

Solutions correcting water, electrolyte and acid-base disturbances

Oral electrolyte solutions

Oral rehydration

Replacement of fluid and electrolytes orally can be achieved by giving oral rehydration salts—solutions containing sodium, potassium and glucose. Acute diarrhoea in children should always be treated with oral rehydration solution according to plans A, B, or C as shown.

Treatment of dehydration: WHO recommendations

According to the degree of dehydration, health professionals are advised to follow one of 3 management plans.

Plan A: no dehydration. Nutritional advice and increased fluid intake are sufficient (soup, rice, water and yoghurt, or even water). For infants aged under 6 months who have not yet started taking solids, oral rehydration solution must be presented before offering milk. Mother's milk or dried cow's milk must be given without any particular restrictions. In the case of mixed breast-milk/formula feeding, the contribution of breastfeeding must be increased.

Plan B: moderate dehydration. Whatever the child's age, a 4-hour treatment plan is applied to avoid short-term problems. Feeding should not therefore be envisaged initially. It is recommended that parents are shown how to give approximately 75 ml/kg of oral rehydration solution with a spoon over a 4-hour period, and it is suggested that parents should be watched to see how they cope at the beginning of the treatment. A larger amount of solution can be given if the child continues to have frequent stools. In case of vomiting, rehydration must be discontinued for 10 minutes and then resumed at a slower rate (about one teaspoonful every 2 minutes). The child's status must be re-assessed after 4 hours to decide on the most appropriate subsequent treatment. Oral rehydration solution should continue to be offered once dehydration has been controlled, for as long as the child continues to have diarrhoea.

Plan C: severe dehydration. Hospitalization is necessary, but most urgent priority is to start rehydration. In hospital (or elsewhere), if the child can drink, oral rehydration solution must be given pending, and even during, intravenous infusion (20 ml/kg every hour by mouth before infusion, then 5 ml/kg every hour by mouth during intravenous rehydration. For intravenous supplementation, it is recommended that compound solution of sodium lactate (see section 26.2) is administered at a rate adapted to the child's age (infant under 12 months: 30 ml/kg over 1 hour then 70 ml/kg over 5 hours; child over 12 months: the same amounts over 30 minutes and 2.5 hours respectively). If the intravenous route is unavailable, a nasogastric tube is also suitable for administering oral rehydration solution, at a rate of 20 ml/kg every hour. If the child vomits, the rate of administration of the oral solution should be reduced.

Oral rehydration salts

Glucose salt solution

| | |
|---------------------|-----------------------------|
| sodium chloride | 2.6 g/litre of clean water |
| trisodium citrate | 2.9 g/litre of clean water |
| potassium chloride | 1.5 g/litre of clean water |
| glucose (anhydrous) | 13.5 g/litre of clean water |

When glucose and trisodium citrate are not available, they may be replaced

| | |
|------------------------|----------------------------|
| sucrose (common sugar) | 27 g/litre of clean water |
| sodium bicarbonate | 2.5 g/litre of clean water |

NOTE. The solution may be prepared either from prepackaged sugar/salt mixtures or from bulk substances and water. Solutions must be freshly prepared, preferably with recently boiled and cooled water. Accurate weighing and thorough mixing and dissolution of ingredients in the correct volume of clean water is important. Administration of more concentrated solutions can result in hypernatraemia

CHOLERA. In cases of cholera, oral rehydration salts containing a higher concentration of sodium may be required to prevent hyponatraemia

Uses:

dehydration from acute diarrhoea

Precautions:

renal impairment

Dosage:

Fluid and electrolyte loss in acute diarrhoea, *by mouth* , **ADULT** 200–400 ml solution after every loose motion; **INFANT** and **CHILD** according to Plans A, B or C (see above)

Adverse effects:

vomiting—may indicate too rapid administration; hypernatraemia and hyperkalaemia may result from overdose in renal impairment or administration of too concentrated a solution

Oral potassium

Compensation for potassium loss is necessary in patients taking digoxin or antiarrhythmic drugs where potassium depletion may induce arrhythmias. It is also necessary in patients with secondary hyperaldosteronism (renal artery stenosis, liver cirrhosis, the nephrotic syndrome, severe heart failure) and those with excessive loss of potassium in the faeces (chronic diarrhoea associated with intestinal malabsorption or laxative abuse).

