Prescribing intravenous fluids: how to get it right

Fluid prescription is an important task, which is often delegated to the most junior team members. Poor understanding can result in inappropriate and potentially dangerous prescriptions. This article aims to improve the confidence of junior doctors when confronted with this problem.

Introduction

Prescribing intravenous fluids appropriately and accurately is as vital as prescribing drugs correctly and yet is often seen as being somehow less important. No doctor would dream of ‘writing up’ medications without knowledge of both the indication and the effect of the proposed treatment on the patient. Intravenous fluids, however, are often prescribed with little consideration and poor knowledge of the components contained within the fluid (Johnson and Monkhouse, 2009). This article considers the basal requirements of patients and how these can be met using commonly available intravenous fluids, and discusses how to correct dehydration and address ongoing fluid losses.

Distribution of body water

Humans are mostly water. An adult male is 60% water – of this, 55% is intracellular and 45% extracellular (Woodrow, 2002; Campbell, 2006). Extracellular fluid comprises plasma, interstitial fluid (between cells) and transcellular fluid (within gut, CSF, aqueous humour, joints). The distribution of total body water is shown in *Figure 1*.

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The cell membrane is freely permeable to water and electrolytes. Sodium, however, is actively pumped out, meaning that it is largely extracellular, while potassium is mainly intracellular. The ionic components of cellular and extracellular fluids are therefore very different, but their osmotic pressures are identical (285–295 mOsmol/kg). Most of the osmotic activity of body fluids is accounted for by their crystalloid components, water moving across the cell membrane if there is a difference in the osmolality across the two sides. An isotonic solution is one which does not cause any net movement of water across cell membranes. Isotonic solutions therefore do not cause any cell shrinkage or swelling. Normal (0.9%) saline and 5% dextrose are isotonic – red cells suspended in these solutions do not change their volume.

What happens when we drink water?

Ingesting water increases the volume of all body fluid compartments as cell membranes are permeable to water. This means that 1 litre of water is distributed throughout the total 42 litres of body water, of which only 3.5 litres (7.5%) is intravascular. Infusing 1 litre of 5% dextrose has exactly the same effect as drinking 1 litre of water. The glucose is rapidly metabolized leaving only water which, although initially infused into the intravascular compartment, is then distributed throughout the total body water. This means that 13 litres of 5% dextrose would be required to increase plasma volume by 1 litre.

What about normal saline?

When a litre of normal saline is infused, it distributes throughout the extracellular fluid because of its high sodium and chloride content, rather than throughout the whole total body water. Extracellular fluid makes up 45% of total body water, with the plasma volume being 3.5 litres (7.5%), and therefore 1/6th remains intravascular. It follows that 6 litres of normal saline need to be infused to raise intravascular volume by 1 litre.

Normal water and electrolyte balance

The typical balance for an adult is shown in *Table 1*. Water requirements for adults and children vary according to climate, health, age and size. Broadly speaking adults require 30–40 ml/kg over 24 hours. For children, the requirements vary depending on the weight; if the child weighs 0–10 kg, 100 ml/kg is needed over 24 hours, 10–20 kg needs 50 ml/kg over 24 hours, and >20 kg will require 20 ml/kg over 24 hours.

Adults and children also require sodium and potassium – sodium at 1–2 mmol/kg/day, potassium at 1 mmol/kg/day (Powell-Tuck et al, 2006). However, humans are very efficient at conserving sodium and can tolerate much lower sodium intakes. They are less good at conserving potassium as there is an obligatory loss of potassium in urine and faeces. Patients who are nil by mouth and are not given potassium replacement quickly become hypokalaemic.

What do intravenous fluids contain?

Standard intravenous fluids contain electrolyte and glucose mixtures carefully proportioned to ensure that the resultant

Figure 1. Distribution of total body water (42 litres) in a 70 kg man.

