Intravenous fluid and electrolyte management in children and young people

Anthony Lander

Abstract

NICE published guidance NG29 in December 2015 entitled *Intravenous fluid therapy in children and young people in hospital* and in September 2016 Quality Standard QS131. These patient safety documents were developed following avoidable deaths in children who were given inappropriate or excessive volumes of intravenous fluids or who were inappropriately monitored, leading to acute symptomatic hyponatraemic encephalopathy. It is not mandatory to apply the recommendations of NG29, but anyone prescribing intravenous fluids should be familiar with them. This article does not reiterate NG29, but aims to help the reader: (i) revise their relevant basic science knowledge, while challenging their understanding of osmosis; (ii) use correctly the terms *tonicity* and *osmolarity* in clinical practice; and (iii) manage some electrolyte derangements.

Keywords Glucose; hyponatraemia; IV fluids; neonates; osmosis; paediatrics; potassium; rehydration; resuscitation; saline

Introduction

There are four principal reasons for giving IV fluids: (1) immediate vascular resuscitation of the profoundly hypovolaemic patient by administering fluids over a few minutes; (2) replacement of previous deficits over perhaps 24–48 hours; (3) replacement of ongoing measured losses, and (4) giving maintenance fluids.

The first three are, and have always been, correctly managed with fluids isosmolar with plasma and low in dextrose – fluids we now call *isotonic*. In contrast, the composition of maintenance fluids has been controversial but has robustly moved to avoiding fluids with low concentrations of sodium – fluids we now call *hypotonic*, even if additional dextrose makes them isoosmolar or hyper-osmolar.

Basic science

Osmosis is central to cell biology, and an understanding helps in daily fluid and electrolyte management. Most doctors who prescribe fluids, describe *osmosis* as a passive physical process in relation to two compartments either side of a semipermeable membrane. However, doctor's mental models vary and they cannot all be right – what is your understanding?

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Before proceeding, spend some time thinking about how you understand osmosis and how you explain it to others, especially when discussing intravenous fluids. If you have not read NG29[1] you should do so.

Our solvent is water and the solutes a mixture of ionic salts, sugars, starch in plants, and occasionally proteins. We think of hypo-osmolar solutions causing red cells to swell and haemolyse. We give hypo-osmolar solutions to revive shrivelled plants; water passes into the plant cells which do not burst as they have a rigid cell wall. In plants, *pressure* builds up to give the cells *turgor*. In contrast, we think of hyper-osmolar solutions shrinking red cells resulting in crenation.

NG29 recommends fluids with sodium concentrations of 131 –154 mmol/l. Where do these two concentrations come from? You should be able to explain these figures.

Stable isotopes of hydrogen, carbon, oxygen and sodium are uncommon and so their atomic weights are conveniently close to memorable integer values: H=1, C=12, O=16, Na=23. In contrast, chlorine has two principal stable isotopes, ^{35}Cl (~76%) and ^{37}Cl (~24%), giving an atomic weight of 35.45. These are sufficient facts for you to determine the molecular weights of sodium chloride (58.45) and dextrose (D-glucose) $C_6H_{12}O_6$ ($6 \times 12 + 12 + 6 \times 16 = 180$).

One mole of NaCl is 58.45 gm and so normal saline, 0.9% ≡ 9 gm/l, is $\frac{9}{58.45} = 154$ mmol/l, (often approximated to 150 mmol/l). One might expect this to ionise to 308 mOsmol/l; however the solution is non-ideal with an osmotic coefficient $\varphi = 0.93$ giving us 286 mOsmol/l. Dextrose 5% is 50 gm/l of $C_6H_{12}O_6$ and has an osmolarity of $\frac{50}{180} = 278$ mOsomol/l with $\varphi = 1.01$. Both fluids are considered to be isosmolar with plasma. Importantly we would not say that they are both isotonic with plasma, and this distinction is very important and central to clinical management.

While here, consider lactic acid, half the size of glucose, being $C_3H_6O_3$ (MW = 90), which gives us sodium lactate $Na^+C_3H_5O_3^-$ (MW = 89 + 23 = 112). Sodium lactate is an important component of Hartmann's solution where it has a concentration of 3.22%, whereas NaCl is added at 0.6%. The sodium content of Hartmann's is therefore $\frac{6}{58.45} + \frac{3.22}{112} = 131.4$ mmol/l.