Measures to compensate for potassium loss may also be required in the elderly since they often take inadequate amounts in the diet (but see warning on use in renal insufficiency, below). Measures may also be required during long-term administration

of drugs known to induce potassium loss (for example, corticosteroids). Potassium supplements are seldom required with the small doses of diuretics given to treat hypertension. Potassium-sparing diuretics (rather than potassium supplements) are recommended for prevention of hypokalaemia due to diuretics such as furosemide or the thiazides when these are given to eliminate oedema (see section 16.3).

For the prevention of hypokalaemia doses of potassium chloride 2 to 4 g (approximately 25 to 50 mmol) daily by mouth are suitable in patients taking a normal diet. Smaller doses must be used if there is renal insufficiency (common in the elderly) otherwise there is a danger of hyperkalaemia.

Larger doses may be required in established potassium depletion, the quantity depending on the severity of any continuing potassium loss (monitoring of plasma potassium and specialist advice required).

Potassium depletion is frequently associated with metabolic alkalosis and chloride depletion and these disorders require correction.

Potassium chloride

Powder for oral solution, potassium chloride 1.5 g (potassium 20 mmol, chloride 20 mmol)

Uses:

prevention and treatment of hypokalaemia (see notes above)

Contraindications:

severe renal impairment; plasma potassium concentration above 5 mmol/litre

Precautions:

elderly, mild to moderate renal impairment (close monitoring required, Appendix 4), history of peptic ulcer; **important:** special hazard if given with drugs liable to raise plasma potassium concentrations such as potassium-sparing diuretics, ACE inhibitors or ciclosporin, for other **interactions:** Appendix 1

Dosage:

Prevention of hypokalaemia (see notes above), *by mouth*, **ADULT** 20–50 mmol daily after meals

Potassium depletion (see notes above), *by mouth*, **ADULT** 40–100 mmol daily in divided doses after meals: adjust dose according to severity of deficiency and any continuing loss of potassium

reconstitution and administration. According to manufacturer's directions

Adverse effects:

nausea and vomiting, gastrointestinal irritation

Parenteral electrolyte solutions

Solutions of electrolytes are given intravenously, to meet normal fluid and electrolyte requirements or to replenish substantial deficits or continuing losses, when the patient is nauseated or vomiting and is unable to take adequate amounts by mouth.

The nature and severity of the electrolyte imbalance must be assessed from the history and clinical and biochemical examination of each individual. Sodium, potassium, chloride, magnesium, phosphate, and water depletion can occur singly and in combination with or without disturbances of acid-base balance.

Isotonic solutions may be infused safely into a peripheral vein. More concentrated solutions, for example 20% glucose, are best given through an indwelling catheter positioned in a large vein.

Sodium chloride in isotonic solution provides the most important extracellular ions in near physiological concentrations and is indicated in *sodium depletion* which may arise from conditions such as gastroenteritis, diabetic ketoacidosis, ileus and ascites. In a severe deficit of from 4 to 8 litres, 2 to 3 litres of isotonic sodium chloride may be given over 2 to 3 hours; thereafter infusion can usually be at a slower rate.

Excessive administration should be avoided; the jugular venous pressure should be assessed; the bases of the lungs should be examined for crepitations, and in elderly or seriously ill patients it is often helpful to monitor the right atrial (central) venous pressure.

Chronic hyponatraemia should ideally be managed by fluid restriction. However, if sodium chloride is required, the deficit should be corrected slowly to avoid risk of osmotic demyelination syndrome; the rise in plasma-sodium concentration should be limited to no more than 10 mmol/litre in 24 hours.

The more physiologically appropriate **compound solution of sodium lactate** can be used instead of isotonic sodium chloride solution during surgery or in the initial management of the injured or wounded.

Sodium chloride and glucose solutions are indicated when there is *combined water and sodium depletion*. A 1:1 mixture of isotonic sodium chloride and 5% glucose allows some of the water (free of sodium) to enter body cells which suffer most from dehydration while the sodium salt with a volume of water determined by the normal plasma Na^+ remains extracellular. Combined sodium, potassium, chloride, and water depletion may occur, for example, with severe diarrhoea or persistent vomiting; replacement is carried out with sodium chloride intravenous infusion 0.9% and glucose intravenous infusion 5% with potassium as appropriate.

