G54 Intravenous fluid therapy

INTRAVENOUS FLUID THERAPY

Intravenous fluid and electrolytes are given to maintain or restore normal body composition when it is not possible or desirable to use the enteral route. Fluid and electrolytes are given as maintenance and/or replacement therapy. In each situation, it is necessary to be cautious as both hyper and hyponatraemia can occur.

Caution

Though uncommon, dilutional hyponatraemia is often an unheralded, but potentially fatal condition. It is due to complex neuro-endocrine mechanisms that can occur in children with a variety of conditions especially in the postoperative period. It is characterised by oliguria and a rapid fall in serum sodium concentration leading to cerebral oedema causing seizures and/or coning of the medulla oblongata. Slow correction and careful monitoring are required to prevent serious morbidity.

To prevent dilutional hyponatraemia and sodium overload, it is recommended that:

1 Body weight be accurately measured or estimated by a professional with substantial paediatric experience. The estimation of body weight can be made using the child's age; Body weight (kg) = (AGE+4) x 2. This weight should be plotted on a centile chart as a crosscheck. If the weight is beyond the 3rd or 97th centile range then the weight must be re-examined.

2 Fluid administration should reflect the composition of fluid lost or in deficit, especially as regards sodium content.

3 A baseline blood sample be sent for serum sodium, potassium, urea and blood sugar estimation. Regular and frequent serum sodium and blood sugar estimation is required and should be documented. This will usually mean at least one specimen per day in general maintenance situations, and at least two blood samples daily in the postoperative period and in deficit and significant ongoing loss situations. An indwelling heparinised cannula or capillary sample will avoid sampling difficulties in the anxious child or those with poor veins. Blood samples must not be taken from the same limb as the intravenous infusion.

4 An experienced doctor must assess fluid balance daily and take appropriate action to correct fluid loss or retention. Measurement of urinary sodium, potassium and urea should be helpful.

5 A child with acute hyponatraemia (<130 mmol/L) needs urgent referral to a hospital with paediatric high dependency facilities (asymptomatic hyponatraemia).

MAINTENANCE THERAPY

For this purpose fluid and electrolytes (chiefly sodium [Na^+], chloride [Cl^-] and potassium [K^+]) are given together with glucose to replace the normal losses of water and electrolytes in quantities needed to maintain correct body composition. In infants and children, maintenance fluid and electrolyte requirements vary as a function of metabolic activity. The following normal requirements are derived from the relationship that exists between body weight and metabolic rate and may be used outside the neonatal period. The glucose requirement is that needed to minimise gluconeogenesis from amino acids obtained as substrate from muscle breakdown.

It is usual to meet these requirements by using a standard solution. For example, glucose 4% with NaCl 0.18% given in the volumes suggested below meets the fasting fluid, saline and glucose requirements for the purposes of most children under basal conditions. Solutions containing 20mmol/L of potassium chloride (KCl) also meet usual potassium requirements when given in the suggested volumes. Adjustments will need to be made if there is an inability to excrete fluids or electrolytes, excessive renal loss or continuing extra-renal losses. The exact requirements depend upon the nature of the clinical situation and types of losses incurred. See cautionary note about dilutional hyponatraemia above.

Fluid requirements/24 hours

Body weight <3kg	150mL/kg (start at 40–60mL/kg if newborn)
3–10kg For each kg between 10–20 kg For each kg over 20kg	100mL/kg add 50mL/kg add 20mL/kg to maximum of 2000mL in adult female and 2500mL in adult male
Sodium requirement	3mmol/kg
Potassium requirement	2mmol/kg
Glucose requirement	2.4–4.8g/kg

REPLACEMENT THERAPY

In general, initial intravenous replacement fluid is required if >10% dehydrated or if 5-10% dehydrated and oral and enteral rehydration is not tolerated or possible. Oral rehydration is adequate if tolerated in the majority of those <10% dehydrated. Subsequent fluid and electrolyte requirements are determined by clinical assessment of fluid balance, including measurement of ongoing excessive renal and extra renal losses, and measurement of plasma electrolytes, bicarbonate and glucose together with calcium, phosphate and magnesium where appropriate. In the United Kingdom oral rehydration is underused and severe dehydration overdiagnosed clinically.

Intravenous sodium is commonly given as a component of maintenance and replacement therapy. It may be given as NaCl 0.9% for initial fluid bolus in acute fluid loss and to replace ongoing gastrointestinal losses from the upper gastrointestinal tract. For maintenance and continuing replacement therapy it is usually given in combination with other electrolytes and glucose, the exact strength depending on the clinical situation. Other uses include promotion of saline diuresis in the management of some poisoning, as a vehicle for reconstitution and administration of intravenous medications and to maintain patency of arterial/venous catheters. It must be given with caution as sodium overload may be easily produced. Particular care is needed in those with renal insufficiency, cardiac failure, other cardio-respiratory disease, hepatic cirrhosis and those receiving glucocorticoids. Conversely, hyponatraemia with serious consequences can occur if maintenance and replacement fluids do not meet sodium requirements. See cautionary note about dilutional hyponatraemia above.