We now understand where the sodium concentrations of 131 and 154 mmol/l come from in NG29. These few facts allow us to go further.

Before leaving Hartmann's, four noteworthy points follow. First, Hartmann's is an excellent fluid in mild to moderate acidosis as the lactate raises bicarbonate levels. Second, consequently, Hartmann's would be an inappropriate fluid for managing the alkalosis of pyloric stenosis. Third, the chloride content of Hartmann's is less than that of normal saline being a more physiological 110 mmol/l which may be beneficial. Finally, Hartmann's contains 5.4 mmol/l of potassium helping avoid hypokalaemia.

Osmotic activity and the nature of the particle

In principal, in the short-term, we do not treat osmotically active particles differently depending on their nature. For example, consider the following thought experiment using red cells. Red cells contain potassium chloride at 100 mmol/l (ionizing to give 200 mOsmol/l) which with other osmotically active particles

summates to ~300 mOsmol/l. Now imagine these cells swelling when placed in a 0.45% sodium chloride solution with ~75 mmol/l ≡ 150 mOsmol/l. Then imagine the swelling of similar red cells when placed in a 2.7% dextrose solution at a similar $\frac{2.7}{180}$ = 150 mmol/l≡150 mOsmol/l. You no doubt imagine these two sets of cells behaving in exactly the same way. The short-term behaviour is independent of the nature of the osmotically active particles.

In clinical practice, we do sometimes treat osmotically active particles differently depending on their nature. In 2007 the National Patient Safety Agency (NPSA) restricted the term '*tonicity*' to the electrolyte component. The NPSA recommended ignoring the glucose component of administered fluids as in the longer-term the glucose is metabolized to water.[2] The NPSA called 4% dextrose with 0.18% NaCl, which contains about 300 mOsmol/l, hypotonic—when it was previously considered to be isotonic. This terminology has survived the NPSA which itself was dissolved in 2012 and superseded by NHS Improvement. Likewise, 0.45% NaCl in 5% dextrose, which is clearly hyper-osmolar, is considered hypotonic. It is very important to appreciate these points.

What drives the net movement of water during osmosis?

You should now have crystallized your thoughts on osmosis. Does the water move across the semipermeable membrane down a concentration gradient of water? Does the solute '*draw*' or '*suck*' the water across the membrane, and if so how? Perhaps the solute binds the water—but then hydrophilic molecules would be more osmotically active than hydrophobic ones? Or is the mechanism something quite different?

Can we understand osmosis as a physical process that can be imagined in a mechanical model? Surgeons like mechanical models. Or do we only have a phenomenological description of solvent movement in relation to solute concentrations?

When we revive dry plants with water, we think of pressure in the cells giving turgor. Let us consider the concept of '*osmotic pressure*'; what is this pressure? Osmotic pressure is the minimum pressure which, when applied to the hyper-osmolar solution, prevents the flow of water across the semipermeable membrane from the hypo-osmolar side to the hyper-osmolar side. Consider Figure 1.

In Figure 1, A and B show water moving from the right (hypo-osmolar) to the left (hyper-osmolar) compartment to equalize solute concentrations, and having achieved this there is a pressure difference related to ΔH. This is the '*osmotic pressure*'. If that pressure were applied to the left compartment at the start there would be no movement of water. If a greater pressure were applied, water would move from left to right. This is the phenomenon which underlies desalination and to which the term *reverse osmosis* applies.

Some educational material describes water moving down a concentration gradient. Indeed, I am embarrassed to say that this was my mental model for some time, and I taught it, and committed it to paper, but it is clearly wrong! A little thought shows why.

What is the concentration of water? H_2O has a molecular weight of 2 + 16 = 18 and so 18 gm of water is 1 mole, consequently 1 litre of water, which weighs 998.2 gm at 20°C, has a concentration of 998.2/18 = 55.5 mmol/l.