Glucose solutions (5%) are mainly used to replace *water deficits* and should be given alone when there is no significant loss of electrolytes. Average water requirement in a healthy adult are 1.5 to 2.5 litres daily and this is needed to balance unavoidable losses of water through the skin and lungs and to provide sufficient for urinary

excretion. Water depletion (dehydration) tends to occur when these losses are not matched by a comparable intake, as for example may occur in coma or dysphagia or in the aged or apathetic who may not drink water in sufficient amount on their own initiative.

Excessive loss of water without loss of electrolytes is uncommon, occurring in fevers, hyperthyroidism, and in uncommon water-losing renal states such as diabetes insipidus or hypercalcaemia. The volume of glucose solution needed to replace deficits varies with the severity of the disorder, but usually lies within the range of 2 to 6 litres.

Glucose solutions are also given in regimens with calcium, bicarbonate, and insulin for the emergency treatment of *hyperkalaemia*. They are also given, after correction of hyperglycaemia, during treatment of diabetic ketoacidosis, when they must be accompanied by continuing insulin infusion.

If glucose or sugar cannot be given orally to treat *hypoglycaemia*, glucose 50% may be given intravenously into a large vein through a large-gauge needle; this concentration is very irritant on extravasation and it is also viscous and difficult to administer. Larger volumes of less concentrated glucose solutions (10% or 20%) can be used as alternatives and are less irritant.

Sodium hydrogen carbonate (sodium bicarbonate) is used to control severe *metabolic acidosis* (as in renal failure). Since this condition is usually attended by sodium depletion, it is reasonable to correct this first by the administration of isotonic sodium chloride intravenous infusion, provided the kidneys are not primarily affected and the degree of acidosis is not so severe as to impair renal function. In these circumstances, isotonic sodium chloride alone is usually effective as it restores the ability of the kidneys to generate bicarbonate. In renal acidosis or in severe metabolic acidosis of any origin, for example blood pH < 7.1, sodium hydrogen carbonate (1.4%) may be infused with isotonic sodium chloride when the acidosis remains unresponsive to correction of anoxia or fluid depletion; a total volume of up to 6 litres (4 litres of sodium chloride and 2 litres of sodium hydrogen carbonate) may be necessary in the adult. In severe shock due for example to cardiac arrest, metabolic acidosis may develop without sodium depletion; in these circumstances sodium hydrogen carbonate is best given in a small volume of hypertonic solution (for example 50 ml of 8.4% solution intravenously); plasma pH should be monitored. Sodium hydrogen carbonate is also used in the emergency management of *hyperkalaemia*.

Intravenous **potassium chloride** in sodium chloride infusion is the initial treatment for the correction of *severe hypokalaemia* when sufficient potassium cannot be taken by mouth. Potassium chloride concentrate may be added to sodium chloride 0.9% infusion, **thoroughly mixed**, and given slowly over 2 to 3 hours with specialist advice and ECG monitoring in difficult cases. Repeated measurements of plasma potassium are necessary to determine whether further infusions are required and to avoid the development of hyperkalaemia which is especially likely to occur in renal impairment.

Initial potassium replacement therapy should **not** involve glucose infusions because glucose may cause a further decrease in the plasma-potassium concentration.

Glucose

Infusion (Solution for infusion), glucose 5% (iso-osmotic), 10% (hyperosmotic), 50% (hyperosmotic)

Uses:

fluid replacement without significant electrolyte deficit (see notes above); treatment of hypoglycaemia

Precautions:

diabetes mellitus (may require additional insulin)

Dosage:

Fluid replacement, *by intravenous infusion*, **ADULT** and **CHILD** determined on the basis of clinical and, whenever possible, electrolyte monitoring (see notes above)

Treatment of hypoglycaemia, *by intravenous infusion* of 50% glucose solution into a large vein, **ADULT**, 25 ml (see also notes above)

Adverse effects:

glucose injections, especially if hypertonic, may have a low pH and cause venous irritation and thrombophlebitis; fluid and electrolyte disturbances; oedema or water intoxication (on prolonged administration or rapid infusion of large volumes of isotonic solutions); hyperglycaemia (on prolonged administration of hypertonic solutions)

Glucose with sodium chloride

Infusion (Solution for infusion), glucose 4%, sodium chloride 0.18% (1.8 g, 30 mmol each of Na⁺ and Cl⁻ /litre)

Uses:

fluid and electrolyte replacement

Precautions:

restrict intake in impaired renal function, cardiac failure, hypertension, peripheral and pulmonary oedema, toxæmia of pregnancy