Solutions available

- ☐ Sodium chloride 0.45% – Na^+ 75mmol/L; Cl^- 75mmol/L; osmolarity 154mOsm/L
- ☐ Sodium chloride 0.9% – Na^+ 150mmol/L; Cl^- 150mmol/L; osmolarity 308mOsm/L
- ☐ Sodium chloride 1.8% – Na^+ 300mmol/L; Cl^- 300mmol/L; osmolarity 616mOsm/L

Other infusion fluids containing sodium – see table.

Extreme care must be taken if giving sodium chloride in solutions stronger than 0.9% and there must be specific indications for their administration.

Intravenous potassium is commonly given as a component of maintenance and replacement intravenous therapy and in the correction of severe hypokalaemia where oral potassium is insufficient or not possible. For maintenance and continuing replacement therapy it is most usually given in combination with glucose and other electrolytes. Whilst it is often added to glucose/saline solutions, ready-prepared infusion fluid containing these together with potassium may be adequate in many cases and their use may decrease the number of errors in its administration. The quantity required is calculated according to usual maintenance requirements with adjustment for any deficit and ongoing loss. As always, the situation must be monitored by clinical assessment and measurement of plasma potassium concentration. Potassium should not be given in established hyperkalaemia and should only be given with extreme caution and close monitoring where there is renal impairment or coincidental administration of drugs which may cause hyperkalaemia. Potassium should only be given as a slow infusion and it is recommended that the concentration of the solution should not exceed 40mmol of potassium per litre. ECG monitoring should be used where there is concern regarding hypo or hyperkalaemia, together with frequent measurement of plasma potassium.

Solutions available

- ☐ Strong potassium chloride (15%)® – K^+ 2mmol/mL; Cl^- 2mmol/mL
- ☐ Strong KCl should be diluted with not less than 50 times its volume of compatible intravenous fluid, mixed well and given as a slow infusion. Where possible, compounding should be performed in a pharmacy. For other infusion fluids containing potassium – see table.

Intravenous glucose is given in maintenance and replacement therapy to minimise gluconeogenesis and is also used specifically in the treatment of hypoglycaemia. For maintenance and continuing replacement therapy it is most usually given in combination with other electrolytes. In hypoglycaemia an initial bolus of 200mg/kg of glucose given as 2mL/kg of 10% glucose over 2-3 minutes is recommended.

Solutions available

- ☐ Glucose 5 % – osmolarity 278mOsm/L
- ☐ Glucose 10 % – osmolarity 555mOsm/L
- ☐ Glucose 20 % – osmolarity 1110mOsm/L

☐ Glucose 40 % – osmolarity 2220mOsm/L
☐ Glucose 50 % – osmolarity 2775mOsm/L

For other infusion fluids containing glucose – see below. Solutions stronger than 10% glucose should NOT be used except in exceptional circumstances because of the dangers of hyperosmolarity.

Intravenous bicarbonate is used in the management of metabolic acidosis. In most circumstances metabolic acidosis is secondary to hypoxia/hypovolaemia/hypoperfusion and treatment of any underlying condition with appropriate fluid replacement and cardiovascular support will improve or correct acidosis.

Bicarbonate may be given to correct the acid-base imbalance in severe metabolic acidosis or in specific circumstances, e.g. renal tubular acidosis. In the acute situation e.g. cardiac arrest, an initial bolus of 1mmol/kg may be given as a slow bolus if required (1mL/kg of 8.4% sodium bicarbonate or 2mL/kg of 4.2% sodium bicarbonate). The volume required of 8.4% sodium bicarbonate to correct a metabolic acidosis = base deficit x body weight (kg) x 0.3 for children other than newborns (x 0.5-0.6 in premature neonate; x 0.4 in term neonates). Half this volume is usually given initially by slow infusion and progress monitored by clinical assessment and measurement of plasma pH or H^+ concentration before giving the remaining half. The standard sodium bicarbonate solutions available are hypertonic. Venous damage or thrombophlebitis may occur at the site of infusion, and extravasation can cause severe tissue injury. Continued administration can lead to hypernatraemia and overdosage of sodium bicarbonate may cause diarrhoea, nausea and vomiting, hyperpnoea and convulsions.

Solutions available

☐ Sodium bicarbonate 1.26% – Na^+ 150mmol/L; $HCO3^-$ 150mmol/L; – osmolarity 300mOsm/L
☐ Sodium bicarbonate 4.2% – Na^+ 500mmol/L; $HCO3^-$ 500mmol/L; – osmolarity 1000mOsm/L
☐ Sodium bicarbonate 8.4% – Na^+ 1000mmol/L; $HCO3^-$1000mmol/L; – osmolarity 2000mOsm/L

THAM (tris-hydroxymethyl aminomethane trometamol) is an organic buffer used for correction of metabolic acidosis. It is an alternative to sodium bicarbonate when there is concern about carbon dioxide retention, hypernatraemia or renal impairment. THAM is available as 3.6% or 7.2% solution, and should be used as 3.6% solution when given intravenously. 1mL of 7.2% solution (2mL of 3.6% solution) is equivalent to 1mmol of bicarbonate ion.