Normal saline 0.9% NaCl has 9 gm/l of salt and ~150 mmol/l of Na^+ and of Cl^- with a molarity of 300 mOsmol/l and by this we mean 300 mmol/l of active particles since it fully ionizes. But what is the concentration of water in this solution? Since salt has a density of ~2 g/cm^3 a guess might be something around $\left(1000 - \frac{9}{2}\right)$ = 995.5 gm/l and it is a good guess as the measured concentration is 992.5 gm/l,[3] which gives us 992.5/18 = 55.1 mol/l.

If pure water is on one side of a membrane (55.5 mol/l) and 0.9% saline (55.1 mol/l) on the other side the concentration difference is 400 mmol/l of water and it is tempting to imagine that this drives solvent across the membrane, but this has to be wrong. Why? Think of the similar calculations using dextrose.

We are familiar with 5% dextrose with 50 gm/l of dextrose having an osmolarity of 50/180 = 278 mmol/l. If we increase the dextrose to 54 gm/l we have 300 mmol/l of dextrose, but what then is the concentration of the water? Dextrose has a density of ~1.5 g/cm^3 and our guess for the water might be something around $\left(1000 - \frac{54}{1.5}\right)$ = 964 gm/l. It is not a bad guess as the published value is 966.5 gm/l = 53.7 mmol/l.

We expect, and experiment confirms, that there is no water movement with 0.9% saline on one side of a semipermeable membrane and 5.4% dextrose on the other, and yet there would be a very impressive water concentration difference of 55.1 − 53.7 = 1.44 mol/l.

Imagine now a dextrose solution of 0.1 mol/l with only 18 gm/l of dextrose. This solution has a concentration of water of 987.3 gm/l = 54.85 mol/l. Now imagine this opposing 0.9% saline across a semipermeable membrane and we have water moving up a concentration gradient of water (see Figure 2).

There is clearly a problem with the idea of water moving down a concentration gradient—it is wrong, but it still appears in educational material and text books.

van't Hoff and the first Nobel prize in chemistry in 1901

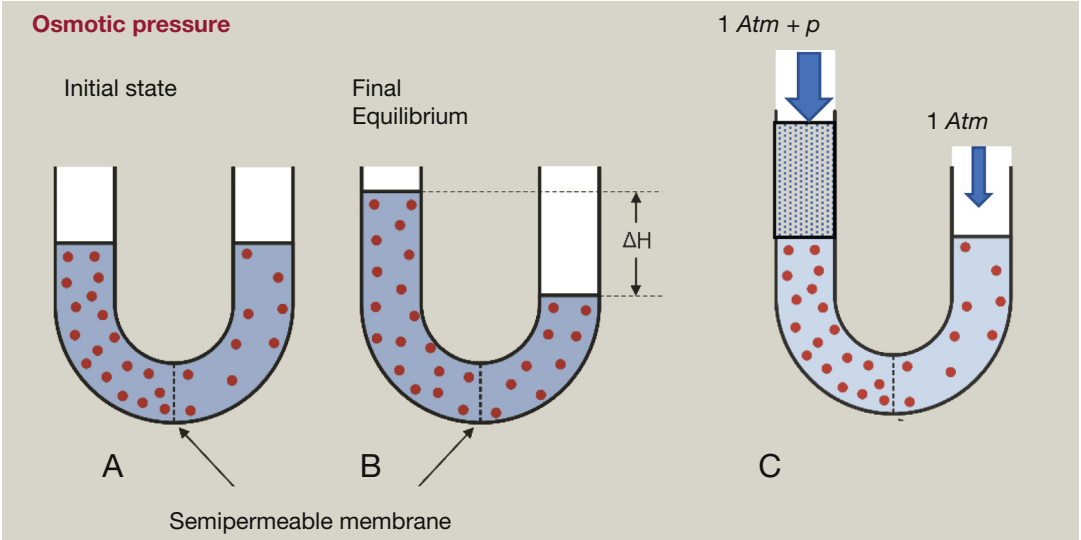
van't Hoff showed that osmotic pressure is a **colligative property,** meaning that the pressure depends only on the molar concentration of the solute but not on its identity. Ionization was not understood in 1901 and he used a factor *i*, which for saline was 2.

van't Hoff considered that the particles behaved like a gas but in a liquid. You may recall that for an ideal gas $PV = nRT$ with T being the absolute temperature and R being the gas constant. To get a pressure van't Hoff used $P = inRT/V$ and of course n/V is related to concentration and i takes account of ionization.