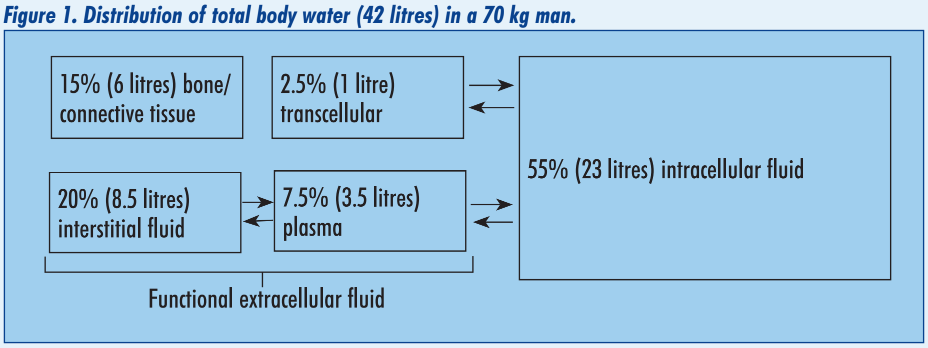

Table 1. Water balance for a typical adult

Input (ml)		Output (ml)	
Drink	1500	Urine	1500
Food	750	Faeces	100
Metabolic	350	Lungs	400
		Skin	600
Total	2600	Total	2600

From Scales and Pilsworth (2008)

solution is isotonic. This means that when they are infused, red cells and other cells will not 'explode' or 'shrivel' as there is no net movement of water across the cell membrane. There are exceptions to this (half normal saline, osmolality 150 mmol/litre and twice normal saline, osmolality 600 mmol/litre) but these are not commonly used and will not be discussed further. The components of some popular crystalloids are shown in *Table 2*.

There are therefore a number of possible combinations of fluid that can be used over a 24-hour period to meet an individual's basal requirements, although all these regimens require supplemental potassium. *Table 2* shows that only Hartmann's fluid contains any potassium at all and even giving three 1 litre bags of this over 24 hours would only provide 15 mmol of potassium, nowhere near the average individual's requirement of 70 mmol/day. Potassium can be dangerous if used without caution but this is no excuse not to meet the patient's basic requirements. There are 'safe' rules for administering potassium and if these are adhered to, no harm will ensue. These are:

1. Know what your patient's potassium level is – if it is low or normal, it is safe to proceed
2. Ensure that your patient's urine output is more than 40 ml/hour
3. Give no more than 40 mmol of potassium in each litre of fluid
4. Give potassium no faster than 40 mmol/hour (Kirk and Ribbans, 2004).

Potassium chloride is usually added to bags of intravenous fluid as ampoules of 20 mmol in 10 ml. Bags of crystalloid are available which come 'ready prepared' with added potassium already and these are probably preferable as they minimize the risk of drug errors. Hartmann's with added potassium is not generally available, however, so potassium replacement is usually given with normal saline or 5% dextrose.

Several possible ways of meeting the basal requirements of an average man who is not taking any fluids orally are shown in *Figure 2*.

The rules for the safe administration of potassium are suitable for most patients, but some have specific additional requirements. Those with gut inflammation and florid diarrhoea often lose excessive sodium, potassium and magnesium, so aggressive replacement is required. These individuals may well require more than 40 mmol of potassium in each litre of fluid to maintain normal serum levels. Another possible exception is chronic renal failure, in which patients may be oliguric for many years, never producing more than 40 ml of urine per hour. These patients may also still become dehydrated and intravascularly depleted and require fluid resuscitation with added potassium as indicated by recent blood electrolyte levels. There are therefore some circumstances in which the rules may be safely deviated from.

Blood electrolyte levels should be checked daily for patients relying on intravenous fluids for their water and electrolytes. It is not possible to prescribe sensibly without up-to-date results. Sometimes doctors on a ward round are asked to 'quickly write up some fluids' for a patient. It is extremely important that the sodium and potassium results are known. If this causes a delay while the most recent results are looked up on the computer, so be it. You cannot accurately prescribe fluid without these results, nor should you prescribe for a patient whose case you are not familiar with. The rule is: 'Never prescribe fluid without knowing both the patient and his/her electrolyte levels.'

