thumb). Once the child's electrolytes are known, and the acute illness is improving or the electrolytes have stabilized, a solution with less sodium chloride may be considered. eg. 0.45%NaCl with or without dextrose. Even though an isotonic solution should always initially be prescribed, electrolyte, glucose and fluid requirements should still be calculated for all children receiving IV fluids, and especially if the fluid volume is restricted. (normal glucose requirements for infants are 5-8mg/kg/minute)

Intravenous solution choice should be tailored to the patient's needs. Some patients with a free water deficit may require the administration of hypotonic solutions, following discussion with a senior medical staff member.

Hypotonic solutions may be considered in the following conditions, after careful consideration and consultation with an attending physician:

1. Serum sodium > 145 mmol/l)

2. Excessive free water loss (ie. diabetes insipidus)

3. Significant total fluid restriction

4. Prolonged intravenous therapy provided:

   a. medical condition is stable
   b. no excessive body fluid losses
   c. normal free water excretion confirmed with regular monitoring

5. Stable TPN

In children with illnesses that lead to fluid overload, such as nephrosis, cirrhosis, congestive heart failure and glomerulonephritis, both sodium and fluid restriction is of paramount importance to avoid worsening fluid overload and the development of hyponatremia.

Recommended Fluid Volumes

Intravascular volume should always be re-established if clinical examination suggests hypovolemia. Hypovolemia is a potent stimulus for the releases of ADH. The replacement fluid should always be an isotonic solution or a colloid, depending on the clinical situation. Blood products may be required for hypovolemia secondary to blood loss.

Applying the standard maintenance fluid rates formula of 100ml/kg/day is nearly always excessive for an acutely ill child. In addition to providing an isotonic solution initially, acutely ill children with increased ADH secretion may benefit from further restriction of maintenance fluids to half to two-thirds of the normal calculated volume. Recent randomized controlled trials in hospitalized children have shown that it is not just fluid volume but tonicity that is important in reducing the chances of developing hospital acquired hyponatraemia.

Daily assessment of clinical status, daily weights frequent and accurate measurement of fluid intake and losses from all sources and measurement of daily electrolytes are important measures to adopt for acutely ill children.

Potassium Requirements

All children should receive maintenance potassium replacement following resuscitation providing normal renal function has been demonstrated (urine output and normal urea and creatinine).

Treatment of Acute Hyponatremia

Treatment of hyponatremia depends upon whether it is acute (<48hours) or chronic.

Asymptomatic acute hyponatremia may only require free water restriction.

Symptomatic acute hyponatremia (vomiting, headache, change in sensorium, seizures, dilated pupils, posturing) requires urgent treatment. 3% sodium chloride is the treatment of choice but should only be given after consultation with an intensivist. (usual dose is increments of 2mls/kg bolus)

Exclusions

Although recognizing that there will be subsets of patients in the neonatal intensive care unit where these considerations apply, this guideline excludes the Neonatal ICU. It also excludes children with DKA, with chronic liver disease, hyperkalemia and renal failure.

References

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