Lactate was previously used in the management of metabolic acidosis but is now not recommended because of the risk of producing lactic acidosis, especially in those with hepatic impairment or poor tissue perfusion. Any solutions containing lactate should not be given to those with impairment of hepatic function.

Solutions available

☐ Sodium lactate M/6 – Na^+ 167 mmol/L; lactate 167 mmol/L

For other infusion fluids, which contain lactate – see table.

Combined intravenous fluids

	Na^+ (mmol/L)	Cl^- (mmol/L)	K^+ (mmol/L)	Other (mmol/L)	Osmolarity †(mOsm/L)	Energy (kcal/L)
Glucose 2.5%/NaCl 0.45%	75	75	–	–	293	100
Glucose 4%/NaCl 0.18%	30	30	–	–	263	160
Glucose 5%/NaCl 0.45%	75	75	–	–	432	200
Glucose 5%/NaCl 0.9%	150	150	–	–	586	200
Glucose 10%/NaCl 0.18%	30	30	–	–	567	400
Glucose 10%/NaCl 0.45%	75	75	–	–	660	400
Glucose 5%/KCl 0.15%	–	20	20	–	318	200
Glucose 5%/KCl 0.2%	–	27	27	–	332	200
Glucose 5%/KCl 0.3%	–	40	40	–	358	200
Glucose 4%/NaCl 0.18% with KCl 0.15%	30	50	20	–	322	160
Glucose 4%/NaCl 0.18% with KCl 0.2%	30	57	27	–	336	160

Intravenous fluid therapy continued

Combined intravenous fluids continued

	Na^+ (mmol/L)	Cl^- (mmol/L)	K^+ (mmol/L)	Other (mmol/L)	Osmolarity †(mOsm/L)	Energy (kcal/L)
Glucose 4%/NaCl 0.18% with KCl 0.3%	30	70	40	–	362	160
Glucose 5%/NaCl 0.45% with KCl 0.15% (Alder Hey Special K)	75	95	20	–	426	200
NaCl 0.9%/KCl 0.15%	150	170	20	–	340	0
NaCl 0.9%/KCl 0.2%	150	177	27	–	354	0
NaCl 0.9%/KCl 0.3%	150	190	40	–	380	0
Ringer's – compound sodium chloride	147.5	156	4	Calcium – 2	310	0
Hartmann's – compound sodium lactate	131	111	5	Lactate – 29 Calcium – 2	278	0
Half Hartmann's with glucose 5%	66	56	3	Lactate – 14 Calcium – 1	418	200
Darrow's – lactated potassic saline	121	103	35	Lactate – 53	312	0

†Osmolarity may differ slightly depending on brand. The figures quoted are mainly for Baxter products.

COLLOIDS

These are used for plasma replacement or expansion. They may be natural products like human albumin solution (HAS) and fresh frozen plasma (FFP), or synthetic: based on gelatin like Gelofusine® (succinylated gelatin) and Haemaccel® (urea-linked gelatin); or hydroxyethyl starches (HES) like Pentastarch®; or dextrans. HAS and gelatins are essentially plasma substitutes, whereas hydroxyethyl starches and dextrans are true plasma expanders – they produce an increase in plasma volume greater than the volume of colloid infused. A meta-analysis of clinical trials has suggested that use of HAS may be associated with increased mortality across all age ranges; a more recent review of studies in newborns could not confirm this finding. NaCl 0.9% is often an effective crystalloid alternative for rapid volume expansion in resuscitation, sepsis and dehydration. There is no justification for use of FFP as a plasma substitute unless there is also a coagulopathy.

4.5% HAS has been the standard fluid used in neonates and infants, but it is expensive and there is a small risk of anaphylaxis or infection. More recently, there has been concern about possible variant CJD (vCJD) transmission from UK sources of HAS. A synthetic gelatin is a cheap and safe alternative to 4.5% HAS. A succinylated gelatin is preferable to a urea-linked gelatin as the reported anaphylactoid reaction rate is lower (0.05% and 0.1% respectively). Dextrans are not routinely indicated because of increased side-effects compared to gelatins and hydroxyethyl starches.

Hydroxyethyl starches (HES) have anaphylactoid reaction rates similar to gelatins but as HES are true plasma expanders the risk of fluid overload is greater. For this reason, HES are probably best restricted to an intensive care setting.

Liver

Acute hepatitis. This is often due to hepatitis A virus infection but it may be the first presentation of serious liver disease. Serology, liver function tests and coagulation studies should be undertaken in all cases. No specific treatment is necessary in the vast majority of cases. All cases not due to hepatitis A virus or where coagulation studies are abnormal should be referred for further investigation.

Hepatitis B. Hepatitis B infection rarely causes acute hepatitis in childhood but may result in chronic carriage. Chronic infection and carriage is more likely to occur the younger the age at which the infection is acquired. It is usually asymptomatic in childhood but, if untreated, carries a high lifetime risk of progression to cirrhosis and hepatocellular carcinoma.