It seems that the '*pressure*' generated by the osmotically active particles decreases the '*potential*' or '*activity*' of the water, a concept which differs from its concentration.

A mechanical model is difficult to conceive, leaving us with an empirical law in which the osmotic pressure, which is negative, follows the gas laws with solvent moving to try and reduce the concentration of the more concentrated solute.

This does seem rather unsatisfactory, in fact van't Hoff got irritated with people asking him how osmosis worked and he simply said he did not know and that the laws simply describe the phenomenon.



A and B show solute movement bringing about equal solute concentrations, at which time there is a pressure difference =ρgΔH. C shows no solvent movement when the pressure on the left is raised by p=ρgΔH. ρis the fluid density and g the gravitational constant.

Figure 1

The dangers of 4% glucose, 0.18% saline as a maintenance fluid

Before 2007, low sodium-containing fluids such as 0.18% saline with 4% glucose were widely used for maintenance prescriptions since they deliver the daily sodium requirement, irrespective of age. This regimen seemed sensible but was not always appropriate since children requiring intravenous fluids were often stressed and tended to hang on to water, leading to a risk of hyponatraemia. For this reason, astute prescribers reduced fluid rates when patients were sick and kept a close eye on serial sodium levels. The astute prescriber increased fluid rates if sodium levels rose and reduced rates if sodium levels fell. The serum sodium was the pauper's serum osmolarity!

Interestingly, an RCT comparing maintenance with (A) 0.9% NaCl in 5% dextrose at full rate, (B) 0.18% NaCl in 5% dextrose at full rate with (C) 0.18% NaCl in 5% dextrose at two-thirds maintenance rate, found hyponatraemia <130 mmol/l in A:1/58, B:8/56 and C:2/53.[4] A Fisher's exact test comparing A and B yields a *p* value of 0.0155, whereas comparing A and C yields a *p* value of >0.6. Though this is a small study, it should be sufficient to illustrate the wisdom of the recommendations of NG29.

The real, and hopefully now historic danger, was from the inappropriate prescription of low sodium-containing fluids for resuscitation or when used to replace fluid and electrolyte deficits. The risk was of precipitating hyponatraemia that in turn can be fatal in children who develop an encephalopathy. Furthermore, an excessively high rate of fluid administration of an otherwise appropriate fluid, could have the same effect.

Postoperative fluid prescriptions

Postoperative fluid prescriptions should be isotonic and chosen from: 0.9% saline, 0.9% saline in 5% glucose, Ringer's lactate/Hartmann's; Plasma-lyte; or similar fluids. Rates can be reduced as seen clinically appropriate.

Correcting previous fluid and electrolyte deficits

Estimated losses are typically between 5% and 15% of body weight. Sometimes the weight loss is accurately known, since weights have been recorded. Replacement fluids should be isotonic 0.9% NaCl with KCl 0.15% (20 mmol/l) carefully considered or Ringer's lactate/Hartmann's solution.

A 15 kg child who is 5% dehydrated has a water deficit of ~750 ml. It is not an uncommon misconception that 10% dehydration can be corrected by increasing maintenance fluid rates by 10%! This is clearly incorrect. It is very difficult to estimate deficits. The signs of sunken eyes, sunken fontanel, lethargy and dry mucous membranes are considered, but their significance can be less reliable than assessing capillary refill and respiratory rate. Severe dehydration >7% is usually

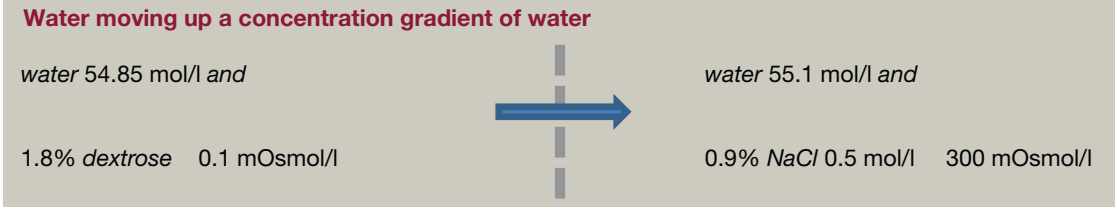


Figure 2

accompanied by decreased conscious level, tachycardia and hypotension. Accurate recent weights may be available.