Correction of dehydration

Patients admitted to hospital as emergencies often do not arrive in a state of normal hydration. Frequently, they have been too unwell to eat and drink properly or have been losing fluid they have not been able to adequately replace orally. These patients therefore require more fluid than their basal requirements to correct the deficit, but how do we know if there is a deficit and, if so, how much it is?

There are a number of ways to assess this, including clinical assessment, observations, urine output, blood tests and central venous pressure measurement.

The dehydrated patient may have dry mucous membranes, loss of skin turgor and tell you that he/she feels thirsty. The patient may have a tachycardia and be hypotensive, as the body struggles to compensate for a reduced circulatory volume. It is worth remembering, however, that patients can lose up to 15% of their blood volume with no changes in pulse or blood pressure. Losses of up to 30% are usually associated with a tachycardia but maintenance of a normal blood pressure. Patients may not become hypotensive until 40% is lost (the 15/30/40% 'tennis' rule of shock). One should therefore never use a 'normal' blood pressure as an indication that a patient is not dry or hypovolaemic.

Urine output is a particularly useful measurement – if hourly output is adequate, the kidneys are satisfactorily perfused and functioning. The colour of the urine can also be an indicator – if it is very dark and concentrated, consider giving more fluids (beware the patient with obstructive jaundice, who has very dark yellow urine even when well hydrated). Central venous pressure can also be useful, particularly in patients with cardiovascular disease in whom you are concerned that vigorous fluid resuscitation will precipitate heart failure and pulmonary oedema. The central line lies within the great veins as they enter the heart or within the right atrium and provides a measure of pressure

Table 2. Content of some crystalloid solutions (electrolytes in mmol/litre)

Fluid	Na+	Cl-	K+	HCO3-	Osmolality
0.9% saline	150	150	0	0	300
Hartmann's	131	111	5	29	280
5% dextrose	0	0	0	0	280
0.18% saline + 4% dextrose	30	30	0	0	286

Figure 2. Meeting the patient's basal requirements.

2 litres (5% dextrose + 20 mmol KCl) + 1 litre 0.9% saline + 20 mmol KCl	Contains 150 mmol Na^+ and 60 mmol K^+
2 litres (5% dextrose + 20 mmol KCl) + 1 litre Hartmann's	Contains 131 mmol Na^+ and 45 mmol K^+
3 litres (dextrose-saline + 20 mmol KCl)	Contains 90 mmol Na^+ and 60 mmol K^+

of blood as it enters the heart. The normal range is 3–8 cmH_2O. A low reading tells you that the filling pressure is down and your patient is dehydrated. A high reading does not, however, tell you that your patient is adequately hydrated. Anything which raises central venous pressure, especially heart failure, will result in a high central venous pressure reading. One-off reading of the central venous pressure can therefore be of limited use. The response to a fluid challenge, or bolus, is a much more sensitive indicator of fluid status. A dehydrated patient's central venous pressure will rise in response to a fluid challenge, then fall again as the body accommodates the additional fluid. If the response to the challenge is a modest sustained rise in the central venous pressure, the patient is well-filled and does not require additional fluid. If the response is a persistent rise of more than 5 cmH_2O, the patient is either over-filled or has a failing heart (*Figure 3*).

Generally speaking, the fluid administered to correct a deficit should be similar in composition to that which has been lost. When administering fluid to correct a deficit, the patient must be regularly reassessed to guide you as to when you have given enough fluid. When the patient's vital parameters have normalized and he/she tells you that he/she no longer feels thirsty, you can be satisfied that you have corrected the deficit.

Ongoing losses

What should you prescribe for the patient who continues to lose fluid and electrolytes in excess of that expected? To answer this, we must consider the composition of some bodily fluids (*Table 3*).