Dosage:

Fluid replacement, *by intravenous infusion* , **ADULT** and **CHILD** determined on the basis of clinical and, whenever possible, electrolyte monitoring (see notes above)

Adverse effects:

administration of large doses may give rise to oedema

Sodium chloride

Infusion (Solution for infusion), sodium chloride 0.9% (9 g, 154 mmol each of Na⁺ and Cl⁻ /litre)

Uses:

electrolyte and fluid replacement

Precautions:

restrict intake in impaired renal function (Appendix 4), cardiac failure, hypertension, peripheral and pulmonary oedema, toxæmia of pregnancy

Dosage:

Fluid and electrolyte replacement, *by intravenous infusion* , **ADULT** and **CHILD** determined on the basis of clinical and, whenever possible, electrolyte monitoring (see notes above)

Adverse effects:

administration of large doses may give rise to sodium accumulation and oedema

Sodium lactate, compound solution of

Compound solution of sodium lactate is a representative intravenous electrolyte solution. Various solutions can serve as alternatives

Infusion (Solution for infusion), sodium chloride 0.6%, sodium lactate 0.25%, potassium chloride 0.04%, calcium chloride 0.027% (containing Na⁺ 131 mmol, K⁺ 5 mmol, Ca²⁺ 2 mmol, HCO₃⁻ (as lactate) 29 mmol, Cl⁻ 111 mmol/litre)

Uses:

pre- and perioperative fluid and electrolyte replacement; hypovolaemic shock

Contraindications:

metabolic or respiratory alkalosis; hypocalcaemia or hypochlorhydria

Precautions:

restrict intake in impaired renal function, cardiac failure, hypertension, peripheral and pulmonary oedema, toxæmia of pregnancy; **interactions:** Appendix 1

Dosage:

Fluid and electrolyte replacement or hypovolaemic shock, *by intravenous infusion*, **ADULT** and **CHILD** determined on the basis of clinical and, whenever possible, electrolyte monitoring (see notes above)

Adverse effects:

excessive administration may cause metabolic alkalosis; administration of large doses may give rise to oedema

Sodium hydrogen carbonate

Infusion (Solution for infusion), sodium hydrogen carbonate 1.4% (14 g, 166.7 mmol each of Na⁺ and HCO₃⁻ /litre)

Injection (Solution for injection), sodium hydrogen carbonate 8.4% (840 mg, 10 mmol each of Na⁺ and HCO₃⁻ /10 ml)

Uses:

metabolic acidosis

Contraindications:

metabolic or respiratory alkalosis, hypocalcaemia, hypochlorhydria

Precautions:

restrict intake in impaired renal function (Appendix 4), cardiac failure, hypertension, peripheral and pulmonary oedema, toxæmia of pregnancy; monitor electrolytes and acid-base status; **interactions:** Appendix 1

Dosage:

Metabolic acidosis, *by slow intravenous injection*, **ADULT** and **CHILD** a strong solution (up to 8.4%) **or** *by continuous intravenous infusion*, **ADULT** and **CHILD** a weaker solution (usually 1.4%), an amount appropriate to the body base deficit (see notes above)

Adverse effects:

excessive administration may cause hypokalaemia and metabolic alkalosis, especially in renal impairment; large doses may give rise to sodium accumulation and oedema

Potassium chloride

Concentrate for infusion (Concentrate for solution for infusion), potassium chloride 11.2% (112 mg, approximately 1.5 mmol each of K⁺ and Cl⁻ /ml), 20-ml ampoule

Uses:

electrolyte imbalance; see also oral potassium (section 26.1.2)

Precautions:

for intravenous infusion the concentration of solution should not usually exceed 3.2 g (43 mmol)/litre; specialist advice and ECG monitoring (see notes above); renal impairment (Appendix 4); **interactions:** Appendix 1

Dosage:

Electrolyte imbalance, *by slow intravenous infusion*, **ADULT** and **CHILD** depending on the deficit or the daily maintenance requirements (see also notes above)

dilution and administration.

Must be diluted and **thoroughly mixed** before use and administered according to manufacturer's directions

Adverse effects:

cardiac toxicity on rapid infusion

Water

Water for injections

Injection, sterile distilled water free from pyrogens, 2-ml, 5-ml, 10-ml ampoules

Uses:

in preparations intended for parenteral administration and in other sterile preparations