Hypovolaemia, should be corrected with a bolus of 10–20 ml/kg of an isotonic fluid or colloid, repeated as necessary followed by a slower correction of residual dehydration with an isotonic fluid, considering ongoing losses, serum electrolytes and urine output.

Maintenance fluid requirements in children and neonates

Maintenance requirements are often calculated using the recommendations of Holliday and Segar (see Table 1). In children outside the neonatal period, 0.45% saline in glucose or Hartmann's or 0.9% saline were options supported by the NPSA. However, in the postoperative period it is not recommended to use 0.45% saline. Isotonic fluids give more than the daily requirements of sodium but the risks of this are known without doubt to be far less than the risks of hyponatraemia if low sodium containing fluids are given. One advantage of Hartmann's solution over 0.9% saline is that it administers less chloride, though it remains less popular with junior prescribers, probably because it has a lower (but physiologically appropriate) potassium concentration of 4 mmol/l than standard bags of normal saline which when designed to deliver maintenance requirements of potassium contain 0.15% KCl ≡ 20 mmol/l.*

In term neonates, less than 48 hours of life, 10% glucose is often given at 60 ml/kg/day. Sodium is then added on day 2–3 depending on renal function, serum sodium and weight. From day 3 maintenance is given with 0.18% saline in 10% glucose at 4 ml/kg/h or 100 –120 ml/kg/day. Preterm babies or those <2 kg require higher rates and frequent assessment. However, in the preterm unfed neonate intravenous nutrition is urgently required as neurodevelopment is affected after just a few days without good nutrition. Maintenance requirements are raised in pyrexia, excess sweating and in hyper-metabolic states and burns.

The reduction of requirements in children on PICU who are sedated and ventilated with humidified gases remains controversial.

Reflection on Table 1 tells you why requirements are met if 0.18% NaCl, 0.15% KCl is administered at the prescribed rates. However, our patients have abnormal physiology, retaining fluid, and the dangers of hyponatraemia outweigh the naïve logic of extrapolating Table 1 into the prescription of maintenance fluids.

Fluids given during operations

During surgery the majority of children may be given fluids without glucose. Blood glucose should be monitored during long operations. Maintenance fluids during surgery should be isotonic. Neonates less than 48 hours old need dextrose during surgery. Preterm and term infants already receiving glucose-containing solutions continue with them during surgery, and those on parenteral nutrition preoperatively should continue to receive this during surgery or are changed to receive a dextrose-based maintenance fluid. Children less than 3rd centile for weight or having prolonged surgery should receive 1–2.5% dextrose and have their blood glucose monitored during surgery. Losses during surgery need to be replaced appropriately. In children over 3 months of age, the haematocrit may be allowed to fall to 25% whereas children with cyanotic congenital heart disease may need a higher haematocrit to maintain oxygenation.

Normal water, electrolyte, energy and protein requirements

Body weight	Water ml/kg/day	Sodium mmol/kg/day	Potassium mmol/kg/day	Energy Kcal/kg/day	Protein g/kg/day
First 10kg	100	2–4	1.5–2.5	75	3.00
Second 10kg	50	1–2	0.5–1.5	75	1.50
Subsequent kg	20	0.5–1	0.2–0.7	30	0.75

Table 1

Postoperative fluid management

Some preoperative surgical conditions are associated with increased ADH production: empyema, sepsis, shock, etc. Operative trauma, pain, nausea and vomiting also contribute to ADH release. Fluid rates in the postoperative period are then calculated using Holliday and Segar's formula, but may be restricted to 70% of full maintenance. Ongoing losses from drains or nasogastric tubes should be replaced with an isotonic fluid with added potassium.

Outside the neonatal period no surgeon now prescribes 0.18% saline, but audits show that many juniors still prefer 0.45% saline with 5% glucose for peri-operative fluids, a prescription allowed but not recommended by NG29. If this is your preferred fluid you need a good argument for using it and robust monitoring to avoid sodium levels falling.

Oral fluids should be started and increased after surgery, whereas intravenous fluids are reduced and then discontinued. The rate at which this happens depends upon the child and the surgery.