Patients will commonly lose fluids via vomit or nasogastric tubes, from stomas (especially if high output) or per rectum as diarrhoea. Gastrointestinal secretions tend to be electrolyte rich. Drinking water will not be sufficient by itself to combat the loss of fluid, as the lost fluid will have been isotonic with the plasma and both sodium chloride and water will be required to rehydrate the tissues. Losses should therefore be replaced using normal saline with supplemental potassium.

When more than 6–10% of body water has been lost, the plasma volume falls and circulatory failure commences. Accurate input/output fluid charts are essential to calculate the volume of supplemental fluid needed in addition to basal requirements (National Confidential Enquiry into Perioperative Deaths, 1999; Lecko, 2007). The total losses (urine, vomit, nasogastric, drains, stoma output and diarrhoea) for the preceding 24 hours are totalled. This volume is then replaced over the coming 24-hour period in addition to the basal fluids. This is why fluid regimens should always be prescribed for a 24-hour period by one individual rather than 'bag by bag' on an ad-hoc basis by different doctors. Only in this way can you ensure that you meet the needs of the patient.

Table 3. Volume and electrolyte contents of body secretions (concentrations in mmol/litre)

Fluid	Volume	Na+	K+	Cl-
Saliva	1.5 litres	15	19	40
Stomach	2.5 litres	50	15	140
Upper gastrointestinal	4.2 litres	145	10	90
Insensible sweat	0.6 litres	12	10	12
Sensible sweat	Variable	50	10	50

Conclusions

Key concepts in fluid management and the prescription of intravenous fluids include knowledge of how total body water is distributed, the basal requirements for water and electrolytes, the composition of commonly used intravenous fluids, how fluids can be prescribed to meet basal requirements, how we can detect and correct a fluid deficit, the composition of bodily secretions and how to manage ongoing fluid losses.

Fluid management is an extremely important aspect of prescribing and patient care and is easy to do well with a little thought and care. Finally, please: 'Never prescribe fluid without knowing both the patient and his/her electrolyte levels.' **BJHM**

Conflict of interest: none.

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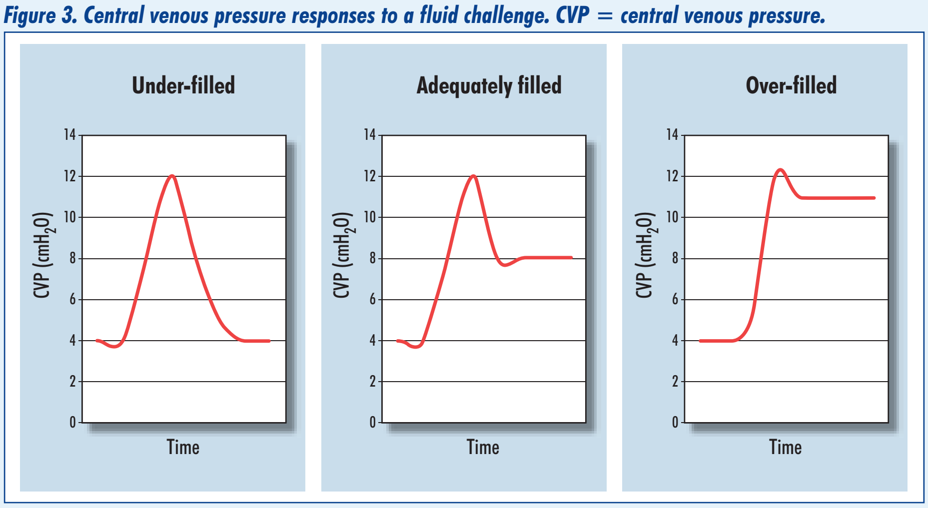
Figure 3. Central venous pressure responses to a fluid challenge. CVP = central venous pressure.



KEY POINTS

- Prescribing intravenous fluids should be undertaken with the same care as prescribing drugs.
- Knowledge of basal water and electrolytes requirements is necessary for accurate fluid prescription.
- Knowledge of the patient's condition and his/her blood electrolyte levels is mandatory.
- Ongoing losses must be charted and replaced with fluid of a similar composition to that lost.