Monitoring of fluid therapy

Serum electrolytes do not need to be measured in all preoperatively healthy children where IV fluids are to be given for the duration of surgery and for a short period thereafter. If there has been bowel preparation or there is un-shunted hydrocephalus, electrolytes should be checked preoperatively. Serum electrolytes need to be measured preoperatively in all children presenting for elective or emergency surgery who require IV fluid to be administered prior to surgery. Where possible, children should be weighed prior to fluids being prescribed. Ideally serum electrolytes should be measured and reviewed by the prescriber every 24 hours in all children on IV fluids or more frequently if results are moving rapidly in one direction or the other. The results do not have to be outside the normal range to bring about a change in fluid rate. Children should be weighed daily while on IV fluids unless this is difficult. A fluid input/output chart must be carefully maintained and checked by the prescribing doctor.

* The molecular weights are K = 39 and Cl = 35.45 and so 1.5 gm/l of KCl ≡1.5/74.45 = 20 mmol/l.

Common electrolyte derangements

Hyponatraemia

Hyponatraemia, now defined as a serum Na <135 mmol/l, may occur in a number of situations, but is commonly seen when inappropriate fluids have been administered or following surgery with any fluid regime. Low sodium-containing (hypotonic) fluids are more likely to precipitate hyponatraemia if fluids rates are inappropriately high. Presenting features of hyponatraemia include seizures or respiratory arrest. Headache is a consistent early sign of hyponatraemia in adults but is rarely seen in children. Hyponatraemic encephalopathy should be managed as a medical emergency on PICU. Hyponatraemic seizures respond poorly to anticonvulsants and initial management is to give an infusion of 3% sodium chloride solution. One ml/kg of 3% sodium chloride will normally raise the serum sodium by 1 mmol/l. Serum Na should be raised quickly until the child has regained consciousness and has stopped fitting or the serum Na is above 125 mmol/l. The amount of Na required can be calculated as follows:

mmol of Na required = (130 − present serum Na) × 0.6 × Weight (kg)

Once seizures have stopped, a slower Na correction should take place using 0.9% sodium chloride solution. Asymptomatic hyponatraemia does not require active correction with 3% sodium chloride solution. The dehydrated child may be treated with enteral fluids or if not tolerated, with intravenous 0.9% sodium chloride solution. The child with asymptomatic hyponatraemia and normal or increased volume status, if taking oral fluids should be volume restricted or if on IV fluids should have fluid administered at 50% of maintenance rate. If eating, salt can be added to the food.

Hypernatraemia

Hypernatraemia (serum Na > 150 mmol/l) commonly occurs as a result of excessive water loss, restricted water intake or an inability to respond to thirst. It may also occur in infants given incorrectly prepared feeds. Hypernatraemia can be fatal. Signs of hypernatraemia are more severe if it develops rapidly or when the serum Na is >160 mmol/l. Chronic hypernatraemia is often tolerated because of cerebral compensation. The true degree of dehydration is often underestimated if clinical signs alone are used compared to loss of weight. Intravascular volume is often well preserved during the initial stages. The management of hypernatraemic dehydration consists of volume replacement with 0.9% sodium chloride in boluses of 20 ml/kg to restore normovolaemia. Complete correction should then be done slowly over at least 48 hours to prevent cerebral oedema, seizures and brain injury. The serum Na should be corrected at a reduction of no more than 12 mmol/l/day with 0.45% sodium chloride or 0.9% sodium chloride in glucose. In hypernatraemic dehydration it is important to give maintenance fluid alongside the fluid given to correct the dehydration.

Potassium imbalance

Hypokalaemia (serum K < 3.5 mmol/l) produces symptoms of cramp, arrhythmias, reduced cardiac contractility and paralytic ileus. If possible oral supplements of 3−5 mmol/kg/day should be given. Orange juice and bananas are rich in potassium. In severe hypokalaemia (serum K < 3 mmol/l), intravenous correction should be no faster than 0.25 mmol/kg/h using a maximum peripheral concentration of 40 mmol/l KCl. For a more rapid correction, the patient should be in PICU and the infusion administered via a central line.

Hyperkalaemia with a serum $K^+ > 5.5$ mmol/l causes muscle weakness and ECG changes when the serum $K^+ > 7$ mmol/l. Immediate treatment of hyperkalaemia is to antagonize membrane effects by giving 100 micrograms/kg of 10% calcium gluconate. This equates to 0.5 ml/kg of a 10% solution (1ml 10% calcium gluconate contains 0.22 mmol calcium). Alongside this it is important to increase the intracellular shift of potassium by giving 1−2 mmol/kg of sodium bicarbonate, an infusion of 0.3−0.5 g/kg/h of glucose with 1 unit of insulin for every 5 g of glucose or to give 2.5−5 mg nebulized salbutamol (5 micrograms/kg in neonates IV). Removal of potassium from the body can be achieved by giving 1 g/kg calcium resonium rectally or orally, by use of furosemide 1 mg/kg or by dialysis or haemofiltration.

Calcium imbalance

Hypocalcaemia (corrected total Ca <2 mmol/l or <1.5 mmol/l in neonates) may produce symptoms of twitching and jitteriness, perioral, finger and toe paraesthesia, masseter and carpopedal spasm, prolonged QT interval and reduced cardiac contractility. Immediate treatment is with 10% calcium gluconate 0.5 ml/kg to a maximum of 20 ml over 10 minutes or 10% calcium gluconate 0.2 ml/kg to a maximum of 10 ml over 10 minutes. The central venous route should be considered for injection with continuous ECG monitoring during injection. Calcium levels appear low in the newborn because of low albumin levels. There is a normal physiological fall in calcium concentration after birth which rises after the second day. Causes of hypocalcaemia in the newborn are encephalopathy, renal failure, Di George syndrome, disordered maternal metabolism or maternal diabetes mellitus.

Pyloric stenosis: correction of hypochloraemia

Children with pyloric stenosis typically present with a mild hypochloraemic alkalotic dehydration. Resuscitation can be based on the serum chloride in most children.

Calculate the chloride deficit and replace over 12−48 hours depending on severity.

The chloride deficit = 2/3 × weight (kg) × (110 − [Cl^-]).

Use 0.9% saline 0.15%K^+ (170 mmol Cl^-/l)

or 0.45% saline, 5% glucose 0.15%K^+ (95 mmol Cl^-/l)

Example: a 3.3 kg boy is mildly dehydrated with a Cl^- of 85 mmol/l:

Deficit = 2/3 × 3.3 × (110−85) = 55 mmol Cl^-.

This is contained in 55/170 = 325 ml of 0.9% saline with 0.15% KCl.

If this fluid is given at 180 ml/kg/day = 25 ml/h he will have had 55 mmol Cl in 13 hours.

Alternatively, if 0.45% saline with 5% glucose with 0.15% KCl is used at 180 ml/kg/day he will have had 55 mmol in 23 hours.

If the serum chloride is then re-measured and the bicarbonate checked he will most likely be corrected. After correction surgery can take place.

Commonly available crystalloid fluids

Fluid		Na^+ mmol/l	K^+ mmol/l	Cl^- mmol/l	Energy Kcal/l	Other
Saline 0.9% (normal saline)	Isotonic	150	0	150	0	0
Saline 0.9% + 0.15% KCl	Isotonic	150	20	170	0	
Saline 0.9% + 0.15% KCl +5% glucose	Isotonic	150	20	170	200	
Hartmann's solution	Isotonic	131	4–5	111	0	Lactate
Saline 0.45%, glucose 2.5%	Hypotonic	75	0	75	100	0
Saline 0.45%, glucose 5%	Hypotonic	75	0	75	200	0
Saline 0.18%, glucose 4%	Hypotonic	30	0	30	160	0
Saline 0.18%, glucose 4%, 10mmol KCl/500ml (0.15%)	Hypotonic	30	20	50	160	0
Glucose 5%	Hypotonic	0	0	0	200	0
Glucose 10%	Hypotonic	0	0	0	400	0
Saline 0.18%, glucose 10%	Hypotonic	30	0	30	400	0
Glucose 20%	Hypotonic	0	0	0	800	0

NOTE the tonicity ignores the glucose component.

Table 2

Conclusions

Great care and respect should be given to intravenous fluid management. It is important to understand the basic science, the risks, and the national guidelines. A table of common fluids and constituents appears in Table 2. ◆

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